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Draft Version 6

Science and Adaptive Management Plan

Missouri River Recovery Program

Draft/Pre-decisional/For Review and Comment

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Science and Adaptive Management Plan

Missouri River Recovery Program

J. Craig Fischenich

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS 39180

Kate E. Buenau

Marine Science Laboratory
Pacific Northwest National Laboratory
U.S. Department of Energy
1529 W. Sequim Bay Rd
Sequim, WA 98382

Joseph L. Bonneau and Craig A. Fleming

U.S. Army Corps of Engineers
Omaha District
Gavins Point Project Office
Yankton, SD 57078

David R. Marmorek, Marc A. Nelitz, Carol L. Murray and Brian O. Ma

ESSA
600 – 2695 Granville Street
Vancouver, BC Canada V6H 3H4

Graham Long

Compass Resource Management Ltd
210 - 111 Water Street
Vancouver, BC Canada V6B 1A7

Carl J. Schwarz

Department of Statistics and Actuarial Science,
Simon Fraser University
8888 University Drive
Burnaby, BC Canada V5A 1S6

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Under Missouri River Recovery Program

Abstract: The Missouri River Recovery Program (MRRP) is undergoing a transformation resulting from 2011 recommendations by an Independent Science Advisory Panel and the Missouri River Recovery Implementation Committee (MRRIC). An Effects Analysis study established the best available scientific information and provided the foundation for an Adaptive Management Plan (AM Plan) that addresses lingering uncertainties and improves management decisions while implementing actions that avoid jeopardizing the three federally listed species in the system. This draft AM Plan includes a process for resolving critical uncertainties using a framework consisting of four implementation levels: 1) research, 2) in-river testing of hypotheses, 3) scaled implementation of select management actions, and 4) full implementation. The decision criteria for moving to higher levels of implementation are included. A NEPA evaluation of alternative management actions identified an initial suite of actions that will be implemented to meet the objectives of the MRRP. This Draft AM Plan accompanies the Draft Missouri River Recovery Management Plan-Environmental Impact Statement and provides the roadmap for the implementation of the selected alternative and for the identification of subsequent management needs should the initial suite of actions fail to meet objectives. The AM Plan will be implemented collaboratively by the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and MRRIC following the governance process outlined in the AM Plan.

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Preface

This report presents the draft Adaptive Management Plan (AM Plan) for the Missouri River Recovery Program (MRRP). Further revision of this document is planned. A finalized draft will be submitted along with the draft Missouri River Recovery Management Plan-Environmental Impact Statement (MRRMP-EIS) in 2017.

The purpose of this draft is not to convey a determined suite of actions for adaptive management (AM) but rather to present AM concepts, methods and decision criteria that might be employed in the final AM plan. Alternative suites of actions and associated research are being evaluated under the National Environmental Policy Act (NEPA) as part of the MRRMP-EIS. The outcome of the NEPA process will be a selected alternative which, in conjunction with Endangered Species Act (ESA) Section 7 consultation outcomes, will constitute the actions for immediate implementation.

The authors have utilized the actions included in the draft EIS (DEIS) to illustrate the concepts, methods and decision criteria necessary to an AM Plan for the MRRP. These actions include those proposed in Planning Aid Letters (PALs) from the U.S. Fish and Wildlife Service (USFWS). Discussion of these actions in this draft report does not constitute selection of any potential actions; their inclusion is merely to help demonstrate how AM might be implemented for various actions. The final AM Plan will be based on the selected alternative in the Record of Decision.

Some details regarding the AM Program will be determined or refined through ongoing interactions with the agencies, stakeholders, and independent reviewers. Recognizing these limitations, it is intended that this draft provides sufficient insight into the scope and nature of the MRRP AM Plan that reviewers can fairly evaluate the plan, offer constructive comments and engage in discussions regarding improvements to be incorporated into the final AM Plan.

We gratefully acknowledge the many people who contributed to this draft. We used materials from previous drafts and contributions to sections of this draft by Robb Jacobson of the USGS and the Pallid Sturgeon EA Team; Mark Harberg, Dan Pridal, Aaron Quinn, Clayton Ridenour, Mary Roth and Randy Sellers of the USACE Omaha District; Todd Gemeinhardt of the USACE Kansas City District; Doug Latka of the USACE Missouri River Division; Tom St. Clair of Louis Berger and Associates; and Natascia Tamburello of ESSA. Technical content was provided by Casey Kruse, Wayne Nelson-Stastny, and Carol Smith of the USFWS, and technical reviews and comments were provided by Chantel Cook, Coral Huber, Brad Thompson, and Tim Welker of the USACE; Wyatt Doyle, Rob Holm, Steven Krentz, Landon Pierce, Dane Schuman and

Ryan Wilson of the USFWS; David Adams, Justin Haas, Gerald Mestl and Kirk Steffensen of the Nebraska Game and Parks Commission; the Upper Bain Pallid Work Group; Michelle Klose, on behalf of a consortium of state representatives; and several members of the AM ad hoc Task Group and MRRIC members at large. Assistance in developing input to the report by Paul De Morgan of Resolve, particularly in incorporating concepts for governance, is gratefully acknowledged.

Unit Conversion Factors

Multiply	By	To Obtain 2
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
ounces (mass)	0.02834952	kilograms
pounds (force)	4.448222	newtons
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

Abbreviations

AAMR	Annual Adaptive Management Report
AAR	After Action Report
AM	Adaptive Management
AMP	Adaptive Management Plan
ANOVA	Analysis-of Variance
API	Application Program Interface
BA	Before-After
BACI	Before-After-Control-Impact
BiOp	Biological Opinion
BSNP	[Missouri River] Bank Stabilization and Navigation Project
CEM	Conceptual Ecological Model
CEP	Critical Engagement Point
cfs	Cubic Feet per Second
CI	Confidence Interval
CJS	Cormack-Jolly-Seber
CORE	Cooperating for Recovery Team
CPUE	Catch Per Unit Effort
CWA	Clean Water Act
CWT	Coded Wire Tag
DEIS	Draft Environmental Impact Statement
DOI	Department of the Interior
DQO	Data Quality Objectives
EA	Effects Analysis
EIS	Environmental Impact Statement
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESC	Executive Steering Committee
ESH	Emergent Sandbar Habitat
FEIS	Final Environmental Impact Statement
FWG	Federal Working Group
FY	Fiscal Year
FY+1	The next Fiscal Year (FY+2 is the year after next, etc.)

HAMP	Habitat Assessment and Monitoring Program
H&H	Hydrology and Hydraulics
HQUSACE	Headquarters of the U.S. Army Corps of Engineers
IDM	Information Data Management
IP&S	Integrated Planning and Science
IRCs	Interception and Rearing Complexes
ISAP	Independent Science Advisory Panel
ISETR	Independent Social Economic Technical Review Panel
ISP	Integrated Science Program
ISPMT	Integrated Science Program Management Team
kcfs	thousand cubic feet per second
Master Manual	Missouri River Basin Mainstem Reservoir System Master Water Control Manual
Mitigation ACT	Mitigation Project Agency Coordination Team
MRBWMD	Missouri River Basin Water Management Division
MRRIC	Missouri River Recovery Implementation Committee
MRRMP	Missouri River Recovery Management Plan
MRRRP	Missouri River Regional Review Panel
MRRP	Missouri River Recovery Program (also Program)
NEPA	National Environmental Policy Act
NRC	National Research Council
NWD	Northwestern Division
NWO	Omaha District
NWK	Kansas City District
O&M	Operation and Maintenance
Panel	Indeprndent Advisory Panel (combined ISAP/ISETR)
P-bud	President's budget for FY+1
PDT	Project Delivery Team
PIR	Project Implementation Report
PIT	Passive Integrated Transponder
PM	Project Manager
PgM	Program Manager
PNNL	Pacific Northwest National Laboratories
PrOACT	Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs
PSPAP	Pallid Sturgeon Population Assessment Program

QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
Reclamation	U.S. Bureau of Reclamation
RM	River Mile
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
RPMA	Recovery Priority Management Area
SAM	Science and Adaptive Management workgroup
SAMP	Science and Adaptive Management Plan
SPA	Strategic Programmatic Assessment task group
SPDT	Senior Project Delivery Team
SWH	Shallow Water Habitat
System	Missouri River Mainstem Reservoir System
TBD	To Be Determined
T&E	Threatened And Endangered
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WG	Work Group
WP	Work Plan
WRDA	Water Resources Development Act

Glossary

Accounts –Human Considerations objectives and performance criteria are organized into four accounts in accordance with U.S. Army Corps of Engineers Planning Guidelines. The four accounts are as follows:

- Environmental Quality (EQ)
- National Economic Development (NED)
- Regional Economic Development (RED)
- Other Social Effects (OSE)

Active adaptive management – The active form of adaptive management (AM) employs management actions in an experimental design aimed primarily at learning to reduce uncertainty; near-term benefits to the resource are secondary.

Adaptive action – A course of action to be implemented as defined in the Adjust step (Step 5b of the AM process) if the performance of a particular management action is not as anticipated and requires correction. In cases where the action is pre-defined, it is referred to as a "contingency action."

Adaptive Management (AM) – Adaptive management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes advances scientific understanding and helps adjust policies or operations as part of an iterative learning process.

Alternatives –A specified combination of management actions that collectively are deemed to meet minimum performance levels for the endangered species. In the Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs (PrOACT) process, the trade-offs associated with various alternatives on multiple interests are explored in order to find the alternative(s) that minimize unnecessary negative impacts and is/are otherwise thought to be the "best balance" of impacts on a wide range of interests. Alternatives are used to address the objectives.

AM Report – Annual or periodic report that documents new learning based on monitoring results, evaluates progress towards meeting species objectives, and contains recommendations for adjustments to management actions. The Annual AM Report is contained with the Annual Report on Biological Opinion (BiOp) compliance.

Annual Work Plan (AWP) – This document includes real estate actions, habitat creation actions, monitoring of physical and biological responses to actions, and research activities for a particular year within the five-year Strategic Work Plan. It is used by product delivery teams to budget and implement management actions annually.

Biological Assessment (BA) – A document prepared for the Section 7 process to determine whether a proposed major construction activity under the authority of a Federal action agency is likely to adversely affect listed species, proposed species, or designated critical habitat.

Biological Opinion (BiOp) – Document stating the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) opinion as to whether a Federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat. Specifically in the MRRP, the USFWS 2000 Biological Opinion (BiOp) found that the operation of the Missouri River Mainstem Reservoir System (System) and the operation and maintenance of the Missouri River Bank Stabilization and Navigation Project (BSNP), as proposed by theUSACE, would likely jeopardize the continued existence of three federally listed species: the piping plover, least tern, and pallid sturgeon. The BiOp was amended in 2003 to note that, with additional actions proposed by the USACE, operation of the System and the operation and maintenance of the BSNP would not likely jeopardize terns and plovers, but would jeopardize pallid sturgeon. In this document, the amended BiOp is referred to as the USFWS 2003 Amended Biological Opinion.

Conceptual Ecological Models (CEMs) – CEMs are graphical depictions of an ecosystem that are used to communicate the important components of the system and their relationships. They are a representation of the current scientific understanding of how the system works.

Contingency action – A pre-evaluated adaptive action that is implemented when triggered by defined decision criteria without the need for further deliberation or decision.

Critical uncertainties – Uncertainties that impede the identification of a preferred alternative management action.

Critical Engagement Point (CEP) – Specific points in the formulation or implementation phases of adaptive management when the agencies engage with the

Missouri River Recovery Implementation Committee (MRRIC) for input. These can be concurrent with, or in addition to, routine MRRIC plenary meetings.

Decision context – Involves defining what decision (question or problem) is being made, why it is being made, and also describing the scope of the playing field (bounds) for the management decision as well as its relationship to other decisions previously made or anticipated.

Decision criteria – Broadly refers to the set of pre-determined criteria used to make AM decisions. Performance metrics, targets, and decision triggers are considered to be different types of decision criteria. They can be qualitative or quantitative based on the nature of the performance metric and the level of information necessary to make a decision.

Decision space – A term used to characterize a range of operational discretion for flows (or potentially other actions) that is "acceptable" to stakeholders, effective in achieving objectives, and within the bounds of actions evaluated under NEPA. Management actions would generally occur within this region, and any operation outside this decision space would require further coordination and approval.

Decision trigger – Decision triggers are pre-defined commitments (population or habitat metric for a specific objective) that trigger a change in a management action. Decision triggers are addressed in the Evaluate step (Step 4 of the AM process) specifying the metrics and actions that will be taken if monitoring indicates performance metrics are or are not reaching target values. In some cases, a decision trigger may be learning a new piece of information that triggers the Continue/Adjust/Complete step (Step 5 of the AM process).

Delphi process – The Delphi process is a method of eliciting expert opinion (Normand et al. 1998). While many variations of the process exist, there are generally three common features: (1) qualified experts provide their responses to a set of questions in a structured format; (2) the answers to these questions are synthesized across all respondents and presented back to the same set of experts; and (3) the experts jointly discuss the reasons for variation in the first set of responses (or lack thereof), and through dialogue potentially revise their opinions. A modified Delphi process was applied by Jacobson et al. (2016b) to prioritize candidate hypotheses.

Effects Analysis (EA) – The purpose of this effort is to conceptually and quantifiably make explicit the effects of operations and actions on the listed species by specifically evaluating the effects of hydrologic and fluvial processes on the Missouri River, as well as ongoing management actions under the USFWS 2003 Amended Biological Opinion and other Mitigation actions, on the status and trends of the listed species (piping plover, interior least tern, and pallid sturgeon) and their habitats.

Environmental Impact Statement (EIS) – A document which summarizes and analyzes environmental impacts of a proposed action and alternatives.

Evaluation – Conduct analyses to compare measured results with anticipated outcomes related to decision criteria for specific management actions to determine whether the implementation should be continued, adjusted, or completed.

Event-driven reporting cycle – In addition to the annual and periodic AM reports (on a routine reporting schedule), reporting may also be event- driven, where new observations or data resulting from an unforeseen event suggest a decision trigger or targets have been reached.

First increment – The suite of proposed actions evaluated in the Management Plan/ EIS that are anticipated to be implementable in the foreseeable future (~10 – 15 years). The First Increment will include actions for pallid sturgeon for Levels 1 through 3 of the Lower Pallid Framework to ensure NEPA coverage for future implementation.

Formal consultation - The consultation process conducted when a Federal agency determines its action may affect a listed species or its critical habitat, and is used to determine whether the proposed action may jeopardize the continued existence of listed species or adversely modify critical habitat. This determination is stated in the Service's biological opinion.

Fundamental objectives – Fundamental objectives are used to formalize the desired outcome of the program in terms of biological response. They are derived to achieve avoidance of jeopardizing the three species from USACE actions on the Missouri River and articulate the ends the program is trying to achieve.

Global hypotheses – Set of possible, biologically important hypotheses, relevant to population dynamics that are derived from conceptual ecological models.

Human Considerations (HCs) – A set of objectives with associated metrics and proxy metrics that are related to the wide array of uses and stakeholder interests on the Missouri River. They form the basis for some of the monitoring and decision criteria in the AM Plan.

Hypotheses reserve – A concept that seeks to explicitly manage the broad suite of hypotheses developed through the (EA) and highlighted in the CEM. In this concept hypotheses can be brought forward or moved back into reserve as information and understanding directs. The hypotheses reserve concept includes (1) hypotheses that are not deemed important to investigate at this time, (2) have high uncertainty and require further investigation, and/or (3) are outside USACE authority.

Initially modeled hypotheses – Subset of working management hypotheses determined by the USACE to be within jurisdiction and applicable authorities, and therefore selected for modeling in Phase 1 of the (EA).

Integrated Science Program (ISP) – The component of the MRRP that is responsible for conducting scientific monitoring and investigations. The ISP monitors federally listed species under the Endangered Species Act (ESA), the habitats upon which they depend, and researches and monitors critical uncertainties.

Interests (interest area) – In MRRIC, the interest areas are categories of values that people have said are important (e.g., agriculture, hydropower, cost).

Implement – Implementation of the selected alternative.

Implementation level (or Level) – Refers to one of four classifications of action that could be implemented to assist pallid sturgeon as part of the MRRP (see also *Pallid Sturgeon Framework*). The levels include the following:

- **Level 1: Research** – Studies without changes to the system (laboratory studies or field studies under ambient conditions).
- **Level 2: In-river testing** – Implementation of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response.
- **Level 3: Scaled implementation** – A range of actions not expected to achieve full success, but which yields sufficient results in terms of reproduction, numbers, or distribution to provide a meaningful population response and indicate the level of effort needed for full implementation.
- **Level 4: Ultimate required scale of implementation** – Implementation to the ultimate level required to remove an issue.

Investigations – Research activities that are intended to generate information that will fill the key gaps in understanding and reduce uncertainty associated with implementation of management actions.

Jeopardy – As defined by the Endangered Species Act (ESA), jeopardy occurs when there is an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Limiting factor – A factor that controls the growth, abundance, or distribution of an organism. For example, factors that limit the survival of terns, plovers, and pallid sturgeon have been identified and serve to identify and organize potential management actions.

Lower Missouri River – The reach of the river downstream of Gavins Point Dam (RM 810) as it pertains to management for pallid sturgeon.

Management actions – Proposed or potential actions to be taken by theUSACE to address species needs on the Missouri River. Management actions were prescribed by the USFWS 2003 Amended Biological Opinion as Reasonable or Prudent Alternatives or actions outside the BiOp if necessary to achieve species objectives.

Management hypotheses – Statements (in affirmative hypothesis form) that a specific management action will be effective in eliminating factors that are thought to be limits to population growth.

Missouri River Recovery Management Plan (MRRMP; also MRRMP-EIS or Management Plan) – A suite of management actions that avoids jeopardizing the continued existence of piping plovers, interior least terns, and pallid sturgeon, thereby permitting the continued operation of the Missouri River reservoir System and the Bank Stabilization and Navigation Program (BSNP). It includes actions proposed by the Missouri River Recovery Implementation Committee, and complies with the National Environmental Policy Act (NEPA) and other statutory mandates, regulatory requirements, and authorizations. MRRMP may also refer to the 3-year process to programmatically evaluate the MRRP and develop a suite of actions that meet ESA responsibilities. The Management Plan or MRRMP-EIS are umbrella terms that include the MRRMP, the Environmental Impact Statement (EIS), and the AM Plan.

Means objectives – Describe ways of achieving the fundamental objectives and specify the way and degree to which the fundamental and sub-objectives can be achieved. They are used to further develop management actions and alternatives and are potentially useful in tracking progress towards fundamental objectives in the near-term when a response in the fundamental objectives may not be detectable in shorter time frames due to a delayed species response to management actions or other reasons.

Monitoring – In the context of the MRRP AM Plan, monitoring is the process of measuring attributes of the ecological, social, or economic system. Monitoring has multiple purposes, including: to provide a better understanding of spatial and temporal variability, to confirm the status of a system component, to assess trends in a system component, to improve models, to confirm that an action was implemented as planned, to provide the data used to test a hypothesis or evaluate the effects of a management action, and to provide an understanding of a system attribute that could potentially confound the evaluation of action effectiveness.

MRRP Adaptive Management Plan – The purpose of this Adaptive Management (AM) Plan is to describe a formal AM process led by the USACE and USFWS in implementing the Missouri River Recovery Program (MRRP or Program).

National Environmental Policy Act (NEPA) – Requires Federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet NEPA requirements, Federal agencies may be required to prepare an EIS.

Naturalization of the flow regime – Naturalization of the flow regime involves incremental changes that move the flow regime towards the hydrological attributes that would exist in the absence of dams and reservoirs, while recognizing social and economic constraints. It does not mean matching the unaltered, historical flow regime. Generally, naturalization refers to the process of using characteristics of the natural ecosystem to guide elements of river restoration, but constrained by social and economic values (Rhoads et al. 1999; Jacobson and Galat, 2008).

No-action alternative – When addressing on-going programs, the Council on Environmental Quality defines no action as “no change” from current management direction or level of management intensity. The MRRP No Action Alternative, therefore, may be thought of as continuing with the courses of action being executed at the time the Notice of Intent for the EIS was published.

Objectives – Objectives define an endpoint of concern and the direction of change that is preferred. Objectives are concise statements of the interests that could be affected by a decision — the “things that matter” to people. In PrOACT, objectives typically take a simple form such as minimize costs and increase population number, increase habitat availability.

Pallid sturgeon framework– An organization of Missouri River pallid hypotheses that allows for the description of activities (research to management actions), decision criteria, uncertainty, risk, impacts, costs, time frame, and constraints.

Passive adaptive management – In passive AM, management actions are focused on achieving resource objectives; development of knowledge through monitoring and assessment for improved decision making is secondary.

Performance metric – A specific metric or quantitative indicator that is monitored and can be used to estimate and report consequences of management alternatives with respect to a particular objective. There are specific species, habitat, and economic performance metrics in this Adaptive Management Plan.

Preferred alternative – The preferred alternative is the alternative that the agency believes would best fulfill its statutory mission and responsibilities, giving consideration to economic, environmental, technical, and other factors.

PrOACT decision-making model – An organized, structured decision-making approach to identifying and evaluating creative options and making choices in complex decision situations. PrOACT is a decision analysis approach currently employed by the USACE in the development of the Missouri River Recovery Management Plan. It is a technique used to provide analytical structure and rigor to values-based questions by clarifying the consequences of alternate solutions, including the impacts on multiple objectives. The unifying features of PrOACT analyses are that they involve: (1) clarifying the Problem to be solved, (2) listing Objectives to be considered (usually with associated performance metrics), (3) developing Alternative solutions to the problem as stated, (4) estimating the Consequences of each of the alternatives on each of the objectives in terms of the metrics (usually in the form of a consequence table of alternatives versus objectives) and (5) explicitly evaluating the Trade-offs that are revealed to exist between the alternatives, usually in a discursive setting.

Problem – A question or concern that is being addressed in the decision-making process.

Program – The “Program” refers to those elements that are at the level of the overall Missouri River Recovery Program such as the Work Plan and the Program Management Plan.

Project Implementation Report (PIR) – Contains site-specific information, alternative designs and project features, the anticipated benefits of the project, and documentation for compliance with the National Environmental Policy Act (NEPA) disclosing the potential affects to the quality of the human environment from project implementation.

Proxy metric – Type of performance metric. Generally, a proxy metric is an indirect metric used to represent a natural metric like population number (e.g., number of boat ramp days). Proxy criteria are those that correlate well with objectives that are otherwise difficult to measure or estimate.

Quantitative predictive models – Numerical models used to predict biological and ecological responses as a function of management or restoration actions.

Recovery plan - A document drafted by the Service or other knowledgeable individual or group that serves as a guide for activities to be undertaken by Federal, state, or private entities in helping to recover and conserve endangered or threatened species.

Risk – An uncertainty coupled with an adverse consequence, ideally expressed as the product of the two components, with uncertainty represented as a probability.

Section 7 - The section of the Endangered Species Act that requires all Federal agencies, in "consultation" with the Service, to ensure that their actions are not likely to jeopardize the continued existence of listed species or result in destruction or adverse modification of critical habitat.

Selected alternative – the alternative identified in the ROD that the agency intends to implement

Spawning habitat – Functional spawning habitat produces a successful hatch of embryos. For successful hatch to take place, hydraulics and substrate must be conducive first to attraction and aggregation of reproductive adults, followed by egg and milt release, fertilization, and deposition of eggs in a protected environment.

Species objectives – see fundamental and means objectives.

Strategy table – A visual tool for combining management actions into thoughtfully crafted alternatives.

Structured Decision Making (SDM) – Organized approach to identifying and evaluating creative options and making choices in complex decision situations. It is used to inform difficult choices, and to make them more transparent and efficient. PrOACT is a specific application of SDM to collaborative problem solving.

Sub-objectives – The sub-objectives are aspects of the fundamental objective described in more detail that need to be addressed to achieve the fundamental objective. They are intended to provide direction in the short term, provide objectives meaningful for adaptive management, and focus efforts on the desired short-term outcomes while contributing to the fundamental objective.

Success criteria – A qualitative or (preferably) quantitative description of the conditions for which the parties agree that the objectives have been sufficiently met. Usually expressed in terms of the performance metrics.

Target – Targets are a specific value or range of performance metric that define success. Targets can be quantitative values or overall trends (directional or trajectory).

Trade-offs (also Trade-off analysis) – A trade-off occurs when one alternative performs well on one metric but poorly on another relative to another alternative. Reasonable people may disagree about which is the best alternative because they value the two metrics differently; thus, value trade-offs involve making judgments about how much you would give up on one objective in order to achieve gains on another objective. By analyzing trade-offs, the PrOACT process tries to help find the alternative that (1) eliminates unnecessary trade-offs and (2) that people agree is the "best balance" of trade-offs possible.

Trigger – A form of decision criteria serving as a threshold or condition that, when met, initiates some action or decision.

Uncertainty – Circumstances in which information is deficient. Leaning while doing under the adaptive management process provides a framework for reducing program uncertainties over time.

Upper Missouri River – Mainstem of the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea, and the Yellowstone River for an unspecified distance upstream of the confluence with the Missouri River.

Variability – A measure of how much a set of conditions differs from the mean or median state.

Work Plan (also Strategic Plan) – A rolling, 5-year plan outlining the management actions, monitoring, assessment, research, and engagement needs for the MRRP. It includes the details for the current FY and the FY+1 President's Budget (P-bud) and planned activities for FY+2 through FY+4 for budgeting and other purposes.

Working dominant hypotheses – Set of plausible, biologically important hypotheses, relevant to population dynamics of pallid sturgeon. Derived from importance values in conceptual ecological model, scored by expert elicitation survey.

Working management hypotheses – Set of management hypotheses linking management actions to working dominant hypotheses. Derived from pathways identified in conceptual ecological models and matched to working dominant hypotheses. Scored by expert elicitation survey.

Executive Summary

Note: An executive summary for Version 5 of the Draft AM Plan was prepared for the MRRIC (AMPV5 Summary, 2016). It targeted those not involved in day-to-day implementation of the program. Chapter 1 of this document serves as a summary of the AM Plan for agency personnel and others involved in its implementation. An executive summary will be prepared and included in the Final AM Plan.

1 Introduction

> **Note:** This is a draft document and is subject to change. Further revision will occur in conjunction with the Draft MRRMP-EIS.

1.1 Overview, background and context

1.1.1 Overview

This introductory chapter serves as an executive summary, provides a guide to the content of the Missouri River Recovery Program (MRRP or “the Program”) Science and Adaptive Management Plan (AM Plan), outlines the content of subsequent chapters and attachments, and summarizes the key points and concepts in each. Chapter 1 serves as an executive summary and provides context to the individual chapters and attachments. Parties intending to focus on only those sections of the document most relevant to their interests should review this chapter to obtain that context. Chapter 2 describes the organizational structure and decision processes for the governance of the AM Plan. Subsequent chapters focus on the plan elements addressing the listed species (Chapters 3 and 4), stakeholder interests (Chapter 5), and describe plans for data management, reporting, and communications (Chapter 6).

The final AM Plan that accompanies the Record of Decision (ROD) will be in a modular format so that individual sections can be extracted and used to guide implementation of the MRRP. Periodic updating of sections is expected, particularly in the first several years of implementation as knowledge of what is needed for efficient and effective operation is better understood. A lesson from the handful of existing AM programs for large-scale ecosystem efforts is the need for early adjustments to the decision process, decision criteria, monitoring programs, data management, and reporting and communications practices. A process that demands self-evaluation, external review, and periodic assessment of potential change is warranted, and agencies and stakeholders must seek and embrace the changes needed to ensure the program’s success.

1.1.2 Missouri River Recovery Program (MRRP)

The Missouri River (

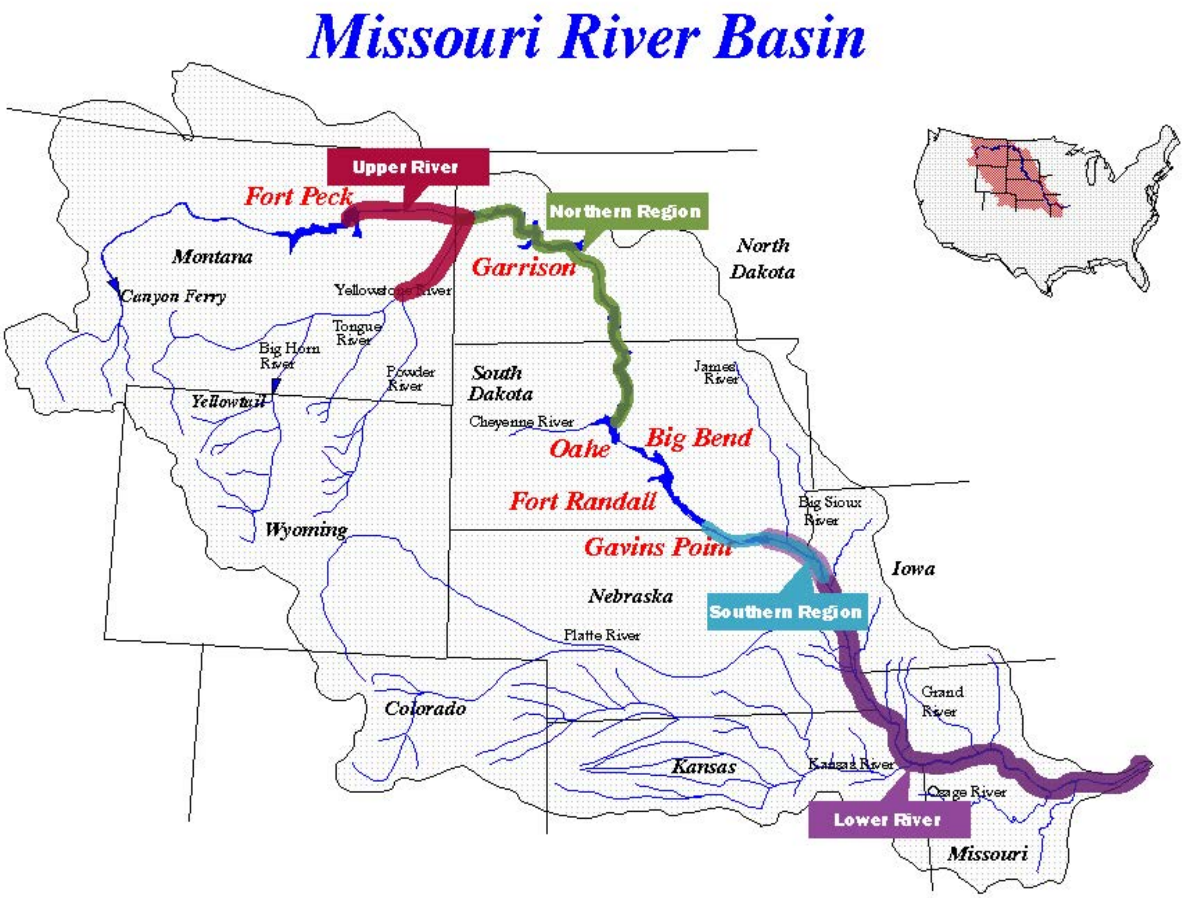


Figure 1) was significantly altered in the nineteenth and twentieth centuries, including the congressionally-authorized construction of six large reservoirs in Montana, North Dakota, and South Dakota that constitute the Missouri River Mainstem Reservoir System (System). The System is operated by the U.S. Army Corps of Engineers (USACE) for multiple purposes, including flood control, hydropower, navigation, water supply, irrigation, water quality, recreation, and fish and wildlife. Downstream of Sioux City, IA, the river was channelized, revetted, and trained to provide a self-scouring navigation channel. The USACE constructed, operates, and maintains this 1200-kilometer (km) (735-mile) reach of the river under the Bank Stabilization and Navigation Project (BSNP).

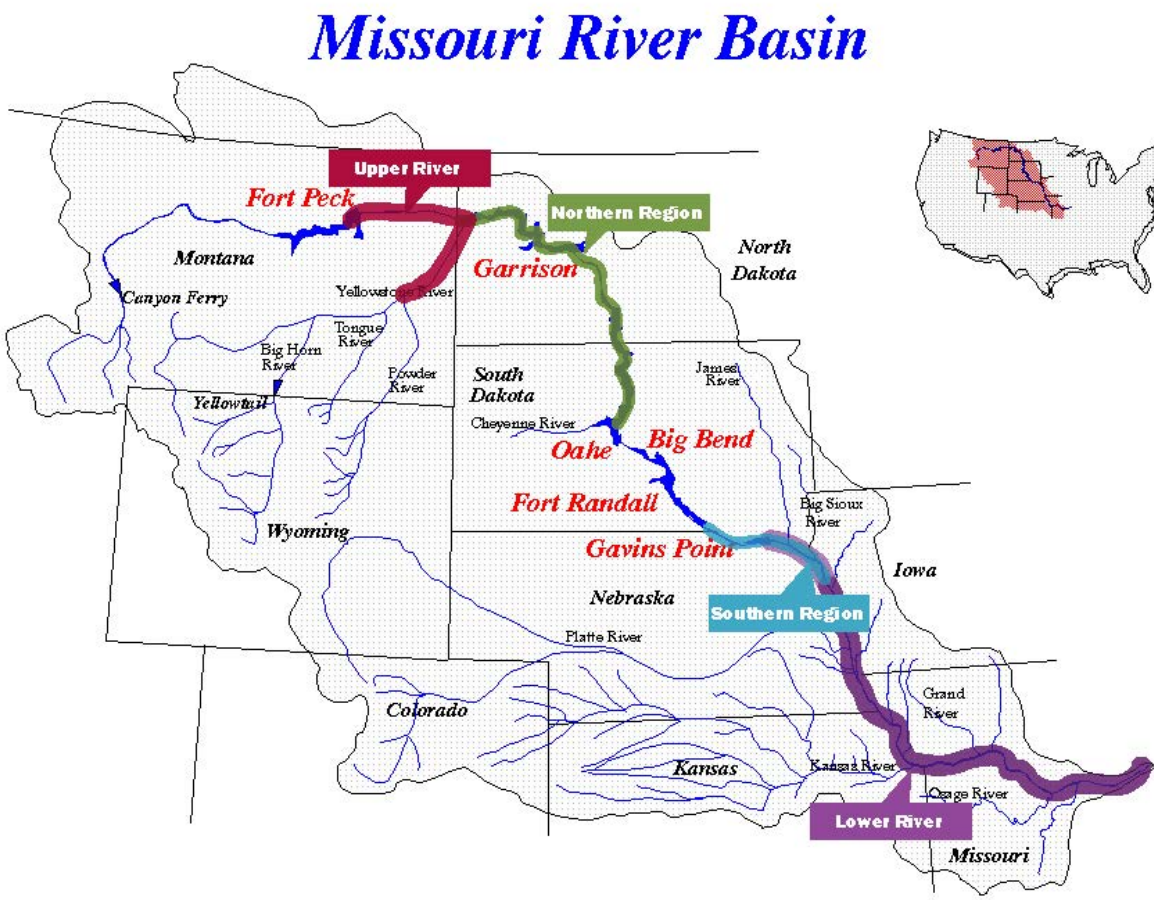


Figure 1. Missouri River Basin showing upper and lower river reaches for pallid sturgeon and northern and southern regions for the piping plover. System reservoirs labeled in red.

Substantial changes in flow and sediment loads due to the System, coupled with the physical alteration associated with the reservoirs and the BSNP, are manifest in changes to the river's channel and floodplain habitats. The river has been reduced in length by almost 320 km (200 miles), and as much as 12,000 km^2 (~4600 $miles^2$) of river-corridor habitats have been lost (National Research Council, 2002; USACE, 2004; Galat et al. 2005). These changes to and losses of habitat have impacted native flora and fauna using the system, including three federally-listed species: the pallid sturgeon (*Scaphirhynchus albus*), interior least tern (*Sternula antillarum athalassos*), and the piping plover (*Charadrius melodus*) (U.S. Fish and Wildlife Service [USFWS] 2000).

The U.S. Fish and Wildlife Service (USFWS) issued a Biological Opinion (BiOp) in 2000 (see Figure 2 for an abbreviated event timeline) that found the USACE operation of the System and the operation and maintenance of the BSNP would jeopardize the continued existence of the pallid sturgeon, interior least tern, and piping plover (USFWS 2000[1]). This 2000 BiOp, which applies to the portion of the Missouri River from Fort Peck, MT, to St. Louis, MO, and identified a Reasonable and Prudent Alternative (RPA) to jeopardy consisting of several actions to be taken by the USACE. New data were obtained regarding terns and plovers and RPA II (Flow Enhancement), and the USACE requested re-initiation of formal consultation and provided a biological assessment with new proposed actions to replace the spring and summer flows element.

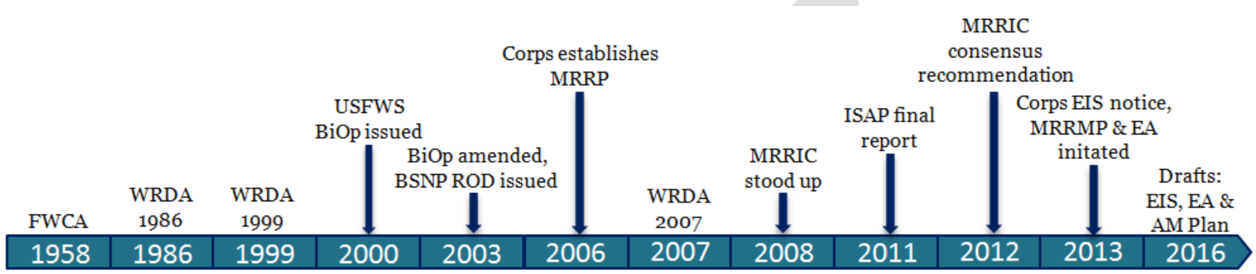


Figure 2. Summary timeline of key events leading to this draft AM Plan,

In 2003, the USFWS provided a determination that the additional actions proposed by the USACE would avoid jeopardizing the continued existence of the two listed bird species, but continued to appreciably reduce the likelihood of both survival and recovery of the pallid sturgeon, thus jeopardizing its continued existence in the wild (USFWS 2003; see Figure 2). The 2000 opinion and 2003 amendment (the USFWS 2003 Amended Biological Opinion) are collectively referred to in this report as “the BiOp.”

The BiOp also called for development of an Adaptive Management (AM) framework for resource management actions on the Missouri River, acknowledging critical uncertainties about how the Missouri River system functions and how species will respond to implemented management actions. For example, the 2003 Amended BiOp noted uncertainties about the effects of the timing, magnitude, and rate of change of releases from Gavins Point Dam on pallid sturgeon survival and that “*adaptive management is intended to address this kind of uncertainty*.” Given the uncertainties faced by the MRRP, AM provides a structured, organized, coherent, and transparent process that assesses and evaluates management actions in relation to program objectives so the program can make adjustments, as needed, to increase the likelihood of achieving desired outcomes.

The USACE established the MRRP in 2006 to implement the requirements of the BiOp and restore a portion of the Missouri River ecosystem and habitat for fish and wildlife,

[1] Please see these documents for a more nuanced and detailed discussion of the findings.

while maintaining the congressionally-authorized uses of the river. The MRRP consisted of the following main elements:

- construction of Emergent Sandbar Habitat (ESH) for the birds and Shallow Water Habitat (SWH) for pallid sturgeon and development and connection of low-lying lands to benefit pallid sturgeon
- changes to releases from the reservoirs
- research, monitoring and evaluation, and AM of the management actions through an Integrated Science Program (ISP)
- acquisition of lands through the BSNP Fish and Wildlife Mitigation project, of which 100,000 acres were directly related to the listed species
- public involvement.

Section 5018 of the 2007 Water Resources Development Act (WRDA) established the Missouri River Recovery Implementation Committee (MRRIC), an assemblage of stakeholders representing local, state, tribal, and Federal interests throughout the Missouri River Basin, to make recommendation and provide guidance on MRRP activities. The MRRIC was stood up in 2008 and is guided by its charter and operating procedures and ground rules (see Attachments 1 and 2). The USACE and MRRIC are assisted by an Independent Science Advisory Panel (ISAP or Panel) and an Independent Social Economic Technical Review (ISETR) Panel, which afford technical oversight by providing advice on specific topics identified by the agencies and/or MRRIC.

The first set of topics presented to the ISAP dealt with expected outcomes from managed spring pulse releases from Gavins Point Dam; metrics, monitoring, investigations, and management actions; and AM. In their 2011 final report, the ISAP noted that "*there is not a comprehensive adaptive management plan for the recovery program or for other recovery program components, all of which are interconnected in their cumulative and interactive effects*" (Doyle et al. 2011). They suggested that such a plan would contain essential components of any sound AM program, including monitoring to collect the data necessary for evaluating management actions; a process to evaluate past and guide future management actions using established performance metrics and decision criteria; and a means to define success or failure. The ISAP also noted that the development of an AM plan should be preceded by and based upon an effects analysis (EA; see Section 1.1.4) that incorporates new knowledge that has accrued since the 2003 Amended BiOp was issued (Doyle et al. 2011). An important component of an EA as outlined by Murphy and Weiland (2011) is the development of an analytical framework that supports quantification of the effects of alternative management plans upon the demographics for the species of interest. This nominally requires population models for the species supported by models of the habitat and other factors affecting those demographics (see Section 1.1.5).

The BiOp also called for development of an AM framework for resource management actions on the Missouri River, acknowledging critical uncertainties about how the Missouri River system functions and how species will respond to implemented management actions. For example, the BiOp pointed out uncertainties about the effects of the timing, magnitude, and rate of change of releases from Gavins Point Dam on pallid sturgeon survival, noting that "*adaptive management is intended to address this kind of uncertainty*." Adaptive management provides a structured, organized, coherent, and transparent process to assess, evaluate and adjust management actions in relation to program objectives to increase the likelihood of achieving desired outcomes (see Section 1.1.6).

In August 2012, the MRRIC made a consensus recommendation to the USACE, which was based upon the ISAP's report, and included seven proposed actions:

1. An EA should be developed that incorporates new knowledge that has accrued since the USFWS 2003 Amended Biological Opinion. As part of this analysis the following should be observed:
    a. The effects of the Missouri and Kansas River Operations on the three listed species should be reviewed and analyzed in the context of other stressors on the listed species.
    b. The quantitative effects of potential management actions on the three listed species should be documented to the extent possible.
    c. These potential management actions should be incorporated into the Conceptual Ecological Models (CEMs).
2. CEMs should be developed for each of the three listed species, and these models should articulate the effects of stressors and mitigative actions (including but not limited to flow management, habitat restoration actions, and artificial propagation) on species performance.
3. Other managed flow programs and AM plans should be evaluated as guidance in development of the CEMs and the AM strategy for the MRRP.
4. An overarching adaptive management strategy should be developed that anticipates implementation of combined flow management actions and mechanical habitat construction, and this strategy should be used to guide future management actions, monitoring, research, and assessment activities within the context of regulatory and legal constraints.

5. Monitoring programs along the Missouri River should be designed so as to determine if hypothesized outcomes are occurring and the extent to which they are attributable to specific management actions.
6. The agencies should identify decision criteria (trigger points) that will lead to continuing a management action or selecting a different management action. A formal process should be designed and implemented to regularly compare incoming monitoring results with the decision criteria.
7. Aspects of how the entire hydrograph influences the three listed species should be evaluated when assessing the range of potential management actions.

The USACE and USFWS agreed to implement these consensus recommendations collaboratively with MRRIC to arrive at a new management plan for the MRRP while (a) using a “structured effects analysis” as proposed by Murphy and Weiland (2011), (b) employing an AM framework, and (c) abiding by the requirements of the National Environmental Policy Act (NEPA). The resulting process, summarized schematically in Figure 3 and described in further detail below, led to the development of this AM plan.

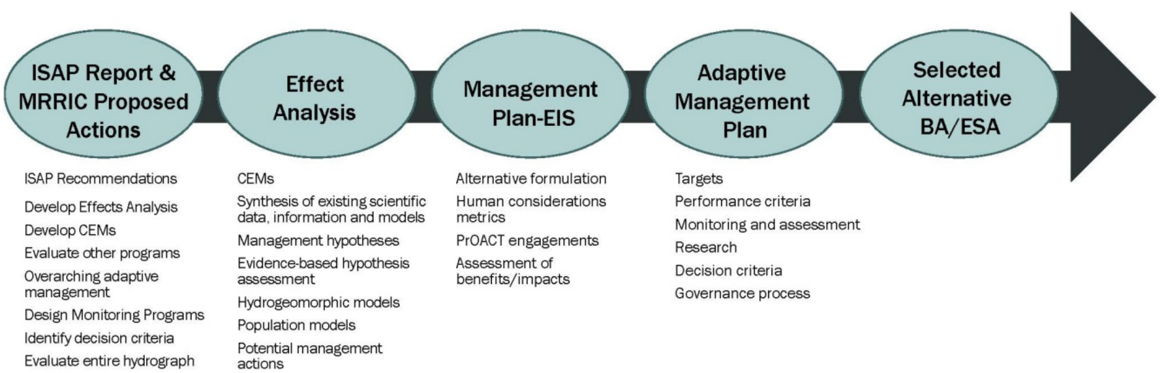


Figure 3. Schematic of the process leading to development of the draft MRRMP-EIS and this draft AM plan. The AM Plan will be revised, as needed, prior to issuance of a record of decision (ROD).

The USACE published a notice in the Federal Register in August 2013 to prepare an Environmental Impact Statement (EIS) for the MRRP and initiated the Missouri River Recovery Management Plan (MRRMP), a multi-year planning effort to evaluate alternatives to avoid jeopardy to the listed species in light of the findings of the EA. The MRRMP-EIS provides a programmatic assessment of the MRRP including its impacts, cumulative effects, and alternatives to accomplish the purposes of the ESA (primarily Section 7), the 1958 Fish and Wildlife Coordination Act, section 601(a) of WRDA 1986, section 334 (a) and (b) of WRDA 1999, and section 3176 of WRDA 2007. The MRRP used the best available science from the EA to develop the integrated MRRMP-EIS and identify a suite of actions that meets ESA responsibilities for the federally listed species using Corps' authorities (see Section **Error! Reference source not found.**).

1.1.3 Purpose and scope of the MRRP

The purpose of the MRRP is to enable the USACE to operate the Missouri River System (main stem reservoirs and BSNP), in accordance with the Missouri River Master Water Control Manual, to meet its authorized purposes without jeopardizing the continued existence of three species (piping plover, least tern, pallid sturgeon) listed under the Endangered Species Act (ESA). The MRRP is the Corp's umbrella program for the following:

- compliance with the USFWS 2003 Amended BiOp on the operation of the Missouri River Main Stem Reservoir System (System), operation and maintenance of the BSNP, and operation of the Kansas River Reservoir System
- acquisition and development of lands as authorized by Section 601(a) of WRDA 1986 and modified by Section 334(a) of WRDA 1999 (aka, the BSNP Fish and Wildlife Mitigation Project)
- implementation of Sections 3176 and 5018 of WRDA 2007, extending recovery and mitigation activities on the Missouri River to the upper basin states.

The MRRP is currently focused on implementing the requirements of the USFWS 2003 Amended Biological Opinion and is structured into several unique components including the following:

- construction of Emergent Sandbar Habitat (ESH) for the birds and Shallow Water Habitat (SWH) with development and connection of low-lying lands to benefit pallid sturgeon
- propagation and hatchery support for the pallid sturgeon
- research, monitoring and evaluation, and adaptive management of management actions through an Integrated Science Program (ISP)
- public involvement

The ESA requires consultation with USFWS in the event that an agency's action may affect a listed species. The MRRMP-EIS is meant to serve as the basis for consultation under the act and the development of the MRRMP-EIS, in coordination with USFWS, is intended to result in a suite of actions that will avoid a jeopardy determination and be implementable within the scope of the Corps' legal authority and jurisdiction. The USFWS provided fundamental objectives, sub-objectives, targets, and metrics for each of the three listed species pursuant to their responsibilities for administering the ESA, and their jurisdiction and their special expertise as a cooperating agency on the

MRRMP-EIS. Achieving these objectives would meet the purpose and fulfill the need of the plan.

The need to acquire and develop riparian and aquatic habitat on 166,750 acres of land, as authorized by Section 334 of WRDA 1999 and recommended and described in the 2003 ROD (2003 ROD) for the BSNP Mitigation Project, is considered still relevant and remains unchanged. Implementation of the mitigation project was expected to take more than 30 years, but an annual rate of implementation was not specified given budget uncertainties. Due to current and anticipated Assistant Secretary of the Army (ASA) budget priorities, it is assumed that land acquisition over the implementation timeframe for the MRRMP-EIS would continue to be focused on lands that can be used to meet endangered species objectives while also contributing to BSNP mitigation. The land acquisition and types of habitat development as described in the 2003 ROD are still considered to be adequate and reasonable to mitigate the effects of the BSNP and are recognized in all the alternatives described in the EIS. Habitat development would be implemented on any acquired lands, which would be credited toward the BSNP mitigation requirements.

1.1.4 Effects Analysis (EA) and modeling framework for the MRRP

The concept of an EA is rooted in the requirement within the ESA to use the best available science when evaluating the effects that actions proposed by federal agencies may have on listed species or designated critical habitat. Murphy and Weiland (2011) advocated for a rigorous approach to an EA that begins with a definition of the proposed action and the area affected. A conceptual model (or models) of the physical and biological relationships relating the action(s) to species outcomes is prepared. Available scientific information, including observations about the stressor and the range of stressor conditions and information on population sizes and trends, is collected and assessed for reliability. The next step includes assessment of the data, using quantitative models to integrate existing information, and identifying and representing uncertainties. The final step is to analyze the effect of proposed actions on the species to determine costs and benefits and to identify alternatives.

The USACE adopted the ISAP's recommendations and MRRIC's corresponding proposed actions regarding the EA, and contracted with an independent team to execute the effort in August, 2013 (see Figure 2). The primary and relevant products of the EA are summarized in a series of reports and embodied in a suite of models. Products of the EA include the following:

- Conceptual Ecological Models (CEMs) (Jacobson et al. 2015; Buenau et al. 2015)

- synthesis of existing models and scientific data/information reflecting the state of science for the species and their habitats (Jacobson et al. 2015; Buenau et al. 2015; Fischenich et al. 2015)
- hypotheses addressing critical uncertainties (Jacobson et al. 2015; Buenau et al. 2015)
- models of reservoir operations and hydraulic conditions (Fischenich et al. 2015), habitat availability (Jacobson et al. 2015; Buenau et al. 2015; Fischenich et al. 2015), and species demographics (Jacobson et al. 2015; Buenau et al. 2015)
- a variety of other papers, reports, methodologies, etc., supporting the development of species targets, management actions and alternatives, and an AM plan.

A crucial component of the EA as outlined by Murphy and Weiland (2011) is the development of an analytical framework that supports quantification of the effects of alternatives upon the demographics for the species of interest. This nominally requires population models for the species supported by models of the habitat and other factors affecting those demographics.

A modeling framework advanced for the EA (Fischenich et al. 2014) and later applied to the MRRMP-EIS is shown in Figure 4. The framework includes a suite of hydrologic, hydraulic, and system operation models that feed critical habitat and population models for each species as well as provides needed input to a wide array of algorithms and models for assessing human considerations (HC) effects. The framework includes models to address economic considerations and structured decision input.

The model types shown in Figure 4 should be regarded as categories of models or as model codes; in all, more than 25 individual quantitative models have been developed to support the combined needs of the EA and MRRMP-EIS. None of these models is stand-alone; in some way, each model serves to support another modeling need or is reliant upon other models for inputs. The specific models used in the framework and their roles in supporting AM are discussed in later chapters of this plan and in the appendices. Separate manuscripts for those models are also under development. Reports detailing the HEC-RAS and ResSim models have been prepared and used for various model reviews (references needed). All of the models have some source of uncertainty; the magnitude and significance of that uncertainty varies, of course, and an important aspect of the AM Plan is to work to improve the models and reduce uncertainty where doing so may result in better decisions.

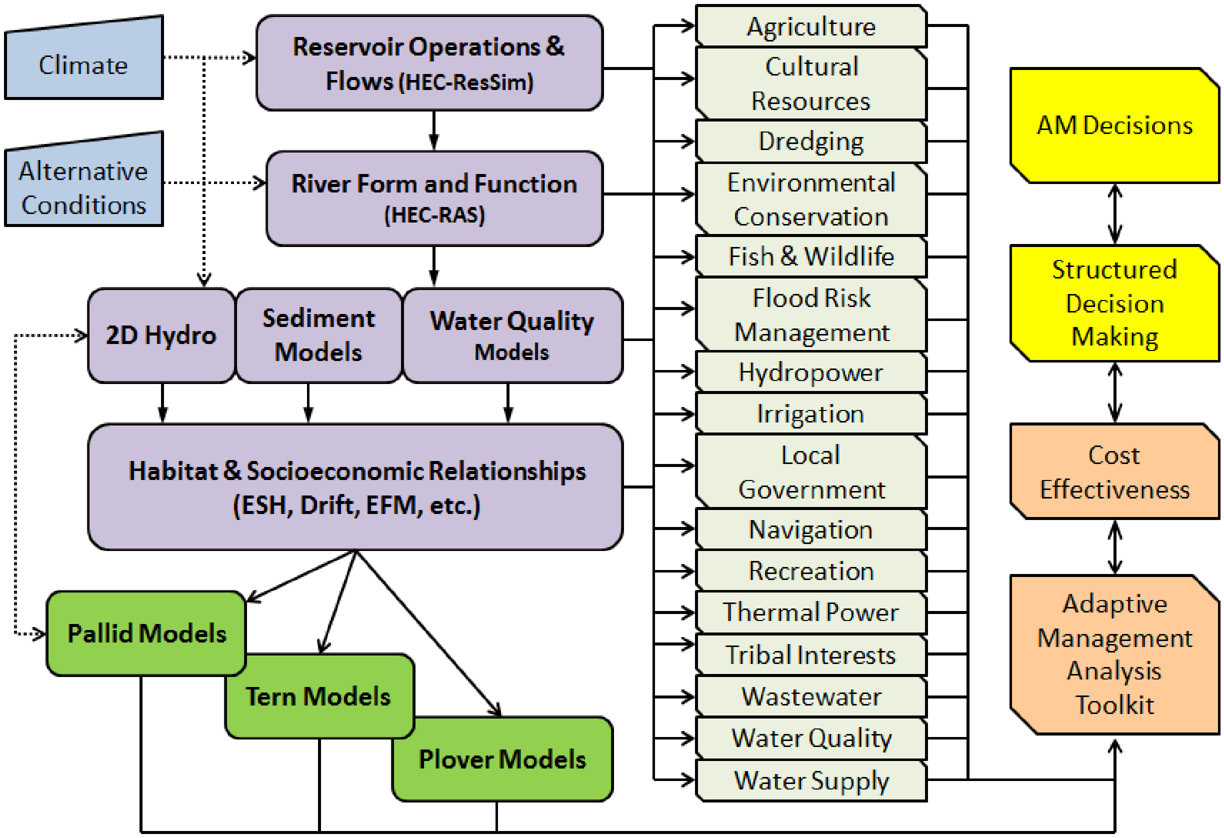


Figure 4. Model framework for the MRRP.

One logical extension of the EA models included projections of habitat availability and population response for various conditions to support alternative assessments and to develop species/habitat targets under the MRRMP-EIS. Another extension was the development of strategies to address the uncertainties and hypotheses identified as part of the EA, including the science, monitoring, and assessment activities identified in this AM plan. These products evolved through interactions among the EA team, the MRRMP Product Delivery Team (PDT), the ISAP, ISETR, the Independent Social Economic technical Review Panel (ISETR), and MRRIC and its committees.

The model framework is indispensable to the MRRP's implementation under AM. As described in detail in Chapters 3 through 5, models are applied in the plan and design phase of AM to determine where, when, and how the various management actions are used to meet objectives. The models are again applied in the evaluation phase to assess the implications of observed performance (population response due to monitored habitat changes) and determine management needs (using model projections of habitat and population for alternative management actions). The models are used to consolidate information, predict outcomes, quantify performance, and provide information needed by decision makers determine the best course of action under AM.

1.1.5 AM and decision-making concepts

At its most basic level, AM has been described as doing, learning, and adjusting. In another simplified characterization (Figure 5), the "doing" part has been expanded to include assessing (covered by the EA); planning, designing and implementing (Steps 1 and 2); the learning includes monitoring and evaluation (Steps 3 and 4); and in addition to adjustments (Step 5b), learning can lead to decisions to continue with implementation (Step 5c) or complete/terminate the action (Step 5a). Adjustment might involve implementing actions that have been previously assessed in the planning process (i.e., adaptive actions) that are triggered by decision criteria, or they may involve more intensive reformulation through the planning process. Central to a progressive AM program is the notion that learning is a primary objective, whether the issue is a balanced portfolio of activities at the program level or the implementation of a specific management action.

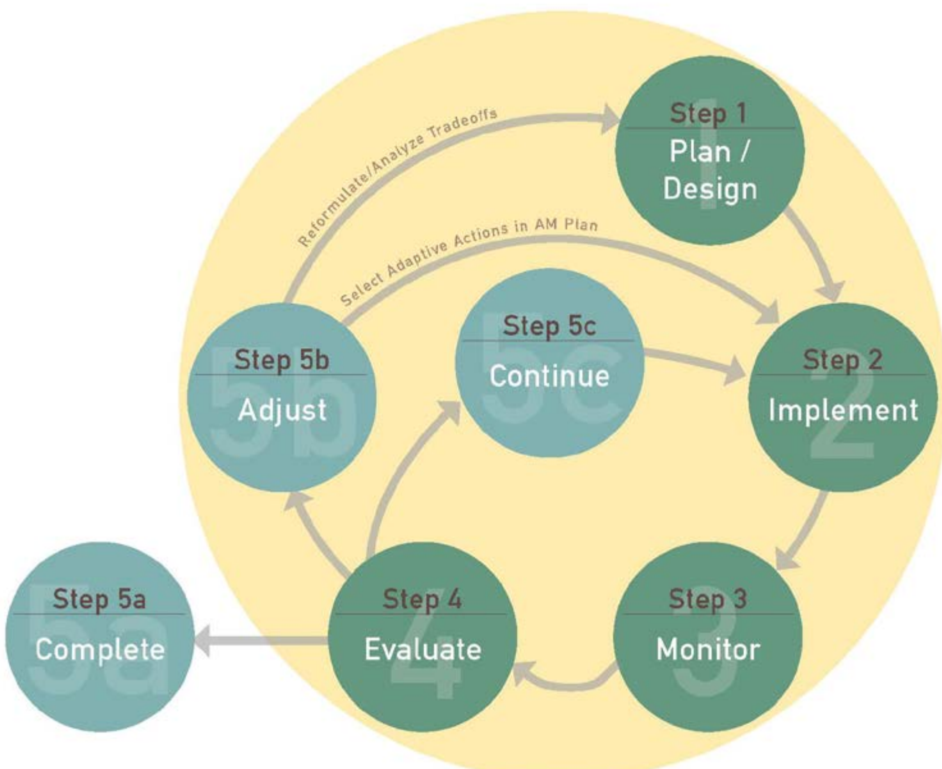


Figure 5. Simplified depiction of the AM process.

AM promotes collaboration, flexible decision-making through deliberately designing and implementing management actions to test hypotheses and maximize learning about critical uncertainties to better inform management decisions (Williams and Brown 2012). Collaborative AM is defined as "a systematic management paradigm that assumes natural resource management policies and actions are not static, but are adjusted based on the combination of new scientific and socioeconomic information. Management is improved through learning from actions taken on the ecosystem being affected. A collaborative AM approach incorporates and links credible science and knowledge with the experience and values of stakeholders and managers for more effective management decision-making" (Sims and Pratt-Miles 2011).

The MRRP AM Plan includes elements of both active and passive AM. Active AM emphasizes knowledge as an intermediate objective toward the fundamental objectives, and uses experiments or alternative management strategies to better understand system behavior (i.e., it is typically hypothesis-driven). The knowledge gained is fed back into the decision-making process, improving progress toward the fundamental objectives. Passive AM is strictly driven by fundamental objectives, considering learning gained through monitoring as secondary to the achievement of the fundamental objectives.

Establishing and implementing a formal monitoring and AM plan allows the USACE and USFWS to determine if the suite of actions being taken are meeting objectives and, if not, facilitates adjustments to those actions or or the identification of new actions that may be required. A collaborative governance process supported by clear objectives, decision criteria, and a science program aimed at quantifying performance while reducing critical uncertainties helps to ensure success.

1.1.6 Relationship between MRRMP-EIS alternatives and actions in the AM Plan

NEPA, in combination with the Council on Environmental Quality (CEQ) and USACE regulations, require the USACE to prepare an EIS evaluating the impacts of a proposed Federal action that will significantly affect the human environment. The EIS must rigorously explore and objectively evaluate all reasonable alternatives that meet the project's purpose and need. A thorough evaluation of the effects of alternatives on the human environment is required so that an informed decision can be made in selecting an alternative for implementation. Prior to alternative selection, the USFWS will be consulted in order to ensure the selected alternative avoids jeopardy to the species. Selection of an alternative will be formalized and documented in a ROD, which will be issued by the USACE following completion of the MRRMP final EIS.

The high level of uncertainty regarding the type and extent of management actions ultimately needed to meet the species objectives (especially for the pallid sturgeon) requires a robust AM plan, which presents a challenge in identifying definitive alternatives for NEPA evaluation. The approach used to address this situation was to develop alternatives that would be initially implemented (over approximately a 15-year timeframe) to begin the AM process. At the end of this timeframe, and potentially sooner, another NEPA process would be undertaken to assess any changes, due to AM or changes in the system, in the selected alternative that would be required to meet the ESA needs. The alternatives in the draft EIS are combinations of management actions derived from the EA findings and further screened based on effects to human considerations and discussions with MRRIC. Speculation regarding management actions that may be necessary to meet the species objectives beyond the 15-year timeframe was not considered in the MRRMP-EIS given the degree of uncertainty. However, effects of the alternatives were evaluated using were based on an 82-year hydrologic period of record in order to provide an indication of effects under the variable hydrologic conditions occurring in the Missouri River basin.

The Draft EIS (DEIS), released in December 2016 and accompanied by this AM Plan, evaluated six alternatives (see Attachment 3 of Appendix A) and identifies a Preferred Alternative. Research and related study activities needed to test hypotheses, including those hypotheses for which specific management actions have not yet been identified but may ultimately be required, are included in each alternative. These activities require little or no ground disturbance or changes to reservoir release and do not cause effects to the human environment. The research activities are thoroughly described the DEIS, the draft AM Plan, and its appendices, and are key components MRRP since any of the hypotheses from the EA (and potentially others not yet identified) may ultimately need to be addressed in order to meet the species objectives.

The AM Plan describes the following:

1. The activities anticipated to be undertaken to assess the effectiveness of actions implemented under the selected alternative,
2. The decision criteria used to determine if changes to management actions or to the selected alternative are necessary,
3. Research and study activities to address hypotheses for which specific management actions have not yet been identified, and
4. A governance process used to collaborate with stakeholders and make decisions.

The selected alternative, when one is identified in the ROD, will represent the agencies' best estimate of the initial set of actions needed to achieve the species objectives. The Final AM Plan will accompany the EIS and serve as the implementation plan for the selected alternative and the MRRP into the foreseeable future. The AM Plan identifies the process and criteria to implement the selected actions, assesses hypotheses, and introduces new actions should they become necessary. The USACE will develop its Biological Assessment (BA) on the basis of the MRRMP-EIS "package" including the selected alternative and the AM Plan. Upon incorporation into a decision document the

Final AM Plan will serve as the implementation plan for the selected action and the MRRP into the foreseeable future.

Establishing and implementing a formal monitoring and AM plan allows the USFWS to determine if the suite of actions being taken are meeting species objectives that would justify the removal or preclusion of a jeopardy determination, and if not, allows for adjustments to those actions or identification of new actions within an AM framework.

Because the AM process may ultimately indicate the need for actions that address hypotheses outside the scope of the selected alternative, a range of potential actions are discussed within this AM Plan. Figure 6 is a schematic showing that the management actions included in the Preferred Alternative are a subset of those in the AM Plan and considered in the MRRMP-EIS, which in turn are a subset of the management actions identified in the EA. The range of actions ultimately implemented could include those in any of the three categories in Figure 6 as well as actions not yet evaluated. However, the pathway to implementation, including required collaboration with MRRIC, additional NEPA analysis, public engagement, and other requirements depends upon the category in which the action lies (see Section 2.2.5). Only those actions that are part of the selected alternative, as described in the ROD, could be implemented without further requirements.

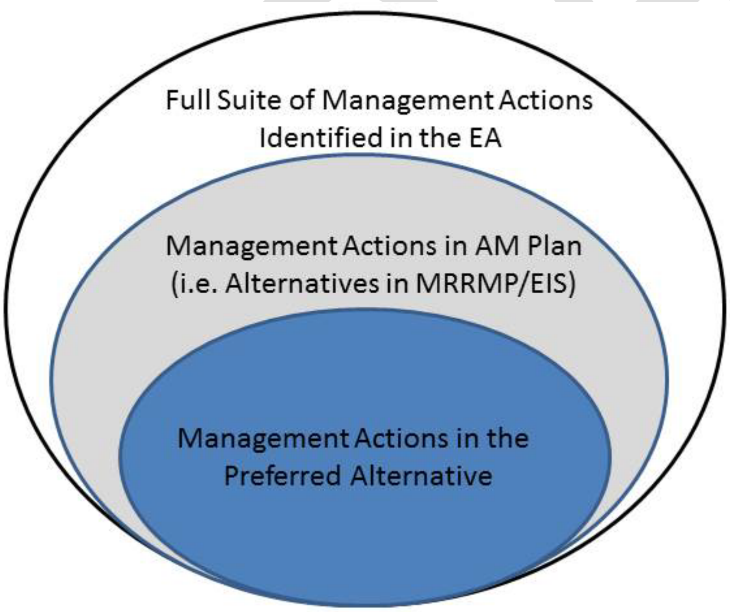


Figure 6. Schematic of management actions considered in the MRRMP-EIS, included in this AM Plan, and included in the selected alternative.

Due to the nature of the interrelated Federal actions on the Missouri River, the MRRMP-EIS employed a programmatic NEPA EIS, which enables the USACE to tier future project proposals from the overarching programmatic EIS analysis, helping to streamline future environmental reviews. CEQ regulations define tiering as covering "general matters" in policy or program EISs with subsequent tiered or narrower environmental analyses, while referencing the general discussion and focusing on the project-specific impacts important to the decision maker. This approach is well suited to the MRRP, as it integrates very well with AM. A programmatic EIS facilitates responsiveness when monitoring indicates change to Federal actions because objectives are not being met or new scientific understanding dictates alternative strategies, thus strengthening the implementation of the plan. Implementation of specific projects or management actions may require subsequent analysis that can be tiered from the EIS. If the AM process provides new and significant information that requires actions not included within the range of impacts and alternatives considered in this EIS, additional NEPA analysis will be required. These considerations are described further in Chapter 4 of the DEIS and in Section 2.4.5 of the AM Plan.

1.2 Adaptive Management (AM) governance

Chapter 2 addresses the governance of the MRRP AM Plan, including a description of what decisions need to be made, who would be involved in the decision-making process, how decisions would be made, and when they would be required. Effective systems of governance contribute to trust-building, knowledge generation, collaborative learning, understanding of preferences, and conflict resolution. The proposed governance structure and process for the MRRP is intended to achieve the program's aims and to promote collaboration among the lead agencies, MRRIC, and others, while maintaining the statutory decision-making responsibilities of each agency. While there are lessons to be learned from other programs, there is no one-size-fits-all strategy; governance of the MRRP needs to be designed for the MRRP, and be flexible enough to evolve as needed.

1.2.1 AM decision needs

Governance of the MRRP involves making decisions about topics ranging from highly technical considerations, such as the selection of monitoring sites and sample sizes, to policy- and value-laden issues, such as whether to adjust reservoir operations criteria. Major policy decisions are made by the Corps' Division and District Commanders—subject to their authorities and appropriations—with input from the USFWS, MRRIC, and the public, when appropriate. Some decisions are a joint USACE and USFWS function (e.g., changes to targets, decision criteria, or management actions). The MRRIC works closely with the USACE and USFWS (agency) leaders, providing input on a full range of decisions, and may provide consensus recommendations on any decision.

Section 2.2 describes the various decision needs, organized according to the AM cycle (Figure 5) and at three levels of responsibility: oversight, management, and implementation. Overlapping needs for the birds and fish are discussed in Section 2.2.2. Program activities generally focus separately on the species, as there are few synergistic or antagonistic effects from the proposed management actions due to the geographic and temporal differences in species life-cycle needs and the limited scope of the actions in the Preferred Alternative. However, decisions may be substantially affected by unpredictable (in the long-term) processes and conditions, such as basin runoff and the intermittent need to create ESH. Balancing species needs that differ over time requires ongoing analysis, planning, risk management, and flexibility, and may require acceptance that one or more objectives may not always be met.

Several processes external to the MRRP may impose important constraints on the timing of decisions, WP development, engagement and implementation of the MRRP (see Section 2.2.3). The most significant of these are the Corps' annual budget process for Civil Works and the development of the Annual Operating Plan (AOP) for the Missouri River Mainstem Reservoir System (System).

A recent study of judicial decisions on AM programs cited lack of decision criteria as one of three key deficiencies that could lead to overturning of agency practice by the courts (Fischman and Ruhl 2016). This AM Plan provides numerous decision criteria that indicate actions based on performance of preceding actions, System status, species populations, or results of hypotheses testing (see Section 2.2.4). New information or understanding can inform adjustments to decision criteria, targets, MRRP objectives, scope, or even MRRP governance structure and process itself (see Section 2.5).

Decision criteria are used in the MRRP to accomplish the following:

- define requirements for compliance purposes (e.g., ESA, NEPA, USACE policies)
- ensure that decisions incorporate best available science
- facilitate complex or time-sensitive decisions
- provide a clear(er) roadmap for participants (i.e., they define the decision space).

Section 2.2.5 discusses the NEPA EIS process and how it affects decisions related to the implementation of management actions. The MRRMP-EIS employed a programmatic NEPA EIS, which enables the USACE to tier future project proposals from the overarching programmatic EIS analysis. Site-specific NEPA assessments may be required in order to implement some elements of the Selected Alternative included in the ROD, while others with adequate coverage in the EIS will be fully implementable. Actions outside the ROD that may later be identified for implementation through the

AM process will require supplemental NEPA analysis and, if they involve flows, will require updating of the technical criteria in the Master Manual.

1.2.2 Program composition, roles, and responsibilities

As proposed in the AM Plan, governance starts with interagency teams working together, with the support of a Technical Team to interpret what has been learned to date and to apply that knowledge to future decisions. The Bird, Fish, and Human Considerations (HC) Teams, which include component MRRIC Work Groups (WGs) that provide expertise and perspective while also keeping the full MRRIC apprised of the teams' activities, propose management actions, monitoring, and assessment. The Management Team integrates the proposals from the Implementation Teams into a draft Work Plan (WP) that is reviewed by agency leadership and the MRRIC. Figure 7 shows the elements that make up the basic governance structure for the MRRP.

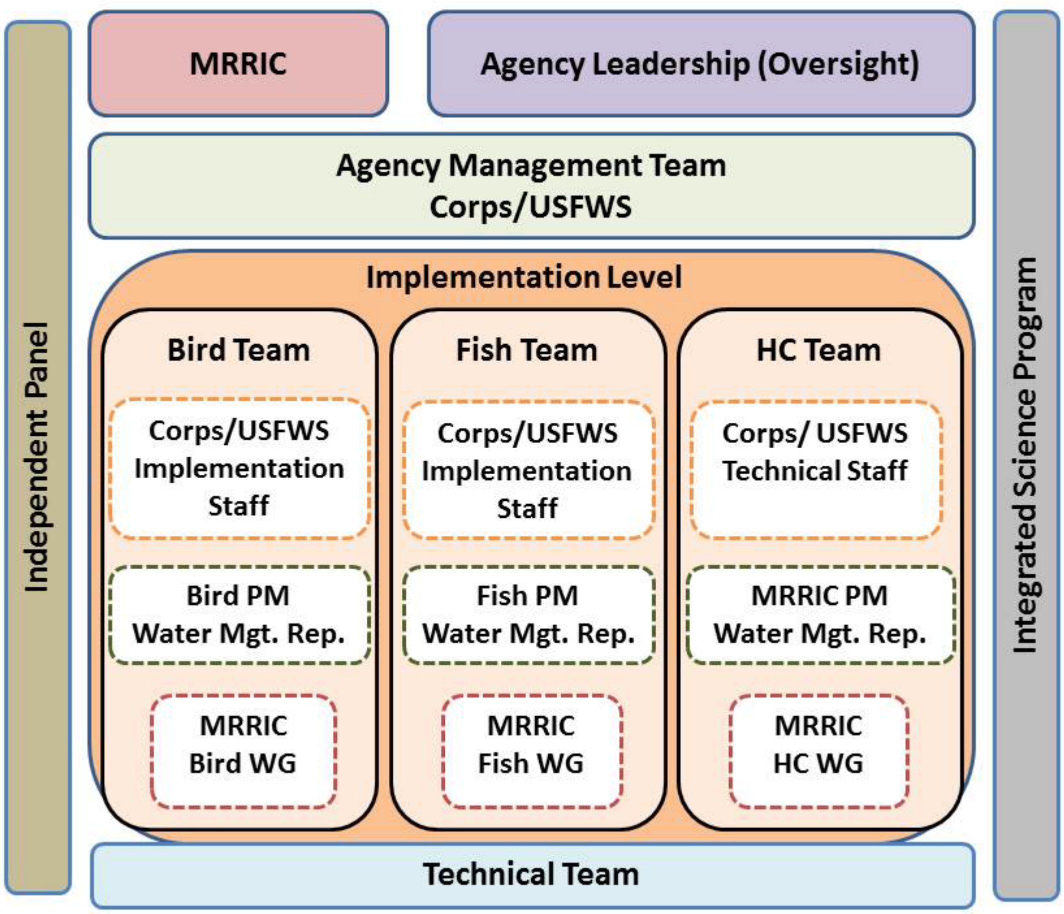


Figure 7. The proposed governance structure for AM of the MRRP.

A Technical Team patterned after the EA provides a non-decisional technical support function for the program (see Section 2.3.4). The Technical Team analyzes data, conducts studies, and generates information used by the other teams for developing decisions. The Technical Team includes subject matter expertise in ecology, biostatistics, hydrodynamics, fluvial processes, decision analysis, river operations, and socio-economics, and includes individuals with expertise and experience in assimilation and analysis of information related to plovers, pallid sturgeon, and the hydrogeomorphology of the Missouri River. Composition of the Technical Team may include Federal and state agency personnel, university professors, and contractors selected to address the underpinning science for the program. The Technical Team is overseen by the AM Program Manager (AM PgM) through the Integrated Science Program (ISP). Section 2.3.5 discusses the role of the ISP in overseeing much of the contracting and implementation of the research, monitoring, and assessment for the program. Attachent 14 of Appendix A provides details on the operation of the ISP.

Bird and Fish Teams comprised of agency implementation personnel and MRRIC WGs, and overseen by the Bird and Fish PgMs, respectively, serve to filter the science and performance information provided by the Technical Team, assess site characteristics and alternative designs for management actions, consider model predictions of future conditions, and make prioritized recommendations to the Management Team regarding management actions for consideration as part of the WP. A description of the teams and their decision responsibilities is provided in Section 2.3.3.1.

Decisions related to the WP process by the Management Team also receive input from the HC Team, which is comprised of agency managers and technical experts together with the MRRIC HC WG (see Section 2.3.3.2). The HC Team reviews and makes recommendations for monitoring and assessment associated with the effects of MRRP actions on HC interests. The Management Team, comprised of senior agency managers (Section 2.3.2) uses input from the species and HC teams and formulates a draft WP for consideration by agency leadership and the MRRIC. The species teams make some on-the-ground implementation decisions, and the Management Team has a number of responsibilities beyond development of the WP, mostly associated with budgeting, resource allocation, product delivery, collaboration, and communications.

Each agency has the sole authority and jurisdiction to make decisions appointed it by law. Senior leaders for the agencies provide oversight for the MRRP and are the ultimate decision makers. The Corps Northwestern Division (NWD) Commander sets direction for the Program, while the District Commanders are responsible for its execution. The NWD Director of Programs provides the day-to-day oversight of the MRRP, frequently represents the USACE in meetings with the MRRIC and/or USFWS, and may make decisions related to the development of the WP, scheduling, resource allocation, and other similar programmatic issues. The Region 6 Director is responsible for input and decisions for the USFWS, while the Assistant Director for Ecological Services is the USFWS counterpart to the NWD Director of Programs. The Oversight level of the MRRP is described in Section 2.3.1.

In addition to the senior leaders and teams described above, Chapter 2 outlines the roles and responsibilities of certain groups supporting leadership, including the ISP (Section 2.3.5), the Executive Steering Committee (ESC) (Section 2.3.6.1) and the Issue Resolution Board (Section 2.3.6.9). Chapter 2 also provides descriptions of a number of the key positions supporting the Program's oversight (see Section 2.3.6).

The (MRRIC) represents stakeholder interests for the MRRP. The MRRIC provides the agencies with input on the Program's implementation, including recommendations for changes to the implementation strategy from the use of AM. An overview of MRRIC role and responsibilities is provided (Section 2.3.7), following a set of guiding principles, an articulation of the MRRIC process and operating rules, and description of the levels of engagement. Section 2.3.7.2 outlines the value and role of WGs to interface between the MRRIC and the agencies on technical issues. By immersing in the science and participating in related deliberations, WGs provide an effective means to build trust, increase knowledge, and promote good decision-making that minimizes impacts to stakeholder interests. The chapter describes the role of an Independent Science Advisory Panel (Section 2.3.7.3) that provides review and guidance on science matters (Section 2.3.7.3), and a Third Party Science Neutral (TPSN, Section 2.3.7.4), which manages the Advisory Panel. The roles of basin states, other Federal agencies, and Tribes outside the MRRIC collaborative process are addressed in Section 2.4.6.

1.2.3 AM decision process

The MRRP employs a rolling, adaptive, 5-year Work Plan. Because of the uncertainty regarding some of the management actions required to meet species needs, future implementation decisions for the MRRP depend upon the performance of earlier actions and results of research addressing critical uncertainties (see Section 0). Knowledge gained from project and system performance informs adjustments to the WP. The process is constrained by several factors, most notably the timing of the Corps' budget cycles, which dictate that updates to the WP include only minor adjustments to the current fiscal year (FY) and the following FY (FY+1) budgets; center on development of the FY+2 activities for budgeting purposes; and include anticipated needs for later years (FY+3 and FY+4).

The processes and procedures by which the decisions are made are summarized in Section 0. The annually recurring engagement process for the MRRP revolves around science updates and the generation and sharing of information about program performance, then using that information for the development/adjustment of the WP. Figure 8 provides an overview of the process, which recurs each year for the Program. The elements in the figure are described in Section 2.4.2.1.

In the beginning of each FY, the Technical Team meets with other entities at a Fall Science Meeting to discuss the previous year's activities and to determine emerging analytical needs and needs for modification of research plans. The Technical Team would then assess actions implemented to date and the overall program performance; summarize significant findings from research, monitoring, and assessment; update the conceptual ecological models and hypotheses; make model projections of habitat and species populations; assess Reservoir System status; and undertake other tasks or studies needed to support decisions (Section 2.4.2).

Information generated by the Technical Team would be presented at an AM Workshop held each February to provide an opportunity for USACE and USFWS decision-makers, technical staff, contractors, and MRRIC to discuss the results of research and monitoring for the previous year and plans for upcoming years (Section 2.4.3). The Bird and Fish Teams would use information generated by the Technical Team to develop a set of prioritized actions and program guidance for each species. The HC Team reviews monitoring and assessment results related to the program's effects on HC metrics and considers needed adjustments to the monitoring and assessment strategy. The Teams (including the MRRIC WGs) would meet during and immediately following the AM Workshop to prepare a report of recommendations and prioritized actions to submit to the Management Team. The MRRIC WGs may prepare a separate joint WG Joint Report to MRRIC and the agencies.

The Management Team would draft updates to the WP (Section 2.4.4) by integrating recommendations and program guidance from the Bird, Fish, and HC Teams, and applying a programmatic perspective that considers many factors, including the existing WP makeup, guidance and direction provided by agency leadership, budget trends, the status of the science, risk management, and effects on authorized purposes. A draft of the revised WP would be prepared in early March and provided to the agencies and MRRIC for review and comment. Proposed revisions would be discussed at MRRIC meetings and by webinar, as needed. Additional analyses and adjustments could be made during this process depending on the feedback received from agency leaders or MRRIC. MRRIC may elect to provide a consensus recommendation at their June meeting prior to the agencies' finalizing any adjustments to the plan.

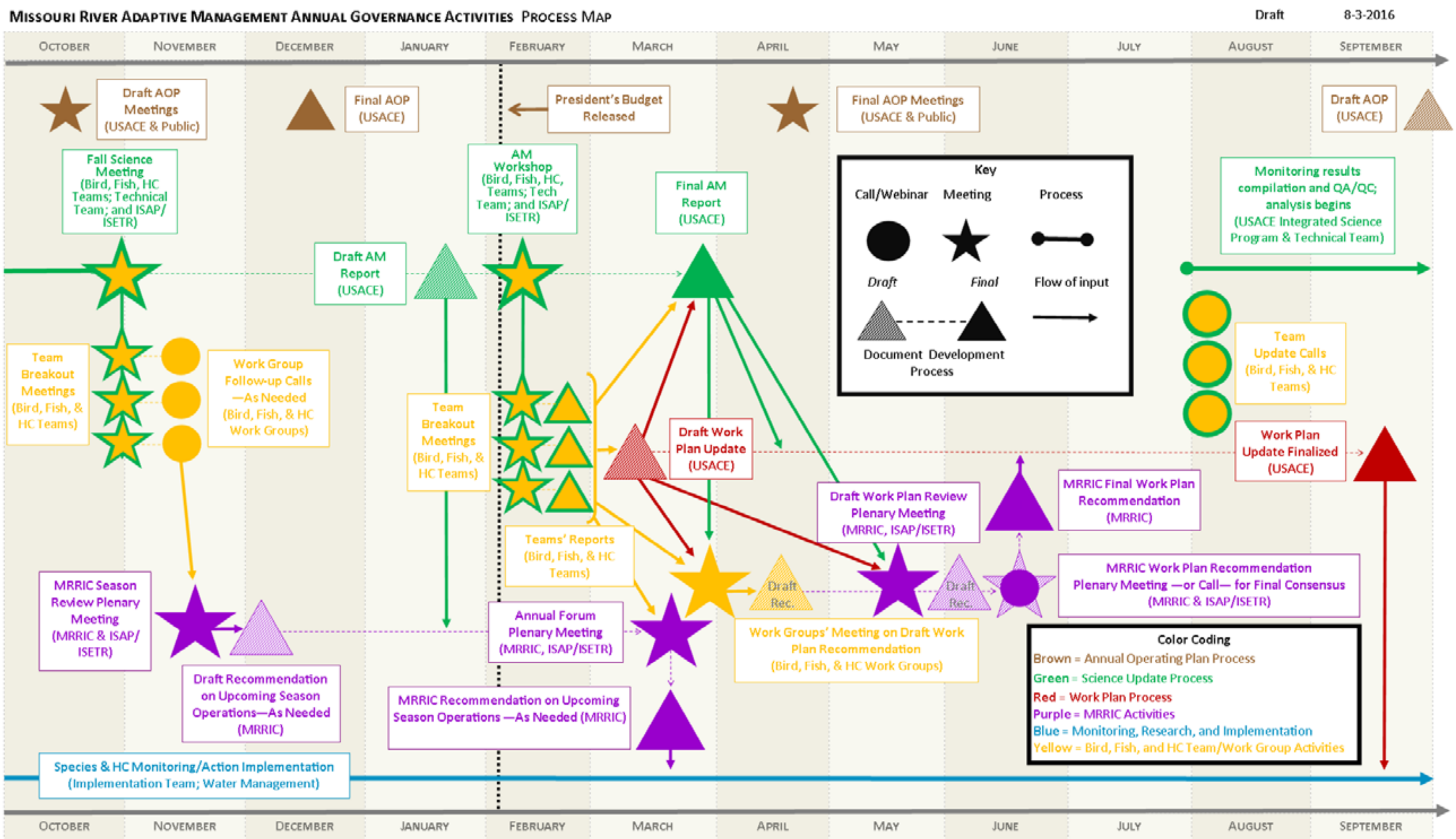


Figure 8. Process map depicting the proposed governance activities to be undertaken annually by the USACE, the USFWS, and the Missouri River Recovery Implementation Committee (MRRIC) in the implementation of Adaptive Management for the Missouri River Recovery Program.

Section 2.4.5 presents the process for considering new management actions, outside those in the ROD. A number of examples built around "decision workflow diagrams" are detail the flow of information, products, and resulting decisions and indicate who is involved in each (see Section 2.4.6). The timing of decisions is important, though constrained by many factors, so the section uses timelines accompanying some of the workflow diagrams as examples. It also addresses how the Annual Operating Plan (AOP) for water management fits in, and does so for the Corps' budgeting process as well. Collectively, these processes along with the MRRIC engagement process, help to define the overall operation of the AM Plan and indicates where issues might arise.

1.2.4 Protocols and procedures

A process section identifies a number of protocols and procedures that are necessary for the administration and implementation of, and changes to the AM Plan (Section 2.5). These include, for example, the procedures or protocols for changing the governance structure, resurrecting reserve hypotheses, dispute resolution, and addressing cultural resources uncovered during operations, as well as a host of other considerations. Details of these procedures are presented as attachments to Appendix A (note: some are placeholders – the details are yet to be developed or are in review/revision).

1.2.5 Other key points and issues

Governance for the MRRP is likely to evolve over time as lessons are learned about how collaboration should occur and as program needs change. To that end, routine and periodic reviews of the effectiveness of the program's governance are needed, along with a mechanism for change. As trust and understanding develop, decisions may be delegated to lower levels and collaborative engagements will likely become less formal and more effective. Section 2.5.6 lays out the processes for routine and periodic reviews and the process for adapting the governance to fit learning and evolving program needs.

1.3 AM for plovers and terns

Managing for piping plovers and interior least terns largely involves ensuring sufficient availability of ESH to support nesting and foraging for plovers, which the USFWS has determined also meets habitat needs for terns, while accounting for any benefits to bird populations from use of reservoir shorelines. Habitat and population models developed for the plovers provide a powerful planning tool for managing the program, but uncertainty about parameter estimates in the habitat models, coupled with observation errors and uncertainty about dispersal, demographic rates, and their trends in the population models provide significant opportunities for improvement in understanding and management decisions.

The greatest near-term source of uncertainty is in estimating future flows, which drives ESH availability. Managers will be required to make decisions about how much ESH to create annually and how best to create it with consideration of the risk of falling short of ESH targets. AM will likely revolve around the above issues, but opportunities exist for meaningful improvements to the ESH construction methods, predator management, and foraging habitat, among other things. Questions regarding the long-term availability of sediments for building ESH in the riverine reaches will challenge team members to find ever more efficient mechanisms to build and sustain needed habitat.

1.3.1 Bird objectives, uncertainties, and targets

The overall objective for piping plovers and least terns is to prevent USACE activities from jeopardizing the continued existence of both bird populations in the Missouri River. Objectives must be met for the Northern Region (Lake Sakakawea, Garrison Reach, and Lake Oahe, see Figure 1) and the Southern Region (Fort Randall Reach, Lewis and Clark Lake, and Gavins Point Reach, see Figure 1). Specific sub-objectives pertain to long-term population persistance, population growth, increasing and maintaining breeding success, and maintaining geographic distribution (see Section 3.1.1).

The EA built upon the Conceptual Ecological Models (CEMs) developed in 2013, identifying critical uncertainties, management hypotheses, and a suite of associated actions (see Section 3.1.2.4, Section 3.1.2.5, Table 1) that can be used to affect bird populations. These overarching scientific uncertainties are the following:

- How much habitat is needed to maintain a resilient population of birds, and how should it be distributed in space and time?
- How are the Missouri River populations of plovers and terns affected by migratory and metapopulation dynamics?
- How will long-term changes in climate and channel morphology affect habitat and species management?
- How can the bird AM program buffer against natural (especially hydrologic) variability and uncertainty for long-term success?
- How can the bird AM program buffer against institutional and socioeconomic variability and uncertainty for long-term success?

The management uncertainties, actions, and hypotheses are summarized in Table 1 and are discussed in Section 3.1.2.5.

Table 1. Critical uncertainties related to bird management actions and associated management hypotheses.

Management Critical Uncertainties	Actions	Management hypotheses
Creating New Habitat What is the most effective and efficient way of creating habitat within the larger context of management and uses of the Missouri River? a. Are there effective and implementable ways of using flow modification to provide and enhance habitat availability and quality? b. Can habitat be mechanically created in an effective and sustainable manner? c. What are the effects of habitat creation actions on HCs?	Habitat-creating flows	Habitat-creating flows of sufficient magnitude and duration increase the area of nesting/brood rearing habitat and foraging habitat on the river by increasing deposition, assuming sediment is available, thereby increasing fledgling productivity.
	Mechanical habitat creation on river	Mechanical habitat creation of sandbars in river segments increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Mechanical habitat creation of sandbars in river segments increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.
	Mechanical habitat creation on reservoirs shorelines or islands	Mechanical habitat creation of habitat on reservoir shorelines/islands increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Mechanical creation of habitat on reservoir shorelines or islands increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.
	Mechanical creation of hydrologically-connected non-ESH habitat on river segments	Mechanical habitat creation of habitat other than ESH or in segments outside of the current ESH scope increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Mechanical habitat creation of habitat other than ESH or in segments outside of the current ESH scope increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.

Maintaining Existing Habitat To what extent can maintaining existing habitat contribute to population objectives compared to creating new habitat? a. Does maintained habitat improve habitat metrics and support production equivalent to new habitat? b. Can flow be used to maintain habitat without increasing net erosion?	Modification or augmentation of existing sandbars	Modification or augmentation of existing sandbars increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation. Modification or augmentation of sandbars increases nesting/brood-rearing and foraging area, which increases food availability and hence survival of chicks to fledglings. Modification or augmentation of existing sandbars increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.
	Vegetation removal (spraying/mowing) on river/on reservoir	Vegetation removal increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation (by increasing area and by removing cover for predators). Vegetation removal increases nesting/brood-rearing and foraging area, which increases survival of chicks to fledglings by increasing food availability. Vegetation removal increases nesting/brood-rearing and foraging area relative to habitat condition and availability of at other breeding areas, thus increasing the number of adults through net immigration from other areas.
	Habitat-conditioning flows	Habitat-conditioning flows are not of sufficient magnitude and duration to create new sandbars, but scour vegetation or deposit new sediment on existing bars, increasing the area of nesting/brood-rearing habitat, thereby increasing fledgling productivity.
Improving Availability of Existing Habitat To what extent can improving existing habitat availability through flows contribute to population objectives compared to creating new habitat?	Reservoir water level management	Declining reservoir water levels between years and/or steady or declining water levels during the nesting season increases the area of suitable nesting/brood rearing and plover foraging habitat on the reservoirs, thereby increasing fledgling productivity.
	Lowered nesting season flows	Lowered nesting season flows increase the area of suitable riverine nesting and brood rearing habitat and foraging habitat, thereby increasing fledgling productivity.
Population Protection To what extent can population protection actions positively contribute to the success of birds on the Missouri River?	Flow management to reduce take	Steady or declining reservoir levels and/or river flows during the nesting season increases survival from egg to chick and chick to fledgling by reducing the risk of nest inundation and chick stranding and by maintaining or increasing foraging habitat.
	Predator removal	Predator removal increases survival of eggs to chicks and chicks to fledglings.
	Nest caging	Nest caging protects plover nests from predators, increasing survival of eggs to chicks, though survival of adults may be negatively affected by cages.
	Human restrictions measures (signs, barriers, education)	Human restriction measures reduce activity on nesting and foraging habitat, increasing survival both by decreasing direct mortality and indirect effects on survival caused by stress.

A suite of models that relate reservoir operations, river flows, ESH availability, and bird populations is discussed in Section 3.1.2.3. The models provide a mechanism for projecting the probability distribution of future habitat area and bird population size. Using historical hydrological data, the models were applied to help establish targets for habitat based on a population viability analysis (see Section 3.1.1 for information on the models). Targets are presented in Section 3.2.3 for both ESH (see Section 3.2.2.1) and species metrics (see Section 3.2.2.2).

ESH targets for the Northern and Southern Regions are presented as a range of standardized ESH values (number of acres above a reference elevation) that should be met in 3 out of 4 years, and exceedance values for available ESH (number of acres at the highest stage during the nesting season) that must be met on a rolling 12-year average (see Table 2).

Table 2. Summary of standardized and available ESH acreage targets.

		Acres of ESH					
		Northern Region			Southern Region		
		2.5%ile	Median	97.5%ile	2.5%ile	Median	97.5%ile
Standardized ESH Acres		200	428	1996	264	782	3907
Available ESH Acres Exceeded for Percentage of Years	75%	140	210	470	280	370	700
	50%	380	630	1000	460	720	1580
	25%	770	1420	2010	780	1370	3285
	10%	1340	2230	3625	1130	2320	5275

Quantitative targets are provided for the piping plover only; the USFWS has determined that, by meeting the plover habitat objectives, the USACE will also fulfill least tern habitat needs for the Missouri River. Quantitative targets for the least tern may be added pending decisions regarding delisting and development of conservation plans.

1.3.2 Implementing, monitoring, and evaluating bird actions

Implementers of the MRRP will be faced with decisions about the above management actions with limited knowledge of future conditions that could significantly affect the amount of habitat and species populations, and without knowing precisely how the habitat and species will respond to those uncertain conditions. The role of AM in managing the birds is to improve decision-making in light of an uncertain future system state—an uncertainty that can never fully be resolved—and through improved understanding of how the system functions and responds to various management actions. This, and the need to balance multiple and sometimes competing objectives for species and HCs, supports the use of a "toolbox approach" wherein many management actions and options are available to accommodate natural variability and socioeconomic uncertainty (see Table 1). The initial set of management actions in the toolbox, and their specifications, will be determined by the action agencies in collaboration with MRRIC and specified in the ROD. As the AM Plan is implemented, knowledge gained about the performance of implemented actions, including their effects on HC objectives, will be used to make adjustments that increase their effectiveness. New knowledge may also result in the addition or removal of management actions from the toolbox. Decisions about such changes will be evidence-based and made in collaboration with MRRIC. HC metrics (discussed in Chapter 5) are also identified in Chapter 3 where applicable to management actions for the birds.

The following metrics will be used when testing the hypotheses in Table 1 and to support management decisions (see Chapters 2, 3 and 5):

- Habitat metrics
  - Standardized ESH (acres)
  - Available ESH (acres)
  - Available shoreline (feet)
  - Inundation during the nesting season (feet)
- Species metrics
  - Population size
  - Population growth rate
  - Fledge ratio
- Metrics of management conditions
  - Standardized ESH (acres) and distribution
  - Vegetated habitat (acres)
  - Storage in reservoirs (million acre-feet) and planned releases (cubic feet per second [cfs])
  - Tributary flows (cfs) and downstream stage (elevation)
  - Bird population density (adults/acre)
  - Budget ($)

Some of these metrics have historically been collected under the Tern and Plover Monitoring Program. Revisions to the monitoring program, which are under development, will be described in Section 3.3 when completed.

Section 0 provides important details for each of the management actions under consideration in the MRRMP EIS, including a description of each action, implementation criteria, constraints to implementation, performance metrics, HC metrics, uncertainties and needed research, criteria for adjusting an action, and the decision and collaboration level. Details are provided for actions in the Preferred Alternative and for those considered in other alternatives. Following the ROD, actions included in the Selected Alternative will be available for full implementation, while actions evaluated but not included may be considered for research or pilot projects. Section 3.2.4.3 includes management actions not evaluated in the MRRMP EIS. These actions have greater uncertainty about effectiveness but have been identified as potential actions that should be evaluated through research, modeling, and pilot projects. The evaluation process includes assessing ESH and population status, management needs, hypotheses, and the updating and validation of predictive models. Assessment of ESH status involves the use of the models, along with remotely sensed imagery, to determine both standardized and available habitat during nesting and fledging seasons. ESH acreage relative to median and 95% confidence intervals for targets, along with trends, are evaluated for planning ESH creation needs (see Section 3.5.1; also see Table 2). Evaluating population requires assessment of population resiliency under current management conditions through modeling and assessment of observed fledge ratios and population growth and their trends (see Section 3.5.2).

Section 3.5.3 provides guidance for the overall evaluation of status and management needs. Table 3 (reproduced from Table 35) categorizes ESH and species status and communicates a recommended management pathway (e.g., continue, increase, or decrease current rates of habitat creation). An evaluation of management conditions including system storage, snowpack, ESH condition, vegetation and predator status, budget, and the pallid sturgeon research and management needs provides understanding of how the decision space may be constrained (see Section 3.5.4).

Chapter 3 also discusses the evaluations needed to address new information (Section 3.5.5), evaluate key relationships, hypotheses, and science questions (Section 3.5.6), update and validate models (Section 3.5.7), deal with ancillary information (Section 3.5.10), and assess unexpected outcomes (Section 3.5.11).

Table 3. Matrix for characterizing status and needs for ESH acreage and bird population. FR = Fledge Ratio (Number of fledglings observed / [number of breeding adults/2]); λ = lambda (population size in current year / population size in previous year).

Population Status	**Emergent Sandbar Habitat Status**			
	Acreage < Lower Bound	**Lower Bound < Acreage < Median**	**Median < Acreage < Upper Bound**	**Upper Bound < Acreage**
GROWING POPULATION **FR and λ > target**	On track to meet objectives *Status:* Small population OR density dependence less than expected *Need:* Continue pace of habitat creation	Meeting objectives *Status:* Moderate population, not habitat limited *Need:* Continue habitat creation at current or slower pace	Meeting objectives *Status:* Moderate to large population, not habitat limited *Need:* Maintain existing acreage and quality	Exceeding objectives *Status:* More birds and much more habitat than needed *Need:* Maintain habitat quality
STABLE POPULATION **FR and λ ≈ target**	Unlikely to meet objectives *Status:* Small to moderate population, becoming habitat limited *Need:* Increase rate of habitat creation	Meeting objectives *Status:* Moderate population, habitat may become limiting *Need:* Continue pace of habitat creation	Meeting objectives *Status:* Moderate to large population *Need:* Maintain existing acreage and quality	Exceeding objectives *Status:* More birds and more habitat than needed *Need:* Maintain habitat quality
DECLINING POPULATION **FR and λ < target**	Will not meet objectives *Status:* Small to large population, very habitat limited *Need:* Rapidly increase rate of habitat creation	Unlikely to meet objectives *Status:* Moderate to large population, habitat limited *Need:* Increase pace of habitat creation	Potential reversal *Status:* Large population returning towards equilibrium *Need:* Continue pace of habitat creation and maintain habitat	Reversal *Status:* Large population returning towards equilibrium OR density dependence much higher than expected *Need:* Maintain habitat quality, consider maintaining acreage

1.3.3 Decisions and planning contingencies

The decision process, decision criteria, necessary information and model projections, as well as guidelines and decision criteria for proceeding with specific management actions are presented in Section 3.6. This section also covers steps to be considered if objectives are not being met. Decisions can range along a continuum from implementing the same actions as in previous years to adjustments of varying degree including changing action specifications or criteria, adding new management actions, and changing targets or objectives. The decision process generally involves using new information from monitoring and research, modeling of habitat and population response, and management conditions (see **Error! Reference source not found.**). Contingency plans that provide a pre-specified roadmap to decisions are identified where feasible owing to their efficiency and effectiveness; however, the system is too complex and variable to pre-specify every contingency in a way that would be preferable to on-the-ground management decisions employing available information. Decisions are outlined for those actions evaluated in the MRRMP-EIS, not just those in the preferred alternative, to provide an overview of the full range of management possibilities prior to the ROD and should actions be added or expanded following the ROD and/or during the course of AM.

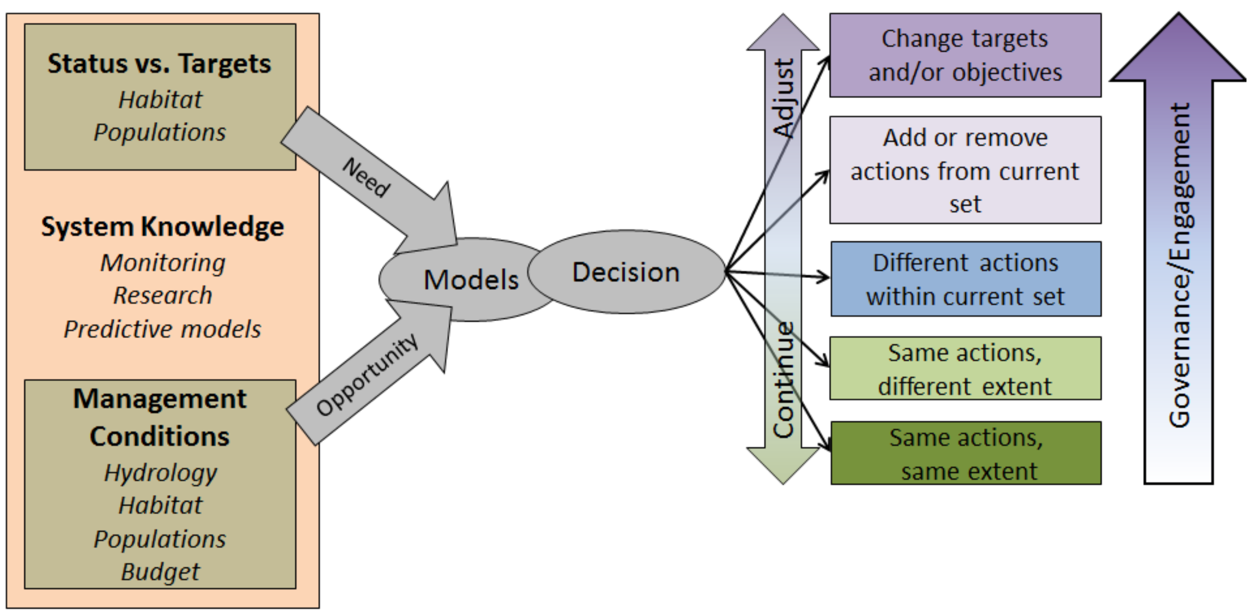


Figure 9. Factors affecting AM decisions for birds and the nature of those decisions.

The incremental costs and benefits of any management action(s) are considered during the decision cycle (as part of the WP development process). When more than one management action is possible, combinations and degrees of intensity for each action should be considered to arrive at an optimum, or at least a preferred alternative. The predictive models are necessary tools for these decision-support efforts. They also provide a means of quantifying the risks associated with any decision. Model projections of management actions are discussed in Section 3.6.2.1.

Decisions about how to create ESH (mechanical vs. flows) are discussed in Section 3.6.3.1. (That description includes flow modifications analyzed in the MRRMP EIS but not included in the Preferred Alternative.) As previously identified, these decisions largely turn on the amount of ESH needed as determined from the assessment stage, coupled with an estimate of available budget (e.g., are funds available to mechanically construct the full amount needed?), the potential for using flows (e.g., is system storage sufficient and other conditions generally acceptable to the needed magnitude and duration of flow releases?), and assessments of potential HC effects (positive and negative), synergistic interactions, additional information learned, and pallid sturgeon management needs. Close collaboration is required prior to implementation of any habitat-creating flows, decisions to do so must be made at the Oversight level and other policy requirements (e.g., NEPA evaluation, adjustments to Master Manual criteria) must be fulfilled.

Section 3.6.3.5 discusses decisions about whether to lower nesting season flows. Flexibility to do so exists within the current technical criteria in the Master Manual under some hydrologic conditions. Lowered summer flows can expose more nesting habitat and delay creation of new ESH (see Section 3.6.3.5). Collaboration on lower nesting season flows (within current Master Manual criteria) occurs through the AOP process, as has been practiced in the past and/or communicated to stakeholders if made in real time by the Missouri River Basin Water Management Division (MRBWMD). If lowered summer flows as a deliberate, planned activity are anticipated, or if adjustments to the Master Manual would be required to accommodate more substantive flow management, a highhigh level of collaboration including public involvement would occur, and those decisions would be made at the Oversight level.

Decisions about modifying existing habitat (Section 3.6.3.4) and predation management (see Section 3.6.3.6) build upon existing knowledge and practice for these activities, as well as proposed monitoring that should enhance understanding of key relationships for these factors. The Management and Bird Teams generally make these decisions with lower level collaboration and related actions would be included in the WP.

Decisions related to experiments and research activities are discussed in Section 3.5.6. In addition to research targeting biological and management hypotheses, opportunities for experimental implementation of management actions can be exercised to develop more productive, efficient, and cost-effective means of achieving objectives. For example, improvements in construction methods and resource (sand/sediment) utilization may make mechanical construction more feasible. Similarly, innovative methods for reducing erosion of ESH or managing vegetation and predators can extend the life of existing ESH and help meet bird targets. Even improvements to monitoring methods and more efficient analytical methods provide potentially significant opportunities for programmatic cost savings and more effective decision-making. Collaboration on research and experimental management actions will vary depending on the nature of the activity, but would generally be consistent with any management action included in the WP.

As models and scientific understanding are updated to reflect learning, the ESH targets are recalculated to promote more efficient management. This occurs often enough to allow learning to improve management outcomes, but not so frequently as to hinder reasonable planning and assessment processes. Decisions to update habitat targets to reflect learning or to revise targets or target criteria are addressed in Section 3.6.5. Changes to the numerical targets to reflect new scientific understanding would be a relatively routine process, but may warrant reviewed by the ISAP. Changes to target criteria, or to objectives reflecting changes in regulations, values, or acceptable levels of risk would involve technical review, but also require a higher level of collaboration and Oversight-level approval.

1.3.4 Other key points or issues

While the understanding of the needs for the birds is significantly greater than for the pallid sturgeon, costs for managing the birds can be high. Moreover, bird populations (especially plovers) respond rapidly to the dynamic shifts in available habitat, and there are many challenges to addressing their needs while minimizing impacts to HCs. These factors contribute to the need for an active, progressive AM strategy as part of the MRRP. Flow management for the birds remains a contentious issue, and should the need for its use emerge, a progressive AM strategy with appropriate levels of collaboration will be required to facilitate its implementation.

1.4 AM for pallid sturgeon

Despite considerable effort in previous years and an exhaustive attempt as part of the EA, the identification of the specific factors causing recruitment failure for pallid sturgeon and a clear nexus between management actions and population response remains elusive for the lower river (downstream of Gavins Point Dam). While fragmentation is clearly the primary factor in limiting or preventing recruitment on the upper river (Ft. Peck Dam to the Lake Sakakawea Headwaters), other secondary factors may also play a significant role and confound management decisions. Given the lingering uncertainties regarding the scope and scale of the management actions necessary for the USACE to avoid jeopardizing the continued existence of pallid sturgeon, a strategy reliant upon a progressive AM program is the most effective way to manage risks to the pallid sturgeon.

1.4.1 Overview of Chapter 4

Chapter 4 is organized around the AM cycle, beginning with the “Assess” step by identifying the goals and objectives for pallid sturgeon (Section 4.1.1) and a summary of the key findings of the EA (Section 4.1.2), including the hypotheses that emerged from the effort, and the EA’s conclusions on those hypotheses. A pallid sturgeon framework (developed jointly by the USACE and USFWS for the Lower Missouri River) is presented in the “Plan/Design” step, and serves as a foundation for much of the AM strategy (see Section 4.2.1). The framework describes four “levels” of action with progressively greater influence on pallid sturgeon populations: Level 1 is research, Level 2 is focused field-scale experiments, Level 3 is limited-scale implementation, and Level 4 is full-scale implementation of management actions. Level 1 and 2 components of the framework are detailed in the appendices (see Appendix C. Detailed Description of Level 1 and 2 Science Components for Pallid Sturgeon). Details for Level 3 and 4 actions are presented in remaining sections of the chapter, and are generally summarized as they pertain to the Upper Missouri River and Lower Missouri River.

1.4.2 Pallid sturgeon objectives and key uncertainties

The fundamental objective for pallid sturgeon, developed by the USFWS in 2013 (written com., September 12, 2013 [Draft Species Objectives, p. 1]), is to keep USACE actions from jeopardizing the continued existence of pallid sturgeon in the Missouri River. Sub-objectives are to increase recruitment to age 1, and to maintain or increase numbers of pallid sturgeon as an interim measure until sufficient and sustained natural recruitment occurs (see Section 4.1.1 for more details). Metrics have been defined for these sub-objectives, but targets for these metrics are still to be determined.

The EA evaluated available reports and models, as well as other scientific literature, to provide an integrated assessment of the current state of the science and understanding of the potential benefits of management actions for pallid sturgeon in the Missouri River, and associated uncertainties in that assessment (see Section 4.1.2). The EA also introduces development of a collaborative population dynamics model developed to support the MRRP AM Plan (Section 4.1.2.3).

Uncertainties for pallid sturgeon identified in the EA have been expressed as Big Questions related to potential management actions with underlying hypotheses. There are six Big Questions each for the Upper River and the Lower River, and each Big Question includes underlying hypotheses. These are summarized in Table 4 and in Table 5 for the Upper Missouri River and Lower Missouri River, respectively. New information (see Sections 2.5.4 and 6.2.5) may arise which leads to a re-examination of hypotheses from the reserve list of EA hypotheses, the addition of new hypotheses, the revision of existing hypotheses, or the removal of some of the existing hypotheses in the event of strong evidence against them.

Table 4. Big Questions and hypotheses for Level 1 and 2 components for the Upper Missouri River. Hypotheses are from Table 1 in Jacobson et al. (2016a).

Big Question 1 – Spawning Cues: Can spring pulsed flows from Fort Peck synchronize reproductive fish, increase chances of reproduction and recruitment?
Associated Hypothesis: **H2.** Attractant flow releases at Fort Peck will result in increased reproductive success through increased aggregation and spawning success of adults.
Big Question 2 – Food and Forage: Can naturalization of the flow regime from Fort Peck contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?
Associated Hypothesis: **H1.** Naturalized flow releases at Fort Peck will result in increased productivity through increased hydrologic connections with low-lying land and floodplains in the spring, and decreased velocities and bioenergetic demands on exogenously feeding larvae and juveniles during low flows in summer and fall.
Big Question 3 – Temperature Control: Can water-temperature manipulations at Fort Peck contribute significantly to increased chance of reproduction and recruitment?
Associated Hypotheses: **H4.** Warmer flow releases at Fort Peck Dam will increase system productivity and food resource availability, thereby increasing growth and condition of exogenously feeding larvae and juveniles. **H5.** Warmer flow releases from Fort Peck Dam will increase growth rates, shorten drift distance, and decrease mortality by decreasing free embryos transported into headwaters of Lake Sakakawea.
Big Question 4 – Sediment Augmentation: Can sediment bypass at Fort Peck contribute significantly to increased chance of reproduction and recruitment?
Associated Hypothesis: **H6.** Installing sediment bypass at Fort Peck will increase and naturalize turbidity levels, resulting in decreased predation on embryos, free embryos, and exogenously feeding larvae.
Big Question 5 – Drift Dynamics: Can combinations of flow manipulation from Fort Peck, drawdown of Lake Sakakawea, and fish passage at Intake Dam on the Yellowstone River increase probability of successful dispersal of free embryos and retention of exogenously feeding larvae?

Associated Hypotheses: **H3.** Reduction of mainstem Missouri flows from Fort Peck Dam during free-embryo dispersal will decrease mainstem velocities and drift distance thereby decreasing mortality by decreasing numbers of free embryos transported into headwaters of Lake Sakakawea. **H7.** Fish passage at Intake Diversion Dam on the Yellowstone River will allow access to additional functional spawning sites, increasing spawning success and effective drift distance, and decreasing downstream mortality of free embryos and exogenously feeding larvae. **H10.** Drawdown of Lake Sakakawea will increase effective drift distance, decreasing downstream mortality of free embryos and exogenously feeding larvae.
Big Question 6 – Population Augmentation. Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?
Associated Hypotheses: **H8.** Stocking at optimal size classes and in optimal numbers will increase growth rates and survival of exogenously feeding larvae and juveniles. **H9.** Stocking with appropriate parentage and genetic diversity will result in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.

Table 5. Big Questions and hypotheses for Level 1 and 2 components for the Lower Missouri River.

Big Question 1 – Spawning Cues: Can spring pulsed flows synchronize reproductive fish, increase chances of reproduction and recruitment?
Associated Hypothesis: **H11.** Naturalization of the flow regime at Gavins Point Dam will improve flow cues in spring for aggregation and spawning of reproductive adults, increasing reproductive success.
Big Question 2 – Temperature Control: Can water-temperature manipulations at Fort Randall and/or Gavins Point contribute significantly to increased chance of reproduction and recruitment?
Associated Hypothesis: **H15.** Operation of a temperature management system at Fort Randall Dam and/or Gavins Point Dam will increase water temperature downstream of Gavins Point, providing improved spawning cues for reproductive adults.
Big Question 3 – Food and Forage: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?
Associated Hypotheses: **H12.** Naturalization of the flow regime at Gavins Point Dam will improve connectivity with channel-margin habitats and low-lying floodplain lands, increase primary and secondary production, and increase growth, condition, and survival of exogenously feeding larvae and juveniles. **H13.** Naturalization of the flow regime at Gavins Point Dam will decrease velocities and bioenergetic demands, resulting in increased growth, condition, and survival for exogenously feeding larvae and juveniles. **H17.** Re-engineering of channel morphology in selected reaches will increase channel complexity and bioenergetic conditions to increase prey density (invertebrates and native prey fish) for exogenously feeding larvae and juveniles. **H18.** Re-engineering of channel morphology will increase channel complexity and minimize bioenergetic requirements for resting and foraging of exogenously feeding larvae and juveniles.

Big Question 4 – Drift Dynamics: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to decreased direct mortality and increased interception of free embryos into supporting habitats?
Associated Hypotheses: **H14.** Alteration of the flow regime at Gavins Point can be optimized to decrease mainstem velocities, decrease effective drift distance, and minimize mortality of free embryos. **H19.** Re-engineering of channel morphology in selected reaches will increase channel complexity and serve specifically to intercept and retain drifting free embryos in areas with sufficient prey for first feeding and for growth through juvenile stages.
Big Question 5: Spawning Habitat. Can channel reconfiguration and spawning substrate construction increase probability of survival of eggs through fertilization, incubation, and hatch?
Associated Hypothesis: **H16.** Re-engineering of channel morphology in selected reaches will create optimal spawning conditions -- substrate, hydraulics, and geometry -- to increase probability of successful spawning, fertilization, embryo incubation, and free-embryo retention.
Big Question 6: Population Augmentation. Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?
Associated Hypotheses: **H20**. Stocking at optimal size classes and in optimal numbers will increase growth rates and survival of exogenously feeding larvae and juveniles. **H21.** Stocking with appropriate parentage and genetic diversity will result in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.

1.4.3 Pallid sturgeon framework

The USACE and USFWS collaborated to develop a framework for adaptively managing pallid sturgeon on the lower river. Referred to as "the Framework", it consists of four levels of activity as described in Table 6. As information is developed through Level 1 and 2 research and experiments (see Appendix C) or through monitoring of effectiveness of management actions, decision criteria described in the Framework and in Chapter 4 will be used to determine when and what actions should follow. Decisions might include (a) accepting that the scientific information supports the hypothesized action and moving to the next issue or level of implementation; (b) determining that the scientific information does not support the hypothesized action and refining or rejecting the hypothesis; or (c) deciding to implement at Level 3 because an agreed-upon time limit has been reached and results remain equivocal (studies at Levels 1 and 2 might continue concurrently). At any time during implementation, it may become apparent that: 1) a particular action is not needed, 2) a proposed action requires modification to be effective, or 3) some new action not previously evaluated is required.

Level 1 and 2 studies are directly tied to those uncertainties and management hypotheses highlighted in the EA that, if resolved, could significantly affect the implementation of management actions. Studies at Levels 1 and 2 may continue concurrently with Level 3 efforts, but are generally intended to inform actions at Level 3. Although Level 2 studies have learning as a primary objective, they can also provide measurable benefits to pallid sturgeon populations and, in such cases, are counted toward targets in the same manner as Level 3 actions. Criteria for accepting or rejecting specific hypotheses, for assessing the results of scaled experiments, and for moving from Level 1 to Level 2 or Level 2 to Level 3 actions, are described in section 4.2.4.

Table 6. Pallid sturgeon framework for the lower Missouri River.

Level 1: Research	Population Level Biological Response IS NOT Expected	Studies without changes to the system (laboratory studies or field studies under ambient conditions)
Level 2: In-river Testing		Implementation of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response.
Level 3: Scaled Implementation	Population Level Biological Response IS Expected	In terms of reproduction, numbers, or distribution, initial implementation should occur at a level sufficient to expect a meaningful population response progressing to implementation at levels that result in improvements in the population. The range of actions within this level is not expected to achieve full success (i.e., Level 4).
Level 4: Ultimate Required Scale of Implementation		Implementation to the ultimate level required to remove as a limiting factor.

The Framework is expected to accelerate the identification of recruitment bottlenecks, resulting in a more strategic and focused implementation of appropriate management actions. This approach has the added benefit of minimizing impacts to stakeholders and avoiding unnecessary implementation costs. Though developed for use on the Lower River, the terminology from the Framework is used in describing needs for the Upper River as well.

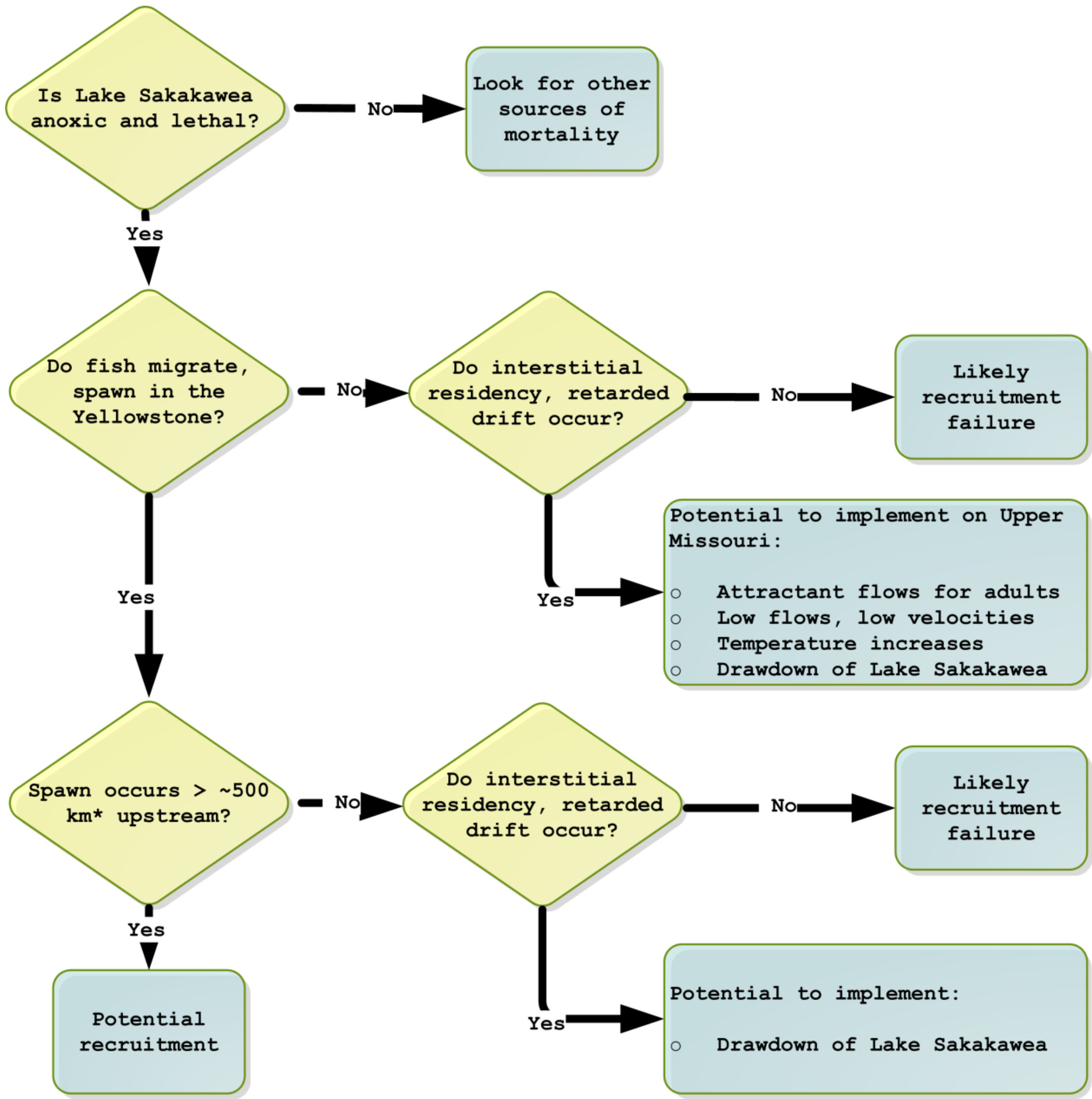
1.4.4 Pallid sturgeon in the Upper Missouri River

For the Upper Missouri and Yellowstone Rivers, fragmentation that limits the available drift/dispersal distance and hypothesized inhospitable headwaters of Lake Sakakawea due to anoxic sediments pose a distinct constraint on recruitment. Big Questions for the Upper Missouri River relate to management actions that are hypothesized to increase natural recruitment (see Table 4). From this broader set of Big Questions and hypotheses, policy determinations have been made to focus implementation on actions that are either currently being implemented and re-evaluated (e.g., population augmentation, under review by the Pallid Sturgeon Recovery Team) or are proposed (e.g., fish passage at Intake Diversion Dam).

Implementation of fish passage at Intake Dam has been identified by the USFWS as sufficient for avoidance of jeopardy, provided the passage is effective (the immediate objective) and results in recruitment (the broader objective). The fundamental scientific uncertainty related to Intake passage is whether reproductive adults will find passage around or over Intake Dam and migrate a sufficient distance upstream for spawning (500 kilometers [km] is the hypothesized distance needed for drift of free embryos). Resolution of this uncertainty will have a profound effect on the ability to predict whether recruitment is possible in the Upper River.

Key metrics for the fish passage structure itself would be, monitored by the Bureau of Reclamation and, are described in the Monitoring and Adaptive Management Plan for the Lower Yellowstone Passage Project (Reclamation 2016). Monitoring under the AM Plan for the MRRP is focused on using telemetry tags on adult pallid sturgeon to test the response of adult spawning in the upper Yellowstone River to improved passage at Intake, assessing drift of free embryos downstream past Intake Dam, and assessing the longer term population response to passage improvements at Intake Dam.

As part of the MRRP, the USACE will maintain support of population augmentation in the Upper Missouri River (as revised by the Pallid Sturgeon Recovery Team) and will undertake a series of Level 1 studies aimed at addressing issues related to anoxia in the headwaters of Lake Sakakawea, interstitial hiding of sturgeon free embryos, and drift of free embryos downstream of Ft. Peck, to determine if related management actions might be effective should fish passage at Intake Dam fail to achieve objectives. These efforts follow a decision tree (Figure 10) outlining the strategy for addressing uncertainties and resultant contingent decisions for this reach. Additional NEPA efforts would likely be required before decisions would be made by regulatory authorities to implement other potential actions identified in Figure 10.



* 500 km distance upstream is a coarse guideline because it would provide about 9 days for drift and development under purely passive drift assumptions.

Figure 10. Diagram of a decision tree for contingent information on the Upper Missouri and Yellowstone Rivers (presented as Figure 64 in Chapter 4). Passage at Intake will result in approximately 400 km of drift.

If pallid sturgeon do not successfully spawn on the Yellowstone River but subsequently recruit at sufficient levels, then the ability to manage for spawning on the Missouri River may hinge on whether delayed drift (interstitial hiding) occurs. If it occurs, then potential actions include flow management (low flows), temperature management (increased temperature), or drawdown of Lake Sakakawea. The question of whether delayed drift (interstitial hiding) occurs is important to spawning on the Yellowstone River as well. The necessary upstream migration distance (and hence available drift distance) could be substantially reduced by interstitial hiding. Interstitial hiding is discussed further (see additional discussion in the EA summary, section 4.1.2).

Implementation of these other actions would require evidence from related Level 1 and Level 2 studies to suggest that some combination of actions would improve survival to first feeding in the Upper River. Each of the potential actions, with associated hypotheses, objectives, metrics, and decision criteria, are discussed in Chapter 4.

1.4.5 Pallid sturgeon in the Lower Missouri River

Uncertainties for the Lower Missouri River center around how pallid sturgeon use the river, its tributaries, and the Mississippi River. Big Questions relate to possible actions to ensure survival and recovery of pallid sturgeon in the Lower Missouri River (see Table 5). In their framework for pallid sturgeon in the Lower Basin, the USFWS and Corps (2015) identified a suite of four actions anticipated to avoid jeopardizing pallid sturgeon in the Lower River, with associated targets and time limits for implementation (Table 7). The four actions include population augmentation, interception and rearing complexes (IRCs), spawning habitat, and (potentially) manipulation of flows.

The uncertainties in the Lower River will bereduced using the framework shown in Table 6. Level 1 and 2 studies are directly tied to those uncertainties and management hypotheses highlighted in the EA that, if resolved, could significantly affect the implementation of management actions. These are presented in detail in Appendix C.

The USFWS and USACE (2015) identified a suite of four actions that, subject to the findings of Level 1 and Level 2 studies and further ongoing coordination, that are anticipated to avoid jeopardizing pallid sturgeon in the Lower Missouri River. They also identified targets and defined time limits for implementation of these actions (Table 7). As knowledge is gained from Level 1, 2, and 3 actions, the timeframe for implementation may be adjusted, targets may be changed, management actions may be refined, and hypotheses may be dismissed. The “rules” by which these decisions will be made are outlined in the decision criteria for the respective management hypotheses, subject to the overarching governance and decision process laid out in Chapter 2 of this AM Plan. Chapter 4 of the AM Plan proposes a more accelerated timeline for high priority Level 1 actions (implemented in parallel rather than sequentially), as discussed in section 4.3.

Table 7. Summary of time limits for implementation and scope of actions.

Action Category	Time Limit*	Minimum Scope	Maximum Scope
Population augmentation	Immediate	Current stocking rate as directed by USFWS Basin-wide Stocking and Augmentation Plan	Variable over time as directed by USFWS Basin-wide Stocking and Augmentation Plan
IRC habitat development	Stage 1 - study phase (years 1-3 post-ROD)	Build 2 IRC sites per year (paired with control sites), adding 33,000 ac-d/yr of suitable habitat, using staircase design[1]. Assess potential for refurbishing existing SWH sites as IRCs.	
	Stage 2 – continue study phase (years 4–6 post-ROD)	Build 2 IRC sites per year (paired with control sites), adding 33,000 ac-d/yr[1] of suitable habitat. Refurbish SWH sites in addition to study sites (rate TBD).	
	Stage 3 - Level 3 implementation (years 7–10 post-ROD)	Continue assessing IRC sites and refurbishing new SWH sites, adding at least 66,000 ac-d/yr[1] of suitable habitat. Determine required rate of Level 3 implementation based on stages 1 and 2.	
	Stage 4 – Level 4 implementation	Remove IRC habitat limitations to pallid sturgeon survival by implementation at Level 4.	
Spawning habitat[2]	2 years	1 spawning site	See decision tree in Figure 78
Spawning cue flows	9 years	Requirement for spawning cue flows (and appropriate scope) depends on the outcome of Level 1 and Level 2 monitoring and modeling studies during years 1–9. [3]	

Notes

1. Units of ac-d/year are calculated based on how the flow regime and channel configuration result in cumulative days of availability of suitable habitat during the growing season. Progression through each stage of IRC habitat development is contingent on outcomes and hypothesis tests (USFWS 2016); efforts could be halted if evidence shows IRCs are not successful. Experimental design for IRC sites, and associated metrics, are described in section 4.2.6.3 and Appendix E. Refurbishment of SWH sites into IRCs is described in section 4.2.6.4.

2. Anticipated as a Level 2 pilot project focused on developing and evaluating high-quality spawning habitat. Spawning habitat implementation will be guided by the decision tree in section 4.2.6.3 (Figure 78). The evaluation of spawning areas will be based on comparing attraction, egg survival, and hatch to existing spawning areas (see section 4.2.6.5).

3. See evidentiary framework in Table 48, section 4.2.6.6. Pallid population modeling will be used to set minimum spawning flow needs. Bird impacts and status, reservoir levels, and HC impacts will inform decisions regarding spawning cue flows below Gavins Point Dam in any particular year.

At any time during the Framework's implementation, it may become apparent that: (1) a particular action is not needed, (2) a proposed action requires modification to be effective, or (3) that some new action not previously evaluated is required.

The artificial propagation program is already taking place at a level having a measurable effect on the population (i.e., Level 3) As knowledge is gained from Level 1, 2 and 3 studies, the timeframe for implementation may be adjusted, targets may be changed, management actions may be refined, and hypotheses may be adjusted or rejected. The "rules" by which these decisions are made are outlined in decision criteria for the respective management hypotheses, subject to the overarching governance and decision process laid out in Chapter 2. Chapter 4 proposes a more accelerated timeline for high priority Level 1 actions (implemented in parallel rather than sequentially), as discussed in Section 4.3.

Improvements to address genetic concerns (e.g., maintaining genetic variation similar to the natural population, minimizing threats of hybridization), disease, stocking size, amount of stocking relative to carrying capacity, etc., would be pursued collaboratively with the USFWS and others to be consistent with the Basin-wide Stocking and Augmentation Plan under development by the USFWS. While population augmentation is *necessary* for recovery of the pallid sturgeon, by itself it is not *sufficient* as the ESA requires a self-sustaining population. Augmentation can help severely depleted populations recover numbers of individuals sufficiently to provide reliable evaluations of the effectiveness of alternative actions.

Level 1 and 2 activities associated with IRCs focus on: (1) the need for additional IRC habitat, (2) refining the relationship between the habitat components and flow (utilizing current operations), and the biological requirements of each habitat type, (3) the needed habitat characteristics and their spatial and temporal distributions, and (4) determining the effectiveness of various mechanical activities and the potential for flow management actions to contribute to future IRC needs. Level 3 actions include physical manipulation of habitats and structures on the Missouri River to create or improve areas having hydraulic conditions to intercept drifting free embryos combined with food-producing habitats and foraging habitats. Actions can be directed at one or any combination of the three components of IRCs. Examples include adjustments to navigation training or bank stabilization structures, channel widening, floodplain modifications or other adjustments to channel geometry, placement of structures to encourage development of needed habitat or habitat complexity, chute development or adjustments to existing chutes, etc. Level 3 actions and outcomes are focused on helping to understand and describe future Level 4 actions and targets, which will be based on bioenergetics requirements of the Missouri River pallid sturgeon population. An experimental design and monitoring plan for IRCs is included in Appendix E of this AM Plan; it involves 12 treatment-control pairs implemented over 7 years (see Appendix E).

The spawning habitat hypothesis (H16) provides an example of application of actions at Level 1 and 2 to reduce critical uncertainties affecting management decisions and targets. An early emphasis will be to utilize information from spawning habitats in the Yellowstone River as the best natural reference condition to inform the design of Level 2 pilot projects on the Lower Missouri River, while also continuing to examine the habitat characteristics of spawning sites on the Lower Missouri. Initially only one spawning habitat would be constructed on the Lower Missouri, in a location and form which maximizes the potential for aggregation of males and females. This pilot project will be monitored for effectiveness based on metrics ranging from observed aggregation and spawning to the number of free embryos in the water column (described in section 4.2.6.5.5 on metrics).

Another example of applying Level 1 research within the Framwork is testing the spawning cue hypothesis, H11 (see Table 5). Observational studies (tracking tagged pallid sturgeon movements and spawning over contrasting flow conditions) would), are to be completed during a period of 9 years after the ROD. Analyses of these data and application of an evidentiary framework (section **Error! Reference source not found.**) will then be used to determine whether it is appropriate to implement a Level 2 action – testing spawning cue flows at Gavins Point. The evidentiary framework will examine the correlations between flows and movement, aggregation, and spawning success, using tagged pallid sturgeon in reproductive condition. Testing hypothesis H11 involves both temporal and spatial contrastsKey points and other issues

The uncertainties for the pallid sturgeon are both extensive and fundamental to management strategies. Therefore, AM for pallid sturgeon will rely heavily upon research conducted in conjunction with the implementation, monitoring, and adjustments of management actions. This research has been prioritized to focus on critical uncertainties that have a strong influence on decision trees. Early implementation of actions will generally be of an experimental nature (i.e., Level 2) and could involve several concurrent studies that are potentially confounding. This will require careful consideration of what studies will be implemented and when, along with sound experimental designs.

1.5 Human Considerations (HC)

The term Human Considerations (HC) is used in the MRRP to address the interests of all perspectives beyond those of the ESA. These include a wide array of objectives related to the authorized purposes for the System and BSNP (e.g., flood control, navigation, fish and wildlife, irrigation, power, recreation, water supply, water quality) as well as the many other services afforded by the Missouri River. Ensuring the USACE continues to serve all authorized purposes and minimizes impacts to HCs, while still fulfilling the requirements of the MRRP, is a fundamental premise. Several aspects of the AM Plan are geared specifically toward achieving this objective. Chapter 5 discusses how HCs could be considered and monitored during the implementation of a possible AM approach to meeting species objectives for least terns, piping plover and pallid sturgeon (the ESA species) described in previous chapters.

1.5.1 How HCs are considered

Section 5.1 provides background on how USACE operates the Missouri River Mainstem Reservoir System and outlines a brief timeline of developments that have led to the need to reconsider operations in the MRRP.

Section 5.2 outlines how HCs are considered in operational decision making. It summarizes the relationship between the Master Manual, the routine annual operational planning cycle and real time System operational decisions. It describes how, during the development of the MRRMP, long-term implications for HCs of a wide range of alternatives were estimated using various tools and approaches and explored with stakeholders over several rounds of engagement. These are of significance in the present context because they may be of use during the implementation of this AM Plan.

Section 5.3 discusses the 'Plan and Design' step in the AM Cycle. It summarizes the management actions considered in the MRRMP-EIS and how each can be considered to fall into one of three categories from the perspective of their potential pathways to implementation. It discusses how HCs are given consideration in site-specific planning and in the design of actions under the preferred alternative, as well as how HCs might be considered in planning and design of actions outside the preferred alternative.

Section 5.4 briefly discusses the 'Implementation' step of the AM cycle from the perspective of HCs.

1.5.2 Monitoring and assessment of HCs

Section 5.5 concerns the AM step of 'Monitoring' HC-related issues. It outlines how the USACE currently monitors HC-related issues, the sources of uncertainty in predicting HC impacts and how those sources might be reduced through monitoring. The section discusses the factors future conversations about HC monitoring requirements should consider when identifying and screening specific monitoring actions. It offers a proposed list of candidate HC monitoring studies, along with a possible study prioritization protocol. These proposals and protocol should be thought of as starting points for future discussion, and they require further review and consultation with the HC Team and with the agencies as part of the implementation of the AM Plan.

The potential monitoring studies to be considered for implementation under the MRRP preferred alternative are introduced and discussed individually. Lastly, monitoring considerations for potential future management actions (i.e., outside the preferred alternative) are discussed on a resource area by resource area basis.

Section 5.6 discusses the AM step of 'Evaluating' the effects of actions on HCs. It begins with an account of how the HC Team — as one of three AM Implementation Teams — will, on an annual basis, review the current status of relevant HC metrics and indicators (the specifics of which will be determined by USACE and the HC Team as the plan unfolds). It will compare the annual and longer term predictions with monitored impacts to improve future predictive ability. If alternative means of meeting species needs are being contemplated, the consequences for HCs should be considered using an appropriate method and, after trade-offs have been considered, perspectives on implications and recommendations communicated to decision makers.

Section 5.7 discusses in further detail how decisions under AM might by made in ways that incorporate HC considerations. It again makes the distinction between decisions made within the scope of the preferred alternative and those that would involve the implementation of new actions outside of the preferred alternative and ROD.

1.5.3 Further considerations

Section 5.8 considers further some of the lessons learned from examination of the MRRMP-EIS alternatives and their effects on HCs. It highlights the specific circumstances under which some of the MRRMP-EIS alternatives are predicted to have disproportionate impacts on HCs. Should any of the flow actions in the MRRMP-EIS alternatives be considered for implementation at a future point in time, this section offers suggestions on how impacts to HCs might be reduced.

1.6 Data acquisition, management, reporting and communications

AM decisions should be based on “best available science,” including information that is relevant, reliable, objective, timely, and accessible, among other attributes. Acquiring and managing the data necessary for the MRRP will be a significant undertaking. An elaborate system is needed just to manage outputs from the dozens of models supporting the program, for example.

Monitoring of discrete projects spread along more than 1700 miles of river and involving physical, chemical, biological, economic, and social metrics will generate considerable data at varying spatial and temporal scales that must be compiled, classified, subjected to quality control (QC) measures, summarized, transformed, or otherwise analyzed, and stored in a system that permits easy identification and acquisition.

The successful execution of the MRRP also requires reporting on project performance, System and species status, and communicating Program activities, analysis results, and key decisions to agency personnel, stakeholders, and to the public. Data and analysis results, unless otherwise prescribed by law, should be made available to the decision makers, stakeholders and the public in useful formats.

1.6.1 Monitoring and other data acquisition issues

Monitoring plays a critical role in AM applications by providing information needed for learning and to support sound decisions. Choice of which attributes to monitor and how to monitor them (frequency, extent, intensity, etc.) must be linked closely to management actions, decisions, and monitoring purpose. Monitoring must be consistent with the analytical requirements and principles in the evaluation step and in each subsequent step of the AM cycle (see Section 6.1).

Monitoring and data acquisition are are addressed for pallid sturgeon (see Section 6.2.1), birds (see Section 6.2.2), and HCs potentially affected by water and land management actions (see Section 6.2.3). The multi-team approach employed for the MRRP has advantages: consistent approach and sustained expertise; improved agency coordination; and reduced bias. Weaknesses include turnover and inexperience of some personnel, challenges in training and QA/QC procedures, and occasional inconsistency in methods. Future monitoring efforts will build upon the strengths and incorporate measures to address weaknesses.

Section 6.2.4 describes a Research data acquisition strategy employing a competitive proposal solicitation process, clear selection criteria, independent peer review, and data submission requirements, and overseen by the ISP to ensure the best return on investment in research and development (R&D).

1.6.2 Data management

Information needs vary at different stages of the AM cycle (see Section 6.1). Users include: agency leadership, MRRIC, the general public, the Management, Fish, Bird, HC and Technical Teams, and researchers (see Section 6.3.1). For optimum learning to occur, a variety of data must be collected in meaningful ways, processed as needed, stored and communicated in accessible formats to serve multiple categories of users, and presented at the right time to assist in decision making (see Section 6.3.2).

The goal of the MRRP Data Management System is to provide a single user-friendly access point for MRRP relevant information that is available on a timely basis, in appropriate formats, and meeting required quality standards. Section 6.3 includes specific discussions of users and their needs for information (6.3.1), purpose and objectives of data management (6.3.2), proposed forms of reporting and communication (6.3.3), a proposed plan for developing a data management system (6.3.4), the proposed structure and functionality of a data management system (6.3.5), and a review of existing data management systems (6.3.6).

Requirements for the Data Management System are being further defined through a user needs assessment initiated in the fall of 2016. Section 6.3.4 summarizes a proposed Work Plan for developing the Data Management System, involving five phases: (1) a requirements analysis describing in detail the functions and work products that each user group will require, when, and how they will interact with the system (developed through the user needs assessment); (2) a detailed review of sytems currently used by MRRP, candidate data portals, and available technologies; (3) identifying implementation barriers; (4) developing a report on system requirements; and (5) prioritized development, implementation, and testing of the Data Management System.

Section 6.3.5 describes some of the intended structural features of the MRRP Data Management System and its functionality, and provides examples of these features from existing data management systems. Potential features include: a single portal to information and tools all users; controlled access for certain information and tools; distributed management by the agencies currently generating those data; comprehensive and searchable metadata; and a variety of user-friendly tools to facilitate information access in tabular, graphical, and map-based formats. Existing data management systems, including the Least Tern and Piping Plover Data Management System (TPDMS) and the Pallid Sturgeon Population Assessment (PSPA) Website, are summarized in Section 6.3.6.

1.6.3 Reporting and communications

Communicating results of monitoring and assessment to decision makers involved in the planning and implementation of the MRRP is a primary objective. Others information and communications needs must be met as well, requiring a range of products and information access, potentially including: an online portal for raw monitoring data, data summaries, calendars, maps and other work products; technical reports; draft and final AM reports; system scale AM evaluation reports, technical memos explaining adjustments to management actions, draft and final WPs, fact sheets, journal publications, science blogs and videos; and model manuals. Chapter 6 discusses how these products can be used with the more traditional face-to-face meetings and webinars to meet the Program's communications needs.

1.6.4 Quality assurance (QA) and quality control (QC)

The complexity of the data collection and assessment operations to support the MRRP AMP demands a systematic process for data QA/QC to ensure that decision-makers and stakeholders have confidence that the data they use are scientifically sound, of known and documented quality, and suitable for their intended use. Section 6.4 lays out the basic principles and objectives for a sound QA/QC program, employing the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) as its basis. All agencies and contractors involved in environmental data acquisition during MRRP implementation are required to adhere to the QAPP.

An independent biennial Quality Assurance Review (QAR) will be conducted to provide MRRP management and stakeholders with an assessment of the state of data quality for MRRP. The goals of the QAR are to identify practices that contribute to data quality, identify problems and best management practices, report on the activities of the AM Teams, and recommend improvements to the quality system for MRRP monitoring.

Data Quality Objectives (DQOs) have been defined for the MRRP to bring awareness to participants of the minimum data quality required. The DQOs define the type, quality, and quantity of data needed to make defensible decisions. They identify the requirements for field investigations and limits on tolerable error rates, and indicate the intended end use of the data, including decisions that may be made based on the information generated.

The ISP, working and coordinating with the various AM Teams is charged with implementation and oversight of the MRRP QA/QC program and will ensure that monitoring adheres to the QAPP. The ISP is responsible for dealing with QA issues, establishing a mechanism for distribution of quality system information and changes, and ensuring data meet or exceed the DQOs of the AMP.

1.7 Summary

Figure 11 illustrates the timeline of events leading to the MRRMP-EIS and this AM Plan. The EA demonstrated that the best available science and current understanding of the effects of the operation and maintenance of the System and the BSNP are not sufficient to clearly identify the scope of actions necessary to avoid jeopardizing the continued existence of pallid sturgeon or its critical habitats. Furthermore, the timing and scope of necessary actions for the piping plover and least tern are uncertain at relevant timescales because of the dynamic nature of those species' critical habitat; predicting needs beyond 1 or 2 years and meeting them within constraints presents challenges and requires trade-offs.

Figure 11. Timeline of events leading to the MRRMP-EIS and the AM Plan.

Given the uncertainties identified by the EA, the lead agencies deemed it prudent to proceed by identifying a Preferred Alternative in the MRRMP-EIS that addresses the priority hypotheses from the EA, but to also prepare an AM Plan that provides the framework, performance standards, decision criteria, and governance processes needed to guide the MRRP's implementation so that knowledge gained over time would translate into refinements of or adjustments to the management actions necessary to meet the Program's objectives.

In lieu of a more definitive but comprehensive set of actions that might have otherwise been prescribed, the AM approach provides (a) time and latitude to implement, monitor and assess actions in a structured fashion to promote learning, (b) opportunities for research and studies that may yield answers to critical questions more quickly than would occur through implementation alone, and (c) the flexibility to reject, modify, or introduce new actions and/or adjust targets based on knowledge gained through the process. This approach recognizes the trade-offs between time and knowledge, and balances the risks and uncertainties so as to benefit of the species, while minimizing costs and impacts.

The AM strategy builds upon the products of the EA, employing rigorous hypothesis testing, project and Program monitoring and assessment, and predictive numerical modeling of habitat, species status and effects of alternative management actions. A science update process affords decision-makers needed information to make annual update to a 5-year strategic WP for the MRRP. Annual updates may include adjustments to plans for the current and next FYs, but are focused on the FY+2 Program to align with the USACE's Civil Works budget needs.

Interagency Bird and Fish teams that include MRRIC WGs use information generated by a non-decisional Technical Team to formulate recommendations and prioritized actions for each species. An HC Team reviews monitoring and assessment results as they relate to effects of actions on HC interests and provides recommendations for related needs. An interagency Management Team drafts adjustments to the WP using the Bird/Fish/HC Team recommendations and guidance regarding resource availability. Draft updates to the WP are vetted through engagements between the lead agencies and MRRIC at plenary meetings that provide opportunities for input, collaboration, and consensus recommendations. The same process is used to address adjustments to the Program's governance, to resolve disputes, etc.

Managing for the birds involves meeting targets for ESH while minimizing impacts to authorized purposes, balancing other Program needs, and accounting for constraints. The challenge lies in uncertain future conditions regarding system runoff and operations, which affect habitat availability and population responses. The habitat and population models provide powerful tools to support management decisions. AM opportunities center on improvements to these tools, better and more cost-effective methods for creating and maintaining ESH, and predator and vegetation management.

Managing for the pallid sturgeon presents more significant challenges. Uncertainties regarding the specific factors causing recruitment failure for pallid sturgeon and the inability to link management actions with population response prevent the clear identification of the System manipulations required to address the species' needs. A framework and strategy reliant upon a progressive AM program is the most effective way to manage risks to the pallid sturgeon, address the key uncertainties, and identify the scope and scale of actions ultimately required.

In addition to the above considerations, this draft AM Plan includes a number of processes, protocols, and procedures that will be necessary for the implementation of the program, a description of the data management, reporting and communications needs and strategy, and a discussion of how HCs can be addressed. An accompanying set of appendices provide important details regarding the needed research, experimental designs for hypothesis testing, monitoring and assessment protocols, etc. Updates and improvements to the AM Plan over time as understanding grows and the needs of the program change have been anticipated, and processes for periodic adjustments have been incorporated into its design.

2 Governance of the AM Program

Chapter 2 addresses the governance of the MRRP AM Plan –the management and decision making structure and process for the program – and describes several important principles and attributes of good governance. The range of decisions required for the plan development and its implementation are discussed in Section 2.2. The roles and responsibilities of the primary entities involved in governance are described in Section 2.3. The decision process, and in particular the interactions occurring around the development and update of the WP are discussed in Section 2.4. The chapter concludes with a presentation of several important protocols and procedures (see Section 2.5). The decision making structure contained in this section is in no way delgation of decision making authority. Nothing in this section is designed to impede or infringe any statutory decision making authority for any party described.

2.1 Definition, principles and key attributes for effective governance

2.1.1 Governance defined

Although several definitions of governance are available, a broadly held view is that it includes a consideration of authority, administration, decision-making, and accountability. Governance for an AM program describes the approach for converting knowledge into improved management through decision making, including:

- **what** decisions need to be made,
- **who** is involved in the decision process,
- **how** decisions are made, and
- **when** decisions are required.

The concept of "adaptive governance" has recently emerged in the context of AM, adding consideration of the need for organizational and institutional flexibility to change, which is a crucial concern for the MRRP AMP given the likelihood that the governance strategy will need to be adjusted to suit program needs, and that the lead agencies and MRRIC will also need to adjust to this way of doing business.

2.1.2 Attributes of governance that enable AM

Although AM has been applied to natural resource management for several decades, implementation has not been easy. Obstacles include concerns that implementing and rigorously evaluating management actions different from the status quo may be too costly, too risky, and/or contrary to values of some stakeholders, as well as perceptions that a shift to AM threatens existing management, research and monitoring programs.

Effective governance can help address these obstacles by acknowledging differences in values/policies (i.e., What do you want?) from alternative beliefs about causation (i.e., How do you get it? See Lee [1993]). The ideal setting for AM is one in which there is agreement around the objectives and policies, while allowing for disagreement around the cause and effect of different approaches. Because it cannot always be avoided, a good AM program should also have processes for resolving value-based conflict.

Effective systems of governance and organizational networks for AM serve several functions, including: (1) trust-building, (2) knowledge generation, (3) collaborative learning, (4) preference formation, and (5) conflict resolution (Green et al. 2015). A robust system of governance that can execute, innovate and learn is preferred for AM (Duit and Galaz 2008). Attributes that enable AM can be divided into three sequential and mutually supportive subsets (Greig et al. 2013). Governance first requires mechanisms of conflict resolution and trust building. Attributes related to problem definition, communication, leadership, executive direction, and organizational structure are the second set of critical elements to establish. If done well, the third set of attributes will follow: community involvement, planning, funding, staff training, and AM science. Table 8 summarizes factors enabling and inhibiting good AM governance.

Table 8. Factors enabling and inhibiting good governance of AM programs.

Factors Enabling Good Governance	Factors Inhibiting Good Governance
Collaborative, interdisciplinary working environment with free-flowing communication and easy access to well-synthesized information.	Communication among components/departments hindered by different mandates or between disciplinary specialists (i.e, stovepiping). Difficult to access required information.
Frequent re-examination of management and restructuring as needed.	Management done the same way for a very long period of time.
Leaders deliberately challenge themselves and staff to recognize change, innovatively adapt to challenges, and take calculated risks.	Leaders resist change, discourage risk and innovation, and create organizational culture of status quo.
Collaborative inputs to decision making over sustained period, generating buy-in and trust, allowing stakeholders to move from positions to interests, clarifying areas of agreement and disagreement.	Institutions isolated from public/stakeholders; very limited and inconsistent consultation. “Inform” rather than listen.
Recognize critical uncertainties and plan experiments to test alternative hypotheses/actions.	Plan based on past experience, practices, procedures established by senior staff.
Stress high-quality science at appropriate scales, with independent review panels. Data made available; different interpretations of data welcomed, used to postulate alternative hypotheses and design management experiments. Wide publishing of scientific findings.	Science discouraged or use of “advocacy science” to support agency’s position (see Section 2.1.3). Data kept internal; selective evidence used; insist on single, dogmatic agency position regarding data analysis.

There is no "one-size-fits-all" approach to effective governance. An effective system will depend on the intended purpose/need and will have clear expectations around outcomes (Rijke et al. 2012). Although lessons can be learned from other AM programs (e.g., Trinity River, Platte River, Glen Canyon), an effective system of governance for the Missouri River requires consideration of how the above attributes and functions apply within the context of the unique ecological and social conditions for the Missouri Basin.

The MRRIC (2011) indicated that the engagement approach for developing and implementing an AM strategy should:

- be understood and trusted by MRRIC members
- provide a satisfactory level of participation in the systematic process for MRRIC members as well as provide
- afford opportunities for MRRIC to identify any social, economic, or cultural issues that may result from the proposed action(s)
- be implementable for both the agencies and MRRIC
- be focused on resolving scientific uncertainties necessary to inform management decisions
- provide for collaboration that allows the agencies to implement the MRRP in a timely manner.

Gunderson and Light (2006) point out that the Comprehensive Everglades Restoration Program has been hindered by long standing feuds among special interest groups (agricultural and environmental) who seek certitude in policy, rather than understanding through experimentation. AM accepts that "failures" will occur and that those failures provide a valuable contribution to learning; other approaches seek to avoid policy failure, which reinforces the status quo and precludes opportunities for learning while doing (Blann et al. 2003; Light, 2001). Governance must recognize that short-term "failures" are critical to long-term success.

To be successful, AM must be applied under and supported by a governance structure that understands AM, values it, and is willing to commit the necessary resources to allow its processes to work (Loftin 2014). AM and accountability are closely linked; both answer questions about whether progress is being made using ecosystem and program information (Puget Sound Partnership 2008). While the USACE is ultimately accountable for executing the program so as to avoid jeopardizing the listed species or their habitats, each of the entities involved in the MRRP must be accountable for their roles in executing the plan. The use of performance metrics, decision criteria, and other triggers can improve accountability (Nie and Schultz 2012) and are therefore emphasized in this plan.

Fischenich (2012) indicated that AM works best when (a) management flexibility is incorporated into the design and implementation of programs or projects; (b) projects and programs can be implemented in phases to allow for course corrections based on new information; (c) interagency collaboration and productive stakeholder participation are fostered; and (d) scientific information is introduced into the decision-making process and guides managers not only during planning, but also after project implementation.

Governance can take several forms. The "governance" implicit in the decision criteria, contingency plans, and other guidance incorporated into the AM Plan, which are decisions agreed upon prior to implementation, are as important as the governance that occurs through post-implementation decisions. A recent review of court decisions (Fischman and Ruhl 2016) suggests they are an essential component of an AM Plan.

2.1.3 Ensuring objective and reliable science in the Missouri River Recovery Program

AM requires reliable information for improved decision making, increased effectiveness of management actions, and increased ability to meet program objectives. Decision makers and stakeholders must be confident that the underpinning science is unbiased and sound. The utility and credibility of science is reduced when influenced, or perceived to be influenced, by agendas, political pressures, advocacy, and bias. This is a common challenge among science programs and especially for those involving contested, controversial, or politically-charged topics. Scientists must adhere to, and organizations must promote, practices and conduct that contribute to the best available scientific data and information, and generate objective, relevant information for decision makers.

The MRRP Integrated Science Program (ISP) relies on partner agencies to conduct research and monitoring, analyze data, and report findings. An advantage of this approach is that significant expertise –often not available elsewhere– exists within these agencies. Work conducted by multiple partners can benefit from the broad perspectives those partners provide. However, partner agencies have their own missions and, in some cases, advocacy roles. For the MRRP, scientists must follow scientific codes of conduct and accurately report findings, even when results do not support agency positions. Potential conflicts of interest and unsound scientific practice must be identified and addressed to prevent their influence on the scientific data and information used in the MRRP. Agency leadership, scientists, independent advisors, and stakeholders all play important roles in addressing this concern.

The potential for bias is ever present and guarding against it by relying upon the Program's ability to identify and engage only unbiased entities is not an effective solution. Because even the perception of bias will undermine credibility and ultimately the utility of science, the solution must be broad, transparent, confidence-building, and continually monitored for effectiveness. The following mechanisms will be employed to help minimize bias, increase transparency, build confidence among agency decision makers and stakeholders, and ultimately maximize the credibility and usefulness of the data and knowledge underpinning decisions for the MRRP:

1. Embrace independent review. Independent review, (e.g. ISAP and external peer review) provides opportunity for critical, independent, and transparent evaluation of experimental designs, science findings, interpretations, and resulting decisions. Independent review, especially when performed transparently with opportunity for engagement by interested parties and open scientific deliberations, serves to dramatically increase trust in a science program. Successful use of independent reviews requires commitment by scientists, stakeholders, and decision makers to embrace the process. In addition to these reviews, subjecting MRRP science to peer-review and publication standards is important and should be a requirement of scientists working on the MRRP.

2. Engage expertise within and outside the basin. When little scientific input or interaction occurs among scientists within and outside the basin (e.g., those studying pallid sturgeon on the Mississippi River, other sturgeon species, or other highly altered river restoration efforts), science efforts can become myopic or suffer from lack of perspective and lessons learned by others. This is especially true for pallid sturgeon and piping plover science efforts given that these species occur and are extensively studied outside of the Missouri River basin. Recurring, structured interactions among system- and subject-matter experts both within and outside the basin, including Recovery Teams, will ensure that science efforts are coordinated, well-informed, and considerate of relevant knowledge and expertise.

3. Diversify partnerships and increase reliance on a competitive proposal process. Striking the proper balance between the need for consistency and development of expertise with the benefits of new partnerships and additional scientific perspective is a challenge for any program. The ISP and MRRP should, where practical, seek to involve new science partners and pursue proposals for research efforts through competitive processes that generate alternative strategies, foster new collaborations, and bring innovative concepts to bear upon the challenges of the MRRP. Because the Program is hypothesis based, scopes of work can be clearly defined, creating a competitive proposal process with several inherent benefits.

4. Maximize transparency. It is critical that the ISP and all parties to the MRRP continue to function transparently, ethically and openly. Maximum transparency regarding collected data, analyses, scientific deliberations, recommendations, and science prioritization should remain a priority. Continued emphasis on frequent and

effective communication is necessary. To this end, the development of a web-based data management and reporting system should be a near-term programmatic objective (see Section 6.3).

5. Predefine data collection and analyses requirements and follow the plan. Clearly defined procedures in the AM Plan increase transparency and reduce opportunities for bias. Monitoring and assessment protocols must be followed, related analyses completed, and results shared, regardless of the findings. Scientists cannot have the opportunity to selectively analyze data or report only those findings consistent with the scientist's or agency's aims. Acceptable monitoring, assessment, and analytical practices, as driven by program needs, will be identified and incorporated into the AM process through compulsory protocols published in the AM Plan and identified in any work orders or contracts.

6. Optimize institutional structure to minimize conflict between policy and science. The ISP cannot act or be perceived to filter information so as to support an agency agenda. Instead, the role of the ISP must be to ensure that sound scientific processes are followed, that appropriate checks and balances are in place to counter inherent bias, and that all relevant information is considered and evaluated. To this end, structuring of the MRRP should provide confidence that science practice is clearly separated from undue influence of advocacy and peripheral agendas.

2.2 Decision needs for adaptively managing the MRRP

Planning, implementing, and adaptively managing the MRRP requires hundreds of decisions ranging from relatively mundane issues like what type of net to use for sampling to significant and potentially contentious issues like whether to adjust flow releases from a reservoir to create habitat. Decisions occur at many points in the process; they are made, for example, when setting or updating goals and objectives, when selecting actions to implement and how they should be monitored, and when determining if or how to adjust the strategy due to new information.

The USACE Commander for the Northwestern Division (NWD) is ultimately responsible for most of these decisions. However, the sheer volume of decisions demands that many decisions be delegated to the District Commanders or others within the agency. USACE's senior leadership cannot be involved in all the day-to-day technical activities of the Program, so they must rely upon recommendations from subordinate staff familiar with the issues and from subject-matter experts engaged by the MRRP for that purpose. They also rely upon input from MRRIC, other agencies, Tribes and the public, where appropriate, when making decisions. The USACE has a long history of operating in this fashion, which is an important consideration when developing a governance structure for the MRRP.

The USFWS is responsible for compliance-related decisions, including policy determinations regarding the application of AM to the ESA. As knowledge about species and their responses to management is gained through implementation, it may be necessary to adjust the targets, decision criteria, and/or required management actions in order to sustain a determination that the operation of the System and BSNP is not likely to jeopardize the listed species or their habitats. The USFWS Mountain-Prairie and Midwest Regional Directors will work closely with the USACE, MRRIC, and the other entities listed above when making these decisions.

MRRIC shares responsibility for the Program performance; their input and recommendations influence agency decisions. MRRIC may provide a consensus recommendation regarding the Program's governance; if all parties agree to the rules of engagement, the potential for conflict is reduced. AM demands the commitment of time, resources, and active engagement of stakeholders, as well as their commitment to actively engage in the governance process and provide the necessary input to decision makers.

Importantly, certain parties are explicitly excluded from decision-making roles. Facilitators promote group participation, trust, mutual understanding, and shared responsibility for decisions, but are not themselves decision makers, so must maintain a neutral posture on any decision. Similarly, technical experts play an important role by helping to link objectives and management decisions to system understanding, but are not themselves stakeholders, so should not be involved in objective/value development or decision making. These entities must be viewed by agencies and stakeholders as neutral third parties, and must be capable of performing as such (see Section 2.1.3).

2.2.1 Scope of decisions in the MRRP

The most evident and essential function of governance for an AM program is to facilitate effective, transparent decision making. However, decisions for the MRRP (and all other large-scale, ecosystem-based programs) are complicated by several important legal, social, political, and economic dimensions. The design of the Program's governance structure and processes must, therefore, anticipate the wide range of decisions needed to translate knowledge gained about the system and species into effective and acceptable management. Governance design should also promote decision making at the lowest practicable level and be sufficiently flexible to allow for efficient, timely decisions, accommodate unanticipated decision needs, and to grow/change with the Program.

Attachment 16 of Appendix A includes a table with examples of the decisions required to adaptively manage the MRRP. The decisions in the table are posed in the form of questions, which are categorized based on the activity to which they apply. The table includes the point in the process at which the decision for each question is needed (i.e., which step of the AM cycle and the program entity generally responsible for making recommendations on each decision as well at the entity that would typically make the decision. Some of the organizational elements listed in the table have not been previously described in thisAM Plan (see Section 2.3 for descriptions of entities involved). Many more decisions will be required than those listed, and some situations that may not be encountered are described because they present challenges better addressed during Program development than during execution, when time may be limited or perspectives complicated by other factors.

Because of the large number of questions and the need to delegate, decisions for the Program may be made at three general levels of authority within the agencies (defined herein as Oversight, Management and Implementation).

1) The Oversight level includes agency senior leaders, who are responsible for decisions related to Federal policies and protocols, the setting of objectives and targets for the Program, and developing protocols for maintaining compliance with the ESA and other mandates. Additionally, Oversight is required for establishing the Program's governance structure and processes, operating procedures, and criteria for changing the above. They also decide the decision space in which the program operates and how it is implemented (e.g., which management actions are included and to what extent). Decisions at this level may significantly affect stakeholder interests or authorized purposes, and therefore involve collaboration with the MRRIC. These decisions are primarily made during the Plan/Design step (Step 1) of the AM cycle as the Program is developed, but are revisited periodically and as needed during the Adjust/Continue step (Step 5).

2) The Management level, which includes agency program managers (PMs), the ISP Manager, and others in similar positions. Management develops the draft WP for the Program with guidance from agency senior leaders. They also manage and, where authorized, make selected decisions regarding several aspects of the Program's implementation, including resource allocation, reporting and communication, and collaboration. They make recommendations on needed changes to the Program's operations and structure, and oversee the implementation of those changes with approval from the Oversight level. MRRIC provides input to the WP and may make recommendations regarding any management-level decisions or processes. Management-level decisions are primarily made at the Plan/Design and Implementation steps (Steps 1 and 3) of the AM cycle, but can include decisions at each step of the process, and are frequently required as part of the Program's operations (e.g., annually).

3) Implementation-level decisions include the wide ranging and numerous judgments needed for the day-to-day operation of the Program. These include how monitoring programs are implemented, how assessments are conducted and reported, how projects are implemented, etc. Note, however, that the real-time flow management decisions made by the Corps' Water Management Division following the procedures and requirements in the Missouri River Mainstem Reservoir System Master Water Control Manual are Oversight-level decisions (see Section 2.3.1).

Decisions occur at each point in the AM cycle (see Figure 5), but tend to cluster by category and authority level, and are especially abundant at steps 1 and 5.

1) During the assessment and plan/design step, (Step 1), decisions must be made at all levels about the scope of the program and how it will be implemented and adjusted. These include policy and process decisions establishing objectives and targets, decision space and criteria (which actions will be implemented, and how) and processes for making decisions and communicating outcomes. The initial phase of this step (assessment) was largely addressed by the EA and the MRRMP-EIS, leading to the establishment of the ROD and thisAM Plan. The assessment phase as defined (and not to be confused with the evaluation step) is needed only infrequently, having last been undertaken in 2003. The plan/design step is frequently revisited (typically annually), however, to ensure the actions implemented are effective and needed adjustments are made following procedures in the Plan's Governance section.

2) During the Implement step, (Step 2), decisions center around research activities, the actions being implemented, needed adjustments due to unanticipated conditions in the field (e.g., high river stage preventing habitat construction) or needed adjustments to enhance effectiveness or minimize impacts. These decisions must be made quickly and are therefore supported by real-time monitoring, modeling, contingency plans, and other mechanisms for improving efficient information flow.

3) Few decisions are made during the Monitor step; (Step 3); monitoring teams should not deviate from established protocols. However, some decisions during monitoring may be necessary to address unusual conditions. To the extent practical, contingency plans that maintain needed statistical rigor but permit altered sampling methods should be developed to address unusual, but not entirely unanticipated conditions or events (e.g., floods, drought, etc.).

4) Decisions are not generally made during the Evaluate step; (Step 4); rather, this step prepares information for decisions in Step 5 (complete/adjust/continue). The need for adjustments to processes, protocols, models, etc., may become evident in the

course of conducting evaluations and result in recommendations to advise decisions regarding changes to those plan components, but decisions to make those changes would typically occur independently of the time during which evaluations are underway.

5) Most decisions occur in the Complete/Adjust/Continue step (Step 5). Decisions may be made to (a) continue actions as planned or previously implemented; (b) adjust how the actions are currently implemented actions are carried out; (c) adjust which actions in the selected alternative are implemented; (d) adjust which actions are included in the selected alternative (adding or removing actions, or expanding definitions beyond what is currently included). Decisions may also be made at this stage to continue or adjust programmatic or policy components as specified in the initial Plan/Design phase (Step 1). In this last case, all or part of Step 1 may be repeated to reformulate the plan as needed.

2.2.2 Balancing needs for the birds and fish

Because objectives and management actions have been identified separately for the birds and fish, the potential exists for actions aimed at one species to adversely affect the other; they can also synergize with or have no measureable influence on the others. A key stage in the planning of actions is the assessment of their effects on the target species, on other species, and on the various HC interests. Where possible, actions should be adjusted to avoid and minimize adverse effects and to maximize benefits. Actions with unavoidable adverse impacts should be judged against associated trade-offs and other alternatives.

Overlapping effects are substantially reduced by geographic realities; aside from that portion of the Southern Region for the birds downstream of Gavins Point Dam, the targeted areas for the birds and fish do not coincide. Direct and localized secondary effects of habitat construction – the focus of the preferred alternative – are therefore generally restricted to the target species (see further discussion in Sections 3.2.5 and 4.2.6.7). The greatest opportunity for intersecting effects occurs with flow management actions. A spring release aimed at pallid sturgeon spawning, for example, might create some emergent sandbar habitat but might also delay bird nesting (see Section3.2.5).

Potentially overlapping effects of management actions are considered at several stages in the process. The initial set of actions included in the preferred alternative, as well as the other actions considered in the full range of alternatives, were evaluated in detail as part of the MRRMP-EIS process (see Chapter 4 of the EIS and Sections 3.2.4 and 4.2 of this AM Plan). Similar analyses will be conducted by the USACE and/or the Technical Team for any new management actions identified in the future, and the cumulative effects of all management actions will be assessed as part of the WP formulation process whenever new actions are proposed (see Section 2.4.5). Management actions should be optimized at the concept and design stages to avoid and minimize impacts (or optimize benefits vs. impacts), and adjusted as needed during the WP formulation to ensure their performance as part of a suite of management actions is consistent with objectives.

Whereas potentially overlapping effects of management actions are few and infrequent, balancing the needs for bird and fish in terms of Program focus and budget will remain an ongoing requirement. For pallid sturgeon, the research and implementation strategy needed to overcome critical uncertainties could fully exploit available Program resources. However, the extent to which the Program focuses on pallid sturgeon needs will likely be driven by habitat requirements for the piping plover. Historical patterns of runoff and System storage – which will presumably continue – have resulted in periodic high flows (e.g., 1952, 1975, 1997, and 2011) that create abundant ESH. These events are typically followed by periods of declining ESH acreage as the sandbars erode under normal operations. When the acreage approaches or drops below targeted levels, construction will be needed to offset losses and maintain sufficient habitat for the birds.

Balancing bird and fish needs that differ over time requires ongoing analysis, planning, risk management, and flexibility. Program resourcing (budget and personnel) will need to be periodically shifted to address changing requirements. The need for additional ESH will seldom be a surprise; erosion rates are reasonably predictable, and modeled acreage projections can be used, to some degree, to identify when shortfalls are likely. Conversely, shortfalls can be abated by an unforeseen high flow event, requiring decisions about alternative use of funding intended for ESH construction and personnel assigned to that purpose. Moreover, decisions about when to begin ESH construction as habitat acreage declines, and how much to build in any year, can be a challenge involving weighing the risks of not meeting targets and required trade-offs in terms of lost opportunity for pallid sturgeon research or project implementation. Management decisions that properly balance these considerations should improve over time, applying the best combination of a) variable budgets that reflect ESH needs, b) trade-offs between the birds and fish, c) occasional use of flows to meet ESH targets, d) acceptance that targets for one or both species may not be met at times, or e) some as yet unforeseen approach.

2.2.3 Timing of AM decisions

Though dramatic shifts in the strategy or emphasis of the MRRP can occur based on new information, changes in system status, or unanticipated budget adjustments. However, change is more likely to be infrequent and slow. Testing of the EA hypotheses requires the exercise of rigorous experimental designs that can take 5 to 10 years before trends are evident and decisions about the effectiveness of a management action effectiveness can be made with any confidence.

Additionally, several processes outside the MRRP impose important constraints on the development and implementation of the WP. The Compliance with policies that apply to elements of the MRRP affects scheduling and execution of the Program (Figure 12), though the most significant Program constraint is the Corps' annual budget process for Civil Works and the development of the Annual Operating Plan (AOP) for the Missouri River Mainstem Reservoir System. USACE Civil Works funding is a two-year development process that can be generally summarized as a develop-defend-execute cycle. The Corps budgets and executes its mission on an FY basis. The FY begins October 1 and ends September 30 the following year. Using January 2017 (FY17) as a starting point, the schedule for development of the FY19 budget is shown in Table 9.

The above realities dictate a "strategic" rather than a "tactical" approach to managing the MRRP. Activities within the current Fiscal Year (FY) or the next FY (or FY+1) may be subject to minor adjustment only given the budgets are already fixed, actions planned, and mechanisms to shift those actions limited. Emphasis should therefore be placed on establishing needs to set the future Program and budget. Defining needs for the FY+2 Program and budget, in particular, should be the focus of the agencies and MRRIC on an ongoing, annual basis. Given the USACE's Civil Works budget process, the Program should be aligned to define those needs no later than June and preferably earlier in any year.

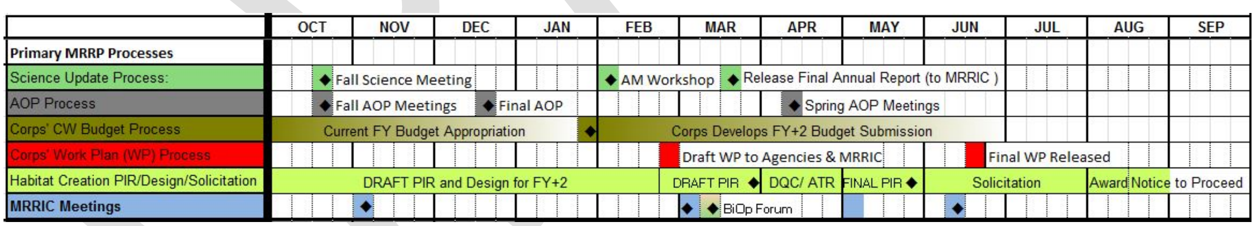


Figure 12. Timeline for budgeting, strategic review, WP development, and the AOP.

2.2.3.1 *Federal water resource budgeting*

Funding availability profoundly affects the ability to execute the MRRP. The year-round budget process engaged in by the USACE and other Federal agencies occurs on a timetable that affects other considerations in the AM Plan.

Congress generally authorizes numerous new USACE site-specific activities and provides policy direction in an omnibus USACE authorization bill, typically called the Water Resources Development Act (WRDA) or more recently the Water Resources

Reform and Development Act of 2014 (WRRDA 2014; P.L. 113–121). The WRDAs do not provide funds to conduct activities, nor are they reauthorization bills. Federal funding for USACE civil works activities is provided in annual Energy and Water Development appropriations acts or supplemental appropriations acts.

USACE Civil Works funding is a 2-year development process that can be generally summarized as a develop-defend-execute program cycle. The USACE budgets and executes its mission on an FY basis. In the absence of congressional passage of an agency-specific appropriation, Civil Works annual funding is generally included in an all-encompassing "omnibus" bill. If a bill has not passed at the start of the FY, Congress typically passes a Continuing Resolution Authority (CRA), which allows the USACE to continue operations until such time as an appropriations bill is passed or the CRA expires. Under a CRA, funding is typically provided on a month-to-month basis (or other similar timeframe) based on the previous year's funding level. Table 9 provides an example of the budget cycle, beginning with budget guidance for FY2019, which is provided in January of 2017.

Table 9. Schedule for the USACE's Civil Works budget development process.

Month / Year	Budget task and responsible parties
JAN 2017	Office of Management and Budget (OMB) provides budget guidance for FY19.
MAR/APR 2017	Headquarters USACE (HQUSACE) provides FY19 budget limits and program guidance within the USACE based on the OMB and additional ASA (Civil Works) guidance.
MAY/JUL 2017	USACE field offices develop FY19 program requirements based on the USACE guidance.
JUL 2017	HQUSACE reviews the field-developed FY19 requirements.
JUL/AUG 2017	The USACE-developed FY19 budget is worked with the Secretary of the Army.
SEP 2017	The Army's FY19 budget program is submitted for OMB review.
SEP-NOV 2017	OMB reviews with and then tells Army and the USACE what its budget will be for Civil Works program planning in FY18. This is referred to as the OMB passback.
DEC-FEB 2017/18	The President's budget for FY19 is finalized and submitted to Congress. It provides the USACE with the specific budget details needed to plan FY18 Civil Works program execution.
FEB-MAY 2018	Congress conducts appropriations (and, if necessary, authorization) hearings to discuss and ask detailed questions about the President's FY19 budget submission. The Assistant Secretary of the Army (Civil Works) and USACE leadership testify before subcommittees to address Congressional concerns about the President's budget for the FY19 Civil Works program.
JUN-SEP 2018	Appropriations bills for FY19 are developed and approved by Congress.
SEP/OCT 2018	President signs the FY18 appropriations legislation into law. The legislation provides the USACE with specific Civil Works program execution guidance by funding category and specifically authorized projects and studies.

OCT/DEC 2018	HQUSACE allocates FY19 funds within the USACE for FY execution.

2.2.3.2 *Annual Operating Plan (AOP)*

The AOP presents pertinent information regarding water management for the Missouri River Mainstem Reservoir System. The information in the AOP is based upon water management criteria found in the 2006 Missouri River Master Water Control Manual (Master Manual).

The AOP is not a decision document, but rather displays the results of applying the Master Manual criteria over the five runoff conditions: upper decile and quartile, lower decile and quartile, and median runoff. Project releases, reservoir elevations, power production, and other project objectives including endangered species objectives are projected for the runoff scenarios.

Other documents related to the AOP provide important context. These include the "System Description", which describes the system and explains the master manual criteria and project purposes and the "Operation and the Summary of Actual Operations", which is produced annually and describes the results of the previous year's operation

The draft AOP is produced and distributed in September of each year. Public meetings are held throughout the basin in October. Written comments are taken through the end of November, and the Final AOP is published in December. Public meetings are then held again in April of each year to present the Final AOP. A spring update on current conditions is provided as it relates to AOP implementation. Monthly conference calls are held from January-May (or as needed) to update on current conditions and release plans. These calls are made with interested Federal, state, county and local government representatives, Tribes, levee districts, and media representatives.

2.2.4 Role of decision criteria in the MRRP

The term "decision criteria" refers to the set of pre-determined conditions that trigger or guide a decision or the implementation of a contingency plan. They can be qualitative or quantitative based on the nature of the performance metric and the available information to support a decision, and occur in a variety of forms. A recent study of judicial decisions on AM programs cited the lack of decision criteria as one of three key deficiencies leading to possible overturning by the courts of agency practice (Fischman and Ruhl 2016).

Decision criteria play several roles in the MRRP; they are designed to:

- define requirements for compliance purposes (e.g., ESA, NEPA, USACE's policies)
- ensure that decisions incorporate best available science
- facilitate complex decisions, or decisions that must be made quickly during implementation
- provide a clear(er) roadmap for participants (i.e., they define the decision space).

Decision criteria utilized in the MRRP take various forms, including quantitative triggers (e.g., the criteria for the Lower River Pallid Sturgeon Framework in Section 4.2.1.3), decision trees (e.g., diagram addressing drift and dispersal in the Upper Missouri and Yellowstone Rivers in Figure 63), planning rubrics (e.g., the matrix for ESH needs in Table 35), heuristics (e.g., the decisions for flow creation vs. construction in Table 36), and schedules and Gantt charts or flowcharts (e.g., the timeline to implement flow decisions in Figure 28). Even guiding principles, which are evident throughout the AM Plan, can broadly be considered a form of decision criteria.

Criteria cannot be developed for every decision faced in executing the MRRP. Some decision criteria may elude development during the initial planning stages; wherever useful criteria simply cannot be developed until details of actions are known. As knowledge grows, it will likely become apparent that some criteria need to be changed. To address these realities, the AM Plan includes a suite of objectives and principles along with a process to guide the development/revision, review, and approval of decision criteria in the future. Attachment 6 of Appendix A provides details on the process to change criteria.

2.2.5 NEPA, the Master Manual, and decisions regarding management actions

The process for adjusting actions, including adding actions not previously implemented or changing the specification of an action, depends on the type, extent, and direction of change needed, and whether the desired action was addressed in the EIS (see Figure 13). If a contemplated action was not evaluated in the EIS, an additional NEPA process (e.g., supplemental EIS) is required before implementation of the action could occur. If an action was evaluated in the EIS but the analysis was no longer considered adequate (e.g., because of changed environmental concerns or site conditions), additional analysis is likewise be required. If the analysis in the EIS was adequate but the action was not selected in the ROD, new decision documentation would is required before that action can be implemented. Finally, if an action included in the ROD involved flows not consistent with the technical criteria in the Master Manual, modification of the Master Manual would be necessary (see Attachment 5 of Appendix A for details on the procedures for changing the technical criteria in the Master Manual).

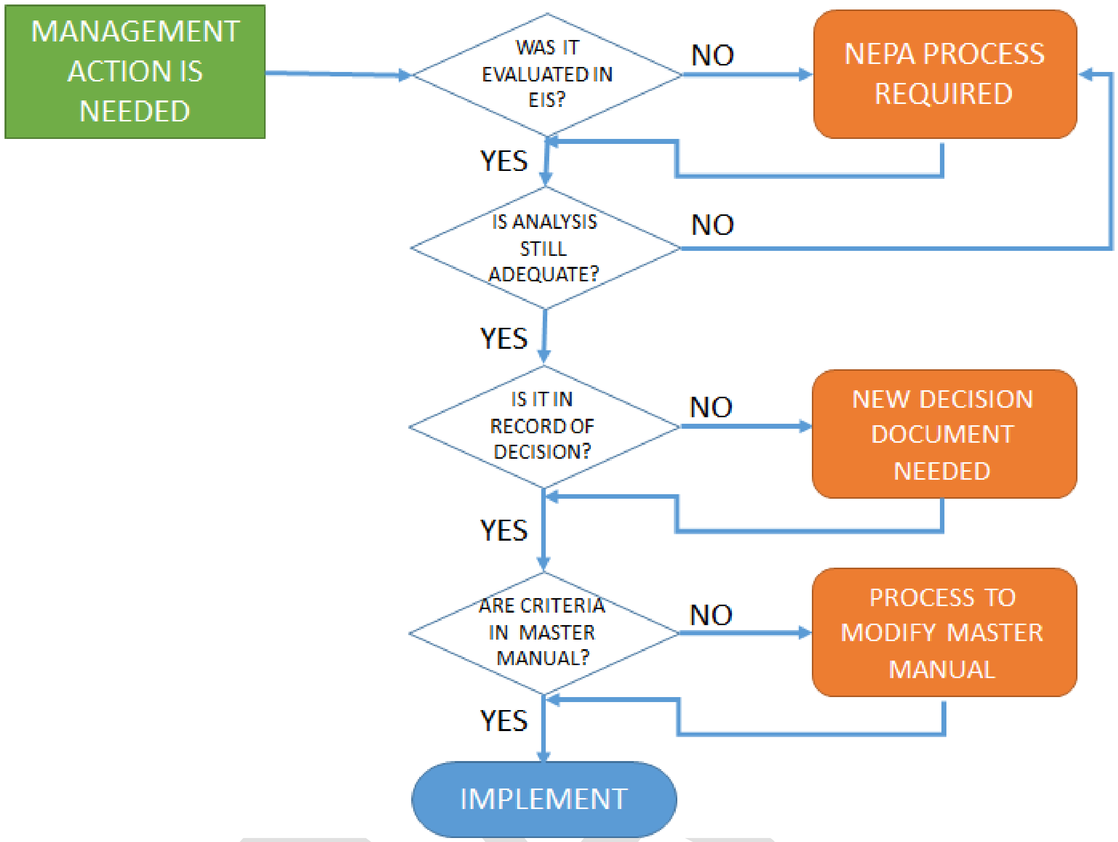


Figure 13. Flowchart for decisions to implement a management action (Step 5b)[1].

2.3 AM program composition, roles, and responsibilities

The MRRP is a collaborative effort amongst the USACE, USFWS, and MRRIC. Notwithstanding the collaborative nature of the Program, the lead agencies have statutory responsibilities that cannot be delegated. The role of MRRIC is similarly defined by relevant legislation (e.g., Sec. 5018 of WRDA, FACA). Descriptions of the composition, roles and responsibilities for the entities outlined in this section are intended to (1) comply with the above requirements, (2) maintain transparency and involve all three entities in the AM learning process and in the formation of recommendations for actions and research, and (3) achieve the Program's goals and objectives in the most efficient manner possible.

[1] Note that the last step, involving technical criteria in the Master Manual, would only apply to flow actions.

Adaptively managing the MRRP is a monumental effort requiring the support of hundreds of individuals from numerous organizations. Not all of those individuals or organizations are represented in this AM Plan. The USACE, in particular, has numerous management and staff positions devoted to supporting the Program that are not reflected in the diagrams, tables, and descriptions in this chapter of the AM Plan. Instead, Chapter 2 focuses on those elements and personnel central to the decision-making process who liaise with and represent the elements of the broader team through engagements among the USACE, USFWS, and MRRIC. Descriptions of the broader team components, which may change over time as the Program emphasis changes, can be found in the Program Management Plan (Attachment 13, Appendix A).

As described above, the central governance structure consists of several elements generally organized around three levels of authority (Oversight, Management and Implementation), along with technical support and independent review groups in non-decision roles. The composition, roles, and responsibilities of the central elements are summarized in Figure 14 and in Table 10, and are discussed in more detail in the following sections and Attachment 13 of Appendix A. Interaction points and the mechanisms by which these elements function together are described in the AM Decision Process Section (Section 0). To enhance vertical continuity there is overlap between team members throughout this structure.

Program success demands the commitment of necessary resources to effectively implement and govern the program, commitment on the part of MRRIC and the agencies to engage in a collaborative, transparent process, and the flexibility to change when and where needed. This includes maintaining staffing and contracting capacity to ensure needed expertise is available to the Program, as well as the flexibility to apply available resources to shifting priorities. The actions needed to achieve the Program objectives are uncertain and may evolve, so MRRIC and the agencies must continue their engagement and willingness to work together to identify solutions.

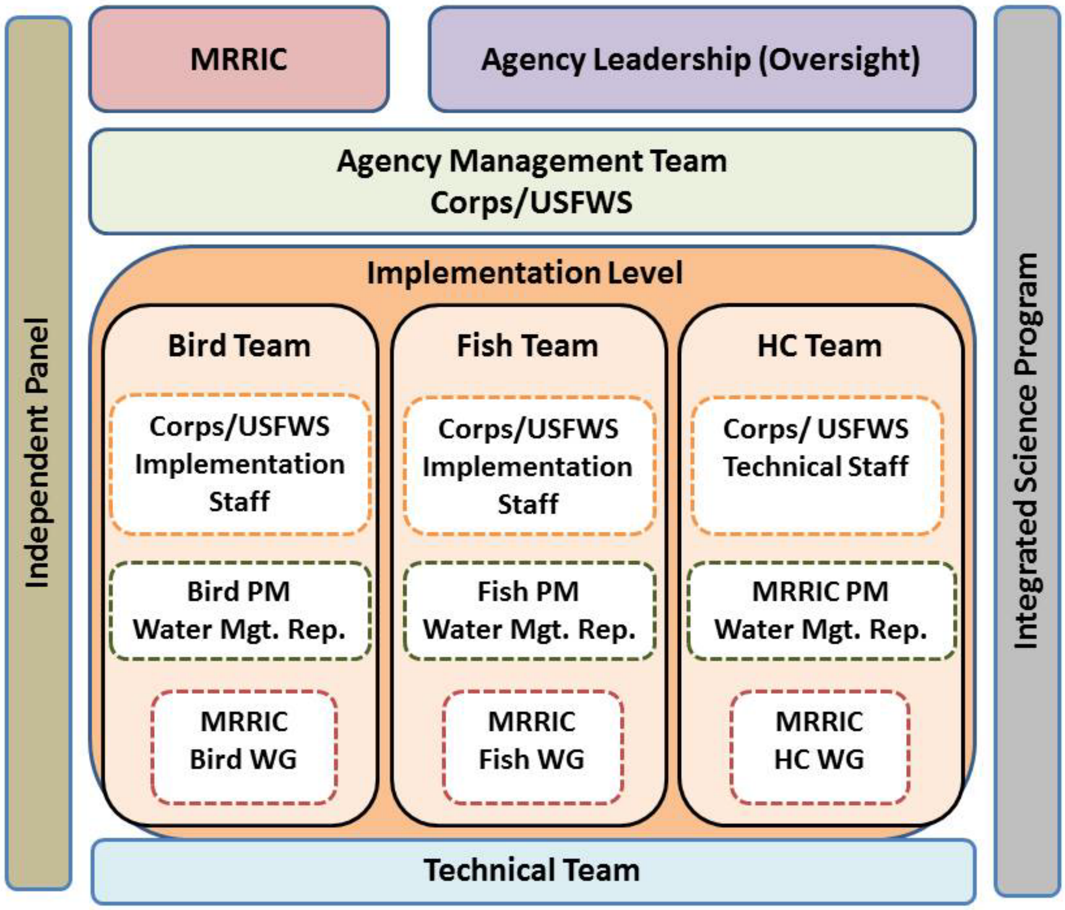


Figure 14. Central components of the MRRP. Entities not shown in this diagram are referenced in later sections and described in attachments to Appendix A.

Table 10. Summary of roles and responsibilities of entities involved with implementing the MRRP. Not all entities are represented. See following sections and attachments to Appendix A for additional details.

Entity	Composition	Primary Roles and Responsibilities
Technical Team (Section 2.3.4)	Independent experts, agency staff, and contractors supporting the MRRP in a non-decision, technical role; organized similar to the Effects Analysis Teams	• Conduct monitoring and assessment of projects • Analyze and evaluate data and hypotheses • Develop and apply models as needed • Interpret results and present findings in reports and at biannual science meetings • Assess potential courses of action and outcomes • Conduct research and/or undertake focused studies as directed

Entity	Composition	Primary Roles and Responsibilities
Bird and Fish Teams (Section 2.3.3)	Implementation PMs for each species USFWS species representatives AM PM Water Management representative Engineering Division representative Planning Division representative ISP Science Coordinators MRRIC Bird and Fish WGs	• Review research, monitoring, and assessment results and make related recommendations • Identify needed research, technical assessments, etc. • Resolve issues related to project siting, construction, operations, etc. • Develop recommendations on prioritizations for management action implementation based on discussions at AM Workshop • Manage contracts, and conduct other “on-the-ground” tasks necessary for implementation
HC Team (Section 2.3.3)	MRRIC PM AM PM USFWS representative Water Management representative USACE technical staff MRRIC HC WG	• Review research, monitoring, and assessment results for HC-related concerns • Make recommendations for monitoring, assessment or special studies related to HCs • Identify needed changes in monitoring or assessment protocols
Management Team (Sections 2.3.2, 2.3.6)	Special Assistant – Missouri River Basin Programs (NWD) MRRP Senior PM USFWS MR Coordinator MRRIC PM AM PM Implementation PMs for each species ISP Manager Water Management Representative	• Make decisions regarding allocation of budget, staff, and material • Make recommendations on action and research prioritization and flow modifications • Prepare Draft WPs • Recommend changes to program components and governance
Executive Steering Committee (ESC) (Section 2.3.6)	Special Assistant – Missouri River Basin Programs (NWD) Chiefs of Programs and Project Management (NWO and NWK) Chief of CW (NWO and NWK) Chief of Planning (NWO and NWK) Chief of MRBWMD	• Review and recommendations on Draft WP • Ensures that the MRRP is implemented according to the direction and guidance provided by the Oversight level • Ensures regional, systems perspective • Resolves district and cross-district disputes • Approves/decides on budget and staffing issues

Entity	Composition	Primary Roles and Responsibilities
Oversight Level (Section 2.3.1)	NWD Commander USACE District Commanders NWD Director of Programs USFWS Region 6 Director USFWS Assistant Regional Director MRRP Senior PM USFWS MR Coordinator Chief of NWD Water Management	• Make decisions about priorities • Make decisions regarding flow actions • Make decisions about targets and objectives • Make decisions about program structure and changes • Resolve disputes
MRRIC (Section 2.3.7)	Plenary As defined in Charter	• Provides input to AM Plan development and subsequent adjustments to the plan • Make recommendations on WPs • Make recommendations on research needs and priorities • Provide feedback and input on HC assessments/issues of concern
	Bird and Fish WGs (Section 2.3.3)	• Works in conjunction with agency staff on Bird/Fish Teams to prioritize the research, project implementation, monitoring, evaluation, and adaptive actions of the MRRP. • Provide information to the full body of MRRIC regarding insights based on science findings, and assist with MRRIC recommendations
	HC WG (Section 2.3.3)	• Works in conjunction with agency staff on HC Team to guide recommendations on HC monitoring and assessment priorities • Provide information to the full body of MRRIC regarding insights based on HC effects, and assist with MRRIC recommendations
Independent Advisory Panel	As defined in enabling documentation	• Participate in biannual science and AM meetings; review substantive products. • Provide independent scientific and technical advice and recommendations to MRRIC and the lead agencies
Integrated Science Program (Section 2.3.5)	ISP Manager AM PM Terrestrial Science Coordinator Aquatic Sciences Coordinator Support Staff (including partners)	• Oversee monitoring and assessment • Oversee research and focused studies • Oversee the Technical Team • Provide program advice to senior leadership and represent the program on science matters
Issue Resolution Board (Section 2.3.6)	NWD Director of Programs USFWS Assistant Regional Director Special Assistant – Missouri River Basin Programs (NWD) USFWS MR Coordinator	• Resolves disputes

Entity	Composition	Primary Roles and Responsibilities
Tribes (Section 2.3.6)	As recognized	• Provide input into the process through communication participation, coordination, and consultation with MRRP
Agencies Outside MRRIC (Section 2.3.6)	State and other Federal agency departments with defined roles outside MRRIC process	• Regulatory compliance and recommendations on site-specific projects
Public	Refers to individuals acting outside the above categories	• Provide input to the MRRP in response to any public notice related to the Program

2.3.1 Oversight level

Oversight of the MRRP is provided by the USACE Division and District Commanders, the USFWS Regional Directors and MRRIC. The USACE Commander of the Northwest Division (NWD) provides Program implementation guidance and direction to the Omaha and Kansas City District Commanders. The NWD Commander establishes clear boundaries for the program, makes major policy decisions, and resolves disputes. Decisions regarding scheduling, staffing, and other resourcing; planning, engineering and design of management actions; management and execution of the ISP; and other corresponding activities undertaken at the USACE District offices are overseen by the Omaha and Kansas City District Commanders.

The NWD Commander may elect to delegate decisions to senior leaders within the command. Decisions regarding the real-time operations of the reservoirs on the Missouri River are typically delegated to the Chief of the MRBWMD, for example. The NWD Director of Programs is the NWD Commander's delegate for the day-to-day oversight of the MRRP. The Director of Programs frequently represents the USACE in meetings with the MRRIC and/or USFWS and may make decisions related to the development of the WP, scheduling, resource allocation, and other similar programmatic issues. The NWD Special Assistant for Missouri River Basin Programs represents the program in most day-to-day issues.

The USFWS Mountain-Prairie (Region 6) Regional Director provides oversight and is the ultimate guidance and decision-making authority on the MRRP for the USFWS. Examples of such decisions include the development of or changes to targets and decision criteria, disposition of hypotheses, introduction of new management actions, advancement of implementation levels for pallid sturgeon, etc. The Region 6 Regional Director coordinates and communicates with the Midwest Region (Region 3) Regional Director. The Regional Director may delegate decisions to subordinate leaders, and frequently relies upon the Region 6 Assistant Regional Director for Ecological Services to represent the agency in meetings with the MRRIC and/or USACE, and to provide guidance to subordinate teams. The Missouri River Coordinator represents the USFWS on day-to-day implementation of the MRRP.

The MRRIC provides guidance and recommendations to the USACE regarding Program implementation and AM. The roles and responsibilities of the MRRIC are discussed further in Section 2.3.7. In addition to input from the MRRIC, including consensus recommendations of the committee, decisions at the Oversight level by the lead agencies are informed by recommendations from the Management Team. An Executive Steering Committee (ESC) provides budgeting and resourcing to the Management Team. Composition of the ESC is discussed in Section 2.3.6.1. Tribal governments, Federal agencies, and states with statutory authority may be key advisors, as may be other agency senior support staff. Input from the Independent Panel and the Technical Team on matters of science also help inform Oversight-level decisions.

Table 11 provides examples of the decisions and responsibilities at the Oversight level. The processes and procedures by which the decisions are made are summarized in Section 0. Some decisions are effectively a joint USACE and USFWS function (e.g., changes to targets, decision criteria, or management actions); each agency works within their authorities to provide decisions that collectively address the broader issue. Their interaction on these issues with MRRIC is primarily through periodic meetings (see Section 2.4.2.4). Interactions between senior leadership at the Oversight level and other agency teams, as well as with MRRIC, are discussed further in Sections 2.3 and 0).

Table 11. Examples of decisions and responsibilities at the Oversight level.

Decision or Responsibility	Responsible Entity[1]
Make decisions with implications for compliance with the ESA and involving significant change to the AM Plan (e.g., targets, decision criteria, new management actions, etc.).	NWD Commander and USFWS Regional Directors
Approve the Final AM Plan and changes to the plan, including objectives, targets, decision triggers, governance, and decision-making structure	NWD Commander and USFWS Regional Directors
Make decisions on program changes that affect HC	NWD Commander
Make decisions regarding flow operations, including non-routine flows (within ROD and Master Manual but outside of standard operations)	NWD Commander
Approve annual WPs for the MRRP	NWD Commander
Convey consensus recommendations of the MRRIC to the agencies	MRRIC Chairperson

[1] In cases where the decision authority is commonly delegated, the delegate is shown as the responsible entity in this table.

Represent the agencies in interactions with MRRIC, including development and presentation of WPs, etc.	NWD Director of Programs and USFWS Deputy Regional Director
Approve program-level budgetary decisions and resource allocations	NWD Director of Programs
Collaborate with the full MRRIC on human considerations and values-driven trade-off decisions (e.g., channel modifications, flow modifications)	NWD Director of Programs
Coordinate as appropriate with Tribes, federal agencies, state and local government, and the public on site-specific project implementation	District Commanders
Approve District level budgetary decisions and resource allocations at the	District Commanders
Decisions related to constructed project design, implementation, operation and maintenance (O&M), etc.	District Commanders
Make decisions regarding flow operations for the authorized purposes and within existing criteria, or real-time operational decisions	Chief, Water Management
Resolve disputes for subordinate teams	District Commanders (for USACE) or Regional Director (for USFWS)

2.3.2 Management Team

The Management Team is co-led by a USACE NWD Representative (e.g. Special Assistant for Missouri River Basin Programs) and the USFWS Missouri River Coordinator, who are responsible for development of the draft WP, resource allocation and related decisions. The MRRP PM serves as the Alternate Lead. Management Team membership includes senior PMs for the MRRP from both the USACE and USFWS with other agency personnel listed in Table 12. Members of the Management Team represent other entities, as shown in Table 12, and are responsible for communicating activities of the Management Team with those entities.

The Management Team develops the Draft WP for presentation draft WP to agency leadership and the MRRIC based upon the recommendations of the Bird, Fish, and HC Teams and following guidance provided by the ESC regarding resource availability, acquisition strategies, etc. The Management Team makes recommendations to senior leadership on issues requiring Oversight-level decisions. They also provide leadership for the HC (MRRIC PM), Bird, and Fish Teams (species PMs), and ensure day-to-day implementation of the MRRP is consistent with requirements in the AM Plan and direction from senior leadership.

Table 12. Composition of the Management Team.

Member	Role	Represents / Liaison With
USACE		
NWD Representative	Co-Chairperson	NWD Leadership; ESC
Senior PM for MRRP	Alternate Chair	District Leadership; District PMs; District PDTs
MRRIC Project Manager		MRRIC; HC Team
AM Process Manager		Other AM Teams
ISP Manager		ISP; Technical Team
Water Management Representative		MRBWMD
Bird and Fish PMs		Bird and Fish Teams;
OC Representative	Ad hoc	District/Division OC
USFWS		
MR Coordinator	Co-Chairperson	USFWS leadership; FAC Supervisors; ES Project Leads
Bird and Fish Team Leaders		Bird and Fish Teams

The Management Team is responsible for the allocation of program resources (staff, budget, and material) with guidance from the ESC and subject to the approval of the District Commanders (DCs). The DCs will resolve any disputes or conflicts on the Management Team. The Management Team makes decisions based upon information provided by the Technical Team, recommendations of the Bird and Fish Teams, and input from the HC Team, and works closely with the NWD Director of Programs. The Management Team participates in the annual Fall Science Meeting and the AM Workshop each spring in advance of the WP preparation. They meet regularly throughout the year with more extensive engagement when developing the draft WP, and meet as needed to address other Program considerations.

In cases where resource allocation may affect legal compliance (i.e., insufficient resources are available to meet all objectives), or when the Management Team deems that changes to the AM Program (objectives, targets, or governance structure and processes) are warranted or that flow modifications might be required to meet targets, they make related recommendations to the Oversight level for consideration. The primary authorities and responsibilities of the Management Team in implementing the MRRP AM are summarized in Table 13.

Table 13. Decisions, recommendations and other responsibilities of the Management Team.

Responsibilities	Step in AM Cycle	Category
Decisions[1]		
Criteria for implementing habitat construction/modifications	Plan/design	Habitat construction
Criteria for implementing the actions	Plan/design	Plan design
How learning is incorporated into decisions	Plan/design	Plan design
How status and decisions will be reported and communicated	Plan/design	Plan design
What monitoring will be conducted	Plan/design	Plan design
Criteria for implementing population interventions	Plan/design	Population interventions
How much new habitat should be constructed	Adjust/Continue	Habitat construction
Should current habitat be modified	Adjust/Continue	Habitat modification
How resources will be allocated to program components	Adjust/Continue	Program-scale
Whether an active hypothesis should be rejected[2]	Adjust/Continue	Research
Whether a reserve hypothesis should be activated[2]	Adjust/Continue	Research
Recommendations		
Make recommendations to the Oversight level to adjust objectives, targets, governance structure and processes	Plan/design	Plan design
Make recommendations to the Oversight level when flow modifications are warranted	Adjust/Continue	Flow management
Elevate decisions regarding human considerations (e.g., channel modifications, flow modifications) that require tradeoff analyses to Oversight level for engagement with MRRIC	Adjust/Continue	Program-scale
What additional basic research (demographics, behavior, habitat quality, etc.) is needed. Note: ISP Manager is primary decision maker[2]	Adjust/Continue	Research
Whether funding for existing research programs should be continued or resources used elsewhere.[2]	Adjust/Continue	Research
Other Responsibilities		
Communicate performance, decisions, and recommendations to the Oversight level, MRRIC, and the Independent Panel, in face-to-face meetings, webinars, and annual and periodic AM reports	Adjust/Continue	Communications
Ensure AM process is implemented throughout the MRRP	Adjust/Continue	Program-scale
Ensure AM process is addressing program needs	Adjust/Continue	Program-scale
Ensure AM recommendations and priorities are reflected in WP	Adjust/Continue	Program-scale

[1] Subject to approval by agency leadership/oversight following MRRIC engagement and deliberation.

[2] Note that the research program is run by the Integrated Science Program (ISP), and the ISP Manager has decision authority over program components. The AM Teams provide input and address resourcing needs.

Responsibilities	Step in AM Cycle	Category
Allocate staff, funding, and other resources for the MRRP within the two agencies, subject to approval of the DCs	Adjust/Continue	Program-scale
Decide based on evaluation results to complete/terminate, adjust, or continue a management action	Adjust/Continue	Habitat construction
Using input from the Implementation Team, develop and finalize WPs, and brief the Oversight level	Adjust/Continue	Program-scale
Approve other recommendations (e.g., revisions to hypotheses, modifications to monitoring efforts)	Adjust/Continue	Plan design
Ensure collaborative process is working and effective	Adjust/Continue	Communications
Engage in the collaborative process at all levels as necessary	Adjust/Continue	Communications
Regularly assess program performance and identify necessary improvements	Adjust/Continue	Program-scale
Responsible for elevating all decisions necessary at Oversight level and ensuring Oversight leadership are provided necessary information to support decision making	All	All

2.3.3 Implementation-Level Teams

The MRRP is implemented by a Bird Team and a Fish Team, each of which includes a PM, a representative from Water Management, USACE District representatives for engineering and planning, USFWS Species Team Lead(s) and other appropriate staff from the lead agencies. A third implementation-level team, the HC Team, addresses monitoring and assessment needs related to the effects of the Program on HC interests, and is overseen by the MRRIC Program Manager. Membership and responsibilities of the Implementation Teams is discussed in the following sections.

2.3.3.1 *Bird and Fish Teams*

Composition of the Bird and Fish Teams roughly parallel each other, with the differences consisting primarily in the expertise of individual members. Each team is chaired by a USACE-appointed PM responsible for implementing the MRRP actions (typically habitat creation) for the respective species. The AM PM serves as an alternate to each Chair. Other USACE and USFWS members are as shown in Table 14, and have responsibilities to represent other entities contributing to the Program to ensure those needs and perspectives are represented during Team deliberations. Members serve to liaise with those elements to keep them informed of deliberations and decisions. MRRIC WGs, one for the birds and another for the fish, serve as components of the Bird and Fish Teams (see Section 2.3.7.2).

The Bird and Fish Teams meet at least three times annually, during the Fall Science Meeting and the AM Workshop to participate in discussions regarding the advancement of scientific understanding, and again in April/May to provide input to the WP. Team members are expected to interact with the entities they represent before and after each engagement, and keep the groups they represent apprised of the activities and decisions/recommendations of the Team. Interactions during the development of the WP generally involve multiple engagements, including at least one joint meeting of the Bird, Fish, and HC Teams. Additional details regarding these interactions are provided in Sections 2.3.6, 2.3.7.2, 2.4.2, and 2.4.3.

Table 14. Composition of the Bird and Fish Teams.

Member	Role	Represents / Liaises with
USACE		
Bird/Fish PMs	Chairpersons	Management Team; District PDTs
AM PM	Alternate Chair	Other Implementation Teams; Management Team
ISP Science Coordinators	Member	ISP; Technical Team
Planning Representative	Member	USACE Planning
Engineering Representative	Member	USACE Engineering
Water Management Representative	Member	MRBWMD
OC Representative	Ad hoc Member	District/Division OC
USFWS		
USFWS Fish/Bird Team Leads	Member	Hatchery managers; FAC project leads; Fish Tech Center Lead; Recovery Teams; MRNRC Coordinator; ES Biologists; States (FWCA)
MRRIC Bird/Fish WG		
WG Members	WG Members	MRRIC; Stakeholders

Members of the species teams are typically responsible for conducting “on-the-ground” tasks for implementing habitat and population management actions and/or actions and activities associated with the research and monitoring program, including making decisions about the way in which many of the actions are carried out. The Teams are responsible for developing a prioritized list of actions for the Management Team to consider in developing/updating the MRRP WP. The Bird and Fish Teams must be able to respond to new knowledge and to changing conditions in the field, to differentiate between AM and O&M needs, and to implement the guidance in the AM Plan with the support of decision criteria and contingency plans. They develop their recommendations based on input from the entities they represent, the Technical Team, and with plans and preliminary designs for candidate projects developed by the District PDTs. Their responsibilities are summarized in Table 15.

Table 15. Decisions, recommendations and other responsibilities of the Bird and Fish Teams.

Responsibilities	Step in AM Cycle	Category
Decisions[1]		
Whether adjustments will be made to project design due to unanticipated field conditions	Implement	Habitat construction
Whether population interventions will be made due to unanticipated field conditions	Implement	Population interventions
Where, how much, and how habitat will be constructed	Adjust/Continue	Habitat construction
Whether construction will be implemented experimentally and/or with additional monitoring to increase understanding	Adjust/Continue	Habitat construction
Whether construction methods or design will be changed to improve effectiveness	Adjust/Continue	Habitat construction
What habitat will be modified, and how it is modified	Adjust/Continue	Habitat modification
Whether habitat modification will be implemented with experimental design and/or additional monitoring to increase understanding	Adjust/Continue	Habitat modification
Whether habitat modification methods will be changed to improve effectiveness	Adjust/Continue	Habitat modification
Whether and how much the level of effort and/or protocols of the current monitoring program will be changed	Adjust/Continue	Monitoring
Whether additional monitoring will be conducted in the long term (current metrics are insufficient)	Adjust/Continue	Monitoring
Whether additional monitoring will be conducted in the short- or moderate-term because of unusual conditions or natural events	Adjust/Continue	Monitoring
What additional monitoring and/or research will accompany a non-routine flow action	Adjust/Continue	Non-routine flow modification
Whether and where population interventions will be implemented	Adjust/Continue	Population interventions
Recommendations		
Whether flows should be implemented in a way to increase understanding	Adjust/Continue	Non-routine flow modification
Additional ways to improve the effectiveness of non-routine flow actions within the current constraints	Adjust/Continue	Non-routine flow modification
Whether routine flow management should be changed during implementation because of HC or species impacts	Implement	Routine flow management

[1] Subject to approval by appropriate agency leadership and following other policies and practices laid out by the agencies and/or described in the AMP.

Responsibilities	**Step in AM Cycle**	**Category**
Whether non-routine flows should be changed or terminated during implementation	Implement	Non-routine flow modification
Whether population interventions should be implemented with experimental design and/or additional monitoring to increase understanding	Adjust/Continue	Population interventions
Whether population interventions methods should be changed to improve effectiveness	Adjust/Continue	Population interventions
Whether flows should be managed during the nesting season to reduce incidental take (inundation of nests or chicks)	Adjust/Continue	Routine flow management
Whether flows should be implemented in a way to increase understanding	Adjust/Continue	Routine flow management
Additional ways to improve the effectiveness of routine flow management within the current constraints	Adjust/Continue	Routine flow management
Whether flow management could be adjusted (magnitude, duration, timing) to reduce impacts or increase effectiveness	Adjust/Continue	Routine flow management
Develop input to Annual Operating Plans for water management	Adjust/Continue	Program level
Other Responsibilities		
Determine costs of habitat projects, population intervention actions, research and monitoring	Adjust/Continue	Program level
Manage contracts for implementing project work	Adjust/Continue	Program level
Decide where to implement habitat and population management actions (site-level)	Adjust/Continue	Habitat construction
Design habitat and population management actions	Adjust/Continue	Habitat construction
Design and conduct research and monitoring programs or related contracted work	Adjust/Continue	Research
Respond to changing field conditions to adjust implementation as necessary	Adjust/Continue	Program level
Provide after-action assessment of project work to the Technical and Management Teams	Adjust/Continue	Program level

2.3.3.2 *Human Considerations (HC) Team*

The HC Team is chaired by the USACE MRRIC PM, who is responsible for convening the team, keeping members informed of relevant issues and activities, and representing the HC Team as a member of the Management Team (see Table 16). The Tribal Lead serves as an alternate Chair. Other USACE and USFWS members are assigned as needed, and are generally technical specialists representing specific interests of the team at that time. Members serve to liaise with those elements to keep them informed of deliberations and decisions. An MRRIC HC WG also serves as a member of the team. See Section 2.3.7.2 for more details about the role and composition of the HC WG.

Table 16. Composition of the HC Team.

Member	Role	Represents / Liaison With
USACE		
MRRIC PM	Chairperson	Management Team; other AM Teams; USACE leadership
Tribal Lead	Alternate Chair	Tribes
USACE Technical Specialists		USACE Planning; ISP
Water Management Representative		MRBWMD
OC Representative	Ad hoc Member	District/Division OC
USFWS		
USFWS Representative		USFWS leadership
HC WG		
WG Members		MRRIC; Stakeholders

The HC Team meets at least three times annually, during the Fall Science Meeting and the AM Workshop to participate in discussions regarding the advancement of scientific understanding, and again in April/May to provide input to the WP. Team members are expected to interact with the entities they represent before and after each engagement, and keep the groups they represent apprised of the activities and decisions/recommendations of the Team. Interactions during the development of the WP may involve multiple engagements, including at least one joint meeting of the Bird, Fish and HC Teams. Additional details regarding these interactions are provided in Sections 2.3.6, 2.3.7.2, 2.4.2, and 2.4.3.

The HC Team provides input to the MRRP monitoring and assessment program, as it pertains to HCs and the effects of Program decisions on conditions of interest to stakeholders (Table 17). The Team is responsible for developing a prioritized list of monitoring and assessment needs for the Management Team to consider in developing/updating the MRRP WP. The Team must be able to respond to new knowledge and to changing conditions in the field, to evaluate monitoring and assessment results provided by the Technical Team, to assess protocols for monitoring and assessment, and to follow the guidance in the AM Plan or recommended changes to the guidance in the event objectives are not being met. Their responsibilities are summarized in Table 17.

Table 17. Recommendations and other responsibilities of the HC Team.

Responsibilities	Step in AM Cycle	Category
Recommendations		
Whether and how protocols of the current monitoring program will be changed	Adjust/Continue	Monitoring
Whether additional monitoring should be conducted beyond the existing program in the long term (current metrics are insufficient)	Adjust/Continue	Monitoring
Whether additional monitoring should be conducted in the short- or moderate-term because of unusual conditions or natural events	Adjust/Continue	Monitoring
Whether ongoing monitoring or studies should be terminated based on changed needs or new information	Adjust/Continue	Monitoring
What additional monitoring and/or research will accompany a non-routine or test flow	Adjust/Continue	Non-routine flow modification
Other Responsibilities		
Identify needs for research or special studies related to HCs	Adjust/Continue	Research
Provide after-action evaluations of existing monitoring and assessment to the Technical and Management Teams.	Adjust/Continue	Program level
Inform MRRIC of activities and provide input on possible Recommendations, as warranted (HC WG only)	Adjust/Continue	Program level

2.3.4 Technical Team

A Technical Team, patterned after the EA, is responsible for developing and compiling the information used by the other teams and by the Oversight level to make decisions regarding the MRRP (Table 18). The Technical Team is not a decision-making body, but provides information and analysis based on research and evaluation results to the agencies and MRRIC. The Technical Team uses information from research and monitoring to develop and provide reports and assessments that all teams use in decision making. The reports and assessments capture and update the knowledge of the habitat and population status, hypotheses including action effectiveness of previously implemented actions on the habitat and species, and conceptual and predictive models. They use the information about System status, assess how AM Plan decision criteria are being addressed together with other criteria and information to evaluate a range of management options, and use predictive numerical models to the fullest extent possible. They provide expertise in AM and perform assessments of Program performance and make suggestions for improvements. They engage with the ISAP/ISETR for discussions supporting independent review of annual reports or other studies. In addition to any specific study reports assigned to the team, they provide a draft annual AM report in advance of the AM Workshop and a final annual AM report following receipt review comments and input from the Science Update process.

The Technical Team includes subject matter experts in ecology, biostatistics, hydrodynamics, fluvial processes, decision analysis, river operations, spatial statistics and socio-economics, and include individuals with expertise and experience in assimilation and analysis of information related to plovers, pallid sturgeon, and the hydrogeomorphology of the Missouri River. Composition of the Technical Team may include Federal and state agency personnel, university professors, and contractors selected to address the underpinning science for the program. The Technical Team works closely with the ISP Manager and is overseen by the AM Process Manager, who are also members of the Bird/Fish and Management Teams and may convey results and recommendations from the Technical Team to those teams.

Technical Team members will likely not be co-located, so they should are given opportunities to meet as needed to execute their responsibilities. They conduct their assignments using best available commercial or public data, and contribute to assessments of these data. At all times, they seek to operate in a transparent, objective manner using accepted standards of professional practice. At a minimum, they participate in the Fall Science Meeting and the AM Workshop, and are represented at any meeting of the Management, HC, Bird, and/or Fish Team, as requested by those teams. Responsibilities include, but may not be limited to the items listed in Table 18.

Table 18. Responsibilities of the Technical Team.

Responsibilities	Step in AM Cycle	Category
Recommend and organize sub-groups with specific expertise, as needed	Plan/Design	Program
Develop experimental design for management actions	Plan/Design	Program
Make recommendations on information management, including data systems, publications, etc.	Plan/Design	Program
Make recommendations about monitoring and research to the Management and Implementation Teams	Plan/Design	Monitoring and Research
Evaluate, test and update numerical and conceptual ecological models (CEMs)	Evaluate	Program
Test and evaluate hypotheses and make recommendations on hypothesis priorities	Evaluate	Program
Update, revise, and prioritize assessments of critical uncertainties	Evaluate	Program

Responsibilities	Step in AM Cycle	Category
Simulate the outcomes of management actions using quantitative models	Evaluate	Program
Provide evaluations and recommendations to the Bird and Fish Teams and the Management Team as needed	Evaluate	Program
Engage with MRRIC, the Independent Panel, and MRRIC WGs as part of the Science Update process	Evaluate	Program
Undertake special studies or conduct research as directed	Evaluate	Research
Recommend ad hoc peer review panels to conduct independent scientific review	Evaluate	Program
Translate new scientific information into the technical component of AM reports	Evaluate	Program
Synthesize and evaluate data to compare monitoring and research results to decision triggers and targets	Evaluate	Monitoring

2.3.5 Integrated Science Program (ISP)

The ISP is the component of the MRRP responsible for overseeing and conducting scientific monitoring and investigations to assist the USACE in avoidance of jeopardy and compliance with the BiOp. The ISP monitors federally-listed species under the Endangered Species Act (ESA), the habitats upon which they depend, and conducts research and monitoring to address key uncertainties in support of AM. The ISP coordinates science activities in a collaborative manner among USACE, state and Federal partners.

The purpose of the ISP includes the following:

1. Implementation of system-wide monitoring activities and focused investigations to address BiOp mandates and jeopardy avoidance for the federally- listed species.
2. Evaluation of MRRP actions on the federally- listed species.
3. Provision of scientific and technical support for MRRP efforts, implementation, design & construction, Operation & Maintenance (O&M), and the AM process; and.
4. Communication of Missouri River Basin science to stakeholders including Federal, state, local agencies, tribal governments, and MRRIC.

Although Corps District staffed and supervised, the ISP is a trans-District organization and works closely with leadership for both Districts and the NWD in support of the Program objectives. The ISP Manager oversees the day-to-day ISP execution and is a member of the Management Team. The ISP is organized into two disciplines: (1)

Terrestrial Science; and (2) Aquatic Science. Senior scientists serve as coordinators for these components of the ISP, report to the ISP Manager, and are members of the Bird and Fish Teams, respectively. The ISP Manager and coordinators are supported by technical staff, a program analyst, and an administrative assistant. Details regarding the composition and roles of the ISP are provided in the ISP Program Management Plan (see Attachment 14 of Appendix A). Details on the requirements and procedures of the ISP are presented in Appendix J.

The ISP implements the focused investigations and research activities of the MRRP and sets the standards and requirements for related activities. The ISP ensures appropriate monitoring, assessment, and research activities are implemented in a timely manner to track progress towards meeting program objectives, reducing uncertainties, and identifying needed program adjustments. The ISP provides contract and staffing support to all science activities and ensures that research and monitoring meet Program standards, and are properly coordinated, collaborative and efficient.

The ISP Manager is responsible for communicating findings in an objective and transparent way to the agencies, MRRIC and Missouri River Basin stakeholders through various reporting mechanisms, such as the annual report, periodic reports, update presentations, and a variety of other reports (see Chapter 6). The ISP Manager is also responsible for planning and conducting the Annual AM Workshop, during which major findings, research results, etc., are reported and upcoming monitoring and research activities discussed (see Section 2.4.3.2).

Details on the requirements and procedures of the ISP are presented in Appendix J. Other decisions and responsibilities within the domain of the ISP include, but are not limited to the following:

- implementation of the Program's monitoring and assessment program,
- compilation of the scientific information necessary to identify and address the uncertainties associated with jeopardy avoidance and BiOp compliance,
- communicating Missouri River Basin science to agency leadership, MRRIC and stakeholders,
- contracting and managing research and monitoring for the Program,
- coordinating MRRP science activities among and across agencies,
- developing and maintaining a data management and reporting system,
- obtaining needed technical expertise through agency staffing and the Technical Team,
- implementing periodic external peer reviews of Program components, and
- coordinating the Fall Science Meeting and AM Workshop.

2.3.6 Other MRRP entities and position descriptions

2.3.6.1 *Executive Steering Committee (ESC)*

The ESC ensures that the MRRP is implemented according to the direction and guidance provided at the Oversight level and that the WP reflects a regional, systems approach to achieving its objectives and is consistent with budget, acquisition, and other constraints. They ensure appropriate staffing and the effective use of district resources, considering the needs of the MRRP, other water resources projects on the Missouri River, and other Civil Works demands in the basin. The ESC meets quarterly or more frequently as issues require. Specifically, the ESC has the following responsibilities:

1. Provide guidance and direction to the Management Team on implementation of the program to achieve program overarching goals and objectives and for intra- and inter-annual variations in program execution based on conditions in the basin.
2. Resolve inter-district/interagency conflicts in support of regional operation.
3. Act as liaison with senior leadership at the district and division.
4. Provide review and approval for MRRP WP budgets prepared by the Management Team.
5. Direct and manage the following:
    a. Staffing, organization, and manning needs
    b. Other resources needed to support the MRRP
    c. Workload balancing between districts to maintain technical capability
    d. Acquisition strategy for MRRP activities.

The ESC is composed of the following members:

- NWD Representative (e.g. Special Assistant – Missouri River Basin Programs or Chief of Planning, Environmental Resources, Fish Policy, and Support)
- Chiefs of Programs and Project Management (NWO and NWK)
- Chief of the Missouri River Basin Water Management Division (NWD)

Ad hoc members of the ESC include the following[1]:

- Chiefs of CW (NWO and NWK)
- Chiefs of Planning (NWO and NWK)
- MRRP Senior PM

[1] The role of the ad hoc membership is to provide continuity between the Management Team and the ESC

2.3.6.2 *NWD Representative (e.g. Special Assistant – Missouri River Basin Programs)*

The NWD Representative is responsible for management, oversight, and coordination of NWD perspectives for program activities related to the MRRP (including the AM Plan/MRRPMP-EIS). The NWD Representative chairs the ESC, is a member of the Issue Resolution Group, and serves as a liaison between the Management Team, other District MRRP AM Teams, and the NWD Director of Programs. The NWD Representative works closely with the PMs to ensure consistent messaging/communication strategies and maintains a collaborative working relationship with Missouri River Basin Water Management, ensuring full integration of water management considerations into Missouri River Programs. The NWD Representative provides support to the Programs Director and/or Planning Chief or represents those entities on boards and committees as authorized, including the MRRP ESC, Missouri River Recovery Implementation Committee (MRRRIC), Missouri River Association of States and Tribes (MORAST), Missouri River Basin Interagency Roundtable (MRBIR), Tribal interactions, and at public meetings.

2.3.6.3 *Senior Program Manager (SPM) for MRRP)*

The role of the SPM is to ensure implementation of the MRRP is consistent with USACE policy, to communicate the MRRP strategic vision, goals, relevant guidance from senior Leadership to all internal and external MRRP teams and stakeholders. The SPM assists the Bird Federal agencies, states, and tribes, and works to ensure that these relationships are maintained. The MRRP SPM serves as the Management Team lead, and coordinates efforts among other Teams to ensure that actions and communication are consistent with programmatic goals. The SPM develops and assigns budgets and tasks for communications, outreach, and tribal consultation, and works with the ESC to ensure the Program is properly resourced to meet its objectives. Specific tasks of the SPM may include the following:

- Development and updating of three-year budget requests and a five-year strategic program plan through full coordination with, and input from, other agency Teams, MRRIC, and senior leadership (Oversight)
- Coordination with the Bird, Fish, and HC Teams and the ESC on the development of a MRRP WP and budget. This WP and budget are integrated among the districts with a goal to achieve 95% or better of annually scheduled program obligations. The SPM coordinates and oversees the preparation of a programmatic WP by the Management Team, based on prioritized recommendations of the species teams and considering input from the MRRIC HC WG and Tribes

- Development, facilitation, and implementation of a Tribal Engagement Strategy with tribes in the Missouri River Basin through close coordination with the MRRP Tribal Lead and district tribal liaisons
- Coordination of all MRRP outreach, communication, and collaboration including support to MRRIC
- Implementation and maintenance of data management and communications systems/programs, including automated reporting, development, and distribution of annual reports, fact sheets, and other MRRP-funded reports
- Attendance and reporting at Project Review Committee (PRC), Project Review Board (PRB), and Mitigation Agency Coordination Team (Mitigation ACT) meetings, as appropriate and needed by each district.

The SPM is ultimately responsible for critical outputs from the MRRP Program, and will track progress toward milestones for all Program products. The SPM will issue tasks to subordinate team members outlining the products for which they are responsible, and ensure they are implemented efficiently and effectively (i.e., cost and quality).

2.3.6.4 *Missouri River Recovery Implementation Committee Project Manager (MRRIC PM)*

The MRRIC PM implements the MRRIC with Federal, tribal, and state partners and stakeholders using an AM approach. The MRRIC PM is a member of the Management Team and coordinates MRRIC-related processes and activities within the USACE, including the vertical team and with the Federal Working Group (FWG). Responsibilities of the MRRIC PM are: (1) plan, support, and manage interactions between the USACE and MRRIC; (2) coordinate input from MRRIC to the MRRP AMP; and (3) plan and manage the MRRIC budget and schedule.

2.3.6.5 *Missouri River Adaptive Management Process Manager (AM PM)*

The AM PM is responsible for coordinating the AM program and works closely with the SPM, ISP, and the AM Teams to ensure AM principles and practices are incorporated into all phases of MRRP implementation. While the ISP PM provides scientific monitoring and research results for the Threatened and Endangered (T&E) species and their respective habitats addressed under the BiOp, the AM PM is responsible for ensuring this information is easily accessible to and understood by members of the AM Teams, other agencies, states, tribes, stakeholder groups, and the public. The AM PM is a member of the Management Team, and an ad hoc member of the Bird, Fish, and HC Teams. Other responsibilities include (1) providing AM expertise for the Program, (2) AM coordination amongst the ISP, AM Teams, and MRRIC, and (3) the preparation and distribution of AM reports.

2.3.6.6 *Tribal Lead*

The Tribal Lead is a member of the HC Team and is responsible for coordinating/ communicating MRRP developments with the 28 tribal nations located in the Missouri River Basin, in addition to any tribe that claims a historical tie and/or holds land within the basin. Much of this coordination is accomplished through the MRRIC; however, the tribal lead coordinates directly with each tribe and ensures that their councils are aware of proposed budgets and activities for each FY. A key responsibility is to communicate concerns expressed by individual tribal nations about specific actions or projects to MRRP management for consideration. The tribal lead coordinates resolution of these issues, recognizing not all requests can be accommodated, and provides feedback to the tribe making the request. If a project should result from the consultation process, the tribal lead serves as PM. For those tribes unable to have representation at each MRRIC meeting, the tribal lead is to ensure tribal governments receive information discussed at these important stakeholder meetings and that they are aware of pending decision-making opportunities. The Tribal Lead coordinates activities with the tribal liaisons of both the NWO and NWK districts.

2.3.6.7 *Missouri River Basin Water Management Representative (WM Representative)*

The WM Representative serves as the interface between the MRRP and the NWD MRBWMD. A WM Representative (there can be multiple and alternate representatives) is a member of each of the Implementation Teams and the Management Team. The WM Representative is responsible for reporting any issues addressing water management decisions and their potential impact on the program. The WM Representative makes recommendations to the teams on strategies to avoid or minimize take, provides information on water management forecasting (effects of the AOP for the Missouri River, and provides technical insights into team discussions regarding potential flow management actions.

2.3.6.8 *Office of Counsel (OC)*

Representatives of the Office of Counsel (OC) for NWD and for the District OC (both NWK and NWO) provide guidance and advice on all legal matters related to administration and implementation of the program. The OC representatives collaborate to address intra-district and inter-district MRRP-related issues. Attorney assignments on inter-district regional activities in the Missouri River Basin are not intended to change existing relationships for intra-district activities and their district OCs, nor for NWD Water Management staff and NWD OC.

Attorneys from OC also work closely with the Implementation (Bird and Fish) and Management Teams, the ESC and MRRIC. Attorneys are regular participants in Team meetings as well as on-call advisors. There may well be both NWD and district attorneys involved in these activities at any given time. Information sharing among the attorneys is important for successful, integrated Missouri River programs. Specific real estate, contracting and regulatory activities will generally be served by an attorney from the OC in the District where the action officer is assigned.

2.3.6.9 *Issue Resolution Board*

The Issue Resolution Board is a group that considers disputes between Program entities, agencies, or between an agency and MRRIC. The Issue Resolution Board consists of the NWD Director of Programs and the NWD MRRP Representative, as well as Region 6 Assistant Director and the Missouri River Coordinator for the USFWS. Every effort should be exhausted before seeking resolution though the Board, and any request for issue resolution should follow the procedures outlined in Section 2.5.1. If the Issue Resolution Board cannot resolve the issue and it cannot be resolved through the normal engagement process, it will be elevated to the NWD Commander for a decision.

2.3.7 Overview of MRRIC roles and responsibilities

The Missouri River Recovery Implementation Committee (MRRIC) represents stakeholder interests for the MRRP. As described in WRDA Section 5018 (3) (B) (i)), "The Committee (MRRIC) shall provide guidance to the Secretary with respect to the Missouri River recovery and mitigation plan in existence on the date of enactment of this Act, including recommendations relating to changes to the implementation strategy from the use of adaptive management." The AM engagement approach laid out in this AM Plan should be considered the vehicle for the MRRIC, in collaboration with the USACE, to achieve this objective. In addition, the Charter for the MRRIC includes, as part of the Committee's purpose and scope [1) a) iii)]: "Provide recommendations and guidance that will include:

1. Recognition of local stakeholders' social and economic, historical and cultural, flood control, irrigation, agriculture, internal drainage, water supply, water quality, navigation, hydropower, thermal power, science, natural resources, conservation, and recreation issues, and any other issues identified by the Committee
2. Identification of impacts to stakeholders
3. Identification of actions that will benefit multiple uses of the river (MRRIC 2014)."

In executing this role, the MRRIC and the agencies each bear responsibilities for Program execution and for effective collaboration and decision making. Adherence to basic principles already outlined and reiterated below will help ensure this occurs. As a practical matter, the MRRIC will continue to rely on WGs, Task Groups, and the Independent Advisory Panel to engage at the necessary level of detail with elements of the agencies and the AM Program and provide the full body of the MRRIC with insights and recommendations (Figure 15). The MRRIC relies upon WGs to collaborate on issues through frequent interactions with agency specialists, and provides input to the agencies and the full MRRIC based on those interactions. The full MRRIC weighs in on the most significant issues based upon WG input, and focuses on WP recommendations.

Figure 15 provides an overview of the roles for MRRIC and its key WGs. The schematic shows that the MRRIC would rely upon three WGs to collaborate on issues through frequent interactions with agency specialists and provide input to the agencies and the full Committee based on those interactions. The full Committee would weigh in on the most significant issues based upon the WG input, as well as focus on recommendations for the WP. More details are given in the following sections, elsewhere in the AM Plan, and its appendices and attachments.

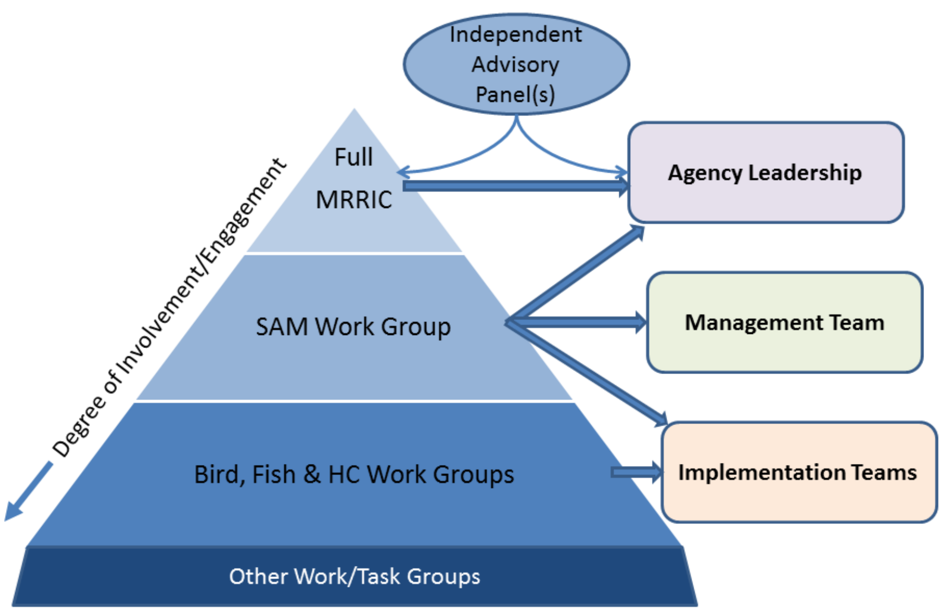


Figure 15. Schematic of MRRIC roles in implementing the MRRP AM Plan.

2.3.7.1 MRRP collaborative forum composition, roles, and responsibilities.

The MRRIC Charter (MRRIC 2014 [amended from 2009]) and Operating Procedures and Ground Rules (MRRIC 2016 [amended from 2009]) establish the objectives for MRRIC and its mechanisms for achieving those objectives (see Attachments 1 and 2 of Appendix A). The MRRIC plenary meetings provide the primary forum for collaborative engagement where a consensus recommendation is needed or desired. Other opportunities for collaboration and input to the MRRP are described in later sections of this chapter (see Section 2.3.7.2 through 2.3.7.4 and Section 0).

MRRIC advanced and approved an engagement strategy for the development and implementation of an AM Plan for the MRRP (MRRIC 2011). That document outlines a set of principles that remain relevant to the current and future efforts under the MRRP (MRRIC 2011, see Sections 2.3 and 2.4.5). In addition, the agencies have engaged with the AM ad hoc WG to develop a collaborative governance process. Those engagements produced useful input to the process and a draft recommendation to the MRRIC that resulted in a consensus recommendation on governance. The following sections draw from that effort in describing a set of WGs that interact with the agency teams and the process for implementing AM to influence the WP.

2.3.7.2 MRRIC Bird, Fish, and HC WGs

Developing and implementing AM strategies requires interactive and timely deliberations. MRRIC established the Science and Adaptive Management (SAM) WG to guide MRRIC recommendations to prioritize the implementation, monitoring, evaluation, and adaptation actions of the MRRP. The SAM also reviews and provides draft recommendations related to the MRRP's WP for MRRIC's consideration. Three permanent WGs (Bird, Fish, and HC) support the MRRIC and function at the implementation level to inform the program as it moves into an implementation phase.

The Bird, Fish, and HC WGs engage with and are part of the Bird, Fish, and HC Teams, respectively (see Figure 14). Each Team includes lead agency staff involved in implementation of the MRRP and its AM Plan. A core group of agency staff on each team works on the Program full time while others engage as needed and at key points of the process or when meetings occur. Members of the team not engaged fulltime in the effort – including MRRIC members on the WGs and supporting agency staff – receive regular information updates and meet at defined times throughout the year.

The main role of the Bird and Fish WGs is to understand the science and technical issues that relate to the piping plover and pallid sturgeon and underpin the Program. This includes understanding what actions are being implemented for the birds/fish, the status of hypotheses related to the birds/fish, and how the models work and the implications of updated model results. The WGs are responsible for providing comments/feedback to the lead agencies (during meetings with Bird, Fish, and HC Teams and through WG reports), keeping the full MRRIC informed of their comments/feedback, and bringing forth issues to MRRIC that may need a formal recommendation from the full committee. A fundamental product of each Team is the development of a prioritized set of actions for each species annually to help the Management Team with development of WP updates. WGs contribute to those products and provide related feedback to the MRRIC.

The composition of the HC WG and the HC Team are similar to those for the birds and fish. However, the role of the HC Work Team is to understand the technical aspects of AM that relate to human uses of the Missouri River System. This includes understanding how HC's are being accounted for in AM and understanding the hydrologic, hydraulic, economic, or other models used to predict effects to HCs. HC Team's recommendations center on monitoring and assessment of the effects of MRRP actions on HC interests. The Team does not provide input to the prioritization of management actions; that is a function of the full MRRIC. The main responsibilities of the HC WG include providing comments/feedback to the Federal agencies (during meetings with the HC Team and possibly during real-time operations), keeping the full MRRIC informed of their comments/feedback, working with the full MRRIC to assess the adequacy of the human consideration monitoring metrics, and bringing forth issues to MRRIC that may need a formal recommendation from the full committee.

While many MRRIC members are likely to have an interest in participating on these WGs, they should have reasonable expectations regarding the level of effort and nature of the work before committing to serve as a WG member. However, members must be able to commit the time and energy to stay involved, understand the issues, and stay meaningfully engaged in the technical discussions regarding application of science to species needs. Reasonable expectations regarding the level of effort are therefore essential before committing to serve as a WG member. WG members should expect to devote up to a month of their time annually in order to effectively engage with the Teams, stay abreast of developments, prepare reports, and maintain sufficient participation.

WG interactions with the teams are coordinated by the Implementation PM for each species team and the MRRIC PM for the HC Team. An MRRIC Representative serves as a point-of-contact for each WG. These interactions are assisted by a third-party facilitator initially and until such time as the MRRIC and agencies agree facilitation is no longer required. These three positions constitute the core of a 'planning group' that identifes and confirms dates for meetings and calls, develops draft agendas for work Team/WG review and considerations, and assists in other administrative preparations as necessary. The WG meetings with the teams will are facilitated, recorded, and summarized by the third-party facilitator. The recording and summary is shared with WG members as well as other interested parties including, but not limited to, the full MRRIC.

The WG Representative and agency lead PM for each Team are responsible for keeping WG members apprised of activities of the Team. The full WG is expected to meet with the rest of the Team as often as necessary to accomplish the tasks assigned to the team, but at a minimum, three times each year as follows:

- In October/November – at the Fall Science Meeting – to obtain briefings on the status of monitoring activities, early performance observations, research in-progress reviews, and other noteworthy activities of the team; and to provide input into the activities of the team for the following quarter.

- In February – at the Annual AM Workshop – to participate in discussions of significant science findings, performance of past management action implementations, prioritization of research needs and project implementation proposals, and recommendations for the WP.

- And in April/May – after the release of the agencies' draft WP – to review proposed project implementation plans, monitoring plans, and other program activities and discuss any significant adjustments to plans due to budget changes.

Each WG contributes to a collective report annually, following the annual AM Workshop, capturing the range of conversations and ideas associated with the area of focus and providing recommendations and priorities for needed research, project implementation, monitoring and assessment activities, etc. The reports from the three teams are integrated and provided to the Management Team for consideration, and will constitute the basis for draft changes to the WP by the Management Team. The WGs have the opportunity to share their observations including the range of their perspectives, provide individual or consolidated reports, and draft recommendations, directly with MRRIC in preparation for potential recommendations to the agencies.

To effectively involve MRRIC in the AM program, it is important to establish and maintain a significant level of understanding of, and trust in, the decisions and associated implementation efforts. Full engagement by all MRRIC members in the AM process is not feasible; however, it is essential that opportunities exist for members to stay engaged and share their perspectives. In addition to active participation as members of the WGs, the agencies will afford opportunities for interested MRRIC members to observe key Team meetings without the attendant commitments required of WG members. It is possible that interest and participation during initial implementation is higher than ultimately optimal for efficienct WG funtion but will serve to increase trust in the process. Therefore, early involvement should be accommodated to the extent possible, with a longer-term aim to reduce the group size to an optimimum.

The Bird, Fish, and HC WGs may function as subgroups of the SAM; the agencies and MRRIC will collaborate during the transition period between issuance of the DEIS and the ROD to refine the composition and operation of the WGs. MRRIC may retain other existing Task Groups or sunset those no longer required, and may establish new Task or Ad Hoc Groups as needed to address specific issues related to the AM program (with consideration for maintaining a total number of subgroups commensurate with the available budget and for the time commitment of members and agency staff).

Note: WG members will be expected to commit to the time and effort necessary to effectively engage in the deliberations of the Teams. It will be important to establish reasonable expectations of members and enforce them. It is not yet clear if the members would be reimbursed for time, travel or other expenses associated with these efforts – doing so may necessitate limits on the number of members on each WG.

2.3.7.3 Independent Advisory Panel

For the last several years, the MRRP has had both an Independent Science Advisory Panel (ISAP) and an Independent Social Economic Technical Review (ISETR) Panel. This structure should be retained during the transition from the DEIS through the ROD. Going forward, it is proposed that the MRRP will maintain a single Independent Advisory Panel (Panel) that is convened, as necessary, to provide independent scientific and socio-economic peer review of work products or to analyze and interpret data. The Panel may be composed of sub-Panels as needed to accomplish their charge. This structure will allow for greater integration across disciplines and more efficient and effective communication with the agencies and MRRIC.

The Panel may review the monitoring and assessment results, research plan, WP, and other relevant materials, or provide expert scientific and socio-economic advice and recommendations to MRRIC, its WGs, and the agencies. Execution of these functions, within the scope of their contract and subject to the availability of funds, is necessary for the proper function of the AM Program and for building trust between the agencies and stakeholders. The Panel has been and will be managed by a Third Party Science Neutral (TPSN) party that maintains Panel membership to ensure appropriate expertise is provided, receives tasks from the agencies or MRRIC, and ensures their activities are within the mandates and the scope of the AM Plan (see Section 2.3.7.4). In accordance with this AM Plan, the TPSN refrains from any reviews and remains neutral on products of the Panel.

The size and composition of the Panel, as well as their role and level of engagement, should be periodically reviewed and updated to ensure maximum benefit to the Program. Presently, the Panel should be comprised of between six to eight science advisors that, in addition to other specific tasks, attend the annual Fall Science Meeting and the AM Workshop and meet with the full MRRIC at least twice annually. The TPSN ensures that expertise on the standing panel meets current and projected Program needs, and generally includes the following disciplines: Aquatic/Riverine Ecology, River Geomorphology/ Hydrology, Least Tern/Piping Plover Specialist, Sturgeon Specialist, Quantitative Ecology/Statistics, Conservation Biology, and Socio-economics. An individual member can fulfill more than one of the aforementioned areas of expertise, and Panel size should be regulated accordingly, if possible. The Panel is charged with independent science support and technical oversight by providing objective advice on specific topics originating from the agencies and/or MRRIC. Interaction with the Panel must be within the scope of their contract, subject to the availability of funds, and must identify specific tasks, products, and timelines. To ensure such interactions meet contractual requirements and are documentable, the following definitions will are used:

- Panel-Initiated Communication. If the Panel considers a topic of sufficient relevance in their role of reviewing and providing independent scientific advice on draft products regarding implementation of the Panel recommendations or MRRIC proposed actions, they may provide written advice or guidance to MRRIC and the AM Teams. Their advice would be provided through the TPSN to the appropriate WG, MRRIC, or the agencies for consideration.
- Inform. Through the appropriate MRRIC WG, the agencies will provide information to the TPSN to assist Panel members in understanding the problem being addressed, the options being considered, and the final decision to be made. The agencies will keep the TPSN informed of the final decisions. The task for the Panel is to review materials as time permits.
- Discuss and Provide Feedback. Through the appropriate work WG, the AM Teams or Technical Team may interact directly with the Panel on a “scientist-to-scientist” basis. During meetings (web or face-to-face), the Teams will seek verbal feedback (e.g., clarification questions, initial reactions, and/or a general sense of direction and progress) from Panel members. The Teams will consider the feedback and then apprise the TPSN and MRRIC (or appropriate WG) as to how the feedback was used. Panel member verbal feedback should be considered informal and does not necessarily represent a consensus statement from the Panel. Documentation of the exchange during the calls/meetings will be provided through meeting summaries.
- Evaluate. Through the appropriate WG, the AM Teams will interact directly with the ISAP seeking a collective opinion. Any document(s) for review and necessary background information will be shared with the Panel along with a specific review

question (or set of questions). Discussion and feedback between the Panel and MRRIC and the relevant AM Team is inherently part of the "evaluate" option. The expected Panel product is a written memo reflecting the collective opinion of all Panel members in response to the review question(s), which will be considered by the AM Teams. The Agency response will be shared in a written memo indicating how the opinion was used/will be used.

Independent advice and reviews provided by the Panel are scientific, while decision-making and policy interpretations are left to the USACE after consideration of consensus recommendations from MRRIC. The AM Teams, particularly the Technical Team, interact with the Panel on an as-needed basis, but at least annually as part of the AM Workshop. Interactions occurs through/with the appropriate MRRIC-designated WG. Requirements of the Panel and procedures for its interactions with the MRRIC and the AM Teams are provided in Attachment 11 of Appendix A.

2.3.7.4 *Third Party Science Neutral (TPSN)*

The TPSN is responsible for selecting and managing the Independent Science Advisory Panel (ISAP), the Independent Social Economic Technical Review (ISETR) panel, and the proposed consolidated Panel, including liaising between the Panel and the MRRIC, the USACE, and USFWS (see Section 2.3.7.3 and Attachment 15 of Appendix A). The TPSN follows guidance from the National Academy of Science (2003) when developing the panel(s).

MRRIC and/or the USACE work directly with the TPSN, to develop topics and questions to be addressed by the Panel. This charge includes instructions to the panelists regarding the topic, expected products, task timelines, and how panel deliberations will be conducted. The TPSN facilitates all Panel deliberations and keeps the panelists on track. All communication regarding the topics under consideration between the USACE, MRRIC members, and candidate or selected panelists, is coordinated through the TPSN.

The TPSN ensures full consideration of multiple perspectives on the issues and a structured process that guarantees the integrity of an independent review, avoids bias, and guides communications between Panel members and the USACE, MRRIC, and other interested parties.

2.3.7.5 *Interactions with MRRIC*

Interaction between the agencies and MRRIC are defined in the Operating Procedures (MRRIC 2016; amended 2016; See Attachment 1, Appendix A), and consist of one-way (inform) and two-way communications (with low, medium, and high collaboration). In

February 2011, MRRIC approved an engagement approach describing how the agencies would interact with MRRIC in developing and implementing AM strategies for the MRRP. The approach was developed to ensure timely exchange of information and development of products, while providing opportunity for appropriate interaction between MRRIC and the agencies at key stages in the development, implementation, and decision- making involved in the AM process. The engagement with MRRIC on the development of the MRRMP-EIS and this AM Plan used this approach, and it remains an effective mechanism for engagement during AM implementation. The intention of the approach is the following:

1. Be understood and trusted by MRRIC members.
2. Provide a satisfactory level of participation in the systematic process for MRRIC members.
3. Provide an opportunity for MRRIC to identify any social, economic, or cultural issues that may result from the proposed action(s).
4. Be implementable for both the agencies and MRRIC.
5. Be focused on resolving scientific uncertainties necessary to inform management decisions.
6. Provide for collaboration that allows the agencies to implement the MRRP in a timely manner.

AM strategies require highly interactive and timely deliberations. To address this requirement, the approach established that engagement is to be conducted primarily through the MRRIC WGs. Agency leads and the AM Teams interact directly with the WGs through conference calls, webinars, and in-person meetings. Implementation of the approach is expected to work as follows: the WGs identified in Section 2.3.7.2 work closely with and at times as a part of their corresponding agency AM Teams. The primary interactions center on the Fall Science Meeting, the AM Workshop, and the WP development, but the Teams will meet at other times as needed to ensure the necessary collaboration and communication occurs. MRRIC WGs have the responsibility to engage with agency personnel on the Teams and reach into the broader MRRIC to solicit input and promote understanding and support for activities and products. WG and Agency briefings will occur at key points to ensure the full MRRIC stays informed.

Communications between the agencies and MRRIC are classified by the level of collaboration (as low, medium, or high). More medium- and high-level collaboration is likely to occur in implementation of the AM Plan, especially among the AM Teams and the MRRIC WGs and early in implementation of the Program. The appropriate types of interactions would depend on the nature of the issue and the groups involved. These interactions may vary over time as well; e.g., an issue initially treated using low-level collaboration may later require a medium-level of collaboration. Thus, a mechanism to change the designated level or the flexibility to adjust the associated collaboration is needed. A summary of potential interactions follows:

- Inform. The AM Bird, Fish, HC and Management Teams will provide information to MRRIC to assist members in understanding the program performance, results of key analyses, alternatives considered, problem being addressed, the status of and predictions for population and system status, and other pertinent information about the Program. Interactions at the Inform level will rely on the WG Representatives as well as e-mail and web meetings to inform the MRRIC. The agencies will inform MRRIC of any Oversight-level decisions regarding program implementation. The Technical Team will provide information to MRRIC and the Panel through the appropriate WG to assist Panel members in understanding the problem being addressed, the options being considered, and decisions that need to be made.
- Low Collaboration. As the AM Bird, Fish, HC and Management Teams "inform" MRRIC of the above issues during facilitated meetings and plenary meetings of MRRIC, they will also seek feedback from MRRIC. Concerns expressed are taken into consideration prior to making decisions regarding the issues discussed, and the use of the input is addressed at the next Team meeting and the next MRRIC plenary meeting. Input from MRRIC WGs during Team meetings is included in summary reports for those meetings produced by the facilitator.
- Medium Collaboration. The AM Bird, Fish, HC and Management Teams will work directly with their associated MRRIC WGs on monitoring and assessment activities and research for the MRRP. This interaction occurs at the Fall Science Meeting and, Annual AM Workshop, and any other scheduled meetings for this purpose. MRRIC WG input is included in the Joint Report, and the facilitator shares WG recommendations with the full MRRIC through meeting minutes, recordings, presentations, or other means. The Teams will ensure concerns and suggestions are understood, and will try to address those concerns to the extent possible within legal and policy constraints. The WGs then communicate to MRRIC and any appropriate Task or WG describing how their concerns were addressed.
- High Collaboration. The AM Bird, Fish, HC and Management Teams will work directly with appropriate MRRIC WGs on certain decisions and recommendations, within legal and policy constraints. A high level of collaboration occurs on the development of the WP, new or controversial information, research and project implementation priorities, etc. The Teams, including their member MRRIC WGs, jointly explore potential solutions and seek agreement on critical issues. The Teams will elevate any concerns or recommendations to the appropriate agency decision entity, and will provide related briefings to the MRRIC. The WGs, in turn, provide

their feedback to the full MRRIC and seek agreement (consensus) on recommendations to the agencies.

Interactions with MRRIC are intended to fall under the same laws and acts that currently guide the Committee and agencies (e.g., Sec. 5018, FACA, WRDA). Notwithstanding the cooperative nature of the Program, the lead agencies (USACE and USFWS) have statutory responsibilities that cannot be delegated and the program structure and interactions are intended to promote collaboration and MRRIC input to decisions. Generally, the recommended interactions provide for the following:

- MRRIC WGs engaging with agency Birds, Fish and HC Teams to assess the latest scientific data/findings, provide input on monitoring, assessment, research and implementation issues, and help decide which issues should be elevated to the full Committee
- MRRIC as a whole to be directly informed about the team process by those members participating in the species- or HC-specific teams (rather than solely by agency staff/contractors)
- MRRIC as a whole involved in the AM learning process and in the formation of recommendations for actions and research
- MRRIC members to remain informed of significant findings through attendance at the AM Workshop and other interactions during the year so they can be informed prior to plenary meetings
- Access by MRRIC members to monitoring results and research findings through data-sharing and program reports
- MRRIC as a whole to examine the science process and provide recommendations for the current (implementation) and next year's (development) WP, and for the 3-5 year strategic plan
- MRRIC as a whole to evaluate the AM program performance and make recommendations for changes to improve performance, accountability, etc.

MRRIC meets nominally three times per year to develop recommendations, building on the results of MRRP WP implementation and reports from the Bird, Fish, and HC WGs/Teams. Additional meetings can be called as needed, subject to available resources and other relevant considerations. Use of a conference call meeting may be required occasionally, but would likely be convened only to reach final consensus on a recommendation that MRRIC already reached tentative consensus on during a face-to-face meeting. MRRIC members may also attend the Annual AM Workshop, as well as participate in Annual Forum and Draft WP Review Webinar, as well as any other webinars/calls established to brief MRRIC.

The interaction strategy described above is intended to permit a consensus recommendation(s) on the MRRP WP in a more compressed timeframe than has historically been employed. This would maximize the effectiveness of the MRRIC's input to the budget and WP processes. A tentative face-to-face plenary meeting schedule with general agenda items is provided below. The timing of each meeting will need to be refined as understanding of the Program's implementation increases and, concurrently, the ability for MRRIC to have the most impact and influence through their recommendations is best understood:

- Meeting #1 (in October/November) which would provide an opportunity to discuss preliminary results of implementation efforts the prior year and information gained from the monitoring efforts and discuss other issues as appropriate (e.g., strategic priorities, programmatic considerations)
- Meeting #2 (in mid- to late-March) which would provide an opportunity to engage on traditional "Annual Forum" agenda items (science presentations and review of the Corps' draft WP), for MRRIC to begin identifying potential areas for recommendations
- Meeting #3 (in late-May) which would provide an opportunity to reach tentative consensus on recommendations related to the Corps' draft WP, hear updates on implementation of the AM activities, and discuss other issues as appropriate (e.g., strategic priorities, programmatic considerations)

2.3.8 Basin states, other Federal agencies, and tribal roles outside the MRRIC collaborative process

Involvement by any Federal Agency, State and Tribe in MRRIC does not change or affect any other authorities relating to these groups. The MRRIC Charter specifically describes the intention to not interfere with these outside processes, stating:

> Participation in the Committee by Tribal entities does not substitute for nor replace federal requirements to consult with Tribal entities pursuant to federal laws and regulations, such as: Executive Order 13175, Tribal Consultation; any federal agency's trust responsibilities to a federally recognized tribe in the Missouri River Basin or a tribe that has historically been on the Missouri River; and/or replace any treaty or right thereof such as: the Portage des Sioux Treaty (July 1815); the Treaty of Ft. Laramie, 11 Stat. 749 (Sept 17, 1851); the Treaty with the Omaha, 10 Stat. 1043 (March 16, 1854); the Treaty of Ft. Laramie, 15 Stat. 635 (April 29, 1868); Title VI-Cheyenne River Sioux Tribe, Lower Brute Sioux Tribe, and State of South Dakota Terrestrial Wildlife Habitat Restoration Act of the Omnibus Consolidated and Emergency Appropriations Act of 1999, PL 105-277, 112 Stat. 2681, 2861-660-670 (October 21, 1988), as amended by Title IV of the Water Resources Development Act of 1999, PL 106-53, 113 Stat 269,

> 385-397 (August 17, 1999), and as otherwise amended; and any other treaty or right. Cooperation with the federally recognized tribes engaged in this process should be interpreted as "in good faith."
>
> Participation in the Committee by State, Tribal, or Federal entities does not limit their discretion; alter, affect, impair, delegate, or relinquish their statutory or other legal rights and responsibilities, including any right to legal remedies; or otherwise waive their sovereign immunity under applicable law; create any new right to any type of administrative review or create any new right to judicial review or any other right or benefit, substantive or procedural, enforceable by or against these entities or any other stakeholder participating in the Committee; and affect Tribal reserved water rights, treaty rights, or water rights administered by the Tribes and/or States, including the "Winters' Doctrine", Winters v United States, 207 U.S. 564 (1908). If the processes and procedures of the Committee would impede the implementation of any action for which agencies of the States, Tribes, or United States are obligated under law, that agency reserves the right to proceed with fulfilling those obligations in such manners as it may deem appropriate. (MRRIC 2009).

Similarly, the governance of this adaptive management plan cannot impede or interfere with any other right of responsibilities of these groups. Rather this AM Plan describes the roles of Agencies, States, and Tribes specifically within the MRRIC framework. MRRIC designed to be an additional forum for these groups to provide valuable insight on the management and operations of the MRRP. Additionally, the expertise of these groups may be utilized by the various work groups and implementation teams. These new forums for collaboration between USACE and Federal Agencies, States and Tribes provide an important additional opportunity for communication and collaboration while protecting any outside processes.

2.3.8.1 *States*

Each state has responsibilities through various federal and state statutory and constitutional authorities, for management of water quantity, water quality, and fish and wildlife resources within their boundaries that could be affected in this process (in either a positive or negative way). As previously stated this governance structure does not change or impede any of the rights and responsibilities of a state codified by law.

Historically, it has been the role of the state fish and game agencies to assist in putting projects on the ground. The USACE and USFWS will continue to plan site-specific projects with State input and continue to coordinate with the appropriate state agency on any and all legal requirements for comment, collaboration, certification, permitting, etc. One statutorily protected consultation role of note is the Fish and Wildlife Coordination Act (FWCA). Under the FWCA, USACE is required to coordinate with the state game and fish agencies and the USFWS for site specific projects. USACE will continue to execute the FWCA in accordance with the National MOU between the USFWS and the USACE. As described in the National MOU, the USFWS will coordinate with state game and fish agencies and provide consolidated comments to the USACE via a planning aid letter as required by the FWCA.

With regard to the regulation of the Missouri River Mainstem Reservoir System, the USACE will continue to provide a draft Annual Operating Plan (AOP) each fall that describes the planned operation of the reservoir system for the coming year under a variety of runoff conditions. The States will have the opportunity to provide comments on the draft AOP at the fall public meetings or by providing written comments during the comment period. Another outside process for states to comment on any issue related to the Management Plan or ongoing AM process is via official letter, which can be submitted to the USACE at any time.

The AM plan contemplates that the States will have an additional role through their representation at MRRIC. It is imperative that MRRIC State representatives are able to effectively relay information presented as MRRIC to interested state agencies and bring their concerns back to the MRRIC table. MRRIC representatives will be able to reach a broader group of interests than the outside statutory structure contemplates being able to inform decisions. State agency expertise also has a potential role to play on various work groups.

2.3.8.2 *Federal Agencies*

Federal agencies are not counted for purposes of Committee quorum requirements and do not participate in the determination of consensus recommendations, however, agency representatives provide input on substantive issues where they have jurisdiction or special expertise and are therefore integral to the AM Process. Like states and Tribes, Federal agencies are consulted on site-specific projects when they have special expertise, statutory responsibilities or authorities. The National Park Service, for example, will continue to be involved in assisting the agencies in planning sandbar habitat construction activities in the Missouri River National Recreational River (MRNRR) reaches below Fort Randall and Gavins Point Dams. Federal agency consultation in this capacity should occur early in the project formulation process through interactions and discussions during meetings of the Bird and Fish Teams.

2.3.8.3 *Tribes*

Tribal members of MRRIC have created a Tribal Interests WG, which provides a venue for collaborating with Tribes on MRRP work products and specific tribal interests and have these taken into consideration in relation to MRRP activities. The MRRP has a Tribal Lead who coordinates MRRP developments directly with all tribal nations and strives to ensure their councils are aware of proposed budgets and activities. A key responsibility is to communicate concerns expressed by individual tribal nations about specific actions or projects to MRRP management for consideration. The Tribal Lead coordinates resolution of issues, recognizing not all requests can be accommodated, and provides feedback to the requesting tribe. For those tribes unable to have representation at each MRRIC meeting, the Tribal Lead strives to ensure tribal governments receive information discussed at these important stakeholder meetings and that they are aware of pending opportunities to provide input to the process. The MRRP will coordinate with the Tribal Lead to make sure information regarding the Program is communicated with the tribes, either through MRRIC or directly via the Tribal Lead.

2.4 AM Decision process, critical engagements, and workflows

2.4.1 Overview of the MRRP AM decision process

The decision process for the MRRP includes the mechanisms by which information about project and program performance, species status, system state, and other knowledge is gathered and evaluated, shared with agency managers, MRRIC, and stakeholders, and used to make improved implementation decisions. The process is constrained by the timing of budget cycles, construction windows, and information availability; by the resources necessary for data processing, QA, analysis, and interpretation; by the need for coordination and communication; and by external factors like regulatory compliance issues.

The process is outlined in a series of diagrams and timelines that identify the needed decision-making steps, who is responsible for those steps, and when they occur. (see Section 2.4.2 – 2.4.6). The process is built around the review of information and application of learning to the development of the WP. The overall process includes several important products and critical engagements that are consistent from year-to-year, but the specific steps can vary considerably depending upon the decision under consideration. The decision process was developed to be as follows.

- Science-Driven. Decisions are based on the ongoing testing of hypotheses and active development, incorporation, and communication of new decision-relevant information arising from research, monitoring, and assessment efforts.
- Collaborative. MRRIC and its WGs are engaged at several points in the process to ensure their access to the latest information and to obtain their input in all key decisions.

- Efficient. Recommendations and decisions are made as close to the implementation level as possible and elevated to higher levels only when programmatic or policy authority is required.
- Specific. The process steps, products, needed engagement and level of decision making are defined explicitly for a range of decisions and vary by decision scope.
- Comprehensive. A range of decisions, including ones likely to be rare, are considered in advance to reduce programmatic uncertainty and increase efficiency through the development of contingeny plans, where warranted.
- Transparent. The decision process requires that information is shared in a timely and understandable manner, and MRRIC participates in the process at all levels.

The USACE Civil Works budget process and the AOP for the reservoir system play an important role in defining the basic MRRP decision process (see Section 2.2.2). A "Science Update" process, which occurs annually and is the primary means by which scientific information is synthesized, hypotheses are assessed, and the results are communicated, including collaboration across various participants in the governance process (see Section 2.4.3). The WP development process, described in Section 2.4.4, includes sub-processes for information development, sharing, and decision making that vary depending on the specific issue being addressed. These are described using a set of decision workflow diagrams that provide a visual comparison of the steps in each decision and the level of engagement with each governance level for different types of decisions (see Section 2.4.6). Should knowledge gained from AM indicate the need for new management actions the necessary steps, engagements, and decisions are described (see Section 2.4.5).

2.4.2 Basic Annual AM engagement process

The annual engagement process for the MRRP revolves around science updates and the generation and sharing of information about program performance, then using that information for the development/adjustment of the WP. Figure 16 provides an overview of the process, which recurs each year for the Program. The elements in the figure are described in the following sections. While the description below provides the basic process as it relates to the information exchange between the agencies and MRRIC regarding decisions on the WP, embedded within are a number of additional decision processes, many of which are described in the remainder of Chapter 2 and in key sections of Chapters 3 through 5. Each process or input flow between major decision points or events (e.g., draft or final documents, meetings, webinars) is described with an associated colored symbol, and combined into a cohesive workflow diagram (Figure 15, see Sections 2.4.2.1 – 2.4.2.4).

2.4.2.1 *Annual operations planning cycle*

Draft AOP Meetings – Annual public meetings held in October by the USACE around the Missouri River basin to present and receive feedback on the draft AOP for the upcoming calendar year.

Draft AOP – Draft AOP prepared by the USACE Water Management office annually based on the draft WP

Final AOP – The finalized AOP based on the approved WP and issued by the USACE Water Management office in December of each year for the following calendar year.

Final AOP Meetings - Annual public meetings held in April by the USACE around the Missouri River basin to present the final AOP for that year's water management operations.

2.4.2.2 *Monitoring, evaluation, and engagement with the Bird, Fish, and HC Teams*

Fall Science Meeting – A Fall science meeting would be held for agency technical staff and MRRIC WGs to be briefed on research and monitoring findings (see Section 2.4.3.1).

Bird, Fish, and Management Team Calls – Conference/webmeetings held throughout the year to review and discuss information, develop recommendations, and plan for and follow up on in-person meetings.

Draft AM Report – Summary of monitoring and assessment results, research, and new information relevant to the MRRP.

Annual AM Workshop – Annual meeting where primary exchange of information between scientists and decision makers occurs. Includes close collaboration with MRRIC WGs with input from agency AM Teams and MRRIC on priorities for the WP (see Section 2.4.3.2).

Bird, Fish, HC and Management Team Meetings – Following the AM Workshop, the Bird, Fish, and HC Teams meet to deliberate on lessons learned, to develop priorities, and to prepare a report of other factors. Included are recommendations for adjustments to the current FY and FY+1 activities, with an emphasis on the FY+2 and strategic (FY+3 and FY+4) recommendations.

Teams' Joint Report – (Optional) Includes a synthesis of MRRIC WG assessments of Program performance, research, and prioritized recommendations from the Bird, Fish, and HC Teams, and draft WP input from the Management Team.

Final AM Report – The Management Team integrates input from the Technical and species teams, with input from the HC WG. They consider budget, AOP, and other constraints and make recommendations on the WP.

2.4.2.3 *WP development*

Draft WP – The draft WP is prepared/updated by the Management Team based on the recommendations of the Implementation Teams, the HC WG, budget, and acquisition constraints and needs.

Final WP – The final WP update is made in June each year following input from all the teams and MRRIC recommendations. Updates to the plan emphasize FY+2 actions, but include adjustments to other years and add FY+4 strategic projections. WP implementation begins October 1 each year.

2.4.2.4 *MRRIC meetings and products*

MRRIC Meetings – Three in-person meetings of the full MRRIC would beare held annually, with a fourth date reserved as needed. Options for meetings using web and telephone are being considered. Includes an Annual Forum for MRRIC to present the final AOP for that year's water management operations and key lessons from the science update process.

MRRIC Recommendations – The MRRIC typically provides recommendations on the WP in June of each year. Recommendations focus on FY+2 Program needs, but can include adjustments to other years and strategic plans for FY+3 and FY+4.

MRRIC Calls – (Optional) A webinar is scheduled in April/May to discuss issues related to the WP development process.

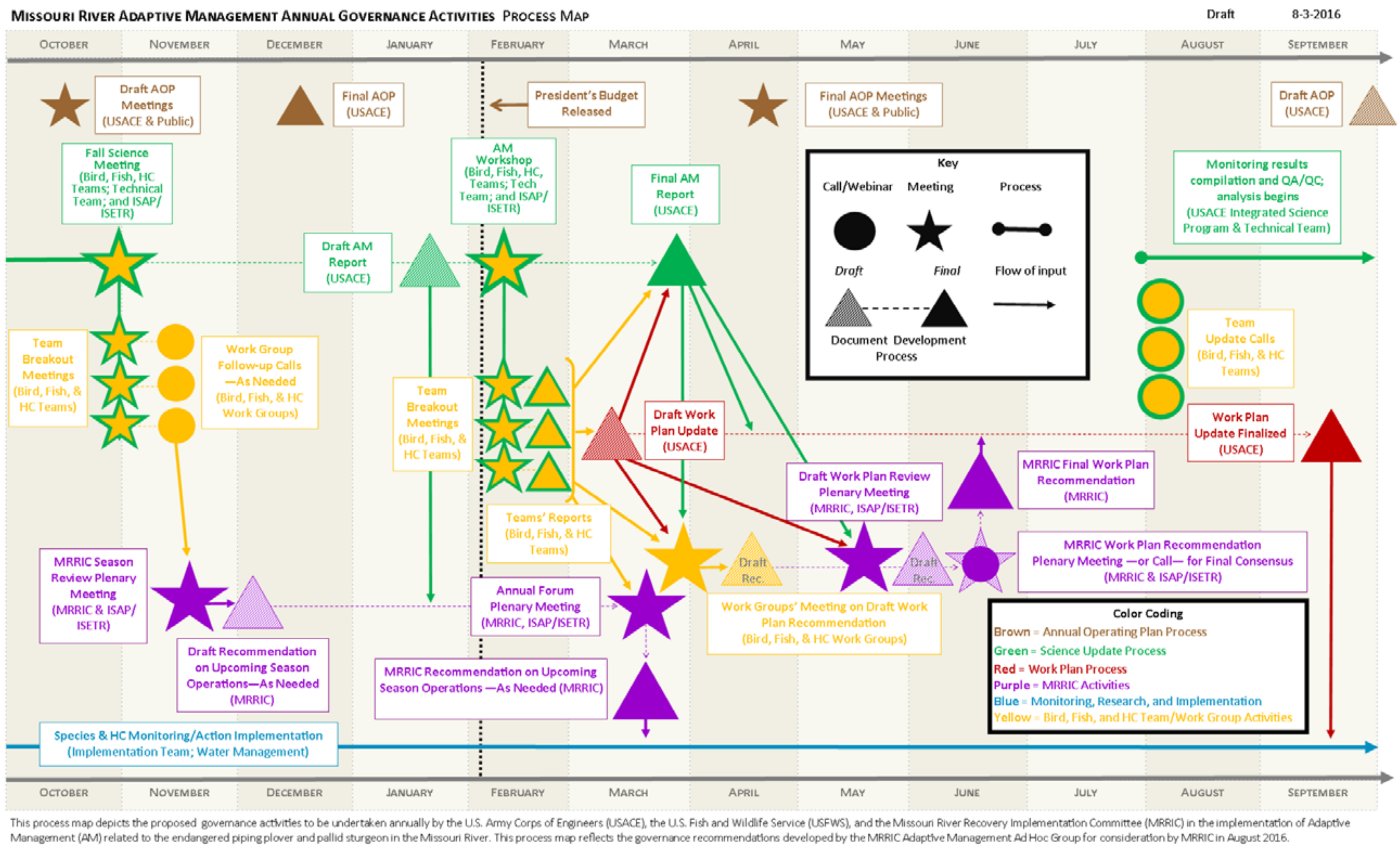


Figure 16. Proposed governance activities to be undertaken annually by the USACE, the USFWS, and the MRRIC in the implementation of AM for the MRRP. This process map reflects the governance recommendations developed by the MRRIC AM Ad Hoc Group for consideration by MRRIC in August 2016. Additional description of labeled symbols provided in Sections 2.4.2.1 – 2.4.2.4.

2.4.3 Science Update process

The Science Update process (Figure 17) occurs annually, in coordination with the WP update process. This process provides several points of interaction across the levels of governance and with stakeholders to ensure analyses and resulting findings are timely, decision-relevant, and adequately communicated. It also provides a forum for collaboration within the AM learning process through research and system evaluation.

The Science Update process begins when system-wide and action-specific monitoring data becomes available, along with preliminary after-action assessments. A Fall Science Meeting (see Section 2.4.3.1) is held to review initial observations from the field season, identify analytical needs with a focus on the AM workshop, and review the Strategic Plan. The Technical Team performs necessary data analysis and synthesis to evaluate action effectiveness and the habitat and species status and needs. The Team conducts any additional analyses as requested by the ISP Manager or Bird, Fish, HC, and Management Teams, and as approved by the SPM. The Technical Team prepares a draft AM report and any additional reports as tasked.

The Technical Team shares their draft AM report in advance of the AM Workshop, which is attended by the Bird, Fish, HC, and Management Teams, leadership at the Oversight level, and the Panel, as well as MRRIC members interested in hearing the presentations and discussion. The Workshop provides an opportunity for communication and discussion among technical staff, decision makers, and stakeholders regarding species and habitat status and needs, hypothesis evaluations, proposed adjustments to research and monitoring, and the application of findings to System management. Feedback received during the meeting and from follow-up meetings may lead to revisions to the Technical Team's annual AM report.

Following the completion and dissemination of the annual reports addressing research, monitoring, and assessment, a summary of the related information is presented at the Annual Forum for MRRIC to summarize species status, science findings, and management implications. Other specific presentations by researchers or technical staff as identified by the Bird, Fish and HC WGs are also be delivered at the Annual Forum.

Two In-Progress Review (IPR) meetings are held annually to permit researchers to share initial findings and obtain feedback from the ISP Manager, Panel, and other researchers. The fall IPR is held in conjunction with the Fall Science Meeting. The spring IPR is held in conjunction with the Annual AM Workshop, during which the major science findings are presented (see Section 2.4.3.2). The ISP is responsible for coordinating and conducting the IPR portion of the Annual AM Workshop. The IPR may include reporting and feedback on major studies not considered “research” in order to discuss assessment needs and adjustments based on new information.

Findings from the IPRs and AM workshop are used by the Bird, Fish, HC, and Management Teams and Oversight to identify needed adjustments to the WP, as well as adjustments to research and monitoring as deemed necessary.

Figure 18 highlights the IPRs, AM Workshop, Annual Forum, and Missouri River Natural Resources Conference (MRNRC) as well as showing the timeline for fish and bird monitoring. An “other” category is included for MRNRC and the Water Management briefing to indicate the role of researchers and the public. The WP process is retained in this graphic for reference; the key meetings occur in time to help the managers draft the WP and to provide MRRIC the information necessary to review the WP and make recommendations based on science progress.

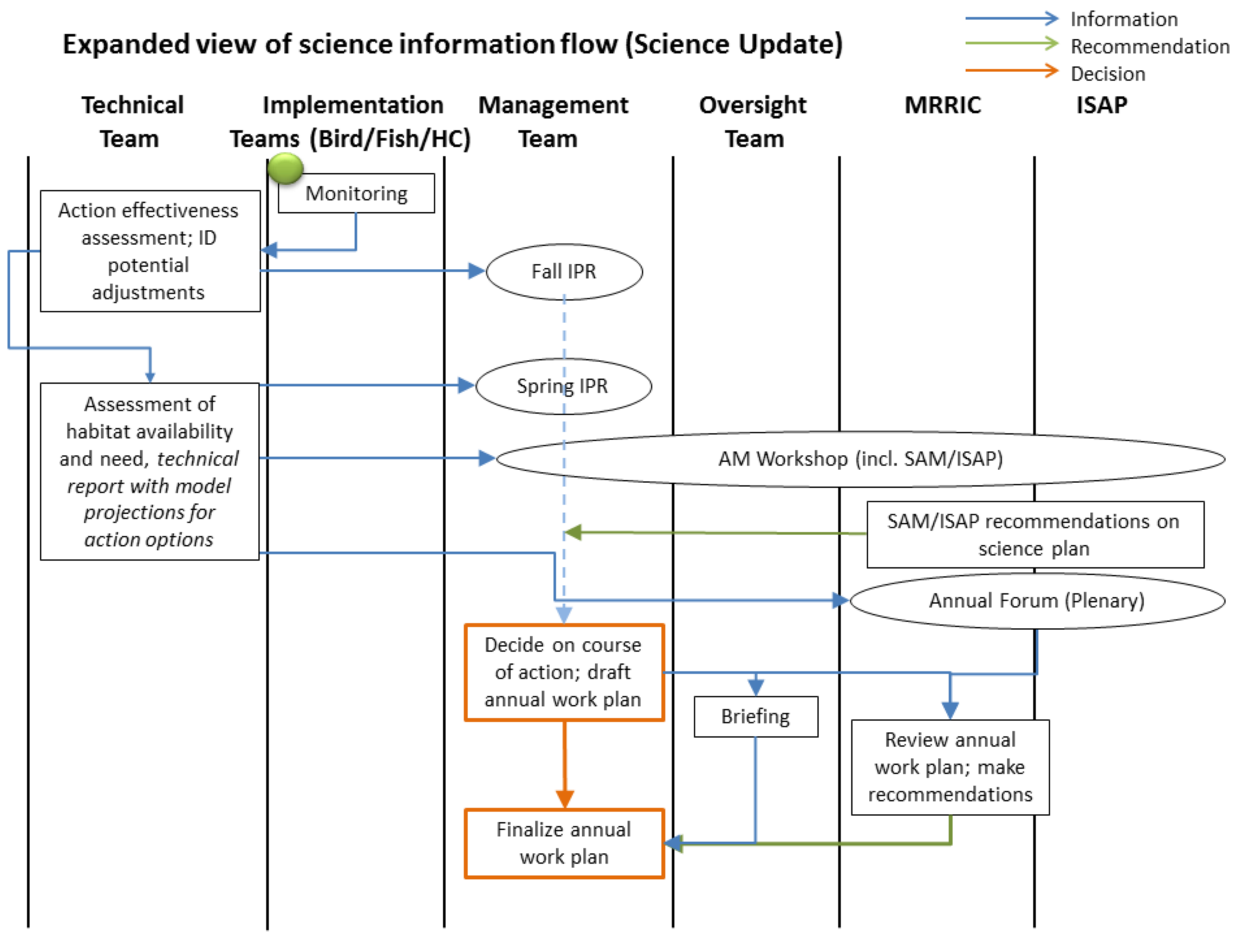


Figure 17. Overview of the science update process.

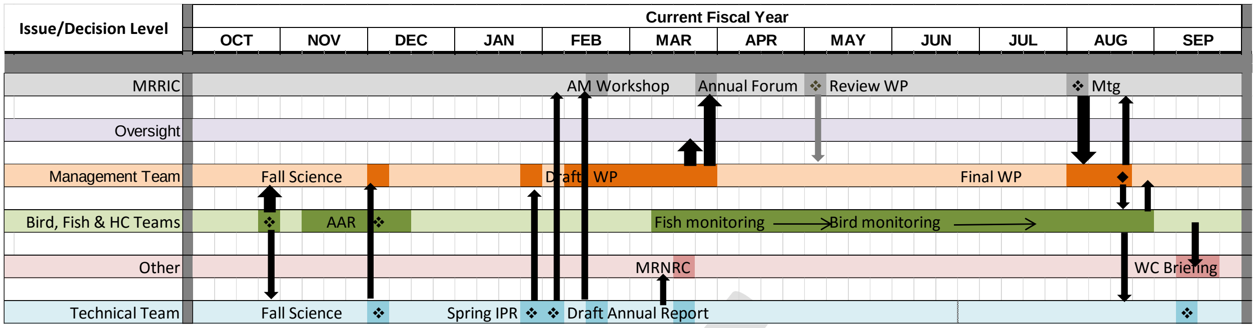


Figure 18. Science update process timeline.

2.4.3.1 *Fall Science Meeting*

2.4.3.1.1 *Purpose, scope, and timing*

The Fall Science Meeting will is held the third week of October[1] each year to provide a regularly scheduled, focused opportunity for the Technical Team, Bird and Fish Teams, HC Team, other MRRIC WGs, and agency Management and Oversight to meet, hear about, question, assess, and understand the technical results and implications of AM Plan implementation efforts. In particular, the Fall Science Meeting is intended to (a) serve as an in-Progress Review (IPR) for ongoing research and technology development activities, (b) provide opportunities for field crews to share early observations regarding system conditions, project performance, and monitoring activities, and (c) identify and assign additional analyses needed for the upcoming AM workship, and (d) allow Water Management to provide a briefing on the draft AOP and receive feedback relative to MRRP needs. The meeting provides MRRIC WGs with face-to-face opportunities to discuss the observations of technical staff involved in the MRRP and implications for potential management action needs. Finally, the event provides the attendees an opportunity to continue building trust in the process and maintains transparency in information sharing and decision making.

2.4.3.1.2 *Attendees*

The Fall Science Meeting is a facilitated, 4-day meeting of key personnel and groups involved in collecting and assessing scientific data for the MRRP, or conducting research for the MRRP, or responsible for developing recommendations or making decisions based upon scientific information.

[1] This date is a placeholder in AMP V5. Actual dates will be adjusted as needed for the Final Draft.

Mandatory attendees include the following:

- The Facilitator,
- The ISP Manager,
- The Lead PI for any research funded by the MRRP,
- Members of the MRRP Fish, Bird and HC Teams,
- Members of the MRRP Technical Team so tasked,
- Members of the MRRP Management Team,
- MRRIC Bird, Fish and HC WG Chairperson
- MRRIC Chairperson, and
- Members of the Panel.

Those encouraged, but not required, to attend include the following:

- Members of the MRRIC Bird, Fish and HC WGs[1],
- Agency staff involved with monitoring or assessment,
- Other Tribal, Federal or State officials with responsibilities related to project implementation, and
- Agency leadership at the Oversight level.

The Fall Science Meeting is open to any member of the MRRIC, other agency or tribe, or general public who wishes to listen to the technical presentations and discussions among participants. Presentations and opportunities for questions and answers (Q&A) are limited to invited attendees in order to adhere to the schedule and achieve meeting objectives.

2.4.3.1.3 *Agenda*

A draft agenda for the Science Meeting is presented in Attachment 8 of Appendix A.

2.4.3.1.4 *Key products*

Presentations and abstracts or other related materials from the Fall Meeting are posted on the MRRP website. The Facilitator will prepares a "Meeting Summary" that outlines the primary presentations, issues, and outcomes and makes this summary available prior to the agencies and MRRIC. The Panel prepares responses to any questions posed by the MRRIC or designated WGs. The ISP Manager prepares summary evaluations and recommendations for on-going research and technology development activities.

[1] These groups reflect current proposals developed in interactions between the agencies and the MRRIC AM ad hoc Work Group as of this draft AMP. The final AMP will reflect the selected names/composition, etc., determined by MRRIC.

2.4.3.2 *Annual AM Workshop*

2.4.3.2.1 *Purpose, scope, and timing*

A facilitated workshop is held in the first week of February[1] of each year to provide an opportunity for agency staff, contractors, and stakeholders to interact and discuss results of research and monitoring efforts for the previous year and plans for the upcoming year. The purpose of the AM Workshop is to report on results of project and Program performance monitoring and promote the exchange of scientific information among technical experts involved with the Program, decision-makers, and stakeholders. Workshop organizers will optimize opportunities for interaction among participants with the aim of supporting program decisions for subsequent years.

The Facilitator is responsible for organization of the AM Workshop, which will be held annually at least three3 weeks prior to the MRRIC Annual Forum and Spring Meeting so that results may be summarized and disseminated prior to addressing the draft WP. The ISP may hold one of the two annual research In Progress Review (IPR) meetings in conjunction with the AM Workshop, provided it does not detract from the agenda.

2.4.3.2.2 *Attendees*

Mandatory attendees of the AM Workshop include the following:

- The Facilitator
- The ISP Manager,
- The Lead PI for any research funded by the MRRP,
- Members of the MRRP Fish, Bird and HC Teams,
- Members of the MRRP Technical Team tasked with presenting information,
- Members of the MRRP Management Team,
- MRRIC Bird, Fish and HC WG Members,
- MRRIC Chairperson, and
- Members of the Panel.

Those encouraged, but not required, to attend include the following:

- Agency leadership at the Oversight level,
- Members of the MRRIC,
- Agency staff involved with monitoring or assessment, and
- Other Tribal, Federal or state officials with responsibilities related to project implementation.

[1] [1] This date is a placeholder in AMP V5. Actual dates will be adjusted as needed for the Final Draft AMP.

The AM Workshop is open to any member of the MRRIC, other agency or Tribe, or general public who wishes to listen to the technical presentations and discussions among participants. Presentations and opportunities for Q&A will be limited to invited attendees in order to adhere to the schedule. Senior managers from the USACE vertical team, the USFWS, and MRRIC are encouraged to participate in the AM Workshop and subsequent formulation meetings to ensure that decision making is well-informed and that appropriate guidance is given to the Teams on plan formulation directions (including scopes of other AM applications).

2.4.3.2.3 *Process*

Attachment 8 of Appendix A provides an agenda for the annual AM Workshop. Adjustments to and deviations from the agenda can be made at the discretion of the AM Planning Group in order to accommodate needs, provided required elements are met, including: a) presentations of research results for all funded research activities; project and program performance monitoring and assessment results; results of hypothesis testing; and identified research needs and proposed research and testing activities; and, b) opportunities for agency decision-makers, MRRIC WG members, and the Panel to question researchers and technical personnel making presentations.

The Facilitator notifies participants and attendees of meeting location and dates at least 3 months in advance. A draft agenda is furnished at least 1 month prior to the meeting; adjustments to the specific order or topic of presentations will, as a practical matter, remain subject to change. Presenters provide full presentations and abstracts or copies of reports or other products at least 2 weeks prior to the workshop. Project Management Plans (PMPs) for each study or other research effort provided at the Fall IPR are provided to attendees and should be updated by researchers, as appropriate.

Presentations are typically 30 minutes, with no more than 20 minutes allotted for presentation (15 minutes preferred), and no less than 10 minutes allotted for questions and discussion. Presentation times can be adjusted to suit specific needs, but opportunities for information exchange in the form of Q&A or open dialogue should not be unduly limited by such adjustments.

In addition to presentations by researchers and staff addressing specific study efforts, the AM Planning Group schedules a summary presentation of the Program; including expenditures, major initiatives, significant findings, and implications of any significant study results. The MRRP and ISP PMs are responsible for coordinating this summary presentation. Results of solicitations for research needs, research proposals, or other similar efforts are also presented. A targeted summary of the status of any “lines-of-evidence” assessments for pallid sturgeon will are provided.

2.4.3.2.4 *Key products*

Presentations and abstracts or other related materials from the AM Workshop are posted on the MRRP website. The Facilitator prepares a "Workshop Summary" that outlines the primary presentations, issues, and outcomes and makes this summary available in draft form to the agencies and MRRIC within 2 weeks of the meeting. The MRRIC Bird and Fish WGs will identify, from the presentations delivered at the AM Workshop, a subset of presentations that should be given or summarized at the Annual MRRIC Forum. Selected presenters may also be required to attend the Spring MRRIC meeting and provide presentations or participate in Q&A.

2.4.3.3 *Annual Strategic Review*

The Annual Strategic Review is the process of developing the Annual Report on the BiOp. As part of that process, AM Annual Reports are prepared by the Technical Team. These reports synthesize information on project actions and monitoring, to assess progress toward program goals, and to describe lessons learned to assist AM Program decisions and to maximize action effectiveness. The four primary report objectives are (1) provide an analysis of monitoring data, especially pertaining to performance of actions relative to the targets, objectives and goals of the MRRP; (2) provide a forecast of outcomes of future management scenarios; (3) outline recommendations for managers and stakeholders; and (4) provide a review of the status of the science, including current published and unpublished research results relevant to management. Results of the Bird and Fish AM Annual Reports are summarized in a Joint Annual Report on the BiOp, which includes input from the MRRIC WGs.

The Annual Report, a requirement of the BiOp, documents USACE activities to comply with the provisions of the BiOp, in collaboration with the USFWS and MRRIC. The report includes the activities and progress of the implementation of the elements of the RPA (if any), reasonable and prudent measures (RPMs; if any), and conservation recommendations. The report details the conditions of the river during the preceding year, the impact these circumstances have had on program implementation and listed species, and specific accomplishments. BiOp requirements, population assessments, research and monitoring efforts, and actions taken to meet reporting requirements are specified in the report. Lessons learned and AM strategies with recommendations for future direction of the program implementation are also discussed. The Technical Team is the lead for the report; however, other Teams and agency staff may prepare submissions for inclusion in the report. In addition, the District Implementation PMs produce a report on the current and future plans for implementation of the Mitigation Program, which is included as an appendix to the Annual Report.

2.4.4 WP development and approval

The MRRP WP is a rolling, 5-year strategic plan for implementation of the management actions, research, studies, and associated engagement process needed to meet the MRRP goals and objectives. The WP follows and builds upon the Science Update Process (see Section 2.4.3), and conforms to the constraints of the USACE Civil Works Budget Process (see Section 2.2.3.1). Annual updates to the WP include minor adjustments to the Current FY (CFY) and the following year (FY+1), center on development of the FY+2 efforts for budgeting purposes, and include anticipated needs for upcoming years (FY+3 and FY+4), as shown in Figure 19.

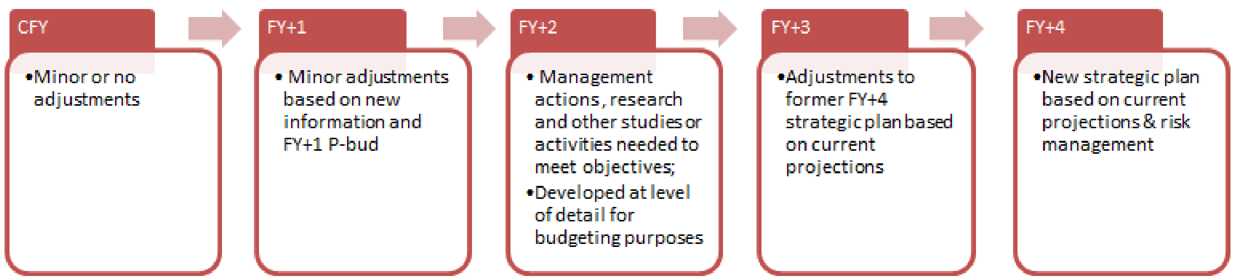


Figure 19. Schematic of the WP showing areas of emphasis for annual updates.

Beginning each FY, the budget appropriation for the CFY occurs between the months of October and March. Following receipt of the appropriation, the WP for CFY is implemented. The Draft FY+1 WP is finalized concurrently with the release of the FY+1 President's Budget (P-bud). Proposed projects in the FY+1 plan are organized via the Project Work Request (PWR) system, which functions as a database for input of proposed project information. Information on each subprogram/project is compiled for input into the PWR system with all work items entered in the PWR database no later than February 1 of each FY.

The WP update for the MRRP is focused on the Corps' development of the FY+2 budget submission, which occurs from January to June of each FY. The WP update process begins in earnest with the Annual AM Workshop, where the scientific findings and results of data analyses from the Technical Team are assessed in terms of Program implications. The WP process ends when the agencies "finalize" the updated plan in June, following a series of meetings, MRRIC engagements, and an opportunity for MRRIC to provide consensus recommendations on the updates. Figure 12 shows how the WP update process relates to the AOP, Science Update, and MRRIC engagement processes and schedules).

A series of important interactions occur annually as part of the WP update process (Figure 20). Information developed by the Technical Team and presented at the AM Workshop includes a performance assessment of actions implemented to date and an overall Program performance assessment, significant findings from research, monitoring and assessment, updates to the CEMs, and an assessment of hypothesis testing activities, model projections of habitat and species populations, assessments of system status, and other tasks or studies. This information is used by the Bird and Fish Teams to develop a set of prioritized actions and recommendations for each species, and by the HC Team to make recommendations regarding monitoring and assessment of HC impacts. The Teams (including the MRRIC WGs) meet separately during the AM Workshop to conduct initial discussions regarding prioritizations, then meet together in a plenary session at the end of the Workshop to share observations. The Bird, Fish, and HC Teams continue to meet as needed over the following weeks, and prepare a report of recommendations and prioritizations for submittal to the Management Team. The MRRIC WGs may prepare a separate Joint Report to MRRIC and the agencies.

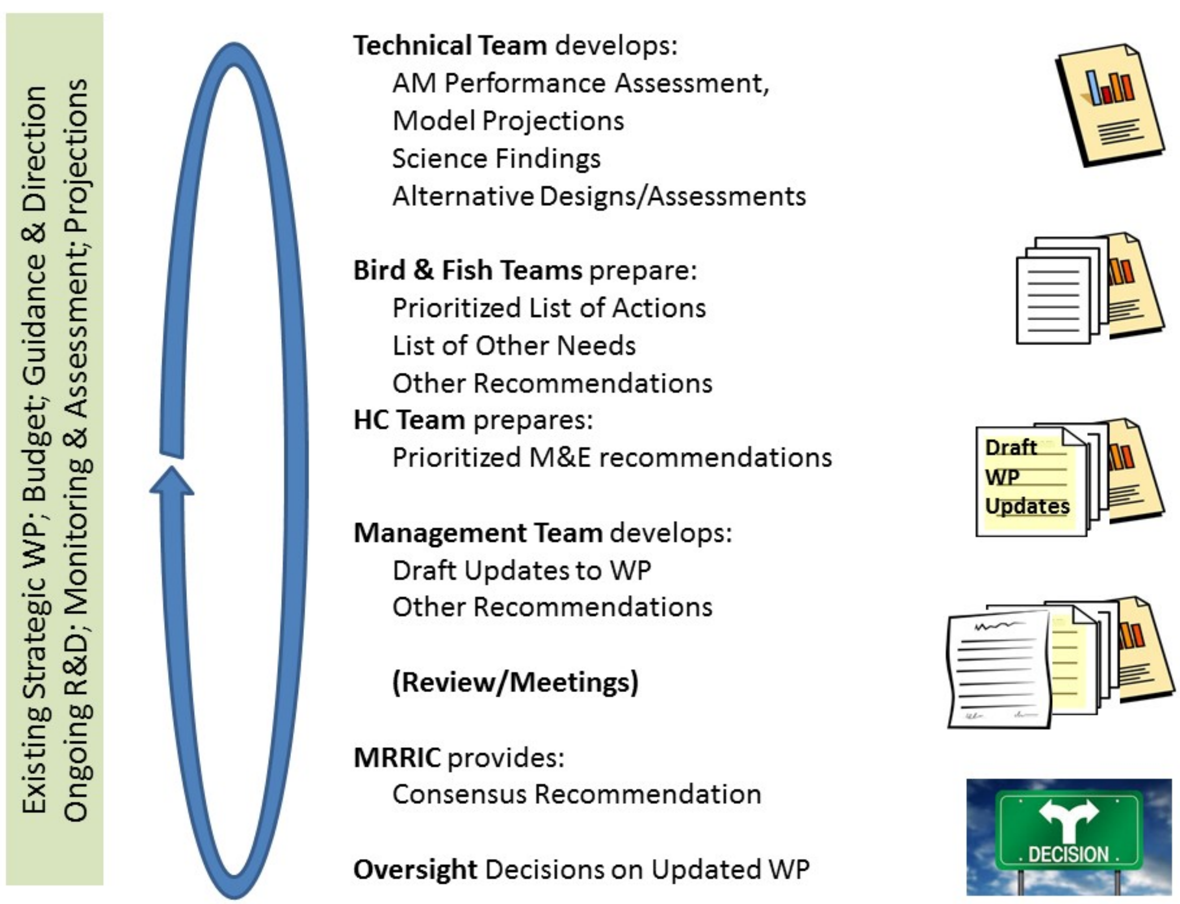


Figure 20. Schematic of interactions occurring annually that lead to the updating of the WP.

The specific steps in the process depend on the issues under consideration (see Sections 2.4.5 and 2.4.6), but the overall approach remains the same each year. The Management Team develops the draft updates to the WP between February and March by integrating needs and recommendations of the Bird, Fish, and HC Teams and applying a programmatic perspective, considering the makeup of the existing Strategic Plan, guidance and direction provided by the Oversight level, budget trends, the status of the science and risk management, HC effects, etc. The Management Team meets at least once with agency leadership in an IPR during this period to review proposed updates. The draft Revised WP is prepared in early March and is provided to the agencies and MRRIC for review and comment. Proposed updates are discussed in MRRIC meetings and (as needed) a webinar. Additional analyses and adjustments may be made during this process depending on the feedback from agency Oversight or MRRIC. MRRIC may elect to provide a consensus recommendation at their June meeting prior to the agencies finalizing the adjustments to the Plan.

As part of the WP development process, the Management Team updates/determines key programmatic and project resource needs, including labor (staff and contractors), and materials for both the current and two upcoming FYs. This allows managers and decision-makers to ensure MRRP project and programmatic activities are implemented in the most efficient and effective way. The MRRP resource determination occurs each year during the USACE' financial cycle and is developed in coordination with associated schedules and budgets, in consultation with USACE branch chiefs. The ISP and the Bird, Fish, and HC Teams are responsible for developing a resource needs with prioritizations for their respective efforts. The Management Team and the ESC are responsible for integrating the resource information provided by the subprogram elements into a programmatic resource needs determination.

A staffing needs estimate is developed for each year concurrently with the resource determinations. The Management Team develops a staffing needs summary for each MRRP subprogram, working with the Bird, Fish, and HC Teams and District branch chiefs. Staffing needs estimates are developed in coordination with the MRRP WP, as well as associated budgets and schedules. Staffing needs estimates serve as a guide for the ESC and senior leadership as resources are allocated each FY. These staffing summaries are dynamic and updated as annual appropriations are finalized and resources are allocated. Staffing needs summaries include provisions for staff turnover, retention, and mentoring as well as a list of those contractors needed and required to assist with MRRP implementation. Additionally, documentation of labor and resource allocation processes includes recognition of existing institutional controls, including P2 and CEFMS, and is used for developing plans to address cross-district labor and resource needs each FY.

2.4.5 Consideration of new management actions

2.4.5.1 *Triggers for the consideration of new management actions*

The EA identified a wide range of management actions that could be utilized to meet the needs of the listed species. The MRRMP-EIS considered those actions relative to program objectives and identified a subset to be applied under the MRRP as part of the "first increment." Following issuance of the ROD, the USACE will implement the identified management actions, monitor their effetivness, and develop annual performance evaluations. Should those actions prove ineffective in meeting targets for the listed species, the USACE, in consultation with the USFWS and with MRRIC engagement will determine the appropriate course of action. That may include continued implementation of the selected alternative, adjustments to the targets, or the introduction of management actions other than those in the ROD.

If knowledge gained through research, implementation and monitoring suggests that actions other than those in the ROD may be required to meet objectives, the USACE should pursue investigation of alternatives for consideration as part of the WP development process. The specific steps required would depend upon the circumstances and the scope of additional measures under consideration (e.g., see Section 1.1.6). Planning and budgeting for a change in the scope of actions under the program could take considerable time and involve a high level of collaboration.

At present, there are no programmatic-level triggers for the introduction of new management actions. The species-specific decision criteria can be applied for this purpose but caution is warranted as they may not offer a sufficient basis for that decision when considered in isolation. While specification of specific contingency plans is not recommended at this stage, the MRRP should work toward the identification of a more comprehensive suite of metrics and associated decision criteria that would define the circumstances under which a decision to broaden or adjust the scope of actions applied under the Program is triggered.

2.4.5.2 *Structured processes for decision making*

There will be a need under the AM Plan to make a wide range of decisions under uncertainty that have complex implications for endangered species, for scientific learning, for the program and for Tribes, states and stakeholders. In general, structuring decision-making processes help increase transparency, efficiency, communication, and accountability. In the implementation of the AM Plan, structured decision-making processes should be used whenever it is clear that they would add value.

Not all decisions warrant the use of formal decision analysis; indeed, most of the decisions that need to be made on an ongoing basis as part of the AM Plan will be technical in nature and will not have significant or complex implications that need to be analyzed in great depth. Many of the day-to-day decision-making concerning Level 1 and (most) Level 2 actions and associated monitoring studies will fall into this category, as will the details of habitat construction designs and associated monitoring. While it is true that structuring even these decisions may often help scientists think carefully about the best way to approach certain issues, it is not usually necessary (nor always desirable, given the additional effort required) to do so for decisions where uncertainties are low and the consequences of action are uncomplicated.

Sometimes, overall decision-making complexity can be avoided through the use of simple decision rules for situations for which consequences are readily understood or for where the potential for a large negative consequence is low. Some of the decision rules noted in Chapters 3 and 4 serve as examples. Another approach to reduce complexity is to bracket-off deeper consideration of trade-offs where those consequences are known to be below a pre-defined threshold (e.g., if expected impacts of a decision are thought to be less than a certain amount, then analysis for an issue could be neglected). In some low-stakes cases, the development of solutions to a problem that are robust to external uncertainties may be preferred without need to resort to deeper analysis. Robust solutions can, however, come with their own trade-offs (e.g., higher cost), which might not necessarily make them the best choice, however.

Despite these examples, even seemingly quite straightforward, technical decisions can suddenly become complex in the context of a large AM Plan where unintended consequences could arise with insufficient thought. Decision analysis in its general sense should therefore be considered as "a formulation of common sense for decision problems which are too complex for informal use of common sense." (Keeney 1982, 806). In these cases, the diverse array of decision contexts in the plan suggests an equally diverse range of decision structuring tools should be considered.

Decision structuring is already mandated by the USACE for certain situations. For example, Cost Effectiveness and Incremental Cost Analysis techniques have long been integral components of the USACE’s water resources, environmental planning, mitigation of fish and wildlife habitat losses, and ecosystem restoration. These particular techniques are most helpful when there is a wide array of potential solutions, when primary performance is readily quantified, and when secondary considerations (e.g., effects on HC) are minor or can easily be monetized. These techniques may be highly valuable for decisions related to mechanical habitat site selection questions, for example.

Cost Effectiveness (CE) and Incremental Cost Analysis (ICA) become less appropriate tools when cost effectiveness is not necessarily the primary driving factor in a decision; when the number of options are small; when the options contain many nuanced issues; and when dialog and engagement are considered a priority. In these cases, other structuring tools, such as decision trees, multiple account evaluation (MAE), and multi-attribute trade-off analysis (MATA) may be preferred.

There are many forms of decision analysis of this type, and numerous tools and methodologies to implement them. Typically, they have in common a more-or-less formal process for working through stages in decision making involving: (1) clarifying the problem definition, (2) identifying issues of importance to people that might be affected by the decision (objectives), (3) developing creative alternative solutions to the problem, (4) estimating consequences of alternatives on objectives, and (5) evaluating the trade-offs thereby exposed. This sequence of steps is sometimes referred to by the acronym PrOACT.

The precise form that an analysis should take is highly dependent on the specifics of a decision context. Some decision contexts will be site-level or involve a much smaller scale of issues than were the case during the development of the MRRMP-EIS. During that process, a consequence table decision analysis format was used to share information on how the direct impacts of habitat construction or hydrological differences might be felt in terms that stakeholders were familiar with, (e.g., in the number of days of boat ramp availability during various seasons.). These proxy metrics have the advantage of being quick to calculate from modeling and help give people a sense of how one alternative might compare relative to another, but they have limitations when they do not fully correlate to more complex implications, particularly in an absolute sense. Later in the DEIS development, more comprehensive economic calculations were performed on a smaller number of alternatives, and more precise information on impacts was learned, though these calculations were intensive and took months and considerable resources to complete.

Moving forward, many of the things learned from both approaches should be reviewed for the suitability (or for their potential to be adapted) in support of ongoing or future planning decisions. In some cases, economic models created or updated for the DEIS may be updated relatively easily and, so new planning situations could best be informed by re-using them. In other cases, where this approach might be too onerous, it may be possible to compare the outputs of proxy metrics with economic outputs for the same alternatives undertaken in the Plan in order to create response curves that may helpfully approximate economic impacts.

Economic impacts are not always the best indicators for impacts, however, particularly where further uncertainties are introduced to a situation through the use of assumptions made to calculate them, or when they address issues (e.g., learning as an objective, or issues for which NED and RED were not calculated) that may be problematic to put into meaningful dollar terms. In some contexts, decision makers and stakeholders are able to discuss trade-off questions more easily when impacts are left in more "natural units," constructed scales or proxy metrics (Keeney and Gregory 2005). Both approaches have their strengths and weaknesses in different decision contexts, and the two can work in complementary ways.

One example of this concerns the value of learning. Any changes to the management of the river could have complex implications for the research programs associated with Level 1 and Level 2 studies. Consideration should be given to whether and how any given change could compromise the quality of information being gathered for studies; if so, a judgment must be made as to whether the proposed change is worth the negative impacts it might have on information quality (as one among many other things). Formal academic approaches to estimating the value of information in dollar terms are available, but these are problematic to apply in highly complex situations, particularly when other policy objectives are being weighed.

For these reasons, and given the widely varying decision contexts that could arise under the AM Plan, the USACE considers it appropriate not to detail a prescriptive process for AM Plan decision making at this time. Rather, working with the HC Team, efforts will be ongoing in the early stages of AM Plan implementation to explore, perhaps through the use of decision scenarios or archetypes, what options might exist to present the species, learning, and HC trade-offs inherent to various types of tough choices faced by decision makers and stakeholders.

2.4.5.3 *Requirements*

The introduction of new management measures may require supplemental analysis under NEPA if there are significant new circumstances or significant new information relating to the proposed action or its impacts, even if the action were previously evaluated under the MRRMP-EIS, and potentially the preparation of a new EIS (see Figure 6). The essential components of an EIS are a discussion of the proposal, its environmental impacts, reasonable alternatives to the proposed action and their consequences, mitigation of adverse impacts, and any irreversible commitments of resources.

Management actions beyond those previously evaluated under the MRRMP-EIS would be subjected to the same types and degree of evaluation applied to the MRRMP-EIS. If the new action involves flows, an update to the technical criteria in the Master Manual may be required. Figure 21 is a schematic showing the update process. The process and requirements are presented in detail in Attachment 5 of Appendix A.

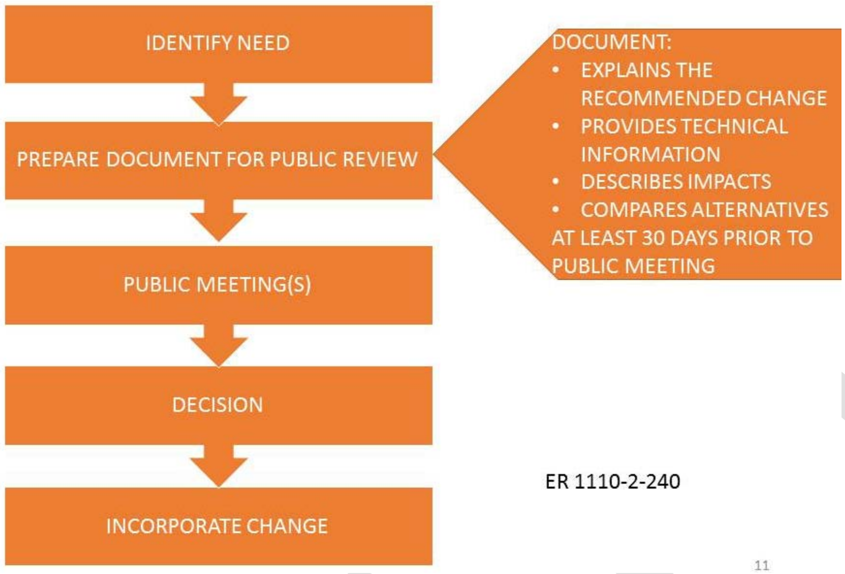


Figure 21. Schematic of the process to update the Master Manual.

Expansion of this section to outline the appropriate and necessary requirements for introduction of new management measures is recommended so those engaged in the MRRP have a reference for the processes.

2.4.6 Workflows for specific scenarios

The process outlined in the previous sections provides a general overview of the information flow for updating the WP. Additional details presented in this section demonstrate the workflow for various types of decisions that might be needed. Decision workflow examples are provided below for 10 decisions/issues:

1. Construct habitat with sufficient resources[1].
2. Construct habitat with insufficient resources.
3. Implement a test flow action included in the ROD.
4. Stop or scale back a flow action during implementation.
5. Scale up flow criteria after implementation or add a flow modification action.
6. Scale back the criteria for a flow action after implementation.

[1] This scenario includes a more detailed description of the process than is provided for other scenarios. Readers are encouraged to read this scenario first; subsequent presentations highlight the differences in the products and decision flow rather than reiterate the details of the basic process.

7. Move between pallid sturgeon action implementation levels.
8. Change species objectives, targets, or decision criteria.
9. Change monitoring and assessment associated with HCs.
10. Change the AM structure and/or process.

Many of the workflows are intended to apply generically to decisions regarding habitat and flow actions for birds and/or sturgeon. For example, workflows 1 and 2 could apply to constructing ESH, IRC, or both during a given year, as well as to prioritization of one habitat type over the other if funding or other resources are limiting. The workflows focus on specific decisions and thus do not reflect every activity that would occur in the MRRP during the course of that decision. In most years, multiple decision processes would be occurring at the same time. For example, annual decisions to construct habitat (Scenario 1 or 2) could occur while a process to evaluate an alteration to a flow action (Scenario 5 or 6), and decisions to adjust targets or decision criteria (Scenario 8) are also be ongoing.

Which workflows apply to a given decision cycle is in itself a decision (e.g., whether to implement flow releases or use construction to create habitat. Typically, information developed during the Evaluate step of the AM cycle indicates which process will need to be followed. Criteria for these decisions are included in the species management chapters in Sections 3.4 and 4.3.

The time frame for decisions is variable. Some processes take place within the WP update cycle, which recurs annually, although the process of moving from evaluation to decision to implementation typically takes 2 years or longer. Other scenarios, such as changes to species objectives or targets, are infrequent and can be addressed at any time through the normal engagement/collaborative process. Various decisions can take more or less time depending upon the level of supporting analyses, NEPA processes, and collaboration required for the decision.

Draft timelines have been created for scenarios 1–4 based on the annual WP development cycle described in Section 2.4.4. They indicate, through shading, processes described in the workflows for each level. Arrows indicate the transmission of information (no marker), recommendations (marked by ❖), and decisions (marked by ◆) between levels. As with the workflows, the timelines do not show all concurrent activities but rather those for a single decision workflow. Typically the decision cycle takes 1 year for these scenarios, with implementation of the planned action taking place 2 to 3 years after initiation of the decision process. In practice, another decision cycle would occur during the year of implementation. These timelines will continue to be developed and used to evaluate whether sufficient time is available for review, collaboration, and approval processes. Dates shown in the timeline are provisional and subject to revision.

> **Note:** Independent panels, states and tribes acting in roles other than MRRIC, and the public are not represented in these diagrams. Similarly, information development, studies, preliminary engineering and design, site-specific environmental assessments and other interactions internal to the agencies are not shown. These needs vary from issue to issue and are left to the agencies to address as needed.

2.4.6.1 *Decision to construct habitat with sufficient resources*

Scenario 1 (Figure 22) describes the process for implementing habitat construction when there are sufficient resources to conduct the desired actions to their full extent. This decision process would also apply to habitat modification and other non-flow actions for which budget and staffing resources must be allocated but water operations are unaffected. The workflow begins following previous implementation of actions under this AM Plan (i.e., in Year 2 or later of implementation).

At the start of the Evaluate stage of the AM cycle, the Bird and Fish Teams meet (typically in conjunction with the Fall Science Meeting) to review the previous FY's activities and the needs for the current and upcoming year, as well as the projected budget and AOP. Using the most current information and estimates (e.g., habitat needs projections, decision criteria and contingency plans, prioritized list of projects carried over from last year, cost estimates for projects and cost per unit estimates, feasible implementation extent, notable constraints on implementation due to site or contractor availability, etc.,), they identify a preliminary set of alternatives and issues related to the WP. They provide this information to the Technical and Management teams, along with a list of analytical needs/studies to be undertaken by the Technical Team. Concurrently, the HC Team meets to review monitoring and assessment results related to HC interests, and to consider whether any changes are needed. They provide any recommendations for changes to monitoring and assessment to the Management Team.

The Technical Team uses information from monitoring and research programs to prepare an updated assessment of the habitat and population status, review the hypotheses, CEMs, and predictive models, and evaluate the effectiveness of previously implemented actions and the Program on the habitat and species, and to assess any impacts on HC interests. A draft report is prepared by the Team, which is provided prior to and presented during the Annual AM Workshop (see Section 2.4.3).

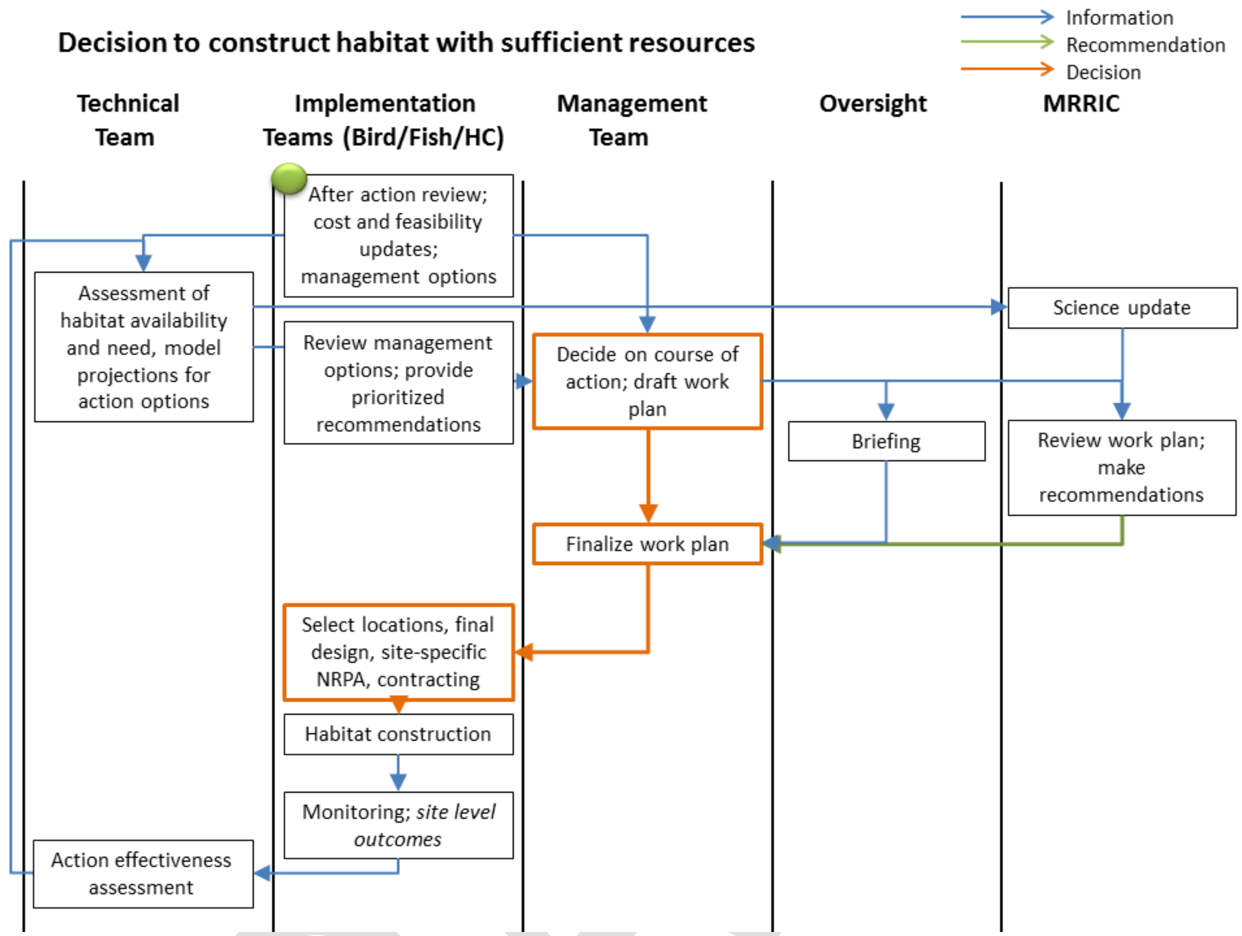


Figure 22. Workflow for decision to construct habitat with sufficient resources.

The Technical Team and/or District planning and engineering PDT uses the information about system status together with the cost and feasibility information (see Section 2.5.13) to evaluate a range of management options. This includes development of feasibility-level plans and preliminary designs for new projects as requested by the Bird and Fish Teams as well as experimental designs for innovative management actions to be tested at Level 2. Potential management actions should be evaluated using predictive numerical models to the fullest extent possible. Model projections should include at least one management option that will meet the objectives, a "do-nothing" option for baseline comparison, and in most cases, at least one alternative.

The Technical Team provides a summary report of their findings, and the District PDT provides preliminary siting, design, and cost information for the management options, along with a summary of related findings to the Implementation and Management Teams. The Technical Team's reports are presented at the Annual AM Workshop. During the presentation, attendees may question presenters on the analyses, the implications of any new findings, etc., and conduct discussions of the relevance of lessons learned to the Program.

Following the AM Workshop, the Bird and Fish Teams use the information from workshop discussions and the reports provided by the Technical Team together with information on budget, staffing, and other resources to develop a prioritized set of management actions, research priorities, and recommendations regarding the following year's AM Plan for each species. They may also develop recommendations regarding other Program needs (e.g., elevating a reserve hypothesis, or changing a component of the AM Plan). Their recommendations, in the form of a report, are provided to the Management Team, as are the HC Team's recommendations regarding needed monitoring and assessment. The MRRIC Bird, Fish HC WGs prepare an additional report with their observations and recommendations and may, at their discretion, present them to the Management Team. This occurs in the initial step of the Adjust/Continue step of the AM cycle.

The Management Team meets to discuss the Program's WP. They consider the prioritizations and other input from the Bird, Fish, and HC Teams, along with the other factors previously listed, and merge the proposals into a draft of the WP. The Draft WP and any recommendations from the Management Team are added to those of the individual Implementation Team requests and provided to the Oversight Team and to MRRIC for consideration at the Spring MRRIC Meeting.

The information generated during the Science Update and WP development processes are retained in a "chain of custody" such that it is clear how information was used to support decisions and where decisions deviate from the recommendations of other Teams. The recommendations of the Management Team, along with the underpinning information and products, are presented at the Spring MRRIC meeting for consideration. If the recommendation meets all objectives within the available resources, there will typically be little need for discussion of the proposed alternative, though other recommendations may demand dialogue. MRRIC has the opportunity to make recommendations prior to finalization of the WP. The decision to approve the proposed WP or to approve it subject to certain alterations or other provisions is made by the Division Commander.

The Management Team receives guidance and direction from the Commander, and the ESC provides direction on resource availability for particular actions, and, when appropriate, allocation to geographic area (e.g., ESH construction allocation for Garrison and Gavins Point reaches) or other provisions. The District PDTs conduct the necessary assessments, finalize designs and cost estimates, and prepare needed information for contracting. Related decisions will be confirmed by the Management Team following finalization of the WP and any adjustments required to accommodate current conditions on the ground. Adjustments to methodologies or design of projects based upon learning from previous implementation may also occur at this stage. Any conflicts that cannot be resolved will be addressed by the conflict resolution process (see Section 2.5.1). This concludes the Adjust/Continue decision step.

The ISP is responsible for providing scientific guidance and support to the Bird, Fish, and HC Teams regarding the application of science to implementation of construction or modification projects and is directly responsible for monitoring of project outcomes as necessary, as well as for species and habitat monitoring. These outcomes are carried into the Evaluate step, and the decision process is repeated.

The timeline for this workflow is shown in Figure 23 for the example of ESH construction. A similar decision process would occur for pallid sturgeon habitat (IRC or spawning) construction, though the timing of planning and implementation may differ. The timeline illustrates the time allotted for creating, reviewing, and finalizing the WP beginning with the after -action review from the Bird, Fish, and HC Teams and initial assessment and the draft report from the Technical Team at the Fall Science meeting. A 4-month review period for MRRIC is included prior to the finalization of the WP. The time lag between the initial assessment of monitoring information by the Technical Team and the construction of habitat is roughly 2 years.

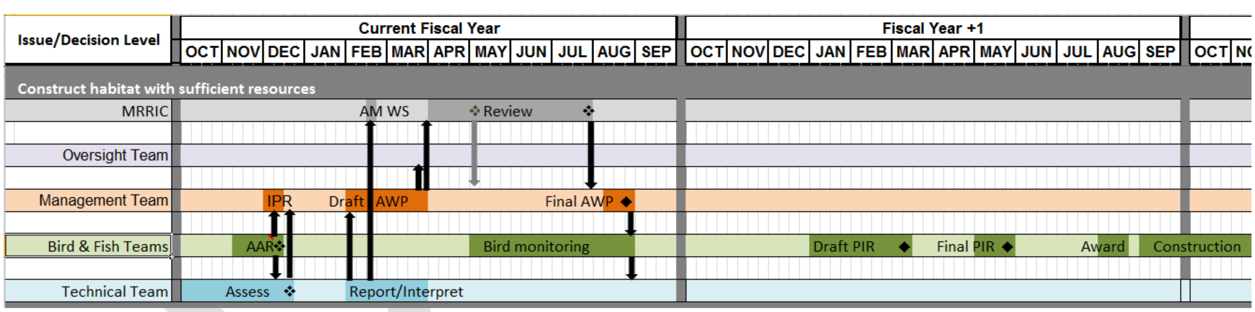


Figure 23. Timeline for decision to construct ESH[1] with sufficient resources.

Note that while the decision process is carried out annually and concurrently with the implementation of the previous year's decisions, evaluation and decision making is forward-looking to the extent possible given natural system variability and potential budget fluctuation. The nature of the decision process is influenced by the projected budget and the risk of a budget shortfall (or plus-up). Thus, feasibility assessments,

[1] Process is the same for IRCs, but the timeframe may shift slightly.

model projections, and management-level decisions are based upon on a 1–3 year budget horizon with the understanding that some adjustments may be made to accommodate current-year system state (e.g., storage, habitat availability, population trends). This scenario provides the foundational decision-making process upon which more complex implementation decisions are based. Information flow among the Technical Team, Bird/Fish Teams, Management Team, Oversight, and MRRIC for the general scenario is shown in matrix form in Figure 24. The matrix will be updated to reflect pending changes in the composition of WGs and AM Teams and to include added detail regarding products and information flow. The following sections primarily describe deviations from this workflow to accommodate different or additional decisions, and may involve additional information and other entities.

From ↓ / To →	Technical Team	Bird/Fish Teams	Other Agencies/ Tribes	Species WGs	Management Team	HC WG	ESC	MRRIC	Oversight
Technical Team	Monitoring & Assessment	AM Performance Assessment Model Projections Science Findings Alternative Designs/Assess.	→	→	→	→	→	→	→
Bird/Fish Teams	Analytical needs	AM Workshop Species Mtgs.			Species Work Plans Other input to AWP	→	→	→	→
Other Agencies/ Tribes		Input on site-specific projects Regulatory compliance input	AM Workshop Species Mtgs.						
Species WGs		Input to prioritizations Input to Species Work Plans		AM Workshop Species Mtgs.				Recommendations on Draft WP	→
Management Team	Analytical needs	Initial guidance on WP distribution to Species Plans			AM Workshop WP Meeting		Draft WP	→	→
HC WG					Input to the Draft WP	AM Workshop WP Meeting		Recommendations on Draft WP	→
ESC					Guidance on resourcing for Draft WP		Agency Strategic Review	Final Draft WP	Final Draft WP w/ recommendations
MRRIC				Issues/concerns		Issues/concerns		Annual Forum MRRIC Mtgs.	Recommendations on Final Draft WP
Oversight					Guidance on Budget & Priorities		Guidance on Budget & Priorities	Final Decisions on WP	MRRIC Mtgs.

Figure 24. Matrix of information flow among entities for the basic process of developing the WP when construction actions only are included.

2.4.6.2 *Decision to construct habitat with insufficient resources*

In some years, insufficient resources (budget, staff, implementation capacity) may be available to conduct all activities considered necessary to have sufficient likelihood of meeting habitat and population objectives. If it has been decided that other options such as flow modification to create habitat are not available, a decision must be made on the allocation of resources with the knowledge that some objectives may not be met. This may require prioritization of one species or one geographic region and subpopulation over another. These decisions may require greater information about management options. Because compliance with ESA requirements may be in question if objectives are not met, decisions about actions are elevated to the Oversight level.

The process (Figure 25) begins in the same manner as Scenario 1 with the provision of cost and feasibility estimates by the Bird and Fish Teams and science and management option assessments and evaluation by the Technical Team, and the Science Update process. Even if it is clear that resources will be insufficient to meet all objectives, the Technical Team will identify an option that does meet all objectives to identify the bounds of the decision space. As this information is provided to the Management team, there may be a need to evaluate additional management options not originally considered in order to find an optimal management pathway. The workflow accommodates an iterative process with the Management and Technical (and, if needed, Bird and Fish Teams) to develop management options. This process requires some additional time that must be accommodated in the overall schedule.

Following evaluation, the Management Team recommends a management option, with justification for the selection and prioritizations included. The USFWS members of the Management Team prepare a draft position on the impacts of the management decision on compliance with ESA or other requirements if objectives for all species are not expected to be met. Because of the potential effects on compliance at the policy level, Oversight must decide to approve the recommendation or choose an alternate option, and may need to address any conflicts of interest that arise within the Management Team from decisions that impact their near-term funding. The Oversight decision makers will serve as arbiters of any disagreement that cannot be resolved within the Management Team.

If long-term budget outlooks suggest that insufficient resources to meet objectives will be ongoing in the moderate to long term, the process to request higher levels of funding in the future and/or to adjust program expectations would be required.

Following Oversight level approval (or adjustment) of the Management Team's recommendations, the draft WP is developed, and the process continues as described for Scenario 1.

The timeline for this scenario (Figure 26) is very similar to the previous scenario, with the exception of a greater amount of time needed for the Oversight level to review and approve the draft WP. This review window compels an earlier initiation of the WP drafting process. The initial assessments shared in the fall IPR (see Section 2.4.3) would need to determine the likelihood of need for Oversight review to approve prioritization decisions.

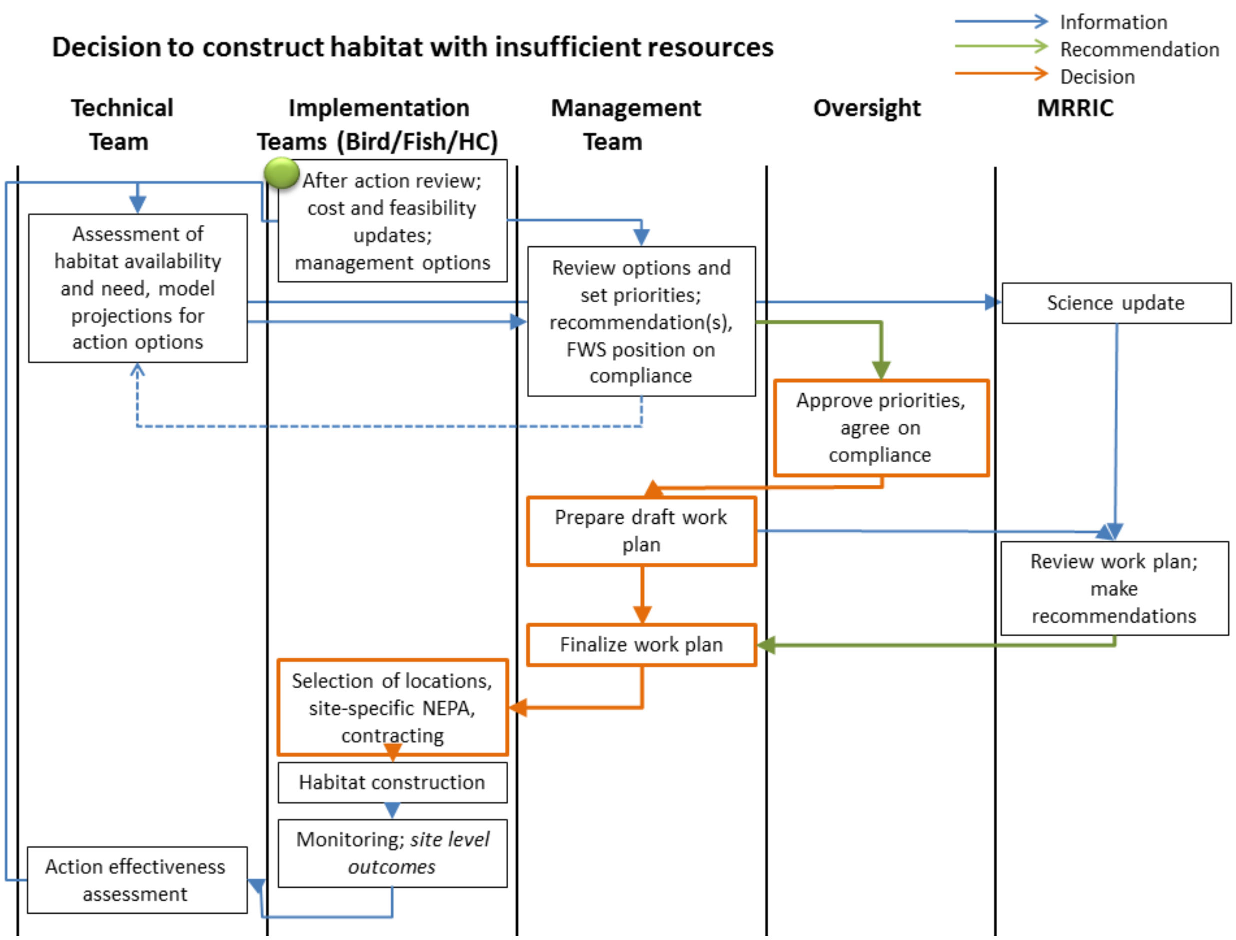


Figure 25. Workflow for decision to construct habitat with insufficient resources.

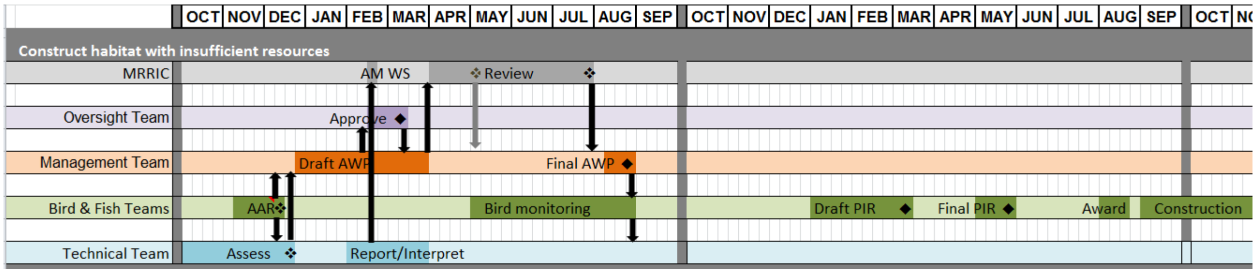


Figure 26. Timeline for decision to construct habitat with insufficient resources.

2.4.6.3 *Decision to implement a flow action included in the selected alternative after the ROD*

In some decision cycles (Figure 27), flow releases to create habitat or spawning cues may be an option (see Section 3.6.1). In many cases, the need for flows will arise as part of moderate-term planning and be identified as a management option prior to the Evaluate step in a given year. In others, the need may be identified by the Technical or Bird Team during that decision cycle's assessments. In either case, the Technical Team evaluates both flow modification management as well as non-flow options.

If the Bird Team includes a flow action in their list of prioritized recommendations, they notify MRBWMD, who ensures their representative on the Management Team addresses the viability of a flow modification option during the Team's deliberations. If the Management Team recommends that option in the draft WP, the MRBWMD provides input at the Oversight level regarding a decision to implement. If approved as part of the WP and if that flow option was included in the ROD and updated Master Manual and the other criteria are met (e.g., system storage, etc.,) then it can be included in MRBWMD's planning and AOP process (see Section 2.4.2.1). If the recommended flow modification was not included in the ROD or was not addressed in the Master Manual, a different decision path would be required (see Section 2.4.6.5).

Note that, even if approved and included in the WP, actual implementation of the flow action would not occur unless and until the criteria for that action were met. During the implementation step, monitoring will occur to evaluate HC metrics as well as flow effects on habitat and/or species outcomes (see Sections 3.3.1, 3.3.5, and 3.3.6). This may include formal or informal impact monitoring and reporting by members of MRRIC or external partners. After-action assessment will include a review of habitat/species and HC outcomes with MRRIC (see Section 3.5).

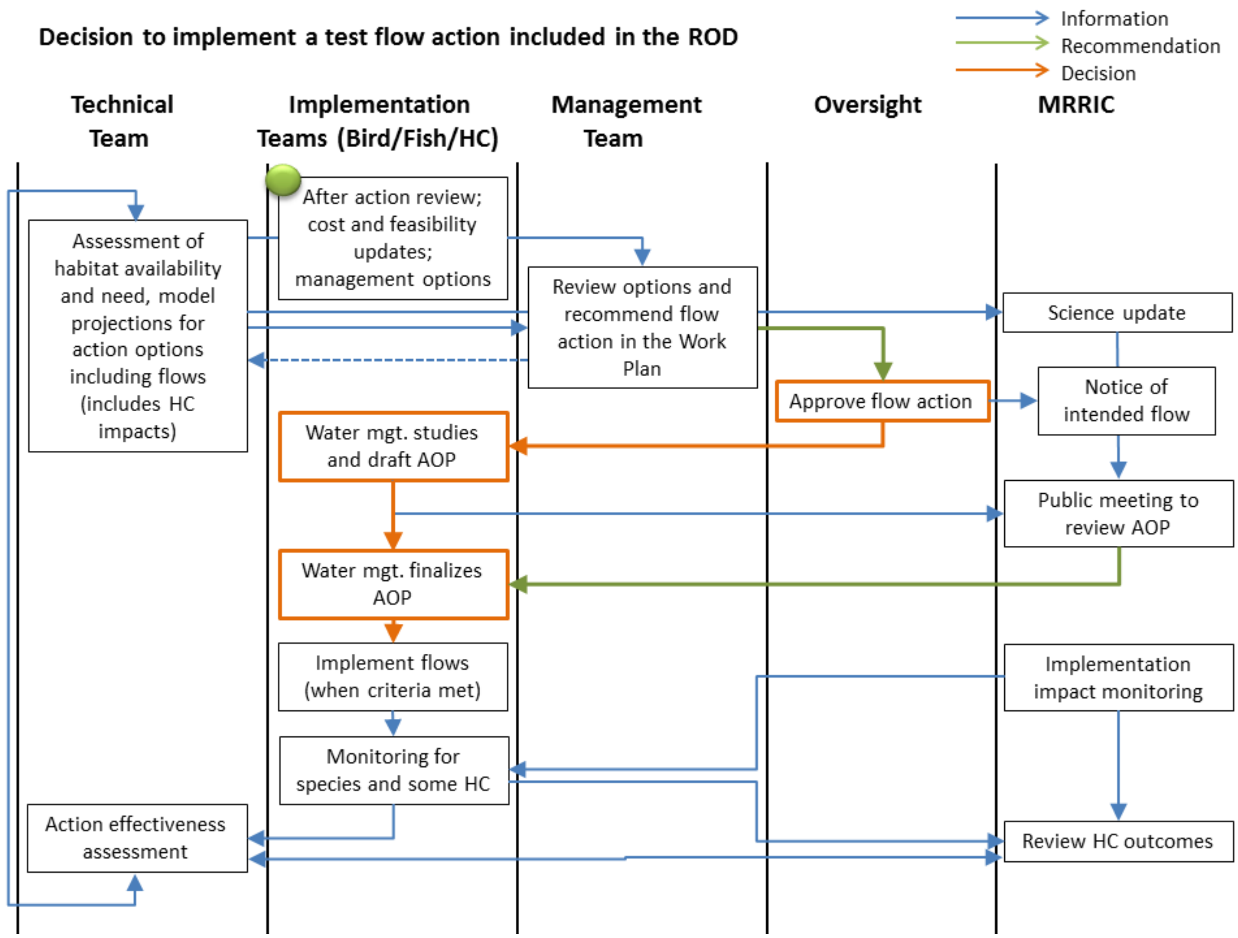


Figure 27. Workflow for decision to implement a flow action.

The timeline for this scenario (Figure 28) is similar to the timeline for constructing habitat with insufficient resources, as it also requires Oversight level approval of the decision to implement a flow in the following FY. The activities of the Bird, Fish, and HC Teams reflect the process of working with Water Management to draft and provide for public review the AOP that would include the planned flow. The timing of the flow depends on the type of action being carried out; a broad window allowing for several potential flow scenarios is included. During the flows, information about forecasts, changes to flows, and any observed impacts are shared between the Implementation level and MRRIC. Following the flow, MRRIC has the opportunity to participate in an after-action review to provide feedback on the flow implementation to the agencies. Formal recommendations from MRRIC, if desired, would follow that process.

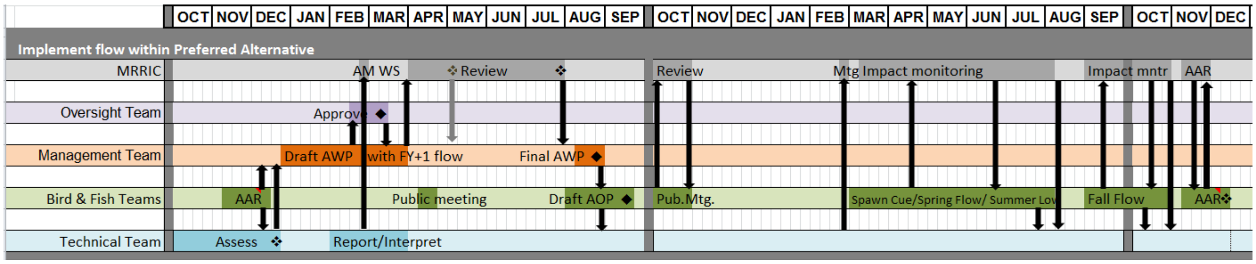


Figure 28. Timeline for decisions to implement a flow action.

2.4.6.4 *Decision to stop or scale back a flow action during implementation*

If a test flow is implemented under the ROD, or if flow actions are added to the MRRP at some future point, flow modification actions may be halted during implementation. Unacceptable HC or habitat/species impact may trigger modifications of planned releases or returns to routine flow operations, for example. Actions may also stop early if monitoring indicates desired effects (objectives of the flow action) have already occurred and no further action is needed.

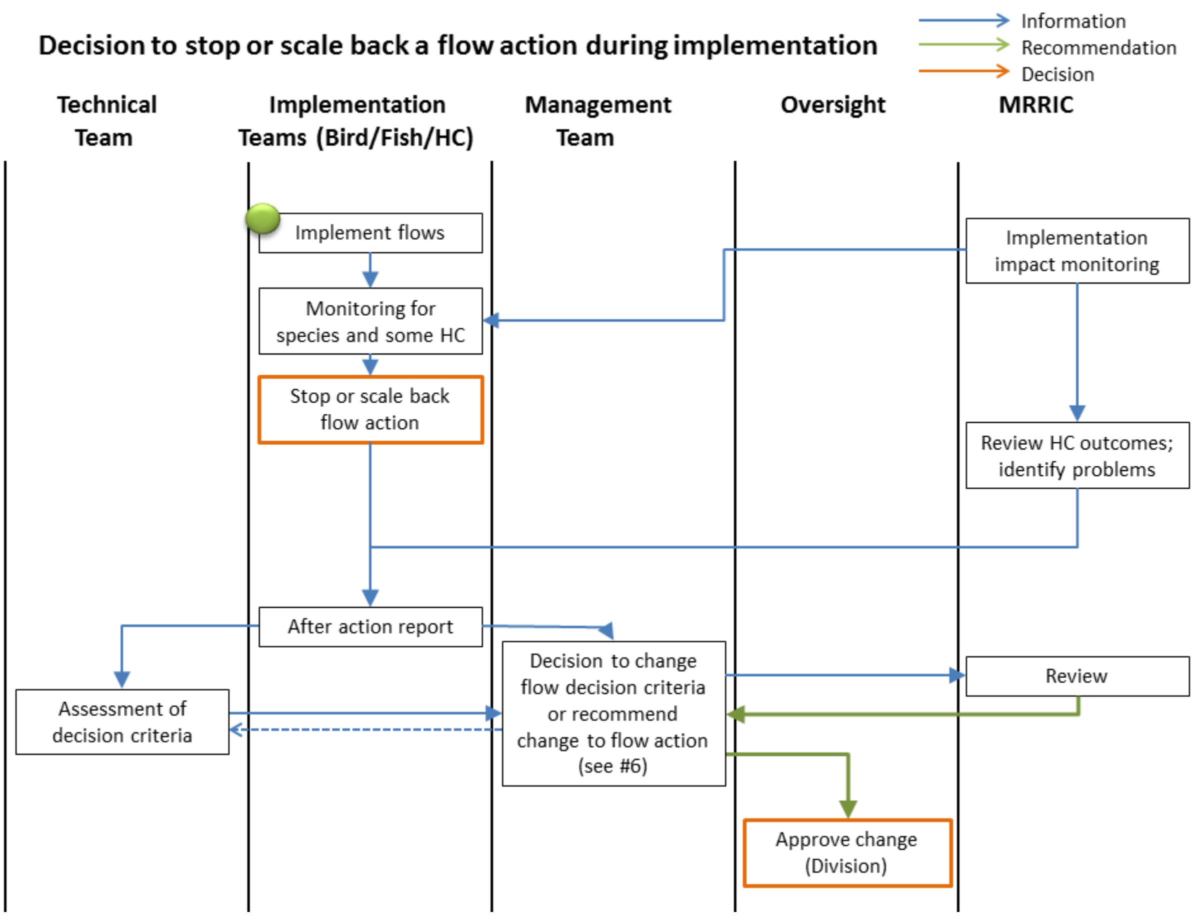


Figure 29. Workflow for decision to stop or scale back a flow action.

This decision pathway is triggered by impact monitoring to HC or species/habitat as described in Section 2.4.6.3, based upon decision criteria specified in advance for any approved flow modification (e.g., Section 4.2.1.3). If flows are stopped or scaled back, the after-action assessment includes an evaluation of what occurred to trigger the adjustment, why it occurred, and if changes would be necessary to prevent repetition of any adverse outcome. Note that in most cases, decision criteria should trigger a cessation or adjustment of the flow prior to actual impacts occurring. MRBWMD would implement the flows in accordance with the criteria in the MM and would make the decision to stop or scale back the flow option based on that criteria listed in the MM. The assessment will determine whether or not negative impacts occurred and whether the abbreviated flow had beneficial outcomes.

The Technical and Bird, Fish, and HC Teams provide these assessments to the Management Team, which considers whether changes should be made to decision criteria and/or the specification of the flow modification itself. If a change is warranted, they craft a recommendation to the appropriate Oversight leadership. The process to make these changes, including MRRIC collaboration, is described in scenario 7.

2.4.6.5 *Decision to scale up flow criteria or add a flow modification action*

Decisions to add a new flow modification or change the specifications of an existing flow modification to increase the frequency, duration, or magnitude of deviation from routine reservoir operations require a reformulation process (Figure 30). This process is initiated if the assessment of implemented flows by the Technical Team determines that the benefits of the existing flow were not sufficient AND that the HC impacts have not been unacceptable and that there is room to expand the definition of the flow action without causing unacceptable impacts. Upon reviewing the assessment, the Management Team can decide to pursue an adjustment to the flow action through a recommendation to the Oversight Team.

An Oversight decision to approve the recommendation initiates the process to change a flow specification. The nature of the process depends on whether the flow action has been previously evaluated in an EIS, included in the ROD, or in the Master Manual (see Figure 6). If the action was not evaluated in the EIS, or the analysis is no longer adequate, then an additional NEPA process will be required, and an adjustment to the Master Manual required (Attachment 5). If the action was evaluated in the EIS and the analysis is still adequate, but the action was not part of the selected alternative described in the ROD, an additional decision document will be required. If the action is not included in the Master Manual, the process to include it will then be followed.

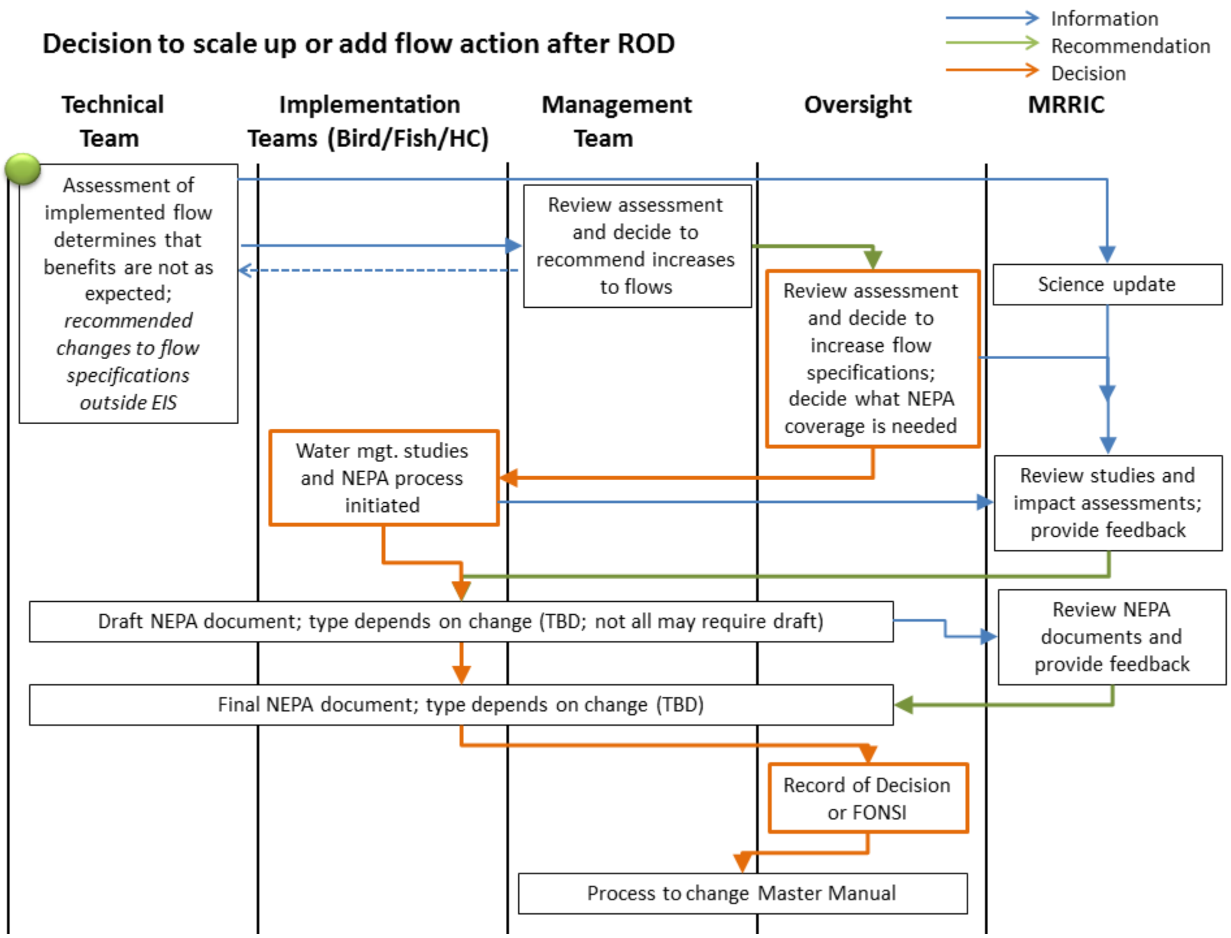


Figure 30. Workflow for decision to add or change a flow action.

> Note: The specific processes to conduct additional NEPA analysis, produce a new decision document, and/or alter the Master Manual are not described in the draft AM Plan, but will be incorporated into the final AM Plan.

2.4.6.6 *Decision to scale back the criteria for a flow action after the ROD*

If the post-implementation assessment of a flow action determines that adverse impacts are unacceptable, or would have been unacceptable had the flow action not be terminated early, the Management Team can recommend that the specifications of the flow action be reduced in duration or magnitude to create a lesser deviation from routine operations in future implementation of the action. The decision at the Oversight level initiates the process to change the flow criteria and produce a new decision document in collaboration with MRRIC and partner agencies (details to be determined). As these changes result in actions of lesser extent than previously evaluated in the EIS or subsequent NEPA analysis, they will not require additional assessment under that process. (Cases where a decrease in one criterion [e.g., flow magnitude], is offset by other criteria such as duration or frequency would be considered a modification under the previous example and may require additional coverage.)

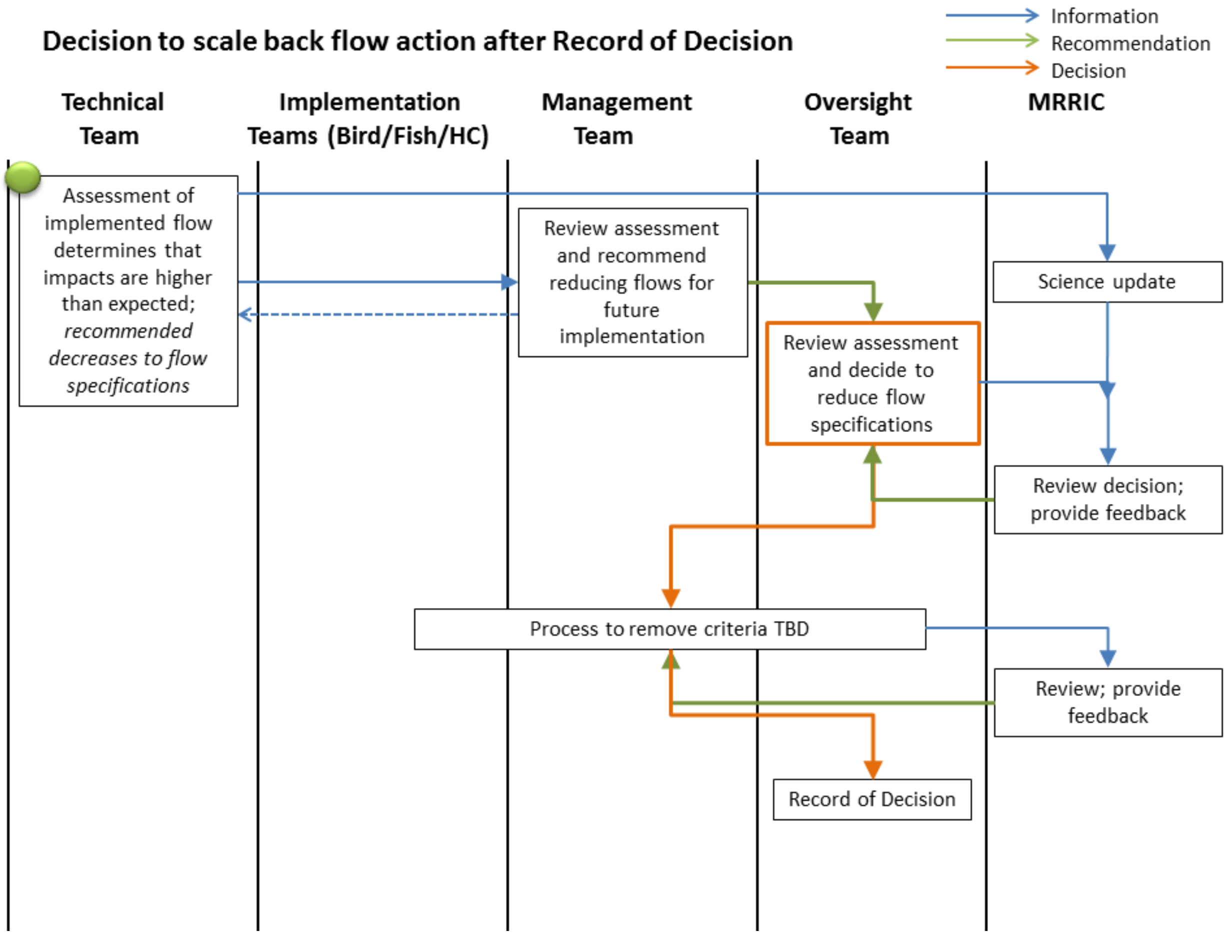


Figure 31. Workflow for decision to scale back a flow action after the ROD.

2.4.6.7 *Decision to move between pallid sturgeon implementation levels*

The workflow shown in Figure 32 summarizes the process to change between implementation levels for pallid sturgeon management actions. Variations on this workflow may occur depending on the trigger for the change, which could be based on (1) the assessment of Level 1 and 2 study results that are sufficient to reject a null hypothesis, (2) results of the lines of evidence assessment procedure (see Section 4.2.1), and (3) in accordance with the decision criteria for timing of Level 3 and/or Level 4 actions (see Section 4.2.1). These assessments occur annually and are communicated as part of the Science Update process (see Section 2.4.3). The Fish Team reviews findings and recommendations from the Technical Team and decides whether a move from Level

1 to Level 2, or from Level 2 to Level 3, is merited, and provides documentation of the basis for their recommendation. Recommendations of the Fish Team are reviewed by the Management Team, which makes its own recommendations and adjustments to the draft WP for consideration at the Oversight level. If the decision to move to Level 4 is made, Oversight must also approve targets and document the decisions and supporting material. If this process results in changes to flow actions, changes are made following the processes outlined in Section 2.4.6.5.

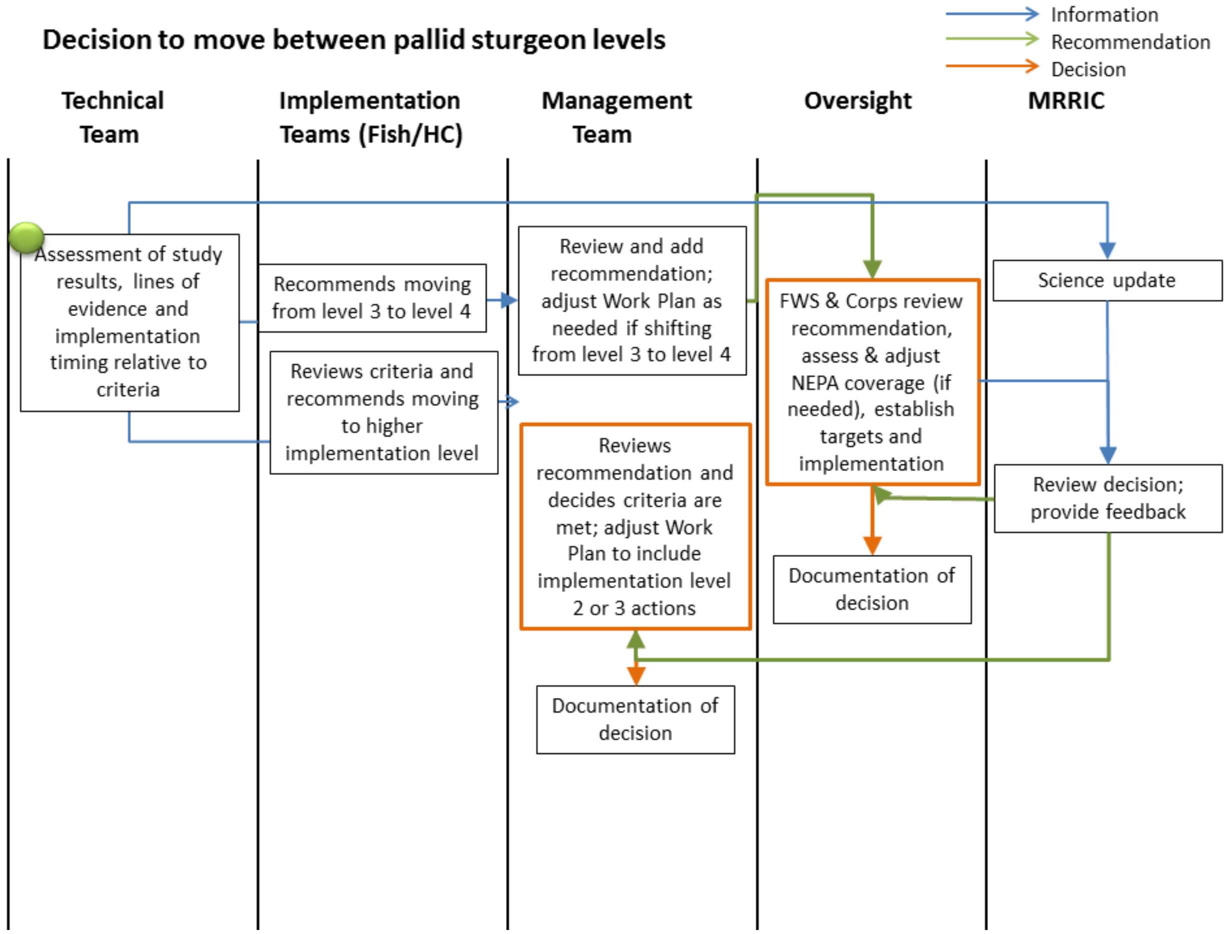


Figure 32. Workflow for decision to move between pallid sturgeon implementation levels.

2.4.6.8 *Decision to change species objectives, targets, or decision criteria*

A decision to change species objectives, targets, or decision criteria may be initiated in several ways:

- Evaluation by the Technical Team determines that targets or criteria are no longer sufficient to meet habitat, species, or program objectives, either as a result of increased system understanding or fundamental changes to the system. They may recommend new targets or criteria as part of the Science Update process and in the report to the Management Team.

- MRRIC may make a recommendation to reevaluate objectives, targets, or criteria including the consideration of adding or removing objectives or criteria. They may also request evaluation from Panel resulting in recommendations.
- Oversight level leadership may request reevaluation of objectives, targets, or criteria, including changes driven by national or regional/divisional changes in regulations, authorities, or other policies.

In the latter two cases, reevaluation will be performed by the Technical Team and draft findings shared through the Science Update or similar process. Depending on the type and magnitude of the change, additional collaboration with MRRIC and/or other partners may be initiated. Final decisions on these changes are made at the Oversight Level and recorded and communicated through a decision document.

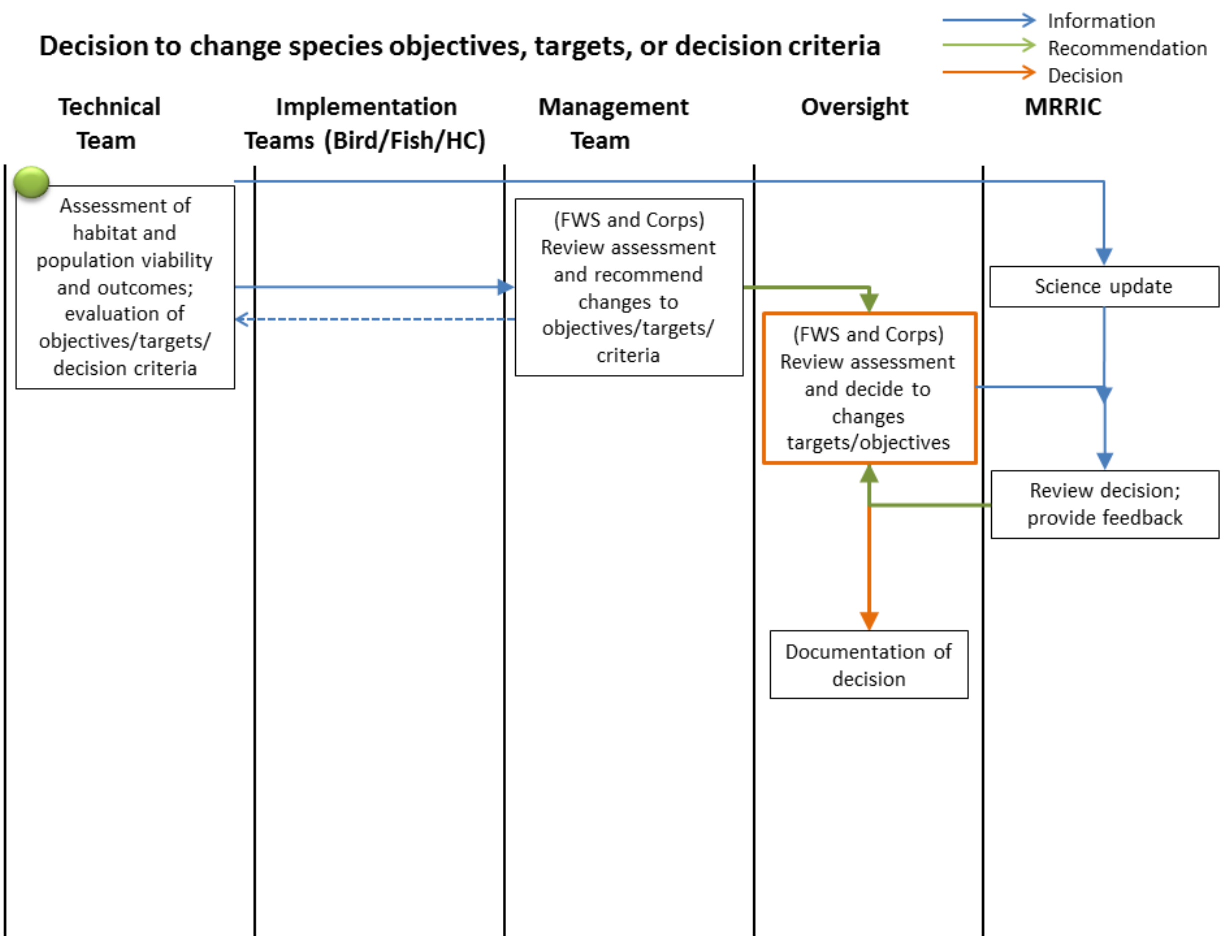


Figure 33. Workflow for decision to change species objectives, targets or decision criteria.

2.4.6.9 *Decision to change monitoring or assessment needs for HCs*

A recommendation to change aspects of the monitoring and assessment of HCs in support of the AM process may be initiated by the HC Team if existing data are found to be inadequate, if ongoing studies are no longer required, or if current practices are inefficient or ineffective. HC monitoring and assessment needs will be considered annually by the HC Team as part of the science update and annual WP development processes. Periodic programmatic reviews will also be conducted and may result in findings that include recommendations for any needed changes to HC monitoring and assessment. Protocols for addressing changes are similar to those for any other component of the AM Plan and the workflow is as shown in Figure 34. Because changes to HC monitoring and assessment are generally considered as part of the WP process, although needs will generally be addressed as part of the Science Update Process. The degree of collaboration and time required to make a change will depend on the change itself as well as the available budget; however, decisions can generally be made within the year they are introduced and can be implemented as soon as the following year. MRRIC may provide a consensus recommendation on the suggested course of action. The AM expertise on the Technical Team may provide assistance to the HC Team and advise changes, and/or draw insights or guidance from other AM programs as beneficial. Final approval of any recommended changes resides at the Oversight Level. Changes are communicated through a summary decision document, usually as part of the approved WP, and revisions are made to the AM Plan (as needed).

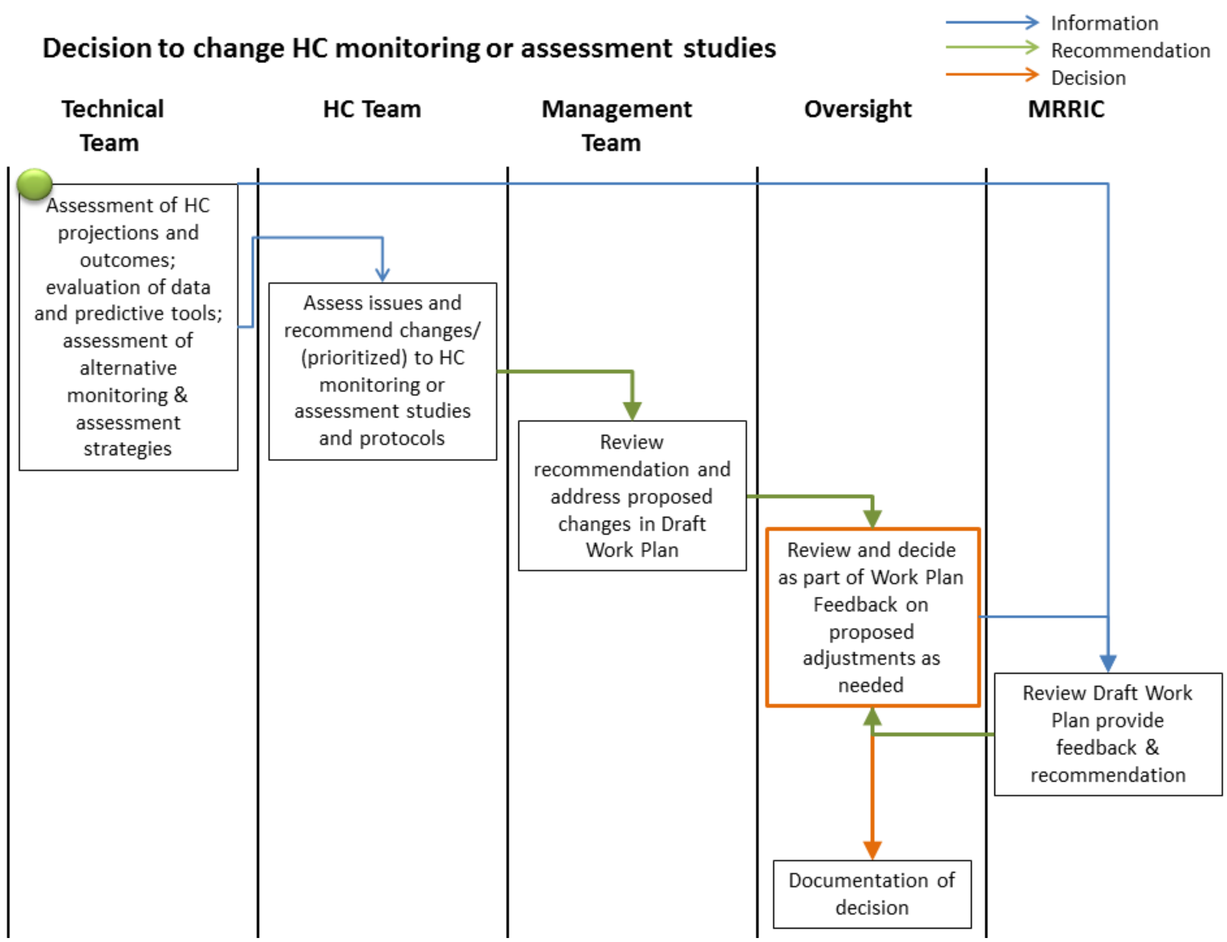


Figure 34. Workflow for decision to change monitoring or assessment needs for HCs.

2.4.6.10 *Decision to change the AM governance structure and/or process*

A recommendation to change aspects of the AM process may be initiated at any level if communication, collaboration, decision-making, or other components of the process are found to be inadequate or inefficient. A periodic programmatic review will also be conducted with findings documented and include recommendations for any needed changes. Protocols for changing significant components of the AM Plan are provided in Attachment 6 of Appendix A. The degree of collaboration and time required to make a change will depend on the change itself; (e.g., reorganization of the Management Team can primarily be handled at that level; reorganization of the MRRIC collaboration process may require collaboration between MRRIC and multiple governance levels within the agencies, and preferably MRRIC consensus on the recommended course of action). The AM expertise on the Technical Team may provide recommendations and advise changes, and/or draw insights or guidance from other AM programs as beneficial. Final approval of any recommended changes resides at the Oversight Level.

Changes are communicated through a summary decision document and revision to the AM Plan.

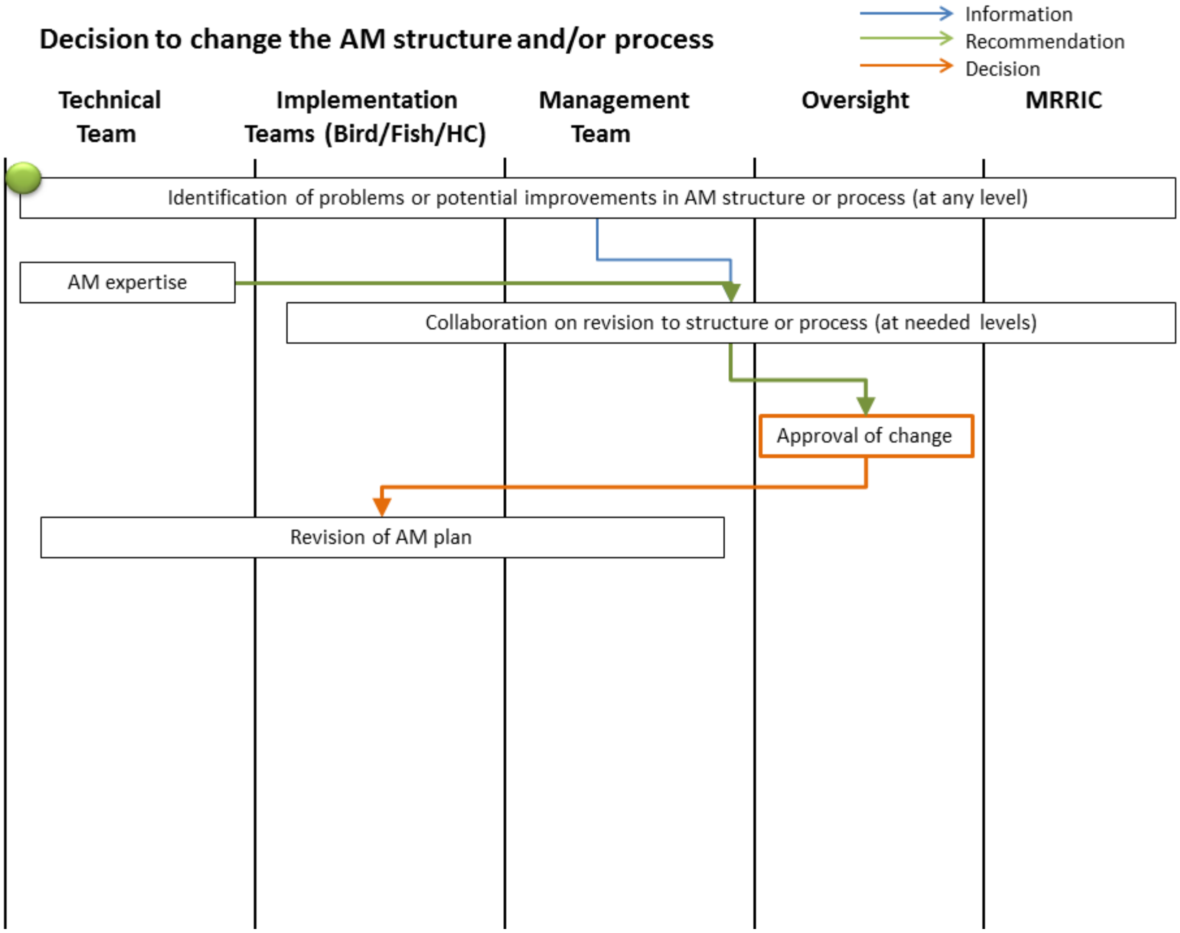


Figure 35. Workflow for decision to change the AM structure and/or process.

2.5 Important protocols and procedures

This section lists and summarizes a number of activities critical to the program's execution and governance. Protocols or procedures for these activities, as needed, are included as attachments to Appendix A.

> **Note:** Details of some processes in this section are under development. Additional process descriptions may be identified and descriptions of listed processes and procedures updated and reviewed for the final AM Plan.

2.5.1 Procedures for dispute resolution

Given the large number of considerations and decisions to be addressed in executing the MRRP, disputes are inevitable. A commitment to the rapid and transparent resolution of disputes/ conflicts is required from all parties and clear processes are needed to achieve resolution of those concerns. The approach for resolving conflicts within the MRRP depends on the nature of the conflict (technical or policy consideration) and the parties involved. The ultimate authority for resolving conflict lies with the agency leadership, but every effort should be made to resolve conflicts at lower levels.

For disputes within a lead agency, In-Progress Review (IPR) meetings provide opportunities to resolve issues and differences of opinion regarding selection of management actions and/or the scope of AM application, as well as documenting their occurrence and resolution. IPR meetings between the USACE AM teams, District Commanders, and the NWD Director of Programs will be held periodically during the development of the WP and in preparation for the primary science meetings. Similar meetings occur among the USFWS teams, PMs, and the Region 6 Assistant Director. Issues that cannot be resolved in these meetings will be elevated to the appropriate district/division commands for the USACE or the Regional Director(s) for the USFWS.

For disputes between lead agencies, Inter-agency IPR meetings aimed at resolving any key differences will be employed. These IPRs will generally involve the key personnel from each agency involved in the dispute, along with the NWD Director of Programs and the Region 6 Assistant Director. The primary objective of these IPR meetings is to discuss and resolve policy issues to ensure that the Program progresses in an orderly manner and that preparation and execution of the WP is not delayed. Issues that cannot be resolved in these meetings will be elevated to the appropriate district/division commands for the USACE or the Regional Director(s) for the USFWS. The agencies will identify any significant differences and report their resolution as appropriate at MRRIC meetings.

While one of the goals of the governance process for the MRRP is to facilitate early coordination and cooperation among the lead agencies and MRRIC through the Team structure, it is anticipated that at times the Teams may be unable to come to agreement. Should this occur, it is recommended that the issue be promptly addressed through the process identified below, depending on the nature of the dispute.

If the Bird or Fish Team fails to reach a consensus on the priorities for work activities, they should note those differences in their report on prioritizations and recommendations to the Management Team. The Management Team will consider the alternate opinions when formulating the draft WP and work to resolve the issue. If the

Management Team cannot reach consensus on an issue in a timely manner or if a significant difference arises from a Bird or Fish Team (e.g., regarding rejection of a hypothesis and associated impacts to proposed actions), a review should be conducted by the Issue Resolution Board. The Issue Resolution Board consists of the NWD Director of Programs and the Special Assistant for Missouri River Programs as well as Region 6 Assistant Director and the Missouri River Coordinator for the USFWS. If the Issue Resolution Board cannot resolve the issue and it cannot be resolved through the normal engagement process, it will be elevated to the NWD Commander for a decision.

Every effort should be made to resolve issues between MRRIC and the agencies through the normal cycle of MRRIC meetings. In the event that significant differences cannot be resolved through these interactions, or when disputes between the lead agencies cannot be resolved by the Issue Resolution Board, the dispute will be considered by the senior leadership, including the NWD Commander (or delegate), the USFWS Region 6 Director (or delegate), and the MRRIC Chair. The Board or senior leadership may task the Panel with reviewing matters involving interpretations of science or other technical disputes. In those instances, the Panel will provide a review and written response (usually within 30 days) for the Issue Resolution Group’s consideration.

An Issue Resolution Board review can be initiated either by request of the applicable interagency Team, or by an individual agency or MRRIC after notification of the other team entities. The request should include: (1) A concise summary of issues in dispute and decisions that need to be made; (2) agency position statements on each of the issues; (3) all supporting rationale and documentation for consideration; and (4) a brief chronology of key actions taken to resolve the dispute. Resolution should be pursued as quickly as possible. The MRRP Issue Resolution Board decisions should be the final and binding resolution of disputes.

Each stage of the issue resolution process should take no more than 15 days. Each agency and MRRIC should be prepared to make this process a priority so as to meet these time frames. If resolution cannot be achieved in a lower-level interactions within these time frames, the MRRIC or agencies may jointly or individually elevate the dispute to the next level. In the event that such an elevation is undertaken without the full consensus of the lower-level group, all other lower-level group members should be notified prior to or simultaneously with the elevation.

Final decisions will be made by the USACE NWD Commander, if required, in the event the Issue Resolution Board cannot resolve a dispute. If a significant dispute persists at that level, the matter may be further elevated to the Chief of Engineers. If not resolved at any of these levels, the Assistant Secretary of the Army for Civil Works, or a designee, will make a final decision on the matter.

2.5.2 Procedures for changing the governance of the MRRP AM Program

Although every effort was made to identify and establish an effective governance structure and process for the MRRP, periodic updates or changes to the Program's governance are likely as lessons are learned regarding governance needs, to improve the efficiency of the governance, or to adapt to changing Program requirements over time. This section outlines the procedure for recommending, evaluating, and adopting changes to the Program's governance.

Proposals for governance changes must originate from a Program Team (i.e., the Bird, Fish, or HC Team or Management Team), a lead agency, MRRIC, Panel, or an independent entity engaged to provide an external review of the Program (see Section 2.5.6.4). A proposal should be presented in the form of a white paper that identifies, at a minimum, (a) the current governance situation, (b) the section(s) of the AM Plan addressing the structure/process under consideration, (c) the suggested revision(s), (d) a rationale for the change (i.e., a brief summary of the problem, benefit of the proposed change, etc.), and (e) a proposed timetable for its implementation.

Proposals for changes to governance by any entity can be submitted to the Management Team for consideration as part of the WP update process as described in Section 2.4.4. Included are suggestions for adjustments to governance arising from external reviews of the Program. The Management Team may add their recommendation to any proposal, including suggested adjustments, but must forward the original proposal for consideration and discussion at the next MRRIC meeting, or the following meeting if the next meeting occurs within 15 days of a proposal receipt. MRRIC and the agencies are encouraged to discuss and comment on any proposal as well as changes proposed by the Management Team, and the proposal can be approved or disapproved at that meeting. Rapid approval of this nature would generally be restricted to minor corrections that are needed quickly or non-controversial adjustments to the composition of one Team. Immediate disapproval would generally occur when a proposal conflicts with policies.

Two other outcomes could (and most commonly would) arise: (1) the proposal could be remanded to a standing or ad hoc Team or Panel for review and input, or (2) the proposal could be returned to the originating entity with suggestions for revision or request for more information. In either of these cases, the revised proposal (with input from the review Team/Panel or submitter's revisions) can be reconsidered and discussed during any MRRIC meeting. MRRIC can make a consensus recommendation regarding proposed governance changes as part of (or separate from) the recommendations they make on the WP updates. The agencies may render a decision on the proposal at any time following the MRRIC meeting in which it is discussed, but are encouraged to wait for a recommendation if one is forthcoming. The agencies will report their decision at the next MRRIC meeting following a decision, and will direct the Management Team to update the AM Plan accordingly.

A process for reconsideration is available in the event that a decision on a governance proposal causes a dispute. A reconsideration request may be made in writing to the Issue Resolution Board (NWD Director of Programs, the NWD Representative, the USFWS Region 6 Assistant Director, and the USFWS Missouri River Coordinator; described in Section 2.5.1). The Issue Resolution Board has 30 days to (a) disapprove and return the reconsideration request based on policy constraints or merit, (b) uphold the request based on merit and task a Team or Panel to make suggested revisions or to investigate and changes, or (c) post the request for consideration and discussion at the next MRRIC meeting. Decisions of the Issue Resolution Board are made on a majority basis with the MRRIC Chairperson providing a tie-breaking vote for issues involving reconsideration of a governance proposal.

2.5.3 Procedures for adjusting objectives, targets, or decision criteria.

As learning progresses under the AM Plan, the need to update objectives, targets, decision criteria, or other similar Program benchmarks may become necessary. These are factors that fundamentally guide the Program, relate to ESA compliance issues, or could impact HCs, so should be changed only after rigorous analysis and deliberation.

Recommendations for adjustments to objectives, targets or decision criteria can be initiated by either of the lead agencies, by MRRIC, the Panel, by any of the Program Teams, or by an independent external peer review of the Program. Recommendations should be provided in the form of a white paper outlining (a) the specific objective, target or criterion to be reconsidered, (b) the basis for the proposed change (studies, reports, monitoring results, data, etc.), and (c) a summary of the rationale and benefits of the change. The recommendation should be submitted to the Issue Resolution Board (the NWD Director of Programs, Special Assistant for Missouri River Programs, USFWS Region 6 Assistant Director, and the USFWS Missouri River Coordinator).

The Issue Resolution Board will meet to discuss the recommendation and, after considering the policy, process, and programmatic implications, will determine if the recommendation should be pursued further. In the event they determine the recommendation should be denied without further analysis, they shall prepare a statement of the rationale/basis for the decision and report that at the next MRRIC meeting. If they determine the recommendation has merit, they will task the Technical Team with preparation of any needed assessments/analyses (unless the underpinning analyses have already been completed). The Panel (or other independent external review group, if warranted) will review the supporting analyses and provide an assessment of the work.

The following steps in the process will depend upon the nature of the proposed change, and could become very involved and lengthy. Some adjustments (e.g., periodic update of fledge ratios and ESH targets) may be of a nature that they can be made as a part of the AM process with concurrence of the lead agencies and input/recommendations from MRRIC. Other adjustments could require additional coordination, biological assessments, or revisions to a biological opinion, and could necessitate re-initiation of consultation on the action. Details of these alternative processes will be identified by the agencies and communicated to the parties early in the process. Results of any decision will be reported at the next MRRIC meeting and any agreed-upon adjustments documented in the AM Plan.

2.5.4 Procedure for addressing significant new information

Information derived as a product of the research and monitoring of the MRRP will be subjected to the review processes outlined throughout this AM Plan. Review is also needed for the occasional "new information" that originates outside the Program but was not identified and addressed by the Technical Team during its annual review process and is of a nature that it could significantly influence Program direction. The procedure outlined in this section is intended to ensure that the MRRP is using the best available and verifiable science information in informing AM decisions and that it is not subject to change driven by incomplete, unsubstantiated data, or research.

Any concerned party may bring to the MRRP new data or other information on the ecology and behavior of the listed species, resources, and habitat attributes that effect those species including environmental stressors, ecosystem processes that are known or suspected to contribute to the survival and recovery of those species, and HC factors that may affect the listed species or be impacted by efforts to protect the species. That new information may include survey data that contribute to time series; analyses that show linkages among the species, their habitats, and the river ecosystem, including its human uses; interpretation of monitoring data; and model outputs presented with mechanistic explanations for phenomena of conservation concern.

The identifying entity can initiate a review process to assess that new information by submitting to either of the MRRP Science leads for the lead agencies an issue paper that concisely explains the rationale for introducing new science information. This paper does not need to document all available information; the objective is to illustrate the importance of the issue and motivate a more-detailed analysis. The paper should include a description of the information and its source, an explanation of its management relevance, and pertinence in confronting the priority management hypotheses that guide the MRRP AM Plan (and may include any non-priority hypotheses that can be linked to the survival and recovery of the listed species or effects of management actions taken under the MRRP). The Science Leads will make an initial, joint determination on whether the new information may have relevance and importance to MRRP decision making. A written evaluation will be provided to the submitter. If the initial determination does not support a detailed evaluation of the issue, the submitter will be given an opportunity to provide additional information.

If the initial determination identifies merit in the issue, the Science Leads will elevate it for consideration by the Technical Team, which will engage in a “joint fact-finding” process and an evaluation of the potential for that information to affect Program decisions. An ad hoc joint, fact-finding team will be established and will include the submitter and one or more members of the Technical Team, depending on the scope of the new information. The ISP will issue a charter and identify the objectives of the joint, fact-finding effort, which will generally include the compilation and analysis of all available data, including new information and contextual information, to determine if and how the AM process should accommodate the new information.

The fact-finding team in consultation with the Bird Team, Fish Team, and/or HC Team (as appropriate), and in consultation with Panel, will consider whether the new information provided is (or might be) reliable knowledge (constitutes best available science) that warrants consideration in the AM program planning process. Only if so, then the fact-finding team will provide a study plan to the ISP and, after review by the ISP and the Panel, proceed with additional data gathering and/or directed studies to substantiate the phenomenon of concern. The fact-finding team will provide the ISP with monthly status reports (if the effort spans more than 2 months) and will participate in a mid-point review conducted by the ISP to ensure the effort is proceeding toward resolution and is utilizing accepted standards of practice. The fact-finding team will produce a draft report with analysis of the new information, analysis of how the new information relates to decisions and management actions, and a draft recommendation for disposition of the issue. Recommended disposition may include the following.

- Note the issue but take no further action (based on lack of merit, no clear relationship to management actions, etc.).
- Recommend additional study (including identification of additional data or scientific information/analyses required to clarify the issue).
- Elevate the issue to a new action hypothesis to be addressed through the MRRP AM process.

The draft report and all data will be provided to the ISP, which will schedule a review and comment period and formal presentation of the study and findings. Review comments may be provided by the agencies and by the Panel. The fact-finding team will respond to comments and the revised document will be submitted to the Panel for final review and concurrence /comment. (Note: The submitting entity has participated in the evaluation as a member of the fact finding team and therefore will not be engaged for further comment on the final product). If the Panel does not concur, the issue will be sent back to the fact-finding team for further consideration. In the event further consideration does not alter the position of either the fact-finding team or the Panel, or if the submitting entity disagrees with the outcome, the issue may be elevated to the Issue Resolution Board (NWD Director of Programs, the NWD Representative, the USFWS Region 6 Assistant Director and the USFWS Missouri River Coordinator), and Third Party Science Neutral (TSPN) for consideration. The TSPN serves as an ad hoc member of the Board for issues related to new information. The Board, by majority vote, determines the disposition of the issue using the above list of potential outcomes. The Board reports its findings to the originator of the issue and at the next MRRIC meeting.

2.5.5 Procedures for elevating and relegating hypotheses

This procedure applies to the management of the broad suite of hypotheses identified in the CEMs, described in the EA reports, and highlighted in various sections of the AM Plan. Hypotheses can be elevated from or moved into reserve as information and understanding dictates. The reserve includes those hypotheses (1) below a priority threshold, (2) having no clear mechanism for investigation or testing, and/or (3) outside current USACE authorities.

As learning occurs through the AM cycle, the list of hypotheses may expand or contract beyond the initial set of hypotheses identified in the EA reports. Hypotheses that are implemented and found to not be effective can be moved into the reserve, and hypotheses that show merit based on research or other further analyses, new information, or improved understanding can be elevated into the active hypotheses category. The Technical Team will be charged with an annual hypothesis evaluation and will report the findings of this evaluation at the Annual AM Workshop.

Based on the analyses of the Technical Team, the Bird and/or Fish Team may recommend the elevation of any reserve hypothesis, and may include prioritized studies or actions to address that hypothesis in the WP development process. The Management Team may also recommend elevation of a reserve hypothesis, independently of the Bird/Fish Team recommendations. The process for approving the elevation of reserve hypotheses or relegation of current working hypotheses to the reserve is similar to the process changing species objectives, targets, or decision criteria highlighted in Section 2.5.3. Elevation/relegation can also be recommended by MRRIC or agency leadership.

In the event the recommendation is made by the Bird and/or Fish Team and is subsequently supported by the Management Team and approved as part of the WP Process, no further action is required. In the cases where the recommendation is made without concurrence at each level, a reevaluation of hypotheses will be performed by the Technical Team and their findings reported and reviewed by the Panel (Note: An exception is made in cases where the hypothesis is relegated to reserve status by policy/authority factors; in those instances the agency makes the determination and reports its rationale at the next MRRIC meeting). The Technical Team's report and the Panel evaluation are submitted to MRRIC and the agencies for review/discussion. Oversight's decision regarding the recommendation is recorded and communicated through a decision document.

2.5.6 Independent external review

The MRRP maintains several established Peer Review Processes to allow for the review of the Program, monitoring and study plans and reports, project designs, and the science program. Assurance that these and other products used for decision making in the AM Plan are of the highest quality and meet standards of practice is essential to trust building and program success. The peer review process relies upon good QC and peer review at the district level as well as external product/program review using independent panels selected because of their expertise on the specific subject matter. These panels are convened to do the reviews only and are not on- going or permanent components of the program, with the exception of the Panel.

All Civil Works planning, engineering, and O&M products must undergo review (see EC 1165-2-209; USACE 2010). All products undergo District Quality Control (DQC), and a subset of these undergoes ATR. Smaller subsets of the ATR group undergo IEPR. Peer reviews are critical to high-quality decision and implementation documents.

2.5.6.1 *District Quality Control (DQC)*

DQC is an internal review process of basic science and engineering work products focused on ensuring the quality requirements of the AM Plan are met. DQC consists of quality checks and reviews — routine checks and reviews carried out during the development process by peers (i.e., supervisors, team leaders, other senior personnel) not responsible for the original work — conducted for any science and/or engineering product under the MRRP. Documentation of all DQC activities is required. The NWK and NWO districts will manage the DQC process in accordance with USACE policies.

2.5.6.2 *Agency Technical Review (ATR)*

ATR is undertaken to "ensure the quality and credibility of the government's scientific information" and was previously referred to as "Independent Technical Review" (ITR). It is mandatory for all decision and implementation documents and other work products, according to a case-specific, risk-informed decision (see EC 1165-2-209 and 08502-CENWD-RBT on EC 1165-2-209).). Decision documents are planning feasibility/reevaluation studies or other project studies that require NWD/HQUSACE approvals. Implementation documents are generated subsequent to decision documents and lead to the implementation of the selected action. Reviews are conducted by professionals outside of the MRRP districts and not affiliated with the development of the project or product. The required ATR team member disciplines and expertise are described in the Master Review Plan. At the conclusion of the ATR, the team prepares a review report, which is then certified by the NWD.

2.5.6.3 *Independent External Peer Review (IEPR) of MRRP Projects*

IEPR is the most independent level of review, applied in cases where the risk and magnitude of the proposed project are such that a critical examination by a team outside of the USACE is warranted. IEPR panels are made up of independent, recognized experts in the appropriate disciplines and are selected using the National Academies of Science (NAS) policy for selecting reviewers.

There are two types of IEPRs. Type I IEPR is conducted on decision documents and supporting work products where there are public safety concerns, significant controversy, a high level of complexity or significant economic, environmental, and social effects to the nation. Type II IEPR is conducted on design and construction activities for hurricane and storm risk management and flood risk management projects, as well as other projects where potential hazards pose a significant threat to human life. This applies to new projects as well as major repairs, rehabilitations, replacements or modifications of existing facilities. A third category, Special Case IEPR, is required when a non-Federal interest undertakes a study, design, or implementation of a Federal project, or requests permission to alter a Federal project. The non-Federal interest must make a risk-informed decision on whether to undertake a Type I and/or Type II IEPR, and this decision process and the reviews must be included in the documents submitted for review or approval.

2.5.6.4 *Independent External Peer Review of the MRRP*

An IEPR of the MRRP should be held after its third and sixth year of operation. Further IEPR needs should be reassessed following the second review. The review should be conducted by an independent entity with related expertise and experience. The scope of the review should be broad, with the aim of (1) identifying overall program performance towards it goals and (2) identifying mechanisms/changes to improve its capacity toward achieving those goals. Included are assessments for the subprograms (birds and fish), as well as for the overall program and its governance. The review should assess the performance of the agencies and of MRRIC, and should make recommendations for the improvement of the Program, its components, and its participants. Reviewers should prepare a report, and an executive summary, to be submitted to the agencies and MRRIC for consideration. Details on the Programmatic IEPR are presented in Attachment 13 of Appendix A.

2.5.6.5 *ISP review process*

The ISP has a science QA process that includes both internal and external reviews to ensure integrity and independence are maintained in the ISP and its products. Internal review involves technical review by PDTs and technical leads, and managerial review of products by the ISP PMs and ISP Management Team (MT). External review is conducted on an as-needed basis and involves ISR and peer review by individuals outside of the action and partner agencies.

The MRRP's Panel is an example of an ISR panel that provides advice on specific topics. This group is a neutral group with expertise retained by the MRRP to provide independent and objective guidance to the program. A Panel review could occur at any level, program, project, study, or report. The Panel can comprise up to six science advisors who meet at least annually and are charged with independent science support and technical oversight. Topics originate from the USACE and/or MRRIC. The general disciplines of expertise on the panel include: Aquatic/Riverine Ecologist, River Hydrologist/Geomorphologist, Least Tern/Piping Plover Specialist, Sturgeon Specialist, Quantitative Ecologist/Statistician, and Conservation Biologist. The Panel website is http://projects.ecr.gov/moriversciencepanel/default.aspx.

2.5.7 Requirements for research and focused study efforts

> Note: This section will be further developed by the AM Team in consultation with the ISP. Appendix J will address details.

The PI for any funded research effort or the Lead Investigator for any Monitoring Program or focused study effort will be required to develop and maintain a Project Management Plan (PMP) for the effort. A project management plan (PMP) is a formal, living document used to define requirements and expected outcomes and guide project execution and control. All continuing MRRP projects are required to develop and maintain a PMP (5–10 pages). Yearly updates of the PMP will be due at the Fall Science Meeting for the program (generally occurring in September). However, the ISP Manager should be informed of significant deviations from the PMP at the earliest possible opportunity during the course of the FY. See Attachment 1 of Appendix J for a PMP template.

Each PI or Lead Investigator will also be asked to prepare and maintain a Fact Sheet (see Attachment 8 of Appendix A for a template) and provide quarterly progress reports on products and expenditures.

Investigators undertaking research funded by the MRRP are obligated to participate in two In-Progress Reviews (IPRs) annually. In addition to oral presentations at each IPR, the PI will submit the required documentation of research progress and milestone status shown in Attachment 3 of Appendix J. PIs can elect to have a colleague present at an IPR, but is responsible for ensuring the alternate is sufficiently familiar with the work to answer detailed technical questions regarding the work. Inability to substantially defend a research effort is grounds for termination of funding for the effort.

Technical publications from the MRRP will adhere to the guidelines in Attachment 2 of Appendix J unless required by their agency to use a different set of guidelines and after obtaining approval of the ISP Manager. All data collected and/or used to support analyses shall be furnished to the ISP following the guidelines and procedures outlined in Chapter 6.

2.5.8 Agendas for the Fall Science Meeting and for the Annual AM Workshop

Attachment 8 of Appendix A presents the standing agendas for the indicated meetings/workshops. These agendas can be modified at the discretion of the ISP Manager to include issues, but the meeting/workshop should address all of the topics on the standing agenda.

2.5.9 Guidelines for technical publications

Research reports and findings of monitoring and assessments constitute important products of work under the MRRP. They influence important decisions regarding program implementation. Money, facilities, and talent devoted to research should always result in a formal technical communication of some kind. It is important that reports be published in a timely fashion, be clearly and concisely written, and be technically correct. The content of a report and the manner of presenting data are governed by the objectives of the investigation and the distribution intended. The ISP Manager may prescribe the level of detail of a report prepared for specific needs.

Attachment 9 of Appendix A provides guidelines for technical publications of the Program.

2.5.10 Example Fact Sheet

Fact sheets outlining the purpose, approach, products, significant findings, and a point-of-contact for research efforts, studies, significant analyses, or other activities of the MRRP are recommended as a mechanism for informing MRRIC and stakeholders of program activities. Attachment 8 of Appendix A provides a template and guidelines for developing and posting fact sheets.

2.5.11 Cultural Resource Plan

Attachment 12 of Appendix A includes a Cultural Resources Plan for the MRRP. The plan addresses the combined requirements of the following:

- Executive Order 13175, Consultation and Coordination with Indian Tribal Governments, 06 November 2000
- White House Memorandum, Government-to-Government Relations, 29 April 1994
- U.S. Army Corps of Engineers (USACE) Tribal Policy and Principles, 18 February, 1998 and 10 May 2010
- DOD American Indian and Alaska Native Policy, 20 October 1998
- Presidential Memorandum, Tribal Consultation, 05 November 2009
- Department of Army American Indian and Alaskan Native Policy, 24 October 2012
- USACE Memorandum for Commanders, Directors and Chiefs of Separate Offices, U.S. Army Corps of Engineers, Subject, Tribal Consultation Policy, 01 November 2012
- Planning, Environmental Resources, Fish Policy and Support Division: Native American Policy CENWD-PDD Policy Memorandum, No. NWDOM 200-1-1
- Missouri River Master Manuel Environmental Impact Statement Appendix A Section 14 Government-to-Government, March 2004.

2.5.12 Program priorities development process

There are two types of priority setting within the MRRP. The first type is the annual request for appropriations, and this is implemented as part of the Corps' 3-year budget cycle process. For example, prioritization during FY18 will provide planning information for implementation of projects in FY20. NWO has the responsibility for requesting the appropriations for the overall program including resources for both districts (NWO and NWK). Appropriation requests are based on three priorities:

1. *Minimum Compliance:* Projects that ensure that The USACE would be in compliance with the BiOp for the appropriation year. This includes continuing contracts and projects that were awarded in a previous year and the real estate acquisitions to ensure compliance with habitat requirements in out years (i.e., it takes a minimum of two years from acquisition to habitat development on most acquired properties).
2. *Long-term Compliance*: Projects that ensure compliance with the BiOp and the Mitigation Program in the out years, particularly for any BiOp "check-in" years.
3. *Capability*: Projects that ensure program capability (i.e., the amount of work that can be accomplished in both districts in that FY). Appropriation requests rarely align with actual appropriations.

BiOp activities are initially prioritized within the multi-agency Bird, Fish, and HC Teams based on decision criteria for their priorities and then elevated to the Management Team for integration into the overall budget, which is ultimately approved by the NWD Director of Programs.

The second type of priority setting is the development of the WP for implementing the actual appropriation (see Section 2.4.4). At the program-level, priorities for the MRRP are linked to the mission, vision, and scope of the program as well as the BiOp and enabling legislative acts (e.g., WRDA 2007). MRRP priorities may change significantly from one FY to the next because (a) system conditions change, creating both demands (e.g., need to build ESH) and opportunities (e.g., storage for a flow release), and (b) information from research and ecosystem monitoring and assessment may reveal the need for significant shifts in program focus.

2.5.13 Cost management

The MRRP cost management program includes planning, estimating, budgeting, and controlling costs so that program execution and recovery projects can be completed within approved budgets. There are three critical elements associated with MRRP cost management: (1) cost estimating – developing an approximation of the costs of resources needed to complete program management activities of restoration projects; (2) cost budgeting – aggregating the estimated costs of individual activities to establish an annual MRRP cost budget for each FY; and (3) cost control – monitoring the factors that create cost variances and controlling approved changes to the MRRP budget. An MRRP cost management plan is being prepared and will become an essential component of program execution.

2.5.13.1 *Cost management plan*

The MRRP will develop a broad, formal cost management plan; the MRRP PM has the responsibility for development and implementation of this plan. The cost management plan will clearly define how MRRP funding will be managed throughout the program's lifecycle. The plan will identify the processes and procedures by which MRRP program and project costs are estimated, measured, and controlled. Additionally the plan will outline the following.

- Who is responsible for management of program and project costs.
- Who has the authority to approve changes to program and project budgets.
- How MRRP costs are quantitatively measured and reported.
- What is the proper format and frequency of financial reports, and to whom they are presented.

2.5.13.2 *Cost estimating*

An initial estimate of MRRP project costs is developed for each PMP based on the project's Work Breakdown Structure (WBS). Estimates are based on experience with similar projects taking into account site-specific conditions. Cost estimates are further refined and detailed during development of the Project Implementation Reports (PIRs), land acquisition appraisals, or scopes of work for ISP activities. Cost estimates are prepared to the level of the WBS needed by PMs to effectively monitor project budgets and track project execution, as determined by the project schedule.

2.5.13.3 *Annual cost budgeting*

Annual project budgeting involves allocating the overall cost estimate to individual activities identified in the project WBS. An annual MRRP budget is developed by using the project cost estimate, anticipated research funding needs, and baseline subprogram costs to estimate costs for each subprogram. The SPM coordinates with the PMs to ensure budgets for each MRRP subprogram and project are reasonable, and to assess risks/impacts and develop contingencies for alternative budget amounts. These individual subprogram budgets are integrated and added to other programmatic costs (cost for Program integration and administration, MRRIC, etc.,) and used to develop an annual program-scale cost budget for the MRRP.

Annual MRRP budget exercises already utilize cost estimating techniques by using three budget scenarios – compliance, long-term compliance, and capability. These budget scenarios allow the Management Team, ESC, and District leadership to estimate costs each FY given the fluctuations in annual appropriations; they also provide transparency to the budget process by clearly indicating what is funded under each scenario.

2.5.13.4 *Cost control*

MRRP programmatic activity costs are the responsibility of the SPM while the other PMs are responsible for individual restoration project budgets. PMs review biweekly Financial Management Reports to ensure the correct labor charges have been made and all contractor costs are correct. PMs communicate with members of the PDT regarding progress on individual activities throughout the program/project lifecycle and bring any problems to the attention of the SPM. The SPM, in turn, alerts the ESC of any budget problems that cannot be resolved by the SPM. A list of factors that generally cause cost variances is used to inform the SPM and PMs so that they are aware of potential budget risks. Quantitative cost thresholds are also defined up front and used to identify when corrective action is required (e.g., program/project is over budget). Finally, a list of corrective actions is prepared in advance and used in the event that changes to the budget are needed.

2.5.13.5 *Cost change control approval process*

When an established cost threshold for a specific MRRP project/activity is triggered, the change control process is initiated. The SPM evaluates the request and makes a determination for changes under <$50,000>; the ESC considers and approves changes over this amount. Project budgets are adjusted and documented to reflect approved revisions.

2.5.13.6 *Value Management (VM) and Value Engineering (VE)*

A VM/VE study should be conducted for all individual habitat development projects that exceed $2 million (ER 1110-1-12; USACE 2006). The PM and PDT will work with the District Value Engineering Officer to decide if a cost-effectiveness review or VM/VE study is required. Because a preliminary cost estimate will be completed during the PIR phase for each site, this is when the decision is made regarding VM/VE study need.

The goal of a VM/VE study is to assure that the most cost-effective approach is taken while meeting the project objectives. Study teams should include USACE and Mitigation ACT personnel experienced with the program and seek, to the extent possible, to maximize development and sharing of lessons learned between the two districts. PMs will review all construction contracts to ensure that Contract Clause 52.248-3 “Value Engineering-construction” is included. This contract clause encourages the construction contractor to develop, prepare, and submit VM/VE proposals (i.e., VECPs) during the course of habitat development activities. If an event or process is identified during any VM/VE study that is significant enough to warrant a change in any processes outlined in this AM Plan, it should be brought to the attention of the SPM for change management procedures.

PMs will undertake steps to ensure the most cost effective techniques are employed, allowing for the need to implement experimental designs that sometimes call for actions with varying costs so they may be properly evaluated. Management actions should be designed to take advantage of natural river processes as much as practical, following the "Engineering With Nature" principles endorsed by the USACE. For actions at Levels 3 and 4, the PDT will seek, where possible, design standards and criteria based on the lessons learned from those previous projects so as to most cost-effectively meet objectives given site/system/program constraints.

2.5.14 Program safety and health requirements

The Safety and Occupational Health Managers (SOHM) are responsible for the District Safety and Occupational Health Program (SOHP). The SOHM is responsible for planning, organizing, overseeing, and evaluating the SOHP, in conjunction with the PgM. The SOHM reviews the Site Safety and Health Plan (SSHP), if required. The SOHM or staff conducts periodic safety surveys, inspections, evaluations of all work and procedures associated with the project to include operational procedures, programmatic safety and occupational health requirements, environmental hazards that could be encountered, construction, recreational and public protection from safety hazards, and personal protective equipment requirements. The SOHM ensures compliance with all applicable safety regulations and provides support to the PgM/PM for overall safety on the project site. Safety requirements for the MRRP are presented in Attachment 13 of Appendix A.

3 Adaptive Management for Plovers and Terns

This chapter is organized according to the five steps of the AM cycle introduced in Section 1:

1. Assess (Section 3.1), which provides objectives and scope for piping plover and least tern management and summarizes the EA.
2. Plan and Design (Section 3.2), which outlines the bird AM framework, performance metrics, and management conditions, targets, and specifies management actions and associated decision criteria.
3. Monitor (Section 3.3), which summarizes the metrics used for monitoring habitat and species status, action effectiveness, and monitoring to capture outcomes of unusual events.
4. Implement (Section 3.4), which summarizes steps in carrying out management actions.
5. Evaluate (Section 3.5), which summarizes the evaluation of habitat and population status, management conditions and options, key relationships and new information, model updates and validation, and the use of ancillary information and unexpected events.
6. Decide (Section 3.6), which summarizes key management decisions and associated tools including predictive models, and decisions to reevaluate metrics and targets.

Associated appendices include Appendix A (Protocols and procedures for decisions), Appendix B (CEMs), and Appendix G (Monitoring protocols related to the birds).

3.1 Assess

3.1.1 Management objectives and scope for least terns and piping plovers

The fundamental objectives for piping plovers and least terns, initially drafted by the USFWS in 2013, are as follows:

> *Fundamental Objective. Avoid jeopardizing the continued existence of the piping plover due to the U.S. Army Corps of Engineers actions on the Missouri River.*

> *Fundamental Objective. Avoid jeopardizing the continued existence of the least tern due to the U.S. Army Corps of Engineers actions on the Missouri River.*

Sub-objectives for piping plovers were also drafted by the USFWS in 2013 and have been revised for clarity and specificity during the AM Plan development process.

> *Sub-objective 1 (Distribution). Maintain a geographic distribution of plovers in the river and reservoirs in which they currently occur in both the Northern Region (Missouri River from Fort Peck Lake, Montana to Fort Randall Dam, South Dakota, including reservoir shorelines) and Southern Region (Missouri River from Fort Randall Dam, South Dakota to Ponca, Nebraska)*[1].

> *Sub-objective 2 (Population). Maintain a total population number of Missouri River piping plovers that has a 95% probability that at least 50 individuals will persist for at least 50 years within both the Northern and Southern Regions.*

> *Sub-objective 3 (Population Trend). Maintain a stable or increasing long-term trend in population size within both regions.*

> *Sub-objective 4 (Reproduction). Maintain fledgling production of breeding pairs at least sufficient to meet the population growth rate objectives within both regions.*

3.1.1.1 *Geographic scope*

The geographic scope of the AM Plan for piping plovers and least terns is the mainstem Missouri River from the upper end of Lake Sakakawea near Williston, ND, to Ponca, NE. Plovers and terns nest in six segments within this geographic area (Figure 36):

1) Lake Sakakawea (shoreline of the impounded river above Garrison Dam; RM 1568-1389.9)
2) Garrison Reach (riverine segment between Garrison Dam and Lake Oahe; RM 1389.9-1304)
3) Lake Oahe (shoreline of the impounded river above Oahe Dam; RM 1304-1072.3)
4) Fort Randall Reach (riverine segment between Fort Randall Dam and Lewis and Clark Lake; RM 880-845)
5) Lewis and Clark Lake (delta segment between Fort Randall Reach and the impoundment of Lewis and Clark Lake; RM 845-811.1)
6) Gavins Point Reach (riverine segment below Gavins Point Dam and above the channelized river beginning at Ponca, NE; RM 811.1-754).

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[1] These regions correspond with two regions (Northern Rivers and Southern Rivers) of the four identified in the *Draft Revised Recovery Plan for the Northern Great Plains Piping Plover* (USFWS 2016). The Southern Region as referred to in this document, however, references only the Missouri River mainstem components and not the tributaries included in the recovery plan.

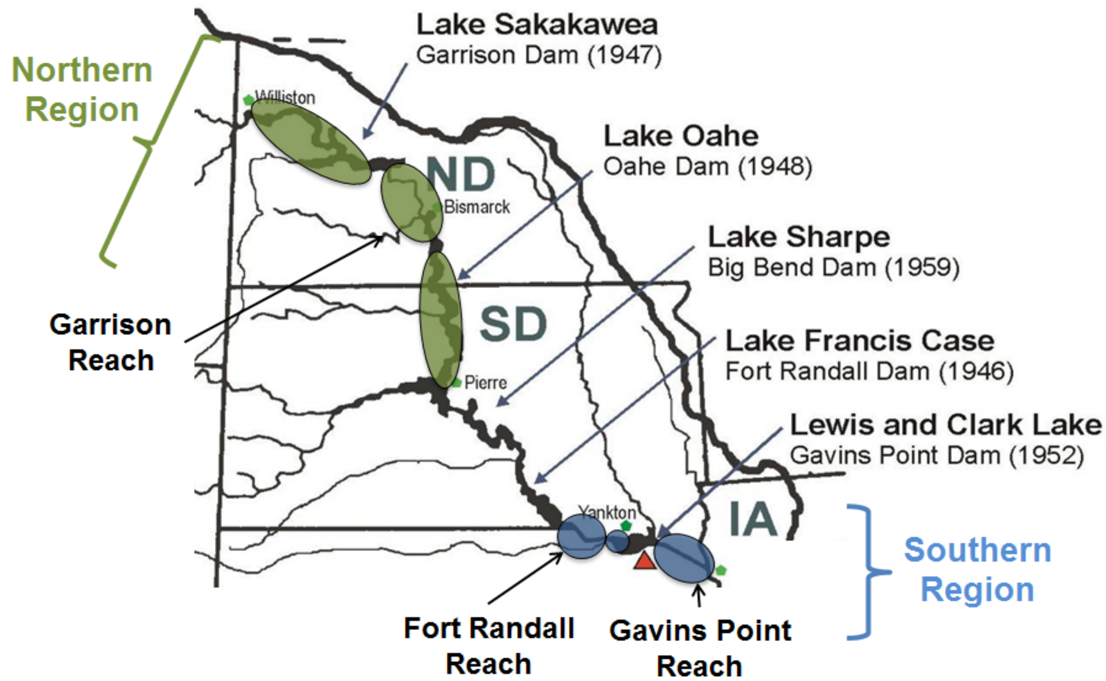

Figure 36. Geographic scope of AM Plan for terns and plovers.

Limited nesting also occurs in the Fort Peck reach upstream of Lake Sakakawea, but as very few plovers have been observed to use habitat on that reach or on Ft. Peck Lake[1], it is not included in the focal areas for plover management.

The design and operation of Lake Sharpe and Lake Francis Case provides little to no nesting habitat. This gap in habitat availability between Lake Oahe and Fort Randall Reach creates a dispersal barrier. Piping plovers have been observed to have high site fidelity, (i.e., they are likely to return to their previous breeding area). Plovers that disperse are more likely to move within segments or between segments within a region than to return to breed in the other region. Therefore, for planning, modeling, and target-setting purposes, the mainstem breeding areas have been divided into two

[1] Since 1997, 0-%–2% of the observed plover population used habitat along Fort Peck Lake or in the reach upstream of Lake Sakakawea. The average was <1% of the plover population.

regions, as indicated in

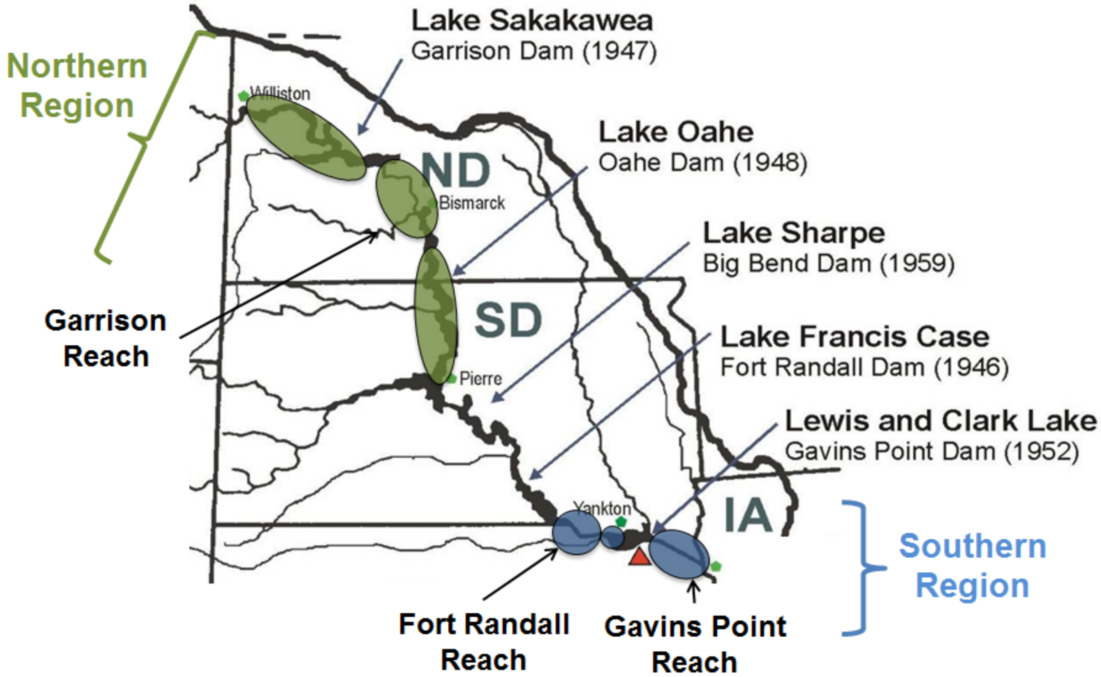

Figure 36. The Northern Region includes Lake Sakakawea, Garrison Reach, and Lake Oahe. The Southern Region includes Fort Randall Reach, Lewis and Clark Lake, and Gavins Point Reach.

The geographic scope reflects the decision-making authority of the USACE. The effects of nearby subpopulations of piping plovers and least terns on MRMS populations (metapopulation dynamics) are not fully understood, and considered a critical uncertainty within the AM Plan (Section 3.1.2.5). Studies underway to measure dispersal between the MRMS and other breeding areas will provide information on metapopulation dynamics. As results become available, the ability to account for and model metapopulation dynamics will be evaluated and developed to the extent possible.

3.1.1.2 *Relationship to species recovery*

The *Draft Revised Recovery Plan for the Northern Great Plains Piping Plover (Charadrius melodus), First Revision* (*henceforth*, Plover Recovery Plan; USFWS, [2016]) identifies four recovery regions (sub-populations) of Northern Great Plains plovers: Prairie Canada, U.S. Alkaline Lakes, Northern Rivers, and Southern Rivers. The mainstem Missouri River comprises the entirety of the Northern Rivers region and a substantial portion of the Southern Rivers region, which also includes the Niobrara, Loup, and Platte Rivers. The Plover Recovery Plan emphasizes the importance of maintaining sufficient habitat in each of the four regions, given the contribution of each region to the overall geographic area and habitat diversity and the limited dispersal observed between regions:

> The population should be broadly distributed to reduce the risk of loss of a significant proportion of the population. It is important for the population to be distributed through the range to maximize viability into the future and to reduce the risk of a stochastic event impacting a large proportion of the population. (USFWS 2016)

The plan also identifies the importance of maintaining a diversity of habitat types, including riverine sandbars, and of not relying on human-created, off-river habitats as a means of achieving long-term recovery. In the MRRP planning area, which includes the river and the meander belt, the plover nearly exclusively nests on in-channel islands and along reservoirs. A very high proportion of recorded plover nesting on riverine islands occurs on the Missouri River. Accordingly, to meet the range-wide goal of conserving piping plovers across as much of their historical distribution as possible and in the full breadth of its known habitats, the MRRP should focus on providing in-channel habitat in an extent and condition sufficient to support stable demographic units that can persist in the face of dynamic environmental conditions

The objectives for the MRRP, as identified above, are to avoid jeopardy to the listed species, not meet requirements for recovery. To the extent that the MRRP can support recovery of the piping plover, it will provide clear benefits to the species and program; however, the MRRP currently has defined targets (Section 3.2.3) that differ from recovery targets, because both the objectives and the methodology for defining targets differ (USFWS 2016). The USFWS has determined that these differences are acceptable and appropriate and do not create a conflict between the Plover Recovery Plan and the MRRP. If, in the course of AM within the MRRP or following updates to the Plover Recovery Plan, the need to adjust MRRP plovers target criteria is identified, that process is defined in Sections 3.6.1 and 3.6.5.

The fourth recovery criterion identified in the Plover Recovery Plan is the following:

> Criterion 4: Ensure commitments are in place and functioning as anticipated to provide long-term funding, protection, and conservation management activities in essential breeding and wintering grounds. …
>
> *Purpose: To make sure that management commitments necessary for piping plovers' continued persistence are in place and functioning, and will continue to operate after the species is recovered.*

In the event the first three recovery criteria are met throughout the range of the Northern Great Plains Piping Plover, the MRRP (and other resource management agencies in the range) will need to demonstrate the commitment to continue providing habitat, population protection, and related management actions. Some requirements may change from the current MRRP objectives, but species recovery will not result in cessation of management for plover and tern habitat on the MRRP.

The Plover Recovery Plan identified reservoirs, channelization of rivers, and modification of river flows; invasive species and vegetation growth; and inadequacy of existing regulatory mechanisms as high threats for both the Northern Rivers and Southern Rivers regions. Density leading to intraspecific aggression, agricultural development, predation, and human disturbance were identified as high or medium threats to both regions. These stressors overlap strongly with the threats identified in the piping plover EA as explained in Section 3.1.2.

The 5-year review of the Interior Least Tern recommended delisting (USFWS 2013). Delisting requires a conservation plan and post-delisting monitoring plan from cooperating agencies, similar to what is described above for plovers. The MRRMP will also serve as the conservation plan for interior least terns and must therefore demonstrate the ability to continue meeting habitat and population protection needs for least terns.

3.1.2 Key findings from Effects Analysis (EA)

3.1.2.1 *Purpose and methods of the EA*

An EA was undertaken to address the requirement within the ESA to use the best available science to evaluate the effects of actions proposed by federal agencies on listed species or designated critical habitat. The EA adapted the rigorous approach advocated by Murphy and Weiland (2011). Before the EA began, the problem was formulated with the definition of the proposed action, the area affected, and a conceptual model of the physical and biological relationships relating actions to species outcomes. After problem formulation, the first step in the EA was to collect reliable scientific information, including observations about the stressor(s), the range of stressor conditions and information on population sizes and trends. The second step included assessment of the data, the use of quantitative models to synthesize existing information, and identification and representation of uncertainties. The third step was to analyze the effect of the actions on the species to determine costs and benefits and identify alternative management approaches.

This section summarizes the EA for plovers and terns as documented in the following reports:

- Summaries of the state of science for the species and their habitats to identify the effects of system operations and actions on species populations and their habitats (Buenau et al., 2015z)
- Conceptual Ecological Models (CEMs) and hypotheses addressing critical uncertainties (Buenau et al. in prep)

- Quantitative assessments and modeling evaluating the effects of management actions on habitat and population dynamics (Buenau et al. in prep.)

The EA used the information and tools described in these reports to provide an integrated assessment of the effects of management actions on piping plovers and least tern habitat and populations in the Missouri River. It also documents and synthesizes the uncertainties in the assessments. The foundation of the EA is the habitat and population models, which synthesize available information to make predictions, assess management hypotheses, predict outcomes of combinations of management actions under evaluation for the Management Plan, calculate numerical targets, and quantify uncertainties and their impacts on management decisions. These tools will continue to be applied and refined through the AM process.

3.1.2.2 *Conceptual ecological model*

The CEMs for plovers, terns, and their habitat relate drivers (social, political, legal, and economic; climate, geology, and land use) to Missouri River management, hydrology, and habitat. They then relate habitat availability to biotic processes: nesting behavior, predation and food availability, and dispersal. These biotic factors affect survival and reproduction to ultimately determine population size. An overview conceptual model is shown in Figure 37. Complete conceptual models for each species are shown in Appendix B. In the complete models, the estimated importance of each relationship is indicated by the type of arrow, with thick solid lines representing the most important relationships and thin dot-dash lines representing the least important relationships. Importance was determined based on the relative effect of each relationship to the affected factor. Uncertainty is reflected by arrow color. Uncertainty in the CEMs represents lack of knowledge, high natural variability, or both.

The CEMs were initially developed in a set of inter-agency workshops in 2013, then reviewed, revised, and used to develop biological and management hypotheses to be evaluated in the EA.

3.1.2.3 *Quantitative modeling framework*

The quantitative modeling framework includes components for hydrology, riverine and reservoir shoreline habitat, and population viability (Figure 38). These components are briefly described here. Details can be found in Fischenich et al. 2015 and Buenau et al. (in prep).

Hydrology and reservoir operations are modeled using HEC Res-Sim, which routes basin runoff through the Missouri River using specified rules for reservoir operations. These rules can be modified to reflect potential changes to reservoir operations, e.g. to release flows capable of creating new sandbar habitat. Currently, the Res-Sim model uses historical runoff and depletions from 1930-2012 as inputs and provides reservoir elevations, dam releases, and river stage at selected locations as outputs. The model uses historical hydrological inputs to cover a range of natural variability in basin runoff. Those inputs are runs through a model of the modern hydrosystem with a consistent set of operation rules for each 50-year run.) Sequences of output with randomly selected initial years are used in the habitat models.

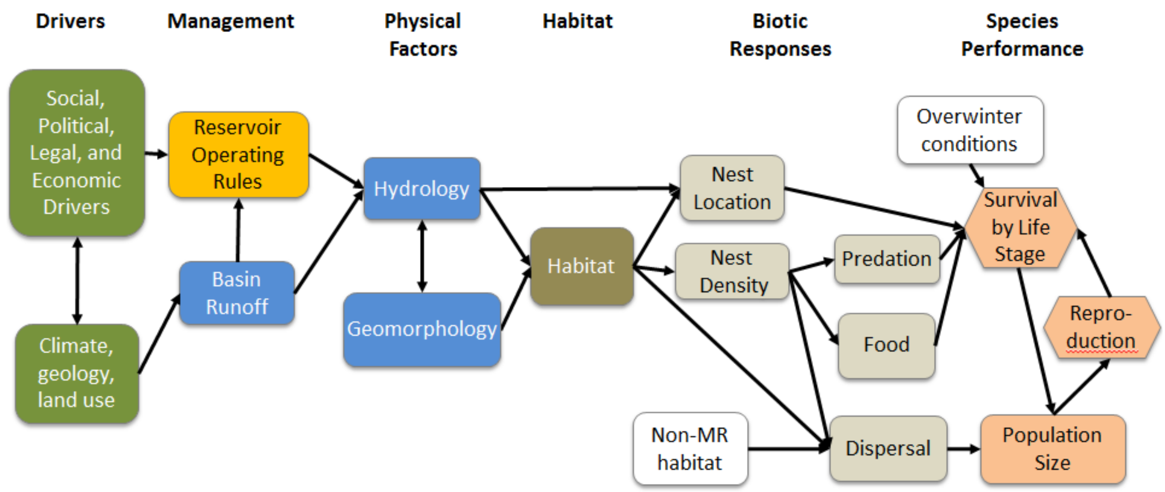

Figure 37. Overview conceptual ecological model (CEM) for plovers (see Appendix B for full set).

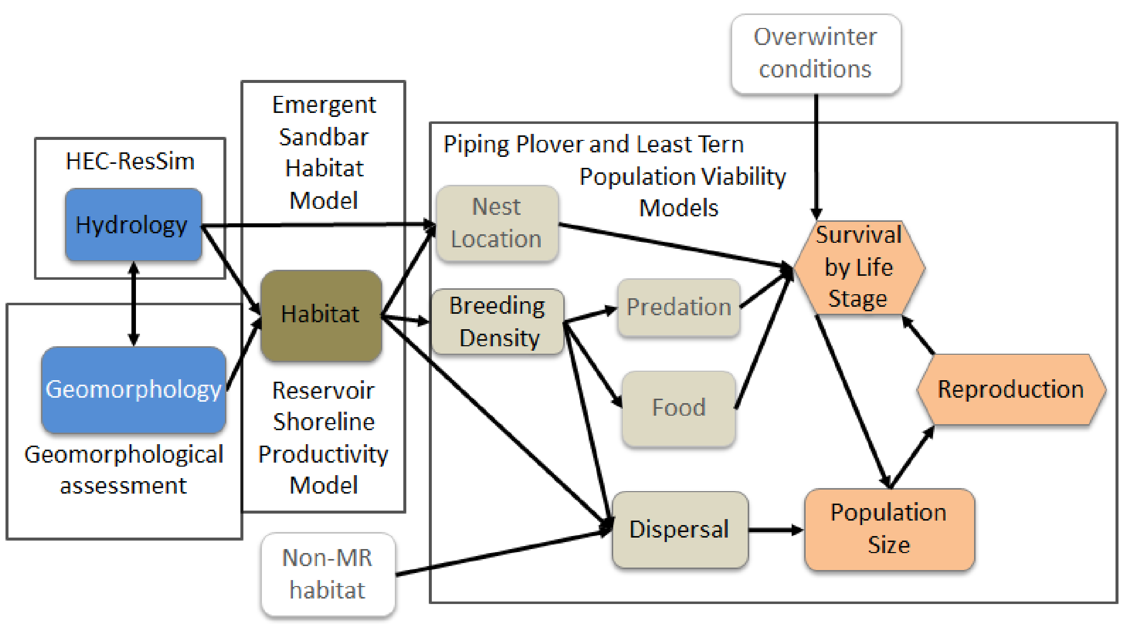

Figure 38. Quantitative model components in relation to conceptual model elements. Elements with black text are represented explicitly in the model; elements with gray text are represented implicitly.

Plover and tern sandbar habitat (emergent sandbar habitat, ESH) under varying flow conditions is predicted using a model of the change in ESH due to vegetation growth and the deposition and erosion of sandbars as a function of flow and ESH area. At low flows, erosion rates are low. Net erosion is greatest at moderate flows, then, as flows increase, net deposition begins to occur. Erosion is greater, at occurs at higher flows, when the existing ESH area is larger. ESH models were based on a mechanistic understanding of sandbar dynamics and parameterized for each of the three riverine reaches individually based upon satellite imagery for all reaches and geomorphic studies for Gavins Point Reach. They use initial ESH area and mean monthly river flows as inputs. Output consists of the standardized acreage of ESH, set to a constant flow for each reach (see Section 3.2.3 for specifications) and available acreage of ESH, adjusted to the maximum July flow in each year to estimate ESH availability for nesting and brood-rearing.

Reservoir shoreline habitat is modeled indirectly. Fledgling production on reservoir shorelines is modeled as a function of two hydrological metrics: the vertical extent (elevation range) of exposed shoreline that had been inundated for at least 160 days in the past two years, and the increase in reservoir elevation during the nesting season. These metrics predict observed fledgling productivity more effectively than estimates of habitat area, which is challenging to quantify and predict on reservoir shorelines. The reservoir habitat-productivity model uses the daily time series of predicted reservoir elevations and breeding pairs as inputs and outputs the number of fledglings produced.

Plover and tern populations are modeled using species-specific population models that account for the number of fledglings produced per pair of adults as a function of population density on riverine habitat and hydrologic change on reservoir habitat, annual survival for life stages (juvenile and adult plovers; juvenile, young adult and older adult terns) and dispersal between river segments and regions. They use the output of available ESH from the habitat models and reservoir shoreline fledgling production rates as inputs and produce as outputs fledge ratios (# fledglings/pair of adults), population sizes and population growth rates for each year and segment simulated. The model assumes equal rates of immigration and emigration with other breeding areas.

The habitat and population models include uncertainty about parameter estimates. Hydrological variability is represented by sequences of years in the period of record (1930-2012) with a randomly selected start year. The population models also include demographic uncertainty (individually-drawn chances of individuals being born and surviving each year), temporal variability (uncertainty in parameter values from year to year, interpretable as environmental randomness due to factors other than flows) and observation error. For any given scenario, models are run 5,000 times with random variables to representing each type of uncertainty (Monte Carlo simulations). Results are presented as metrics reflecting the distribution of results, e.g. median and confidence intervals.

3.1.2.4 *Effects of management actions on plovers and terns*

The management actions evaluated in the EA affect bird populations through several mechanisms: by improving the retention and formation process for habitat, by increasing habitat structure, by increasing availability of existing habitat, or by reducing the mortality of eggs and chicks. The mechanisms have a cascading effect (Figure 39) such that actions that improve habitat structure or availability will, all other factors being equal, also reduce egg/chick mortality and thus improve population metrics. Consequently, if sufficient habitat is available, then less effort will be required on actions to directly improve egg and chick survival. The opposite is also true, such that a lack of habitat requires more intensive population protection in order to meet objectives.

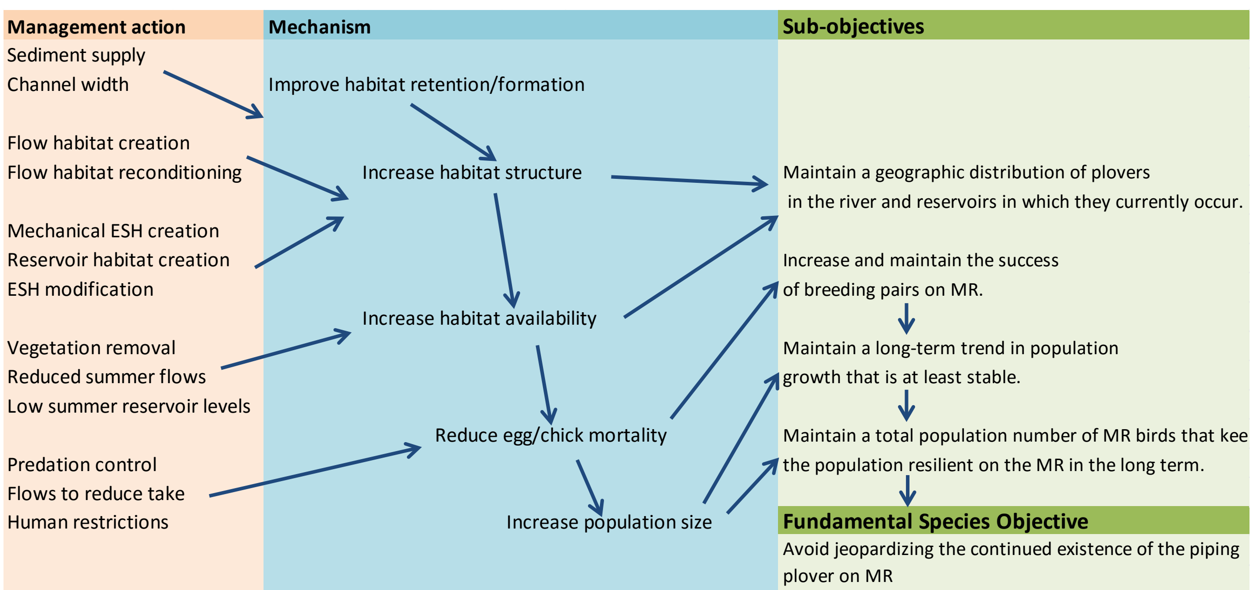

Figure 39. The management actions evaluated in the EA, their mechanisms for affecting habitat and species and consequent effects on the fundamental species objectives and sub-objectives.

A related finding of the EA is that management actions for plovers and terns are highly interdependent: both the opportunities for and effects of a given action depend on how much habitat is available, how dense the breeding bird populations are, and what other actions are taking place (see Section 3.5.4). Decision-makers must take a synthetic approach, considering the status of the system as a whole, the needs of the species, and the management opportunities before choosing a course of action, rather than making separate decisions about whether to implement specific actions (Sections 3.5.3 and 3.6.1, for example). Quantitative models (Section 3.1.2.3) are fundamental to this process, allowing for as many relevant factors to be taken into account as the current state of knowledge allows.

3.1.2.5 *Hypotheses and uncertainties*

Bird management is made challenging by four sources of uncertainty:

1) **Environmental variability:** Future climate and weather cannot be known with certainty. The greatest source of environmental variability for MR birds is basin runoff and resulting system storage and flows, which are major drivers of habitat availability. Local weather, including storms and high temperatures, also affect reproduction and survival. This type of uncertainty is largely irreducible, though advances in modeling can lead to better estimates of the likely distribution of future conditions.
2) **Structural uncertainty:** While the fundamental relationship between hydrology, habitat availability and reproductive success is supported by evidence described in the EA, uncertainty remains about the functional form of some relationships. For example: What is the shape of the relationship between flow, ESH area, and sediment transport? What aspects of habitat quality affect fledgling production? What factors best predict reproductive success on reservoirs? How are Missouri River populations affected by metapopulation dynamics? Structural uncertainty can be reduced through research, monitoring, and improvements to models.
3) **Parametric uncertainty:** Once the structure of relationships is known, uncertainty remains about their strength. How much sand is eroded or deposited at a particular flow? How much habitat is available at a given river stage? What is the survival rate for birds during their first winter? How strongly does population density affect chick survival? As with structural uncertainty, these uncertainties can be reduced through research and monitoring and incorporated into models. However, they may vary with time and location.
4) **Observation uncertainty:** Population and productivity surveys are not 100% accurate. The degree of error and direction of bias can vary by habitat type, conditions and level of effort, and thus tend to differ by location and year. The design and level of effort in a monitoring program can reduce observation error and, in some designs, estimate the error in the survey, which allows for more accurate use of the resulting information.

All types of uncertainty affect the ability to make effective and efficient management decisions, from uncertainty about future conditions (e.g., How much water will be in the system? How many birds will survive and return to breed in specific locations?), to uncertainty about effectiveness of management actions (e.g., How long will created habitat last? How much foraging habitat will be available, and at what quality? How much will predation be reduced by a planned level of control effort?)

While research and monitoring may increase certainty about of system dynamics, long-term trends may decrease that certainty without ongoing or periodic updates. Changes in climate can change hydrological trends and variability; changes in the sediment budget will affect ESH dynamics. Stressors on the Missouri River, wintering habitat, or nearby breeding areas that would affect productivity, survival, and/or dispersal may also change over time. Ongoing or periodic assessments will be necessary to detect and adjust to changing conditions.

The overarching scientific and management uncertainties for plovers and terns are summarized in the following questions, which AM must seek to address.

Overarching Critical Uncertainties

- How much habitat is needed to maintain a resilient population of birds and how should it be distributed in space and time?
    - How should habitat be quantified and what determines habitat quality?
    - What is the relationship between habitat quantity and quality and bird productivity and success on river and reservoir habitat?
- How are the Missouri River populations of plovers and terns affected by migratory and metapopulation dynamics?
    - How are conditions in overwintering habitats affecting the Missouri River breeding populations over time?
    - How do habitat conditions in other breeding areas and dispersal to and from those habitats affect the Missouri River breeding population over time?
- How will long-term changes in climate and channel morphology affect habitat and species management?
    - How will climate affect hydrology including the timing, magnitude, and variability of basin runoff and the frequency, intensity, and duration of extreme events?
    - How will sediment dynamics change over time and affect the ability to create and maintain habitat through various means?
- How can the bird AM program buffer against natural (especially hydrologic) variability and uncertainty for long-term success?
- How can the bird AM program buffer against institutional and socioeconomic variability and uncertainty for long-term success?

In addition to the overarching critical uncertainties, there are questions about management approaches and specific management actions. Each management action has a testable hypothesis about its mechanism and effectiveness. Table 19 lists these uncertainties and hypotheses.

Table 19. Critical uncertainties related to bird management actions evaluated in the EA and associated management hypotheses.

Management Critical Uncertainties	Actions	Management hypotheses
Creating New Habitat What is the most effective and efficient way of **creating habitat** within the larger context of management and uses of the Missouri River? a. Are there effective and implementable ways of using flow modification to provide and enhance habitat availability and quality? b. Can habitat be mechanically created in an effective and sustainable manner? c. What are the effects of habitat creation actions on Human Considerations?	Habitat-creating flows	Habitat-creating flows of sufficient magnitude and duration increase the area of nesting/brood rearing habitat and foraging habitat on the river by increasing deposition, assuming sediment is available, thereby increasing fledgling productivity.
	Mechanical habitat creation on river (ESH)	Mechanical habitat creation of ESH in river segments increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Mechanical habitat creation of sandbars in river segments increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.
	Mechanical habitat creation on reservoirs shorelines or islands	Mechanical habitat creation of habitat on reservoir shorelines/islands increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Mechanical habitat creation of habitat on reservoir shorelines/islands increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.
	Mechanical creation of hydrologically-connected non-sandbar habitat on river segments	Mechanical habitat creation of habitat other than sandbars or in segments outside of the current ESH scope increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Mechanical habitat creation of habitat other than sandbars or in segments outside of the current ESH scope increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.

Maintaining Existing Habitat To what extent can **maintaining existing habitat** contribute to population objectives compared to creating new habitat? a. Does maintained habitat improve habitat metrics and support production equivalent to new habitat? b. Can flow be used to maintain habitat without increasing net erosion?	Modification or augmentation of existing sandbars	Modification or augmentation of existing sandbars increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation. Modification or augmentation of existing sandbars increases nesting/brood-rearing and foraging area, which increases food availability and chick survival to fledglings. Modification or augmentation of existing sandbars increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.
	Vegetation removal (spraying/mowing) on river/on reservoir	Vegetation removal increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation (by increasing area and by removing cover for predators). Vegetation removal increases nesting/brood-rearing and foraging area, which increases survival of chicks to fledglings by increasing food availability. Vegetation removal increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, increasing the number of adults through net immigration from other areas.
	Habitat-conditioning flows	Habitat-conditioning flows are not of sufficient magnitude and duration to create new sandbars, but scour vegetation or deposit new sediment on existing bars, increasing the area of nesting/brood-rearing habitat, thereby increasing fledgling productivity.
Improving Availability of Existing Habitat To what extent can **improving the availability of existing habitat through flows** contribute to - population objectives compared to creating new habitat?	Reservoir water level management	Declining reservoir water levels between years and/or steady or declining water levels during the nesting season increases the area of suitable nesting/brood rearing and plover foraging habitat on the reservoirs, thereby increasing fledgling productivity.
	Lowered nesting season flows	Lowered nesting season flows increase the area of suitable nesting and brood rearing habitat and foraging habitat on the river, thereby increasing fledgling productivity.
Population Protection To what extent can population protection actions positively contribute to the success of birds on the Missouri River?	Flow management to reduce inundation of nests and chicks	Steady or declining reservoir levels and/or river flows during the nesting season increases survival from egg to chick and chick to fledgling by reducing the risk of nest inundation and chick stranding and by maintaining or increasing foraging habitat.
	Predator removal	Predator removal increases survival of eggs to chicks and chicks to fledglings.
	Nest caging	Nest caging protects plover nests from predators, increasing survival of eggs to chicks, though survival of adults may be negatively affected by cages.
	Human restrictions measures (signs, barriers, education)	Human restriction measures reduce human activity on nesting and foraging habitat, increasing survival both by decreasing direct mortality and indirect effects on survival caused by stress.

3.1.2.6 *Implications for AM*

Managers on the MR must make decisions without limited knowledge of *what* conditions will occur in the future that will affect both the habitat and species and the ability to manage them, and *how much* those conditions will affect habitat, species, and the effectiveness of management actions. Additional uncertainty remains regarding how effective some management actions are. In comparison to pallid sturgeon, structural uncertainty about bird dynamics—how key elements of the system relate to each other—is relatively low, but the strength, and in some cases form, of those relationships is still uncertain. If these uncertainties are not dealt with explicitly and thoughtfully during the management process, management will be haphazard and inefficient at best, and wasteful and ineffective at worst.

The role of AM for management of terns and plovers is to improve decision making in light of uncertain future system state—an uncertainty that can never fully be resolved—and by improving understanding of how the system functions. The agencies retain discretion and ultimately the decision making authority in determining how to address this uncertainty; the AM Plan improves the process, information and understanding surrounding the needed decisions.

The strong role of variable hydrology in driving plover and tern habitat and populations (Buenau et al. 2014) compels a management program to adapt to accommodate droughts and high flows, which affect both the need for action and the ability to act. Simply reacting to these circumstances is not AM. Rather, AM requires that adjustments be made according to the best available science, which is deliberately invested in and improved upon as part of the AM program.

Management decisions for the birds can be improved with learning. Management actions directed towards meeting habitat and bird objectives (passive AM) can add valuable information to ongoing assessments of key processes and relationships if their outcomes are monitored with sufficient and known accuracy. Natural variability broadens the range of conditions for estimating relationships. Opportunities to manage in a way to prioritize learning (active AM) by exploring management options where uncertainty is higher and incorporating experimental design into management planning will accelerate the learning process. For a long-term management program with high resources use, deliberate intent to both learn and use the knowledge gained for improved decision making can lead to significant efficiencies, lowered costs, and improved likelihood of success.

Models integrate learning in the AM process by both projecting the outcomes of different management scenarios and summarizing and quantifying uncertainty. Models can also be used to prioritize information needs and track the benefits of learning over time. Hypotheses about the effects of management actions, developed in the EA (Section 3.1.2.5), are routinely confronted with new information during the AM process to determine the level of support for the hypotheses, revise hypotheses, and develop new ones if warranted.

3.2 Plan and Design

3.2.1 Bird Framework

The key decision-making information and range of decisions for bird AM is illustrated in Figure 40. System status together with the management conditions affecting potential actions provide the information needed to make decisions. That information is interpreted in the context of the current understanding of the system, as synthesized by models, to make decisions. Rather than a dichotomy of continue/adjust, as AM decisions are often portrayed, decisions range from continuing the current activities exactly, to continuing actions with adjustments, to changing the actions that are implemented, to adjusting fundamental components of the program. As the breadth and significance of decisions increases, the level of governance and stakeholder engagement increases accordingly.

The variability of the MRMS and the need to balance multiple and, at times, competing species and HC objectives support a toolbox approach to managing for plovers and terns. The approach consists of having multiple flexible management actions and options available to ensure effective management in a context of natural variability and socioeconomic uncertainty. The set of actions initially in the toolbox and their specifications will be determined by the USACE and USFWS in collaboration with MRRIC. As the AM Plan is implemented, learning about actions is applied to use them more effectively. Learning may also result in changes to the bounds and conditions under which actions are applied, or the addition or removal of management actions. Decisions to make changes are evidence-based and involve collaborative processes with MRRIC when HC’s are affected.

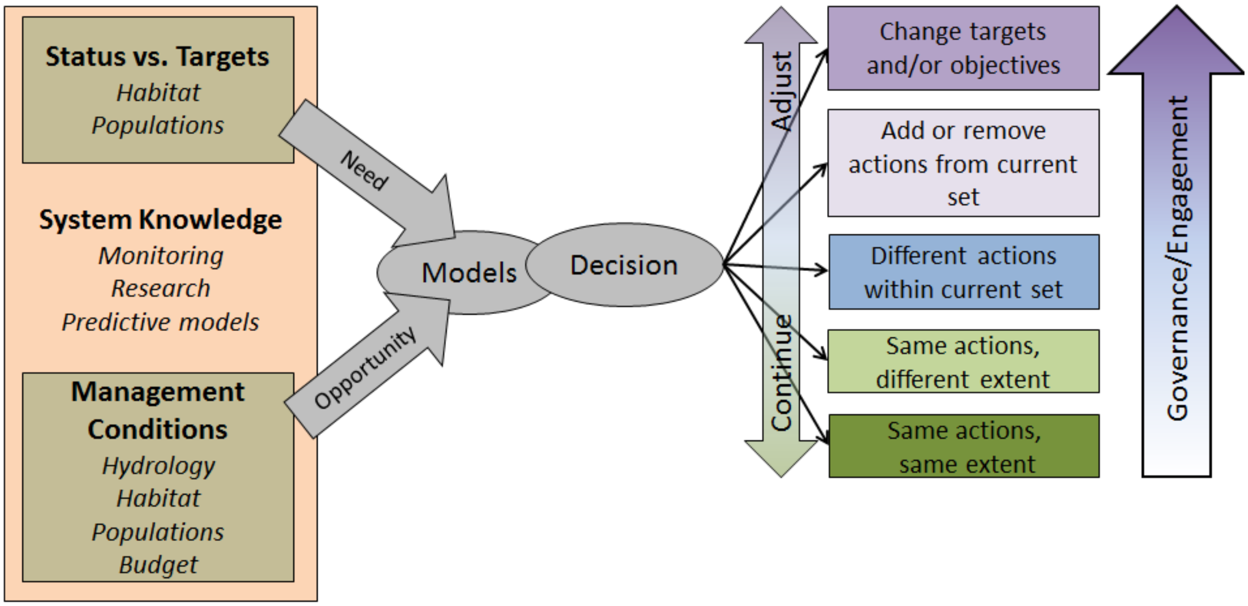

Figure 40. Factors affecting AM decisions for birds and the nature of those decisions

The "toolbox" concept is illustrated in Figure 41. The hypothetical set of actions (A-E) defined in the ROD is available for use. Within that set, several may be selected for use in a specific year (A, C, E), while others are not (B,D). Other actions may have been evaluated in the EIS but are not included in the ROD (F,G), or were not evaluated in the EIS (H,I); actions in either of these categories are not available for immediate implementation. Numbered arrows in Figure 41 indicate the range of AM adjustments that are possible:

4. Reduce the scope (e.g. location, magnitude, duration, timing) of future implementation of an action, most commonly because of the potential for adverse impacts if the action were implemented as currently specified (Section 2.4.6.6);
5. Increase the scope of future implementation of an action, to improve benefits if adverse impacts are found to not be a concern (Section 2.4.6.5);
6. Remove an action from future implementation because of insufficient positive effect or unacceptable negative effects (Section 2.4.6.6);
7. Change how an action is implemented (e.g. techniques and engineering design) without changing the scope;
8. Add an action that was evaluated in the EIS but not part of the ROD, for which the evaluation is still sufficient, requiring a decision document (Section 1.1.6) and, if necessary, adjustments to the Master Manual (Section 2.4.6.3 and Attachment 5);
9. Add an action that was not evaluated in the EIS, requiring additional NEPA analysis (Section 2.2.5). If findings are acceptable, adjustment 5 would be applied next.

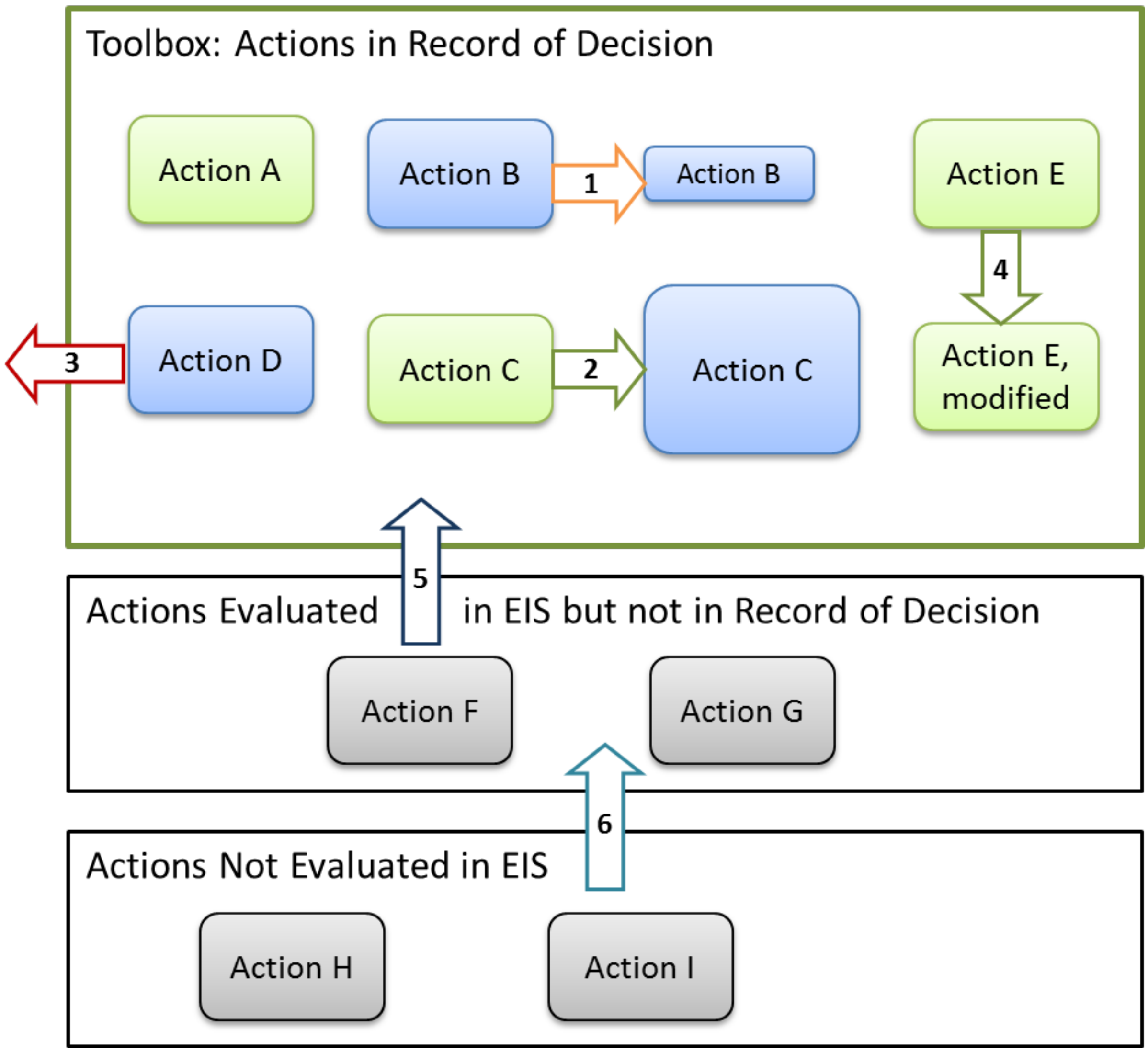

Figure 41. Illustration of "toolbox" concept for AM, indicating action status and a range of potential AM adjustments to actions. Green boxes (A,C,E) indicate actions implemented in a given year; blue boxes (B,D) indicate actions not implemented that year; gray boxes (F-I) indicate actions not currently implementable.

Bird management actions evaluated in the EIS have evidence for their effectiveness based on prior implementation and/or modeling. Other potential management actions were either screened from the EIS alternatives due to uncertainty about their effectiveness relative to impacts, not included in EIS alternatives due to feasibility or authority, not included in the scope of the EA, or identified after alternatives were formulated for the EIS. The AM process includes learning about management actions for which identifiable causal links suggest the potential for species benefits, even if those benefits and any corresponding impacts are not yet understood sufficiently for full implementation. As such, actions not in the ROD with some evidence for effectiveness are identified for research and possible pilot-scale implementation.

The pallid sturgeon AM framework identifies four levels of implementation (Section 4.2.1.1). Research or pilot-scale implementation for birds is analogous to Level 1 and Level 2 actions for pallid sturgeon, respectively. Bird actions included in the ROD are analogous to Level 4 actions in the sturgeon framework. Because ESH targets have been established, there are no bird analogues to Level 3 actions in the sturgeon framework. Additionally, while Level 1- and Level 2-type actions have been identified for birds, research and implementation timelines have not been defined because of the identified sets of Level 4 actions capable of reaching targets in all EIS action alternatives.

The decision space for an action is bounded by what is effective and what is implementable (an example for a flow action is described graphically in Figure 42). Determination of effectiveness is provided by the EA and subsequent assessments, supplemented by learning from implementation. An action is deemed implementable following collaboration with MRRIC and evaluation in the programmatic EIS or subsequent NEPA analyses to determine the extent to which the action can be used. The overlap of these regions is the usable decision space. If there is no overlap, the action cannot be used unless adjustments to the boundaries are made.

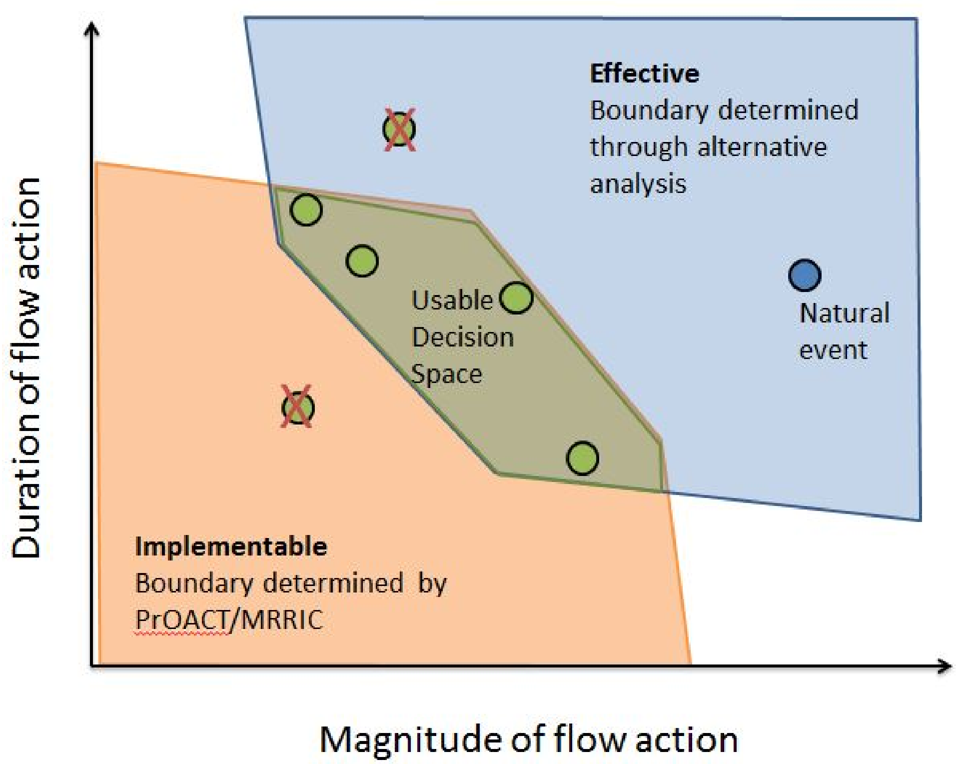

Figure 42. Schematic of decision space using flow management for ESH creation

Actions can be implemented with any combination of parameters that fall within the effective and implementable decision space (green circles.) Depending on circumstances and opportunity, they may be below the upper bounds of what is implementable (e.g. actions implemented at less than their full scope).

Implementation outside the usable decision space (green circles with red X's) is not planned as part of species management as they are expected to either be ineffective or have unacceptable levels of impacts. On occasion, events such as naturally high runoff may occur that lead to reservoir releases outside of the decision space (blue circle.) While not considered an action for habitat or species management, these are important learning opportunities.

The bounds of the implementable and effective regions may be adjusted through AM. If impacts are found to be greater or less than expected, the implementable bound may be adjusted through collaboration with MRRIC (Sections 2.4.6.5 and 2.4.6.6). If effectiveness is found to be greater or less than expected, the effective boundary would be adjusted through the Science Update process (Section 2.4.3). These adjustments may have the effect of increasing, decreasing, or eliminating the usable decision space.

3.2.2 Metrics and management conditions

Habitat and species metrics contain the necessary information to evaluate the overall status of habitat and bird populations on the Missouri River and are directly related to the objectives.

> **Note:** the details of some metrics will depend on decisions about the monitoring program. Some redundancy may be included in the following list; though similar but distinct metrics have benefits for understanding the system, some may not be retained in future drafts.

3.2.2.1 *Habitat metrics*

Emergent sandbar habitat acreage is estimated from satellite imagery acquired during the nesting season. Wet or dry sand with less than 30% vegetation cover is delineated as ESH. The area delineated from imagery will depend upon the flows occurring when the imagery was acquired. To measure ESH in a consistent and meaningful way, the delineated area is adjusted using discharge-area relationships to reflect area available at two different flows:

1) **Standardized ESH (acres)** is the area above water if releases were 31.6 kcfs from Gavins Point Dam, 30.5 kcfs from Fort Randall Dam, and 23.9 kcfs from Garrison

Dam[1]. Estimating ESH acreage at constant flows each year allows for the detection of changes in sandbar structure due to erosion, deposition, construction, or mechanical modification.

2) **Available ESH (acres)** is the area above water during the maximum July release for each reach for the specified year. The acreage available at this flow is used to represent the limiting amount of habitat available during the brood-rearing season, when plover chicks are foraging. It reflects some of the effects of flow management during the nesting season.

Habitat quantification is binary; land cover is or is not classified as habitat, with no further distinction as to quality. The AM program will work to develop metrics that determine habitat quality as a function of sandbar form (e.g. elevation, cutbanks), land cover, and landscape characteristics (e.g. channel width, distance to trees) as appropriate. Habitat quality metrics will allow improved estimates of bird productivity and inform planning for habitat construction and modification actions and project design.

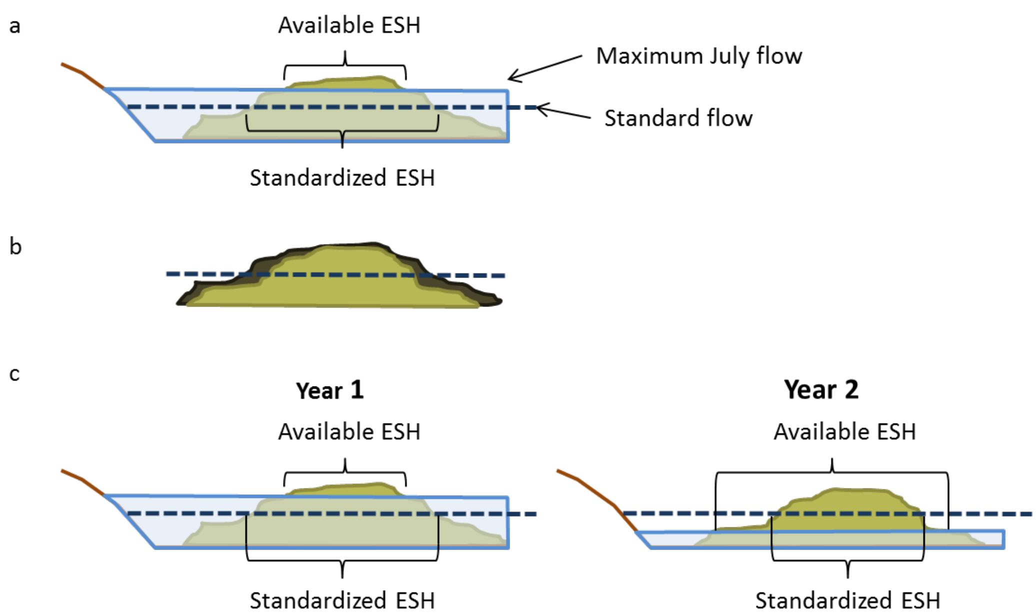

Figure 43. ESH characterization. a) Available ESH is measured at the maximum July flow (blue outline) observed in that year. Standardized ESH is observed at the same flow (dashed line) each year. b) Standardized ESH measures changes in sandbars due to erosion from an earlier year (dark profile) to a later year (light profile). c) Available ESH area may increase from one year to next if flows are lower, even though standardized ESH area decreases from erosion and vegetation growth.

[1] The Gavins Point flow is based on releases from Gavins Point Dam needed to meet downstream flow targets during the July Median, Upper Quartile, and Upper Decile runoff conditions from the Master Manual. The flows for the other segments are based on an average of the July average daily outflows from 1967-2010. The choice of flows is somewhat arbitrary; what matters is that the same flows are used consistently through time and across models and metrics.

The EA found that fledgling productivity on reservoir shoreline habitats was best estimated using two metrics that reflect the change in water elevation along the shoreline between and during nesting seasons:

1) **Available shoreline (feet)** is the difference between the maximum shoreline elevation that has been inundated for >160 days during the previous two years and the shoreline elevation inundated on May 15th, the beginning of the current nesting season. If the elevation on May 15th is higher than any elevation that has been inundated >160 days in the previous two years, the metric is zero. This metric estimates the relative amount of shoreline that has been inundated recently and for long enough that it is free of vegetation. Because the shoreline slope varies, this metric does not directly correlate to area[1].
2) **Inundation (feet)** is measured as the difference between the minimum and maximum reservoir elevation during the nesting season. The difference is positive or negative to distinguish between an increase in water levels during the season, which might inundate nests, and a decrease, which typically provides more foraging area.

Available ESH and the two reservoir shoreline metrics were determined during the EA to be the best available predictors of observed fledgling production. Targets have only been specified for ESH, but tracking reservoir habitat metrics enables prediction of bird productivity on reservoirs as part of overall population assessment.

3.2.2.2 *Species metrics*

Population monitoring provides metrics to describe the status of the population and reproductive success:

1) **Population size**[2] estimated using one or both of the following techniques:
    a. **Population size (number of adults)** is the number of adults observed on riverine and reservoir habitat during the nesting season survey.
    b. **Minimum breeding population estimate (pairs)** is estimated from the daily sum of active nests plus all previously hatched nests plus nests failed during incubation within the previous 5 days. It provides a minimum estimation of pairs as not all nests may be detected.

[1] Habitat area was evaluated as a predictor of reservoir habitat productivity. Not only is habitat area on reservoirs difficult to quantify compared to riverine habitat, area did not predict productivity as well as the metrics defined here.

[2] Decisions yet to be made about the monitoring program will determine if total adult birds can be estimated, or only the breeding population. If the total number is available it will help determine if conditions have reduced the proportion of birds able to breed in a given year.

2) **Population growth rate, λ,** is the change in population size between years expressed as a ratio (N_t/N_{t-1}) and indicates whether the population is growing (**$\lambda > 1$**) or declining (**$\lambda < 1$**) and to what extent.
3) **Fledge ratio** is the number of fledglings observed/(number of breeding adults/2).
4) **Population density**[1] will be estimated as one or both of:
   a. The number of adult birds/available acres of ESH in a riverine segment.
   b. The number of breeding pairs/available acres of ESH in a riverine segment.

All metrics are measured at the reach or reservoir scale and also reported at the region and system scale to provide a thorough understanding of system dynamics. Targets are defined at the region scale (Section 3.2.3).

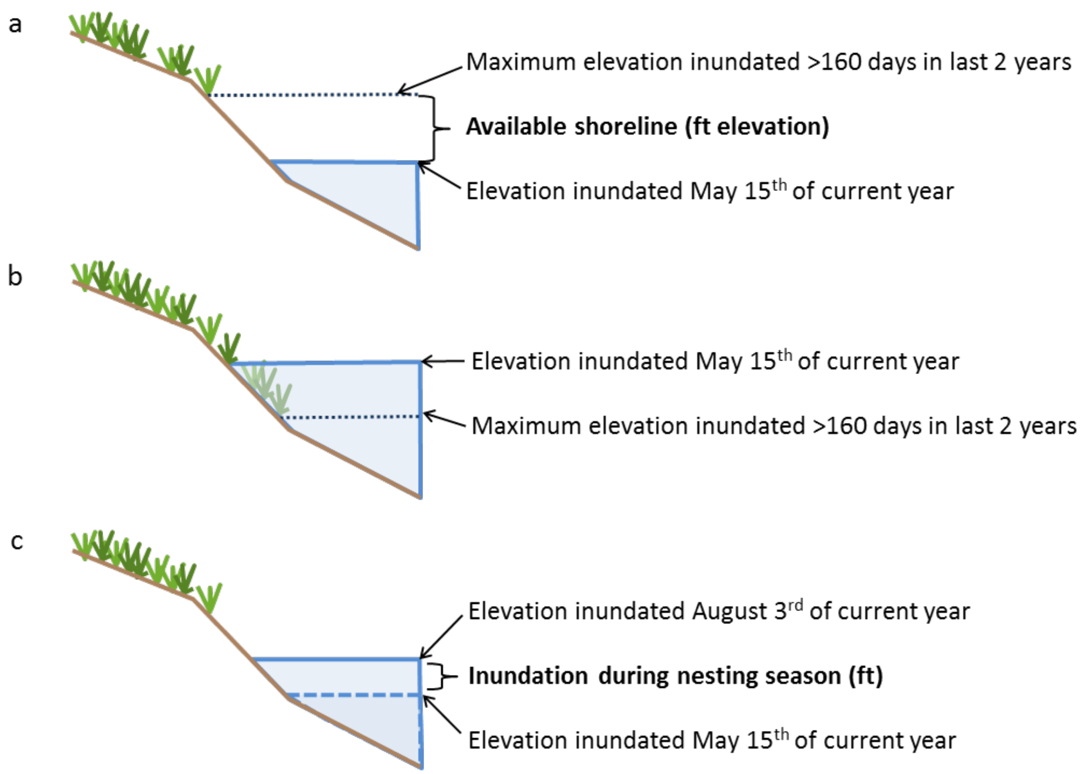

Figure 44. Shoreline habitat characterization. a) Available shoreline is measured as the difference between the maximum elevation inundated >160 days in the previous 2 years (dotted line) and the elevation inundated on May 15th of the current year (solid outline). b) If the elevation inundated on May 15th is higher than the maximum elevation inundated >160 years, the available shoreline metric = 0 ft. c) The inundation metric is the change in elevation between May 15th (dashed line) and August 3rd (solid line) and may be a positive number if water levels increase (shown) or a negative number if water levels decrease (not shown).

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[1] Decisions about the most effective means of monitoring population size may determine if only one of these metrics will be used, and which one. As with population size, breeding population density is the primary metric for estimating and tracking the relationship of fledgling production to habitat availability. If the monitoring program allows for the estimation of the total number of birds, total population density would help determine whether conditions are limiting nesting and not just nesting and brood-rearing success. Pending outcomes of monitoring program development, the same metric(s) will be estimated every year.

3.2.2.3 *Management Conditions*

The following metrics define opportunities and constraints for management actions in a given year. There is some overlap with the habitat and species metrics, but all are listed below to explain their applications.

1) **Standardized ESH (acres) and distribution** affect the outcome of flow modification actions. How much sand flows erode or deposit is partly a function of existing sandbar area. The effects of nesting season flows on habitat availability also depend on the structure of existing ESH. The location of existing sandbars will also determine where new sandbars can be mechanically constructed and whether existing sandbars can be augmented or modified to improve quantity or quality of ESH.
2) **Vegetated sandbar area (acres)** determines the potential and extent of vegetation removal as a management action. The age of vegetation affects the methodology for removing vegetation and the outcome. The extent of vegetation on sandbars also affects predation risk, erosion rates, and potential for scour.
3) **Storage in reservoirs (million acre-feet) and planned releases (cfs)** determine whether water is available for flow management actions and the possible range of nesting season flows. Increased reservoir releases during ESH construction or vegetation management seasons will affect the opportunity to implement those actions.
4) **Tributary flows (cfs) and downstream stage (feet**) determine downstream effects of reservoir releases, thus influencing both routine flow management and flow modification actions. Unlike system storage, which changes slowly and relatively predictably, tributary flows and river stage may change abruptly due to precipitation events and thus cannot be forecasted very far in advance.
5) **Breeding population density (breeding adults/acre)** influences the need for habitat creation and predation management. If ESH availability is low but populations are small, less additional habitat is needed in the short term than if populations are large. Higher population densities attract predators, increasing proportional impacts on the bird populations. Predation management, particularly predator removal, is more practical to implement when birds are constrained to nest in limited areas.
6) **Budget ($)** determines the extent to which management actions can be implemented. Mechanical habitat construction and modification are most likely to be constrained by budget, but other management, monitoring, and research activities may also be constrained. The budget category also captures the effects of other logistical constraints that might only indirectly affect costs (e.g. contractor availability).

3.2.2.4 *Timing*

The utility of information for decision making depends upon its availability and timeliness (see Section 0). Hydrological information (system storage, stage) is available on a near-real-time basis. Other information is collected only periodically and model projections may be needed during the decision-making process. ESH imagery is acquired during the nesting season but must be processed prior to providing acreage estimates. The processing step requires 3-5 months to complete for all reaches. Population metrics are available in the fall once monitoring data has been compiled and reviewed for quality. Decisions made for upcoming years (Section 2.4.2) are based upon habitat and population information from two years prior to the year being planned for (e.g. information about habitat present in FY20 would be used in FY21 to determine the amount of construction planned for FY22; see Section **Error! Reference source not found.**). Projections can be made using observed and/or predicted flows to estimate ESH availability and other conditions for the upcoming or in-progress season.

3.2.3 Targets

Habitat and demographic targets for piping plovers, as specified by the USFWS (USFWS 2015, Buenau 2015), are described in this section. Because of the greater ESH acreage needs for piping plovers which defend territories for nesting and foraging, compared to colonially-nesting least terns, the USFWS has determined that meeting the plover habitat targets will also fulfill habitat needs for least terns on the Missouri River[1]. Therefore habitat targets for least terns have not been specified at this time.

Pending the delisting process for the least tern, conservation plans will be developed for the least tern under an ESA section 7(a)1 consultation process. The plan will include post-delisting management commitments. Should management commitments result in quantitative demographic targets for least terns, they will be added to the AM Plan. The USACE monitoring program will continue to monitor and record least tern metrics as per the USFWS post-delisting monitoring plan protocol (in development).

Targets are organized by sub-objective, each of which are necessary to ensure the fundamental objective is met. A description of how the EA models were used to develop targets and related analyses can be found in Buenau (2015). Additional information about how targets will be used in decision making is found in Section 3.6; Section 3.6.5 outlines decision processes for when targets are not met.

[1] As terns and plovers do not compete for food or use the same habitat for foraging, there are typically not conflicts between nesting plovers and terns, and they have not been observed to compete for space.

Fundamental Objective: Avoid jeopardizing the continued existence of the piping plover due to the USACE actions on the Missouri River.

Sub-objective 1 (Distribution): Maintain a geographic distribution of plovers in the river and reservoirs in which they currently occur in both the Northern Region (Missouri River from Fort Peck Lake, Montana to Fort Randall Dam, South Dakota, including reservoir shorelines) and Southern Region (Missouri River from Fort Randall Dam, South Dakota to Ponca, Nebraska)[1].

Means objective: Meet sub-objectives 2, 3, and 4 in both the Northern and Southern regions.

Sub-objective 2 (Population): Maintain a population of Missouri River piping plovers with a modeled 95% probability that at least 50 individuals will persist for at least 50 years in both the Northern and Southern Regions.

Means Objective (ESH): Provide sufficient ESH (in-channel riverine habitat) on the Missouri River to meet the persistence target.

Metric: Number of standardized and available ESH acres measured annually.

Target: From Table 2 in this document:

		Acres of Emergent Sandbar Habitat					
		Northern Region			Southern Region		
		2.5%ile	Median	97.5%ile	2.5%ile	Median	97.5%ile
Standardized ESH Acres		200	428	1996	264	782	3907
Available ESH Acres Exceeded for Percentage of Years	75%	140	210	470	280	370	700
	50%	380	630	1000	460	720	1580
	25%	770	1420	2010	780	1370	3285
	10%	1340	2230	3625	1130	2320	5275

Timeframe: Median standardized ESH targets (428 acres in the Northern Region; 782 acres in the Southern Region) must be met for 3 out of 4 years. Median available acres must be met or exceeded for the specified percent of years over a running 12-year interval.

[1] These regions correspond with two regions (Northern Rivers and Southern Rivers) of the four identified in the *Draft Revised Recovery Plan for the Northern Great Plains Piping Plover* (USFWS 2016). The Southern Region as referred to in this document, however, only refers to the Missouri River mainstem components and not tributaries.

Sub-objective 3 (Population Dynamics): Maintain a stable or increasing long-term trend in population size in both regions.

Metric: Population growth rate (lambda, λ): the ratio of population size N between the current year and previous year (N_t/N_{t-1}); calculated annually.

Target: $\lambda \geq 1$

Timeframe: The growth rate target must be met as a 3-year running geometric mean[1] calculated as the cube root of the product of the growth rates for each of the three years (i.e. $(\lambda_1 * \lambda_2 * \lambda_3)^{1/3}$).

Sub-objective 4 (Reproduction): Maintain fledgling production by breeding pairs sufficient to meet the population growth rate objectives within both the Northern and Southern Regions on the Missouri River.

Metric: Fledge Ratio: Number of fledglings observed/(number of breeding adults/2), calculated annually.

Target: ≥ 1.14 chicks fledged per breeding pair.

Timeframe: The fledge ratio target must be met as a 3-year running arithmetic mean.

If some or all of the targets are not met over the defined timeframes, a process to determine the cause of the shortfall and identify potential remedies is defined in Section 3.6.5. Note that while the inability of the program to meet targets may lead to reinitiation of Section 7 formal consultation with the USFWS, this occurs at the discretion of the USFWS and after the process described in Section 3.6.5 has been followed.

[1] The 3-year geometric mean is defined as the n^{th} root of the product of n numbers and is the appropriate calculation to describe the average of proportional metrics such as λ. The more familiar arithmetic mean, $(\lambda_1 + \lambda_2 + \lambda_3)/3$ would overestimate the actual population growth over the three-year period.

3.2.3.1 *Notes on derivation and application of targets*

3.2.3.1.1 *How targets were derived*

Hydrological, ESH, and plover population models were used to develop ESH targets. The suite of models was run for 50 years with 5,000 replicates for each trial. The trials assumed an ESH target for each reach to be met by annual ESH construction until an amount of ESH was provided that resulted in meeting the population objective: less than a 5% (± <0.1%) risk of dropping below 50 individuals at any point in the 50 years, within either of the two regions. Modeled hydrology based on basin runoff and depletions from the period of record of 1930-2012 was used under reservoir operating rules from the 2006 Master Manual; i.e. no flow modifications to create ESH. High flows within those operating rules that created ESH (e.g. 1997, 2011) were included and resulting ESH contributes to the targets. Fifty-year sequences of modeled reservoir releases over the period of record with random start years were used for each model replicate. A full description of the models used is provided in Buenau et al. (in prep). Model runs for targets are described more thoroughly in Buenau (2015).

ESH targets have been provided rather than plover population targets. Because of the dynamic nature of both riverine and reservoir habitat availability, long term (> 10-20 year) population persistence is driven much more strongly by habitat availability than by population size. That is, a relatively large population is unlikely to persist if sufficient habitat is not available in the long run. Smaller populations can persist and grow to larger sizes if sufficient habitat is available most years. If sufficient habitat is provided, population viability after 50 years is similar across a range of initial population sizes. Note that this does not indicate that population size is not important for populations in the short term as small population remain more likely to become very small or be extirpated if faced with several bad years or consistently inadequate habitat. A single target population size is difficult, if not impossible, to derive for multi-decadal persistence goals. If sufficient habitat is provided, population numbers are not expected to become small, and small populations should be able to rebound once habitat is provided. If populations become small despite sufficient habitat availability, identification of causes for unexpected outcomes (Section 3.5.11) is necessary to determine if other management actions are required to avoid jeopardy to the species. Further explanation and exploration of the use of habitat acres rather than population size is also included in Buenau (2015).

3.2.3.1.2 *Role of reservoir habitat and other habitat types*

While targets for reservoir shoreline habitat availability have not been specified, plovers nesting on reservoir shorelines are included in the modeling to develop ESH targets. Reservoir conditions and resulting plover productivity on shorelines influence the population viability in the Northern Region and thus the amount of ESH determined to be necessary on the Garrison Reach to meet viability targets. That is, bird populations on the reservoir count towards meeting the ultimate goal of population persistence. Good nesting conditions on the reservoirs reduce the amount of ESH required to meet population persistence targets. The current targets assume no significant changes to reservoir operations from the 2006 Master Manual. If reservoir operation rules change in a way that improves nesting conditions on the reservoirs and thus population viability in the Northern Region, targets should be recalculated to accommodate the changes and give "credit" to management actions that improve reservoir habitat. Conversely, if reservoir operations become more limiting to fledgling production, targets should be recalculated to ensure sufficient riverine habitat is available to support the population.

The habitat targets defined within this document are specifically for in-river ESH. If at some point birds use habitat types other than ESH as defined in this document or reservoir shorelines, and/or management actions involving the creation of other habitat types are broadly implemented (i.e. beyond pilot projects following determination of effectiveness), additional means objectives and associated metrics and targets for Sub-Objective 2 will be developed.

When evaluating demographic metrics (population growth rate and fledge ratio), birds nesting on reservoirs will be included. Evaluation of system state (see section 3.5.2) will include calculation of population metrics on both reservoirs and the riverine segments as well as the regions and river as a whole to understand system dynamics and guide management decisions. Good nesting conditions on the reservoirs can offset poor conditions on the river, and vice versa, in order to meet targets. The status of the populations is evaluated holistically; if populations are doing well and expected to continue to do well even if ESH acreage is below the median target, less focus will be placed on ESH construction and targets may be recalculated to address the current conditions. However, it is important to recognize that responses of plover populations to changes in habitat availability may lag in time by one or several years; the lack of an immediately apparent response to ESH availability dropping below target does not indicate targets are inaccurate.

3.2.3.1.3 *Time frame requirements*

Standardized targets are required to be met 3 out of 4 years. This frequency was calculated based on the proportion of time standardized ESH was above target in the model runs used to calculate the target values. A moving window of 12 years is used for available ESH. This allows for calculation of the exceedance probabilities over a meaningful time frame, long enough to accommodate naturally occurring periods of drought and high runoff that affect ESH quantities.

Three-year time frames were specified for the growth rate and fledge ratio parameters. These moving averages allow for brief periods of lowered productivity or population growth (e.g. high-water years that limit or preclude nesting; poor conditions on winter habitat that reduce overwinter survival and population size). At the same time, they are short enough to be responsive to management actions and provided indication of potential problems in time to intervene. Other time frames could be considered if the 3-year interval is found inadequate for supporting management decisions.

3.2.3.1.4 *Use of fledge ratios to measure productivity*

Fledge ratios are used to measure productivity rather than simple counts of fledglings. Fledgling numbers are valuable information, but must be understood in the context of the number of adult birds nesting on the MRMS. For example, 200 fledglings produced by 200 adults would produce a fledge ratio of 2, which indicates excellent potential for population growth and that habitat is not limiting the population. The same 200 fledglings produced by 600 nesting adults would produce a fledge ratio of 0.67, which is not sufficient to support a stable or growing population and suggests that habitat may be limiting reproductive success. The use of fledge ratios to measure productivity versus measuring nest success and chick survival is a topic of continued discussion. Considerations include accuracy, cost, disturbance and feasibility of monitoring to acquire the necessary information to use one or more of these metrics to sufficiently estimate breeding success on Missouri River habitats.

Fledge ratio targets were derived from the population models. The relationship between the fledge ratio for a given year and λ the following year over a number of model scenarios was used to calculate a fledge ratio that, on average, corresponded with $\lambda = 1$ (a stable population.) Thus the target fledge ratio is an estimate of the fledgling production per pair required to support a stable population. By meeting or exceeding this fledge ratio, the population would be expected to remain stable or grow, respectively, other factors remaining equal. These targets are minimum values; if population density is low, higher values are to be expected and necessary to support a stable or growing population.

Targets for ESH and fledge ratios are dependent upon current system knowledge, as synthesized in the hydrology, habitat, and population models, and upon current conditions including climate, sediment supply, reservoir management practices, and conditions in wintering habitat. As knowledge increases and/or conditions change, the targets described in the AM Plan will likely no longer accurately reflect ESH amounts and demographic rates necessary to meet population viability goals. Target values should be updated periodically or following significant changes to models or conditions (see Section 3.6.5)

3.2.3.2 *Incidental Take*

Incidental take consists of harm or harassment to threatened or endangered species that may occur during an otherwise lawful activity that is not the purpose of the activity. In the context of the MRRP, incidental take refers to negative effects upon plover reproduction and survival caused by system operations to serve authorized purposes and implementation of the actions described in the MRRMP-EIS and AM Plan. The USFWS generally recognizes that some incidental take is anticipated, but that the USACE will seek to minimize such take. Included in the issuance of a new Biological Opinion, the USFWS will provide an Incidental Take Statement that will include a statement of anticipated incidental take and reasonable and prudent measures, with accompanying terms and conditions, to minimize take. When the statement is available, the AM plan will incorporate the requirements and appropriate considerations related to monitoring and implementation.

3.2.4 Management Actions

Management actions for birds serve three general functions: 1) create habitat with construction or flows, 2) improve habitat quality or availability through construction, modification, or flows, or 3) directly protect nests, chicks, and/or adults to improve survival. A set of potential actions for birds was identified and evaluated in the EA. Those actions, and several additional actions identified since the initial EA process, are listed with their associated critical uncertainties and management hypotheses in Table 19. As described in Section 3.2.1, a subset of these actions were evaluated as part of management alternatives in the DEIS. Some actions were included in all alternatives, while others were included in only one of the 6 alternatives.

A preferred alternative has been identified for the DEIS and a selected alternative will be described in the ROD. (This process is described in Section 2.2.5). This version of the AM Plan reflects the determination of a preferred alternative but not the ROD. As the set of actions selected for implementation may change prior to the ROD or during AM following the ROD, this document retains the broader set of management actions and associated decision criteria. They are organized into three sections within this document:

1) Actions that have been evaluated in the EIS and identified as part of the Preferred Alternative. If included in the ROD they would be available for full implementation.
2) Actions evaluated in the EIS but not identified as part of the Preferred Alternative. Following the ROD, this section will include actions in the EIS not included in the Selected Alternative. They would not be available for full

implementation after the ROD, but may be explored through research and pilot-scale implementation.

3) Actions not evaluated in the EIS. They would not be available for full implementation after the ROD, but may be explored through research and pilot-scale implementation. These actions would need supplemental programmatic EIS analysis if later chosen for full implementation.

Table 20 summarizes how the bird management actions have been addressed in the EIS and how they are organized in this chapter.

Table 20. Summary of management actions for birds, their primary mechanism, whether they have been evaluated for the MRRMP-EIS and in which alternatives, and whether or not they have been included in the preferred alternative in the DEIS. References to the section of this document in which the action can be found are also listed.

<table>
<tr><th>Action</th><th>Function</th><th>Evaluation in EIS</th><th>In Preferred Alternative?</th><th>Section</th></tr>
<tr><td>Sandbar construction in river channel</td><td>Create habitat</td><td rowspan="6">Yes; all alternatives</td><td rowspan="6">Yes</td><td rowspan="6">3.2.4.1</td></tr>
<tr><td>Sandbar augmentation and modification</td><td>Create habitat; Improve habitat quality</td></tr>
<tr><td>Vegetation management</td><td>Improve habitat quality</td></tr>
<tr><td>Flow management to avoid take</td><td>Population protection</td></tr>
<tr><td>Predation management</td><td>Population protection</td></tr>
<tr><td>Human restrictions measures</td><td>Population protection</td></tr>
<tr><td>Habitat-forming flow release (fall)</td><td>Create habitat</td><td>Yes; Alternative 5</td><td rowspan="3">No</td><td rowspan="3">3.2.4.2</td></tr>
<tr><td>Habitat-forming flow release (spring)</td><td>Create habitat</td><td>Yes; Alternative 4, 2*, 6*</td></tr>
<tr><td>Lowered nesting season flow</td><td>Improve habitat availability</td><td>Yes; Alternative 2**</td></tr>
<tr><td>Reservoir habitat creation (shoreline)</td><td>Create habitat</td><td rowspan="4">No</td><td rowspan="4">No</td><td rowspan="4">3.2.4.3</td></tr>
<tr><td>Reservoir habitat creation (island)</td><td>Create habitat</td></tr>
<tr><td>Habitat creation connected to river channel</td><td>Create habitat</td></tr>
<tr><td>Reservoir water level management to provide/improve shoreline habitat</td><td>Improve habitat availability</td></tr>
</table>

*The spawning cue flows in Alternatives 2 and 6, while not designed to create ESH, may create some ESH in the spring when conducted, depending on magnitude and duration.
**Evaluated based on the flows prescribed in the USFWS 2003 Amended Biological Opinion, not based on outcomes of the Effects Analysis.

3.2.4.1 *Actions and Decision Criteria for Full Implementation (Included in Preferred Alternative in the DEIS)*

> **Note:** Some decision criteria have yet to be specified and are being developed through the collaborative process. Where criteria are not final, examples are provided, enclosed in “< >” in this draft. Further analyses, comments from the EIS review process, and deliberations among the agencies and MRRIC will be used to establish the criteria initially implemented under the AM Plan.

The actions described in this section have been evaluated in the MRRMP-EIS and included in the preferred alternative. If included in the ROD they will be available for program-wide implementation. Actions in this section are analogous to Level 4 actions as described for pallid sturgeon (Section 4.2.1.1).

3.2.4.1.1 *Sandbar construction*

Definition and function: Sandbar construction creates in-channel ESH using dredges and earth-moving equipment to provide nesting habitat. Sandbars are constructed to the desired condition including foraging habitat at a range of river stages.

Implementation criteria: The predictive ESH model is used to determine how many acres of sandbar habitat are needed to meet the standardized ESH target with a 60% chance of remaining above the median standardized ESH target for the next 2 years. If existing ESH is above the target, construction will begin if the acreage is expected to drop below target in the next 2 years. If logistics or funding does not allow for all necessary construction, river segments with higher plover population densities and lower fledge ratios and/or population growth rates will receive priority. Planning for construction on Garrison Reach will also consider current and expected conditions and productivity on the reservoirs; a more robust river sub-population may be required to support the northern region population objective if reservoir sub-populations are doing poorly. Model predictions of a range of options should be used to determine the best expected outcome for construction allocation.

Sandbars can be constructed in the spring after ice melts and before birds arrive in early May, or in the fall, after all birds have left and before ice forms (September through October or November.) To avoid inefficiencies, ESH should not be constructed in the season prior to a planned flow release to create habitat.

ESH construction sites are identified and prioritized using the ESHERs spatial decision support system tool developed by ERDC. Potential sites are selected and prioritized using three general criteria: avoidance of sensitive resources, utilization of areas of natural sand accumulation, and nesting history of terns and plovers. Staging areas must be available nearby, and may incur additional costs. Attachment 6 of Appendix G provides further description of the ESHERs tool.

Constraints: Flows should be less than 35 kcfs for construction to be practical and effective. Sandbars should be located in areas where flow velocity and resulting erosion are expected to be low; depending on the extent and locations of existing ESH, vegetated bars, and islands, highly suitable sites for new construction may become limiting. Additional practical and regulatory constraints may apply, depending on location.

Performance metrics: Acreage of standardized and available ESH on constructed sandbars over time is used to track total area and sandbar longevity. Nesting site selection and fledge ratios are used to assess the effectiveness of constructed habitat and its contribution to overall population dynamics. Metrics for nesting vs. foraging habitat and overall habitat quality will developed under the AM Plan.

Human considerations metrics: Metrics for assessing whether constructed ESH has any impact on HC interests, particularly as relates to localized flooding, ice jam formation, bank erosion and localized scour and deposition of sediments are under consideration. The AM Team and agency technical specialists engaged in a screening exercise to identify concerns and potential monitoring and assessment needs related to those concerns. The HC Team will, as its central charge, make recommendations for monitoring needs and priorities as part of the WP development process (see Section 2.4.4). Those deliberations will help determine which metrics may be employed.

Uncertainties, research and active AM: Previous research and monitoring has provided substantial evidence for the general suitability of constructed sandbars for plover and tern nesting. The amount of habitat needed to support resilient bird populations (ESH targets) and the rate it must be created are uncertain. Improvements in ESH and bird modeling, supported by research and monitoring, will result in more accurate estimates (see Section 3.3.7 for examples).

While the amount of habitat is known when ESH is created, habitat longevity and quality over time is uncertain, both scientifically and because of variable conditions (flow, wind and ice scour). How to most efficiently and effectively construct sandbars can be answered through tests of different approaches and assessments of related performance metrics (Table 21). At minimum, annual evaluations of habitat and bird productivity should incorporate information about sandbar size, form, and landscape context. Sandbars deliberately constructed with a range of characteristics will increase the potential for learning about optimal project design. Experimental design of sandbars should include at least 3 years of monitoring of treated and control sites.

Table 21. Questions and study summaries for ESH construction research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty: What is the most effective and efficient way of creating habitat within the larger context of management and uses of the Missouri River?			
Associated Hypotheses: Mechanical habitat creation increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Mechanical habitat creation increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.			
How large should sandbars be? Are single large sandbars or several small more effective?	Construction of one large and one or more small sandbars during the same year, controlling for as many landscape and location factors as possible.	ESH area, foraging habitat and nesting habitat area, # adults, # fledglings.	Assess effect of sandbar area on productivity with historical sandbars; control for age, vegetation, landscape features.
What ratio of nesting to foraging habitat is necessary to support successful productivity?	Construction of sandbars of similar size but different nesting/foraging habitat ratios during the same year.	ESH area, foraging habitat and nesting habitat area, # adults, # fledglings.	Assess historical sandbar edge/area and other metrics and site selection/ fledgling production.
Where should sandbars be constructed relative to other sandbars used for nesting?	Construct new sandbars of similar size and design during the same year at a range of distances from sandbars currently used for nesting.	Site fidelity, adult and nest density, movement between sites, probability of human disturbance.	Assess use of historical sandbars relative to distance from other sites used for nesting.
Where should constructed sandbars be located relative to landscape features?	Construct new sandbars of similar size and design during the same year at different distances from key landscape features, including distance to trees, width of river, distance from the dam.	ESH area, # adults, # fledglings, predation rates, probability of human disturbance.	Assess use of historical sandbars relative to distance from landscape features.
Is adequate substrate currently available for creating sandbars? Does enough course material remain to support creation of new habitat? Does enough fine nutrient-rich material exist to create adequate foraging habitat?	Assess sediment samples throughout river reaches; compare to any samples or assessments taken prior to the 2011 flood. If possible, manipulate sediment composition on constructed sandbars.	ESH area, foraging habitat and nesting habitat area, # adults, # fledglings, forage quality (prey surveys).	
What ESH construction techniques are most cost-effective? What techniques can be used independent of flow magnitude? What construction strategies are most resilient?	Assess ESH developed using alternative construction methods (e.g. hydraulic dredging, mechanical dredging, placement of structures to trap sediments), including alternative containment/stabilization materials and designs.	Cost per unit area of standardized ESH; maximum annual production levels; erosion rates; range of implementable flows	

Criteria for adjusting action: *During implementation* of construction projects, adjustments may be required to accommodate unexpected flow conditions. Contingency plans should be included with sandbar design to accommodate changes to conditions that would affect the outcome. *After implementation of projects:* Results from annual habitat evaluations and experimental design of sandbar construction will help determine best practices for sandbar location and design. These results, along with observations and recommendations from the Bird Team or Technical Team, will be captured in annual reporting and used to inform future project design. *Programmatic adjustments:* If the rate of habitat construction needed to meet targets estimated by the model is not producing the desired results, there may be bias in the model and/or flows are consistently in more or less erosive ranges than expected. If effective adjustments to the ESH model or hydrological predictions cannot be made, adjustments to the criteria for determining how much to implement and when may be needed.

Decision and collaboration level: The Management Team allocates budget and other resources to ESH construction, based upon recommendations of the Bird Team and the balance of other MRRP needs. The Bird Team and implementation staff decides the location, methodology, and design of construction activities based on best practices, and the assigned PM manages contracts and monitoring. MRRIC is informed through the WP. See Section 2.4.4.

3.2.4.1.2 *Flow management to avoid inundation of nests or chicks*

Definition and function: Once birds have initiated nesting, reservoir releases are managed to minimize nest inundation or chick stranding by using a steady release/flow-to-target release strategy. This approach recognizes that tributary inflows below Gavins Point Dam typically decrease over the summer, potentially requiring increases in releases from Gavins Point in order to meet downstream navigation targets. Such increases can inundate nests at low elevations or inundate entire sandbars, leading to mortality of pre-fledged chicks. By setting releases somewhat higher than necessary to meet navigation targets at the beginning of the nesting season, later increases can be avoided.

Implementation criteria: Steady releases are set in May based upon forecasts and navigation expectations. Increases in flow above the elevation of known nests are avoided to the extent possible. Short-term reductions in releases from Gavins Point Dam may be used in cases of high discharge from downstream tributaries, to reduce flood risk; if reductions are short enough that birds do not initiate nests at lower elevations, releases can be returned to higher levels once downstream flood risks have passed with low risk of take. Once eggs have hatched, releases can be increased gradually as needed to meet navigation targets. The initial steady release is set in anticipation of reduced tributary flows later in the summer to limit the necessary increase. The range of flexibility for flows depends upon the sandbar elevation profiles relative to target releases and resulting river stage. Releases may also be adjusted to avoid having low-elevation sandbars just above the river stage that attract nesting birds but are likely to be inundated.

Constraints: Releases from Gavins Point are also managed to meet flood control, navigation, and water supply needs.

Performance metrics: Releases (cfs) during nesting season (including slope and direction of changes), number of nests inundated, chick mortality, fledge ratios.

Human considerations metrics: Flow and stage are regularly monitored by the MRBWMD at several locations on the Missouri River and serve as the basis for monitoring of outcomes of flow management actions. No additional direct monitoring of HC metrics is envisioned for this management action; however, additional studies may be undertaken and additional metrics may be employed to address flow management following the guidance and process outlined in Sections 2.3.3.2 and 5.5.5.

Uncertainties, research, and active AM: The effectiveness of flows to avoid inundation of nests or chicks is assessed by observations during the nesting season, but nest detection is not perfect. Loss of chicks is difficult to attribute to specific causes. Flow management during the nesting season may also cause sub-lethal stress by inundating foraging habitat or decreasing forage quality. Erosion rates may be affected when flow is varied to meet downstream targets. Targeted research may be required to determine lethal and sublethal effects of nesting season flow management and effectiveness of steps to reduce those effects (Table 22). Inundation risk is difficult to model beyond the current season given current capabilities. Information on sandbar and nest elevation, together with model refinements, would improve predictions.

Criteria for adjusting action: *During implementation:* flows are adjusted in response to downstream flood control targets and navigation, information from productivity monitoring on nest elevations and at-risk nests, in balance with meeting other authorized purposes. *After implementation:* Effects of flow management on egg/chick mortality and outcomes of research may be used to adjust implementation rules, with consideration of HC effects. This may require adjustments to the Master Manual.

Table 22. Questions and study summaries for research and active AM regarding flow management to reduce take.

Question	Study Summary	Metrics	Related studies
Management Uncertainty: To what extent can population protection actions positively contribute to the success of birds on the Missouri River?			
Associated Hypotheses: Steady or declining river flows during the nesting season increases survival from egg to chick and chick to fledgling by reducing the risk of nest inundation and chick stranding and by maintaining or increasing foraging habitat.			
What are the predicted effects of different magnitudes, durations, timing and frequencies of flows to reduce take on ESH, species, and HC metrics?	Modeling studies to assess a range of flow options; should be repeated following significant new information for ESH, population, and/or HC models as needed.	ESH acres (standard and available); fledgling production; population size; HC metrics (TBD)	
How do flow increases in July/August affect breeding success directly by flooding nests or by stranding chicks?	Additional focused monitoring of effects of flow increases during nesting season; if possible, explore range of flow increases when navigation requirements allow.	Nest success; egg loss; chick mortality.	Assessments of flow variability effects on nest success and chick mortality within normal operations (detection of chick mortality and ability to associate with cause is low with historical monitoring).
How do flow increases in July/August affect breeding success indirectly (starvation, etc.)?	Additional focused monitoring of effects of flow increases during nesting season; if possible, explore range of flow increases when navigation requirements allow.	Forage habitat; prey density and diversity; chick growth and weight.	Assessments of flow variability effects on forage habitat availability within normal operations currently or historically.
What are the effects of nesting season flow changes on erosion of ESH?	Additional focused monitoring of effects of flow increases during nesting season; if possible, explore range of flow increases when navigation requirements allow.	ESH acres; nesting and foraging habitat metrics; elevation profiles.	Assessments of flow variability effects on ESH area and nesting/foraging habitat within normal operations. Geomorphic assessments and monitoring of stage/area relationships.
What are the effects of flows to reduce take on HC metrics?	See Chapter 5		

Decision and collaboration level: These flows are routinely implemented by Water Management. Changes to operations needed to address unusual circumstances will be made by Water Management following guidelines in the Master Manual. Changes to how these flows are operated must be approved by MRBWMD at the Oversight level.

3.2.4.1.3 *Sandbar augmentation and modification*

Definition and function: Existing sandbars can be augmented or modified to increase ESH area and elevation and/or improve the quantity and quality of foraging habitat across a range of likely river stages. Modifications may include reshaping to increase edge/area ratios and reduce slopes or cutbanks. Augmentation or modification may be combined with vegetation removal.

Implementation criteria: Augmentation and modification should be used when practical to extend the life of existing sandbars at reduced cost. Preference may be given to sites with sufficient nesting area but low quantity or quality of foraging area. Quantitative criteria and thresholds for ratio of nesting area to foraging area will be determined in the course of AM. Sites with low nesting use relative to area, and sites with lower fledge ratios than expected may be suitable candidates for modification. Modification of existing sandbars may be contraindicated, however, if predation, human activity or other persistent or recurring disturbances have been observed to affect fledgling production or adult survival.

Constraints: Similar to sandbar construction, though modifications may require less time, budget, and equipment than the creation of new sandbars. Implementation is only meaningful when sandbars are of moderate age. It may not be practical to reshape highly degraded sandbars, or as efficient for overall habitat creation as building new sandbars.

Performance metrics: Acreage of standardized and available ESH on constructed sandbars over time is used to track total area and sandbar longevity. Nesting site selection and fledge ratios are used to assess the effectiveness of constructed habitat and its contribution to overall population dynamics. Metrics for nesting vs. foraging habitat and overall habitat quality will developed under the AM Plan.

Human considerations metrics: None identified. HC Impacts from augmentation would likely be similar in type but of lesser magnitude than those that might be identified during new construction. The AM Team and agency technical specialists engaged in a screening exercise to identify concerns and potential monitoring and assessment needs related to those concerns. The HC Team will, as its central charge, make recommendations for monitoring needs and priorities as part of the WP development process (see Section 2.4.4). The outcome of those deliberations will determine which metrics (if any) may be employed.

Uncertainties, research and active AM: Little information currently exists on how suitable modified habitat would be relative to newly created sandbars. Before-after-control-impact experiments with sandbars of similar size and shape to track evolution of the sandbars and bird use and productivity would provide evidence for effectiveness. Comparisons of bird use of and productivity on modified sandbars compared to constructed or flow-created sandbars, using multivariate analysis to control for sandbar size, age, and other factors, should be used to test the effectiveness of modified sandbars and/or particular designs of modified sandbars . Sandbar modification studies are listed in Table 23.

Table 23. Questions and study summaries for sandbar augmentation and, modification research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty: To what extent can maintaining existing habitat contribute to population objectives compared to creating new habitat?			
Associated Hypotheses: Augmentation/reshaping of existing sandbars increases nesting/brood-rearing and foraging area, which increases survival of eggs to chicks and chicks to fledglings by reducing predation and increasing food availability. Augmentation/reshaping of existing sandbars increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.			
How does sandbar modification influence use of sandbars by nesting plovers and fledgling productivity? Under what conditions should sandbars be modified?	Modify selected sandbars and compare with unmodified sandbars of similar characteristics; use before-after-control-impact study design.	ESH acres; nesting and foraging habitat; elevation profiles; bird use and fledgling production.	Once general effects of modification have been studied, effects in conjunction with vegetation modification should be evaluated.
What ratio of nesting to foraging habitat is necessary to support optimal productivity?	Modify selected sandbars and compare with unmodified sandbars of similar characteristics; use before-after-control-impact study design.	ESH area, foraging habitat and nesting habitat area, # adults, # fledglings.	Assess historical sandbar ratios of nesting to foraging habitat and other metrics and site selection/fledgling production.
What designs for modification of sandbars are effective?	Compare modification techniques on otherwise similar sandbars; use before-after-control-impact design.	ESH area, foraging habitat and nesting habitat area, # adults, # fledglings.	Once general effects of modification design have been studied, effects in conjunction with vegetation modification should be evaluated.
Does modified ESH have higher predation risks than new construction?	Measure predation rates on modified sandbars and similar new sandbars.	Predation observations; fledge ratios	May overlap with studies for vegetation modification

Criteria for adjusting action: *After implementation:* adjustments may be needed if modifications do not last. If performance metrics do not respond as expected, than either modification methods were not well-designed of sufficient in magnitude, location is unsuitable (e.g. especially vulnerable to erosion due to proximity to thalweg) or unusual flows adversely affected the habitat form. If modified sandbars are less used or less productive than newly constructed bars or predation increases, and problems cannot be corrected, the overall effectiveness of modification as a tool for habitat management should be reevaluated. Cost-effectiveness should be considered with the aid of modeling to determine value of continuing modifications (e.g. do large amounts of moderate quality modified habitat produce as many birds as small amounts of high quality newly-constructed habitat for the same or lesser cost.)

Decision and collaboration level: The Management Team decides on the budget available for habitat modification as well as construction, as informed by the Technical and Bird Teams. The Bird Team and implementation staff decide on location, methodology, design and contracting based upon identified best practices. MRRIC is informed through the work plan.

3.2.4.1.4 *Vegetation management*

Definition and function: Vegetation management includes any non-flow means of reducing or preventing vegetation growth on sandbars to improve ESH area and quality and reduce predation. Spraying post-emergent herbicides in the fall, aerially or via land-based equipment, is thought to be an effective means of controlling vegetation. Mowing may be used on established vegetation, but removal or burning of biomass will generally be required if treated habitat is to attract nesting birds.

Implementation criteria: Vegetation management should be implemented whenever possible on early vegetation growth, before woody vegetation such as cottonwoods and willows become established. Larger areas may be treated more effectively and quickly through aerial applications.

Constraints: The extent of sandbar area that can be gained through vegetation control is limited to the amount of vegetated area in early successional states. Vegetation control may not be implementable if flows are too high during the fall, though higher flows of sufficient duration may also remove vegetation or limit growth. Limits on the use of herbicides might restrict application in certain locations.

Performance metrics: Area of standardized ESH and reduction in vegetated area; bird nesting use and fledging success on vegetation-managed habitat.

Human considerations metrics: MRRIC members have previously expressed concerns about water quality when spraying is implemented. The AM Team and agency technical specialists engaged in a screening exercise to identify concerns and potential monitoring and assessment needs related to those concerns. The HC Team will, as its central charge, make recommendations for monitoring needs and priorities as part of the Work Plan development process (see Section 2.4.4). The outcome of those deliberations will determine which metrics (if any) may be employed relative to vegetation management.

Uncertainties, research, and active AM:: An initial before-after-control-impact study suggests that spraying is effective at reducing the establishment of emergent vegetation, but additional evidence of vegetation dynamics on treated sandbars and bird use and productivity is necessary. Experimental spraying, mowing, and burning of *Phragmites* on sandbars in the Lewis and Clark Lake delta is underway to determine if effective removal is possible. Comparisons of bird use of and productivity on vegetation-managed sandbars compared to constructed or flow-created sandbars, using multivariate analysis to control for sandbar size, age, and other factors, should be used to test the effectiveness of vegetation management and/or particular methodologies.

Criteria for adjusting action: *After implementation:* if vegetation-managed sandbars are not used for nesting at levels comparable to newly created sandbars, and/or fledgling production is not comparable, use of methodologies should be reevaluated. The AM process will identify thresholds that should be exceeded for continued application. (E.g. if bird use of a treated site is less than <50%> of comparable unvegetated sites or if fledgling production is less than <75%> of comparable sites or target fledge ratios, then the methodology or choice of sites should be reevaluated.) Cost-effectiveness should be considered with the aid of modeling to determine value of continuing management (e.g. do large amounts of moderate quality vegetation-managed habitat produce as many birds as small amounts of high quality newly-constructed habitat for the same or lesser cost.)

Table 24. Questions and study summaries for vegetation management research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty: To what extent can maintaining existing habitat contribute to population objectives compared to creating new habitat?			
Associated Hypotheses: Vegetation removal increases survival of eggs to chicks and chicks to fledglings by reducing predation (by increasing nesting/brood-rearing area and by removing cover for predators). Vegetation removal increases nesting/brood-rearing and foraging area, which increases survival of chicks to fledglings by increasing food availability. Vegetation removal increases nesting/brood-rearing and foraging area relative to the condition and availability of habitat at other breeding areas, thus increasing the number of adults through net immigration from other areas.			
Does spraying vegetation reduce the amount of vegetation on sandbars to provide for suitable nesting habitat?	Spraying of test sites with before-after-control-impact design (some studies already conducted/underway). Age, successional stage, and species of vegetation must be taken into account.	Transects and imagery assessments of vegetation before and after treatment and relative to control sites; bird use and productivity at treated vs. control sites; predation rates.	Once understanding of effects of vegetation modification, may experiment in conjunction with sandbar augmentation.
Can Phragmites and other wetland vegetation be successfully removed from sandbars in the Lewis and Clark Lake delta?	Spraying, mowing, and burning of wetland vegetation on Lewis and Clark Lake sandbars (study underway). Age, successional stage, and species of vegetation must be taken into account.	Transects and imagery assessments of vegetation before and after treatment and relative to control sites; bird use and productivity at treated vs. control sites; predation rates.	

Question	Study Summary	Metrics	Related studies
What are the successional dynamics/revegetation rates of sandbars following flow creation, mechanical creation, or vegetation management action? Are they different between habitats created by different methods? How have these activities influenced the seed source for revegetation?	Treatment of test sites on habitat previously created, modified, and/or treated through different means.	Transects and imagery assessments of vegetation following the management action annually. Take core samples to measure seed bank.	
What are the direct or indirect effects on invertebrate prey base for piping plovers from vegetation control, either through the loss of vegetation or effects of herbicides on prey (if any). How does the effect on prey base affect productivity?	Spraying of test sites with before-after-control-impact design.	Measure invert abundance along transects and organic nutrient content, Transects and imagery assessments of vegetation before and after treatment and relative to control sites; bird use and productivity at treated vs. control sites. Measure for residual herbicide.	
How does vegetation (species, density, distribution, etc.) affect erosion rates for ESH and what are the tradeoffs between erosion and productivity?	Assess bars with different vegetation conditions using a BACI study design.	Erosion rate and productivity as a function of vegetation type, density, distribution, location on the bar, and age.	Constructed bars with vegetation used to assess construction strategy or design.
Does vegetation-controlled ESH have higher predation risks than new construction?	Measure predation rates on modified sandbars and similar new sandbars.	Predation observations; fledge ratios	May overlap with sandbar modification studies.

Decision and collaboration level: The Management Team decides on the budget available for vegetation management as well as construction, as informed by the Technical and Bird Teams. The Bird Team and implementation staff decide on location, methodology, design and contracting based upon identified best practices. MRRIC is informed through the work plan

3.2.4.1.5 *Predation management*

Definition and function: Predation management includes nest caging for plovers and predator removal to reduce mortality of eggs, nests and adults and increase fledge ratios. Nest caging is not suitable for terns.

Implementation criteria: Nest caging should be initiated when the density of both plovers and terns exceeds a threshold (TBD during AM process) or when predation effects begin to be observed. The presence and extent of vegetation, connectivity to shore, proximity to trees, and other factors that increase predation risk should be considered when determining the need for predation management.

Constraints: Effectiveness is primarily linked to the ability to detect nests (for caging) and detect and remove predators. Predation rates are typically lower and management less necessary when bird population densities are low (habitat is relatively abundant); thus benefits gained from management are primarily observed when densities are high. Caging of plover nests can result in increases in mortality for adult plovers.

Performance metrics: Predation observations (it may not be possible to estimate rates); number of predators removed; nesting success and fledgling production on sandbars with predation management.

Human considerations metrics: None identified. Relevant metrics that emerge from the MRRIC engagement will be added to the next version of the AM Plan.

Uncertainties and opportunities to improve management decisions: A relationship between population density and predation has not been quantified, nor have thresholds been identified due to limited data. Causes of nest loss and chick mortality are not always known, and mortality may be undetected, especially for new nests and chicks near fledging. Some data exists for effectiveness of nest caging and predator control and effects of cages on adult mortality, but most data has been collected on other habitat types (e.g. alkali wetlands, ocean beaches) rather than the MR and high uncertainty remains about effectiveness. Enhanced monitoring or research to detect predation, quantify density-predation relationships, and identify other risk factors at the local or landscape scale as well as experimental design of management practices would aid in measuring effectiveness and predicting population impacts. The use of cameras to detect predators has been studied and may provide useful data in lieu of more extensive monitoring.

Table 25. Questions and study summaries for predation control research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty: To what extent can population protection actions positively contribute to the success of birds on the Missouri River?			
Associated Hypotheses: Predation removal increases survival of eggs to chicks and chicks to fledglings.			
At what acreage and nest density does predation have significant population effects?	Increase monitoring at study sites to improve detection of predation (may be able to use cameras).	Presence/absence of predators and predator evidence. Percent of nests lost to predation through the field season relative to ESH area and nesting density.	

Question	Study Summary	Metrics	Related studies
What are the predominant predators? Do they vary spatially? Does predation decrease as the field season progresses (as other species initiate nests or predators tend to their own young)? Does this decline then allow for adequate productivity rates to support a growing population? Does it vary predictably year to year?	Evaluate presence/absence of predators and predator evidence and the rates of predation on nests and chicks throughout the field season. Identify predominant predators. Assess predator type spatially along the river corridor.	Presence/absence of predators and predator evidence. Percent of nests lost to predation through the field season and year over year. Shifts in predator composition with space and time.	
Can we successfully implement predation management actions? Under what conditions (if any) can predation management be successful?	Implement predation control program measured against similar habitat areas with no predation control	Successful nests, # of fledglings compared to similar non-treated areas	If predation management is successful - determine the factors that created success

Criteria for adjusting action: *During implementation:* observations of high density nesting and/or predation trigger initiation of or increases in management, if resources allow, during the nesting season. *After implementation:* Experimental design of management practices and/or more intensive monitoring should be used to assess effectiveness of predation management and identify adjustments.

Decision and collaboration level: Implementation staff decide on amount and locations as informed by the Technical Team, Bird Team, and ongoing monitoring during the season.

3.2.4.1.6 *Human restrictions measures*

Definition and function: Human restrictions measures include signs and symbolic fences, as well as education, to restrict people from entering nesting areas. These measures are intended to reduce stress on birds and decrease mortality of eggs, chicks, and adult from people, vehicles, and pets.

Implementation criteria: Generally implemented for all sandbars where nesting is observed. Not always used on isolated areas of reservoir shoreline with low human activity.

Constraints: Human restriction measures require low effort and resources to implement, but are difficult to enforce.

Performance metrics: Evidence of nest/chick loss attributable to human activity (detection rates may be low); evidence of human presence on sandbars; nesting and brood-rearing success on sandbars with human restriction measures in place.

Human considerations metrics: Human restriction measures limit access to sandbars for recreation during the nesting season. Relevant metrics that emerge from MRRIC engagement will be added to the next version of the AM Plan.

Uncertainties, research, and active AM: As with predation, the effects of human activity are not well known as not all nests are detected and not all cause of egg/chick loss can be accurately identified. Adverse, especially sublethal, effects of human disturbance (stress, impacts on foraging) are difficult to quantify. Thus the contribution of the action to population dynamics is difficult to estimate and predict.

Criteria for adjusting action: *During implementation:* observations of problematic human activity or nesting in known sites of high activity trigger increased management during the nesting season. *After implementation:* Experimental design of management practices and/or more intensive monitoring should be used to assess effectiveness of human restrictions measures and adjust as necessary.

Decision and collaboration level: Restriction measures are implemented by default; the Bird Team and implementation staff make any necessary decisions on locations and methods.

Table 26. Questions and study summaries for human restrictions measures research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty To what extent can population protection actions positively contribute to the success of birds on the Missouri River?			
Associated Hypotheses Human restriction measures reduce human activity on nesting and foraging habitat, increasing survival both by decreasing direct mortality and indirect effects on survival caused by stress.			
What level of human activity occurs on sandbars with and without signs? How often do lethal impacts occur?	Observation of control and treated sites, particularly during weekends/holidays, to observe effectiveness of signing or other restriction measures.	Evidence of human activity. Number/percent of nests lost to human impacts through the field season relative to sandbar location and management activities.	Monitoring/cameras to detect predation may also increase detection of human activity.

Question	Study Summary	Metrics	Related studies
Are there alternative measures of reducing human activity in nesting areas that are more effective?	Observation of sites with alternative restriction measures, particularly during weekends/holidays, to observe effectiveness of signing or other restriction measures.	Evidence of human activity. Number/percent of nests lost to human impacts through the field season relative to sandbar location and management activities.	

3.2.4.2 *Actions for Research and Pilot-Scale Implementation (Evaluated in the MRRMP-EIS)*

Actions described in this section were evaluated in the EA and as part of the alternatives in the DEIS and found to have beneficial effects for plovers, but were not included in the preferred alternative. If it is determined after the ROD that there is need for these management actions, steps will be taken prior to implementation that may include additional NEPA processes if the EIS analyses no longer suffice. Additional decision documents and changes to the Master Manual may also be required before full implementation. (Section 1.1.6).

Uncertainty remains about the effectiveness of actions in this section. The AM process may take advantage of events occurring within typical system operations (e.g. high or low releases necessary according to the current Master Manual) to conduct research about the potential effects of flow modifications. The research and pilot-scale implementation (e.g. flow tests) described in this section are roughly analogous to Level 1 and Level 2 actions for pallid sturgeon (Section 4.2.1.1). However, unlike for sturgeon, timelines have not been established for implementation of these studies or actions, as the set of actions in the preferred alternative have been determined during the EIS process as able to meet piping plover targets. Pilot projects or flow tests may be implemented using site-specific NEPA processes or within the scope of water management rules following the ROD and any ensuing Master Manual revisions.

Changes made to the set of bird actions included in the selected alternative as identified in the ROD could result in changes to this section of the Plan.

3.2.4.2.1 *Habitat-forming flow release*

Definition and function: Releases exceeding 30kcfs from Garrison Dam, 40kcfs from Ft. Randall Dam, and 50kcfs from Gavins Point Dam are expected to deposit more sand than is eroded, increasing the amount of standardized ESH. The amount of ESH created depends on the magnitude and duration of the flow release and the area of sandbar present prior to the release (ambient ESH). These flows occur occasionally when high runoff requires above-normal releases, but have not been implemented with a goal of creating ESH. A deliberate release of flows in the spring (March through May) or fall (October through December) to create ESH is expected to be an effective management action for plovers and terns.

Implementation criteria: *If selected as a management action for full implementation:* Habitat-forming flow releases under evaluation in the DEIS are the following:

- A spring release initiated on April 1st consisting of a 60 kcfs release from Gavins Point and Fort Randall dams and 42.5 kcfs from Garrison dam for a 5.5 week duration. System storage must be greater than 42 MAF.
- A fall release is initiated on October 17th consisting of a 60 kcfs release from Gavins Point and Fort Randall dams and 42.5 kcfs from Garrison dam for a 5.5 week duration. The service level must be greater than 35 kcfs.

Implementation may include releases of lesser magnitude or duration than as specified, but will not exceed these magnitudes or durations without a formal process to change the flow definitions (See Attachment 6).

If implemented as a flow test: Criteria for any potential implementation as a test flow (including requirements prior to testing and conditions under which it would not be tested) will be determined following the review period for the DEIS.

Constraints: (*If selected as a management action for full implementation)* Habitat-forming flows will not be used more frequently than once every 4 years, nor within 4 years of any naturally-occurring flow that created 250 acres or more of standardized ESH. They will not be used when ambient ESH levels exceed 25% of target acreage in the reach of concern, or when system storage is less than 42MAF for a spring release or the service level is less than 35 kcfs for a fall release. If combined releases plus tributary flows exceed flood thresholds (71kcfs at Omaha, 82kcfs at Nebraska City, or 126kcfs at Kansas City), releases are decreased by 5 kcfs increments until downstream flow criteria are met or the release falls below 45 kcfs, at which point it is terminated.

The effectiveness of habitat-forming flows is a function of ambient ESH acreage; when acreages are high, flow releases may erode more sandbar area than is created.

Performance metrics: Standardized ESH acreage before and after the flow release measures the effectiveness of the releases. Sandbar elevation profiles should be surveyed to measure effectiveness of flow releases for creating habitat available across a range of typical nesting season flows. Nesting bird densities and fledge ratios are used to assess the quality of flow-created habitat and its contribution to overall population dynamics.

Metrics for nesting and foraging habitat and overall habitat quality have not been used historically but will be developed under the AM Plan. Flow releases may result in more habitat on reservoirs the following season; reservoir habitat metrics and bird productivity should also be assessed as an outcome of habitat-forming flows.

Human considerations metrics: For any implemented flow action, the MRBWMD monitors flow throughout the basin by tracking observed stage at key locations, and calculates flow and stage at remaining locations using calibrated and validated models and rating curves. Additional HC-specific metrics could be identified to assess outcomes of action implementation. Section 5.5.5 outlines the process by which the AM Team and agency technical staff have assessed uncertainties and potential monitoring and assessment opportunities. Pending the recommendations of the HC Team and decisions regarding the Work Plan scope (see Sections 2.3.3.2 and 2.4.4, respectively), both pre- and post-monitoring assessments of identified HC metrics may be needed to assure the flows are not impacting HC interests.

Uncertainties, research, and active AM: The amount of habitat created by any specific combination of flow magnitude and duration is variable and uncertain and depends upon the initial distribution and supply of sediment, among other factors. The longevity of created ESH is also uncertain, as it is dependent upon the subsequent flows, which are unknown but can be statistically represented. Habitat quality and long-term availability will depend upon the elevation of sandbars created by the flow; current predictive capacities are limited in this respect. Each implementation, therefore, will provide valuable information for model development and/or validation, which will help refine future implementation decisions.

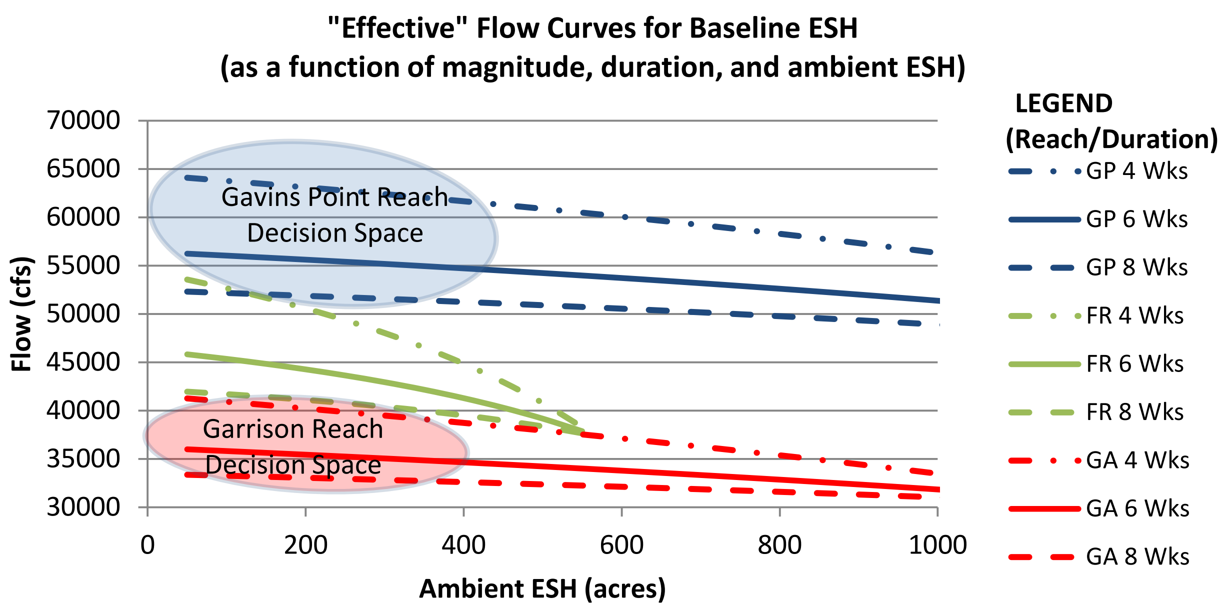


Figure 45. Anticipated range of “effective” combinations of flow and duration that meet standardized acreage targets given initial ambient ESH, with presumed “decision space” shown for Gavins Point and Garrison reaches.

Learning can be enhanced by a) implementing flows when possible given the necessary conditions exist, b) monitoring sandbar evolution during “natural” flow events, and c) implementing a range of flow magnitudes, duration, and timing, even if conditions allow for a release that could be more effective but has already been implemented. Additionally, monitoring of key HC metrics will validate/improve existing relations between habitat creation flows and impacts to interior drainage and flood risk concerns. Further discussion can be found in Section 3.5.7.

Table 27. Questions and study summaries for habitat-creating flow research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty Are there effective and implementable ways of using flow management to improve habitat availability and quality? What are the effects of habitat creation actions on Human Considerations?			
Associated Hypotheses Habitat-creating flows of sufficient magnitude and duration increase the area of nesting/brood rearing habitat and foraging habitat on the river by increasing deposition, assuming sediment is available, thereby increasing fledgling productivity.			
What are the predicted effects of different magnitudes, durations, timing and frequencies of habitat-forming flows on ESH, species, and HC metrics?	Modeling studies to assess a range of flow options; should be repeated following significant new information for ESH, population, and/or HC models as needed.	ESH acres; fledgling production; population size; HC metrics (TBD)	

Question	Study Summary	Metrics	Related studies
What is the relationship between proposed habitat-creating flows and ESH area created?	Implement flows when conditions permit; explore effects of different initial conditions and flow parameters; track evolution of habitat.	ESH acres; nesting and foraging habitat; elevation profiles; bird use and fledgling production.	Geomorphic assessments of flow variability effects on ESH within normal operations.
What are the effects of habitat forming flow implementation on HC metrics?	See Chapter 5		
How will changes to sediment supply and channel morphology (including aggradation/degradation) alter the effects of flow releases on ESH deposition?	Conduct a numerical modeling study to assess the effects of decreasing sediment supply, coarsening of sediment gradation and lowering of bed profile on ESH/flow relationships. Validate model study results using trends from monitoring over time.	"Effectiveness" of flows (magnitude and duration) in creating ESH (acres) as measured by departure from current response curves.	Geomorphic investigations of sandbars in the Garrison and/or Gavins reaches.

Criteria for adjusting actions: *During implementation*, if combined releases plus tributary flows exceed flood thresholds (71kcfs at Omaha, 82kcfs at Nebraska City, or 126kcfs at Kansas City), releases are decreased by 5 kcfs increments until downstream flow criteria are met or the release falls below 45 kcfs, at which point it is terminated. *After implementation*, monitored impacts will be compared with the level of acceptable impact determined in coordination with MRRIC. If results fall outside the acceptable range, adjustment to the action specification (i.e. the "decision space") may be made to avoid or reduce risks in the future. Similar adjustments might be made if the observed benefits deviate significantly from projected values. However, given the complex nature of the system, any adjustments should be made with the best possible understanding of *why* the deviation occurred, the expected range of natural variation and the likelihood of re-occurrence. E.g. an extreme hydrological event during implementation may skew many outcomes and not give a realistic assessment of action effectiveness and impacts. The tolerance for unusual outcomes and the ability to repeat actions despite them will be different for actions with unexpectedly high HC impacts versus those with unexpectedly low ESH creation, as repeating instances of the latter carries lower risk.

Decision and collaboration level: (See Section 0; Workflows 3-6). For flows within the decision space of the ROD, the Bird Team can recommend a flow action as a management option. The Management Team will balance this option with other management needs and expected positive and negative effects. Should the Management Team recommend a flow, implementation must be approved by MRBWMD, who informs MRRIC of intent, monitors for impacts and reviews after-action assessment with MRRIC. If the Management Team decides the decision space for flows needs to change based on evaluations from the Technical Team or Bird Team recommendations, Oversight must approve the proposed changes after consultation with the MRBWMD and MRRIC.

3.2.4.2.2 *Lowered nesting season flow*

Definition and function: The availability of ESH during the nesting season (~May 15-August 15) depends on flows. Lowered flows expose more ESH and may also reduce erosion of ESH during the year, depending upon how water held back is released. Lowered nesting season flows are limited to Fort Randall and Gavins Point dams. If water is held back, lowered nesting season flows reduce nesting habitat availability in the reservoirs relative to if flows had not been reduced.

Implementation criteria: *As implemented according to the 2006 Master Manual:* Opportunity to provide low summer flows exists under the current Master Manual, dependent primarily on system storage level and the status and location of commercial navigation on the river. Plate VI – 1 in the Master Manual shows the service level related to system water supply. If the water supply is such that water must be evacuated from the system low summer flows would not be likely during the nesting season. However during droughts when water conservation is a priority and service level is less than full service low summer flows are likely.

Section 7-13.1.1 of the Master Manual describes the manner in which day-to-day regulation of the system to support navigation will be accomplished. Anticipated traffic or the absence of traffic at the control points will have a bearing on the selection of the control point for providing the service level. After selection of the control point, System releases are adjusted so that in combination with anticipated tributary flows they will meet the target flow at the control point. This affords an opportunity to provide low summer flows if navigation traffic is below Omaha so the control point is Nebraska City or Kansas City and enough tributary flow is present to allow for low summer flows. [1]

If implemented specifically for providing ESH: If available ESH has been below percent exceedance targets over the period of evaluation, the ability of reduced flows to increase the likelihood of meeting targets should be evaluated. Similarly, if standardized ESH area is below the median target and the ability to create new habitat through flows or construction in the near future is projected to be limited (e.g. insufficient system storage

[1] The years 2007 and 2008 provide an example of water conservation and high downstream flows coupled with missing navigation targets in the Sioux City and Omaha reaches produced very low releases from Gavins Point during the bird nesting season. Releases ranged from 10.5 kcfs to 21.5 kcfs in 2007 and 13.1 kcfs to 22.8 kcfs in 2008. For comparison purposes the average release from Gavins Point since the system filled in 1967 ranges from 28.5 kcfs to 36.6 kcfs during the bird nesting season.

or budget), lowered summer flows should be given additional consideration as they can increase the longevity of existing habitat by reducing erosion and/or allow for habitat-creating flows in the fall. If the standardized ESH area is very low, benefits of lowered nesting flows are less and may not be worth impacts to reservoir habitat and/or HC.

Bird population densities should be greater than <TBD> for lowered nesting season flows to be beneficial; at lower densities additional habitat is not needed. As reduced flows in the southern reaches affect habitat in the northern reservoirs (Sakakawea and Oahe), consideration should also be given to habitat and population trends in the reservoirs, with lower flows a higher priority when the southern region is less likely to meet habitat and/or population targets than the northern region. Model evaluation of habitat availability and expected population density should be used to assess benefits prior to implementing flows. [Note: Implementation criteria will be quantified following additional hydrological modeling and finalization of the bird EA report.]

Constraints: The ability to lower nesting season releases from Gavins Point Dam depends on downstream flows to meet targets, inflows downstream of Gavins Point Dam and basin hydrologic conditions. Lowered nesting season releases from Garrison Dam have not yet been investigated; additional constraints would apply should lowered nesting season releases be applied to the Missouri River between Lakes Sakakawea and Oahe.

Performance metrics: Standardized and available ESH during lowered releases measures the effectiveness of lowered flows increasing the availability of nesting and foraging habitat. Standardized ESH measurements in the year following the flow are used to assess any net effects on erosion. Reservoir habitat metrics must also be evaluated to measure the tradeoff between downstream ESH and reservoir shoreline habitat. Fledgling production in both river and reservoir segments should be evaluated to determine net effects of lowered flows.

Human considerations metrics: For any implemented flow action, the MRBWMD monitors flow throughout the basin by tracking observed stage at key locations, and calculates flow and stage at remaining locations using calibrated and validated models and rating curves. Additional HC-specific metrics could be identified to assess outcomes of action implementation. Section 5.5.5 outlines the process by which the AM Team and agency technical staff have assessed uncertainties and potential monitoring and assessment opportunities. Pending the recommendations of the HC Team and decisions regarding the Work Plan scope (see Sections 2.3.3.2 and 2.4.4, respectively), both pre- and post-monitoring assessments of identified HC metrics may be needed to assure the flows are not impacting HC interests.

Uncertainties, research, and active AM: Uncertainty remains in the estimation of the relationship between flow/stage and sandbar habitat availability; this relationship varies with time and location and thus requires periodic re-evaluation, particularly following high flow events. Imagery acquisition, LiDAR and/or elevation surveys during lowered flows provide additional information about flow/area relationships and sediment dynamics at lower flows. Implementation of a range of reduced flows under different conditions would accelerate learning.

Table 28. Questions and study summaries for lowered nesting-season flow research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty To what extent can improving the availability of existing habitat through flows contribute to -population objectives compared to creating new habitat?			
Associated Hypotheses Reduced summer flows increase the area of suitable nesting and brood rearing habitat and foraging habitat on the river, thereby increasing fledgling productivity.			
What are the predicted effects of different magnitudes, durations, timing and frequencies of lowered nesting-season flows on ESH, species, and HC metrics?	Modeling studies to assess a range of flow options; should be repeated following significant new information for ESH, population, and/or HC models as needed.	ESH acres (standard and available); fledgling production; population size; HC metrics (TBD)	
What is the relationship between lowered nesting season flows, nesting and foraging habitat, and fledgling production?	Implement varied flows when conditions permit; explore effects of different initial conditions and flow magnitude and duration.	ESH acres; nesting and foraging habitat; bird use and fledgling production.	Assessments of flow variability effects on ESH area and fledgling production within normal operations. Geomorphic assessments and monitoring of stage/area relationships.
What are the effects of lowered nesting season flows on HC metrics?	TBD: See Chapter 5		
How will changes to channel morphology (including aggradation and degradation) alter the effects of nesting season flows on habitat availability?	Conduct a numerical modeling study to assess the effects of decreasing sediment supply, coarsening of sediment gradation and lowering of bed profile on ESH elevations. Validate model study results using trends from monitoring over time.	Exposure of ESH (acres) at low discharge values and trends therein.	Geomorphic investigations of sandbars in the Garrison and/or Gavins reaches.

Criteria for adjusting action: Actions are implemented within a range of acceptable risks (of undesirably high impacts, undesirably low benefits, or both). If results fall outside the acceptable range, adjustment to the action specification (i.e. the “decision space”) may be made to avoid or reduce risks in the future. Similar adjustments might be made if the observed benefits deviate significantly from projected values. However, given the complex nature of the system, any adjustments should be made with the best possible understanding of *why* the deviation occurred and the likelihood of re-occurrence. E.g. an extreme hydrological event during implementation may skew many outcomes and not give a realistic assessment of action effectiveness and impacts. The tolerance for unusual outcomes and the ability to repeat actions despite them will be different for actions with unexpectedly high HC impacts versus those with unexpectedly low ESH creation, as repeating instances of the latter carries lower risk.

Currently, lowered flows in summer can be implemented when other requirements such as navigation do not need to be met or when runoff is very low as described above. These modifications are constrained by other authorized purposes and not focused on optimal effects for bird nesting. In the case that lowered summer flows are determined to be both effective and necessary for more regular implementation or implementation triggered by ESH or bird population conditions, a supplemental EIS would be prepared if not already covered by the MRRMP/EIS, and the process for changing the Master Manual technical criteria would be exercised, if required (see Attachment 6 of Appendix A).

Decision and collaboration level: For flows within the decision space, the Management Team recommendation to implement must be approved by MRBWMD, who informs MRRIC of intent, monitors for impacts and reviews the after-action assessment with MRRIC. If the Management Team decides the decision space for flows needs to change based on recommendations from the Technical Team, Oversight must approve the proposed changes after consultation with the MRBWMD and MRRIC.

3.2.4.3 *Actions for Research and Pilot-Scale Implementation (Not Evaluated in the MRRMP-EIS)*

Actions described in this section were identified in the EA or the PrOACT process as potential management actions but were not evaluated as part of the alternatives in the DEIS. Additional evidence for the effectiveness of these actions from research and/or field testing is required to determine whether full-scale implementation should be considered. The research activities and pilot-scale implementation described in this section are roughly analogous to Level 1 and Level 2 actions for pallid sturgeon (Section 4.2.1.1). However, unlike for sturgeon, timelines have not been established for implementation of these studies or actions, as the set of actions in the preferred alternative have been determined during the EIS process as able to meet piping plover targets.

Pilot projects or tests may be implemented using site-specific NEPA processes or within the scope of water management rules following the ROD. If evidence for action effectiveness supports broader implementation, supplemental programmatic NEPA coverage will likely be required prior to full-scale implementation. New actions that may be added during the course of the AM process would be added to this section.

3.2.4.3.1 *Non-sandbar habitat creation or modification*

Definition and function: The USFWS has determined that created habitat other than sandbars must be hydrologically connected, i.e. it regularly comes into contact with the mainstem river or reservoirs, in order to contribute to bird objectives for the MRRP. Projects must fall within the USACE' management authority. Habitat types that have been proposed include:

- Habitat creation or modification on reservoir shorelines: habitat that is created, modified, or maintained to improve physical characteristics (slope or substrate), reduce or remove vegetation growth and reduce non-avian predation (e.g. through fencing); may be employed at different elevations to provide habitat when reservoirs are filling over multiple years.
- Created islands in reservoirs: habitat that is created in reservoirs but not attached to the shoreline, to reduce predation and other disturbances. In some locations such as small side bays water control measures may be considered to provide habitat less subject to inundation during the nesting season.
- Areas connected to the river but not in the channel (e.g. backwaters): sandy areas with limited vegetation that provide foraging habitat for plover chicks. Such habitat would be subject to fluctuating water levels but flow velocities may be lower, limiting erosion or supporting deposition; may be associated with pallid sturgeon habitat projects or created specifically for plovers.
- ESH, attached to the floodplain or not, located in areas not currently managed for sandbar habitat: potential is very limited in channelized portions of the river but some habitat could potentially be formed in association with sturgeon habitat projects.

Hydrologically disconnected habitat (e.g. sandpits separated from the river) is not included in this category. Most non-sandbar habitat types are conceived as providing habitat that is either available when most other habitat is not (e.g. during high water) or may will persist longer than ESH due to less exposure to erosive flows. A tradeoff is that habitat that is less affected by river flows than in-channel sandbars will require ongoing and possibly extensive habitat maintenance and predation management in the absence of natural processes that occur on sandbars. Each type of non-sandbar habitat identified now or in the future will be evaluated for effectiveness separately.

Implementation criteria: To implement pilot projects: TBD To implement at broader scales: TBD

Constraints: Habitat must be hydrologically connected to the mainstem Missouri River and provide wet sand foraging habitat accessible to plover chicks hatched at the site. Some non-ESH that least terns have used for nesting will not be suitable for piping plovers due to lack of foraging habitat. Property ownership and access may limit capabilities to construct/maintain habitat types. Suitable topography and substrate must be available, or costs may increase considerably.

Performance metrics: Area of suitable habitat (as defined by ESH habitat criteria of suitable substrate and <30% vegetation cover) area of foraging habitat, number of birds nesting at the site, fledge ratios, predation observations.

Human considerations metrics: TBD; will likely depend upon project type and location.

Uncertainties, research, and active AM: Data on nesting and brood-rearing success, site selection, and site fidelity on habitat other than sandbars and reservoir shorelines is extremely limited due to the absence of such habitat on the Missouri River. A few sites outside of the ESH-managed segments on the Missouri River have been used for nesting by terns, but not by plovers. Some data exists for hydrologically disconnected habitat on the Central Platte River, but differences in substrate type, groundwater, creation of sites, and the general lack of in-channel habitat in that section of the Platte River limit the ability to consider those sites as analogous to potential alternative habitat creation on the Missouri River. Monitoring data is more limited on the Lower Platte and precludes comparative analysis. The numerical plover and habitat models can be revised to include alternative habitat types, though analyses will be limited by the lack of empirical data. Feasibility studies will be required prior to pilot implementation; a study on the feasibility of created reservoir habitat was previously conducted and estimated low benefit. Pilot-scale projects would need to be evaluated over multiple years to understand habitat suitability, and plover nest site selection and site fidelity over time and relative to a range of potential conditions on the river (e.g. when ESH or reservoir shoreline habitat is abundant vs. when it is scarce.)

Information from projects not implemented by the MRRP may be used to address this management uncertainty if sufficient information is collected. At minimum, site area, number of nesting adults, and number of fledglings produced at a site, using the same metrics and definitions as for the MRRP monitoring, is necessary to evaluate action effectiveness. Information on additional management actions (i.e. predator control, vegetation management) including treatment type, level of effort, and/or area treated is also required. Observations of predation rates, nest success rates, dispersal, and site fidelity are useful and will be included in action effectiveness assessments if available.

Table 29. Questions and study summaries for non-sandbar habitat creation research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty To what extent can non-sandbar habitat creation actions contribute to the success of birds on the Missouri River?			
Associated Hypotheses Non-sandbar habitat creation contributes to the fledgling production and population growth on the Missouri River by providing additional habitat and habitat that may be available at times when ESH and/or reservoir shoreline habitat is not available.			
Non-intervention research studies (Level 1)			
Is <non-sandbar habitat type> creation feasible?	Assessment of site availability, access and suitability, construction requirements and costs; maintenance requirements and costs	Number, location and area of suitable sites; costs	
Are there analogous sites or conditions that provide evidence for the effectiveness of a habitat type?	Assessment of evidence from MRMS and other plover breeding areas	Area of suitable habitat; site selection; site fidelity; adult numbers; breeding bird density; number of fledglings and fledge ratio	
What are the site, region, and population-scale effects predicted by models for a range of habitat creation locations and levels?	Modeling studies using data if available; expert opinion if not (with results indicating the impact of using expert opinion vs. relying solely on existing data)	Fledgling production, number and proportion of birds nesting at alternative habitats, response of population size and viability metrics to number of sites and area of alternative habitat	
Pilot projects and/or field experimentation (Level 2)			
Does a pilot project provide habitat and support fledgling production similar to sandbar or reservoir shoreline habitat in the same region?	Pilot-scale implementation of one or a small number of sites; additional monitoring of sites and nearby sandbar/reservoir shoreline habitat may be required to assess effectiveness; banding to assess site fidelity and dispersal	Area of suitable habitat; site selection; site fidelity; adult numbers; breeding bird density; number of fledglings and fledge ratio; return rates	

Criteria for adjusting action: The process to move from research to pilot projects and to move from pilot projects to broader or full-scale implementation depends on the nature of the action and the extent to which it was studied as part of the MRRMP-EIS. Section 1.1.6 provides an overview of the considerations involved. While some limited, one-time "test flows" might be implemented under the current ROD and Master Manual criteria, the remaining flows evaluated in the EIS would require the release of a new ROD, would need new technical criteria to be accepted for the Master Manual, and may require additional environmental assessment before they could be broadly implemented. Actions outside those evaluated in the EIS would require all the above. Additionally, any acceptance of new actions outside the ROD would follow a high level of collaboration among the agencies and the MRRIC (Section 0).

Decision and collaboration level: The Management Team allocates budget and other resources to research and pilot-scale implementation activities, based upon recommendations of the Bird Team and the balance of other MRRP needs including pallid sturgeon management activities. The Bird Team and implementation staff decides upon the sites, methodology, and design of construction activities based on best practices and manages contracts and monitoring.

3.2.4.3.2 *Reservoir water level management to provide shoreline habitat or reduce take on shorelines*

Definition and function: Reservoir releases expose potential shoreline habitat. Exposed shoreline that was previously inundated for >160 days in the past two years are expected to increase the unvegetated area available for nesting. Increases in reservoir elevation during the nesting season can inundate nests and lower fledgling production on reservoir shorelines. Such increases commonly occur as part of routine operations, particularly in Lake Sakakawea. In contrast, stable or declining reservoir levels during the nesting season can reduce or prevent nest inundation and provide additional foraging habitat.

Implementation criteria: Reservoirs are not currently managed to provide plover habitat or manage nest inundation. This category includes management modification specifically intended to improve nesting conditions by managing changes in reservoir elevation to provided unvegetated shoreline habitat or by limiting the increase in reservoir elevation during the nesting season. Opportunities exist to manage releases for populations nesting on shorelines while meeting other reservoir management requirements may be identified following the draft MRRMP-EIS.

Constraints: Maintaining reservoir levels in the optimal storage range and releasing water at rates necessary to support authorized purposes and limit nest/chick take in riverine reaches are currently prioritized over managing for reservoir habitat. Depending on timing, ESH availability and elevation, releases may have downstream impacts on habitat availability or inundate nests. Overall population effects of reservoir management depends upon the relative population size and productivity of birds nesting on reservoir shorelines vs. reaches and between the Northern and Southern regions.

Performance metrics: Available shoreline and inundation; plover population size, fledgling counts, and fledge ratio on reservoir shorelines. Effects on ESH and fledgling production on riverine segments should also be evaluated.

Human considerations metrics: TBD; Effects on HC metrics will depend on the initial elevation of the reservoir prior to any modification of releases, as well as the changes during the season.

Uncertainties, research, and active AM: While the general effects of water elevation changes on plover productivity on reservoir shorelines can be estimated based on routine operations, the ability and opportunity to manage for desirable reservoir shoreline habitat metrics while meeting other requirements and having a net positive effect on plovers is uncertain. Limited modeling conducted to date has shown small positive effects for birds of “unbalancing” reservoirs to improve shoreline habitat availability; additional modeling to explore different potential management rules would be necessary before test actions could be specifically defined. Monitoring of plovers nesting on reservoirs tends to be less accurate than on river reaches due to the length of the shoreline that must be surveyed. The ability to understand the effects of shoreline habitat availability on nesting plovers during normal operations is affected by the precision and accuracy of that monitoring.

Table 30. Questions and study summaries for reservoir water level management research and active AM.

Question	Study Summary	Metrics	Related studies
Management Uncertainty To what extent can improving the availability of existing habitat through flows contribute to -population objectives compared to creating new habitat?			
Associated Hypotheses Declining reservoir water levels between years and/or steady or declining water levels during the nesting season increases the area of suitable nesting/brood rearing and plover foraging habitat on the reservoirs, thereby increasing fledgling productivity.			
Non-intervention research studies (Level 1)			
Are there options for managing reservoir water levels for shoreline habitat and take reduction that provide net positive benefits to birds and acceptable HC impacts?	Modeling studies to determine potential for managing water levels to improve reservoir habitat; effects on plover productivity (riverine and reservoir) and reservoir use; effects on HC metrics	Reservoir shoreline habitat availability and inundation, ESH availability, plover adult # and fledge ratio, HC metrics TBD	Interactions with modeling for habitat-forming flows, as they also affect reservoir elevations compared to routine operations.
How do plovers respond (site use, dispersal, and fledgling production) to changes in water	Monitoring, potentially with increased effort as needed to ensure sufficient statistical	Reservoir shoreline habitat availability and inundation, ESH	Dispersal/metapopulation studies could inform assessment of site

Question	Study Summary	Metrics	Related studies
elevations on reservoir shorelines?	power to detect effects, banding to monitor site fidelity and dispersal to other segments or non-MR nesting areas	availability, plover adult # and fledge ratio, site fidelity and dispersal	selection, fidelity, and dispersal.
Pilot projects and/or field experimentation (Level 2)			
Does management of reservoir water elevations improve plover nesting on the reservoir and net positive benefits to the population?	Modification of releases within operational flexibility; TBD	Reservoir shoreline habitat availability and inundation, ESH availability, plover adult # and fledge ratio, HC metrics TBD	Flow modifications for other purposes may affect reservoir shoreline habitat; ensure sufficient monitoring on reservoirs to detect effects

Criteria for adjusting action: *To move from research to pilot projects:* To be determined during AM implementation. *To move from pilot projects to broader or full-scale implementation:* To be determined during AM implementation.

Decision and collaboration level: Management Team recommendations to implement test releases must be approved by MRBWMD, who informs MRRIC of intent, monitors for impacts and reviews after-action assessment with MRRIC. If the Management Team decides the action should be elevated from test releases to broader applications, Oversight must approve the proposed changes after consultation with the MRBWMD and MRRIC.

3.2.5 Effects of Pallid Sturgeon Actions on Terns and Plovers

Actions for pallid sturgeon generally only affect birds if they modify reservoir operations. Channel reconfiguration or sediment augmentation activities are separated geographically from the areas where the vast majority of plovers and terns nest, and propagation has no mechanism to affect bird habitat or populations. The effects of all proposed actions (including those not in the Preferred Alternative) are summarized in Table 31.

Changes to reservoir operations in the Upper Missouri River (Fort Peck Dam to headwaters of Lake Sakakawea) for pallid sturgeon would affect shoreline nesting habitat on Lake Sakakawea. The degree of the effects would be dependent on releases from Garrison Dam; adjustments to Garrison releases to accommodate differences in inflow may in turn affect birds nesting in Garrison Reach or Lake Oahe. A drawdown in Lake Sakakawea has the potential to affect habitat availability for plovers, but the long-term effects would depend on the extent of the drawdown and the topography of the shoreline. The same volume of water would create larger fluctuations in the elevation of a drawn-down reservoir. The effects of any proposed action of this type could be evaluated with modeling.

Flow modifications for pallid sturgeon in the Lower Missouri River (Fort Randall or Gavins Point Dam) would have direct effects on ESH availability in the Gavins Point Reach and could have indirect effects on habitat availability on reservoir shorelines. Spawning cues have the potential to create ESH, though not necessarily as efficiently as habitat-forming flows. Flows of lower peak magnitudes have the potential to cause net erosion of ESH rather than deposition. The second pulse of the spawning cue would occur during the nesting season and has the potential to inundate nests initiated prior to the release. As birds may be able to renest after the peak of the flow release, overall effects on productivity are uncertain. As empirical evidence for bird responses to flow patterns such as these is not available, the ability to estimate effects of this action through modeling are constrained and uncertainty is high.

Table 31. Effects of pallid sturgeon management actions on piping plovers and least terns

Action	In Pref. Alt.?	Geographic overlap*	Direct effect on bird habitat	Direct effect on bird reproduction or survival	Constraints on bird actions (other than budget)	Uncer-tainty
Alter Flow Regime at Fort Peck	No	Yes, Lake Sakakawea, downstream depending on Sakakawea releases	Positive or negative effects on reservoir shorelines, depending on Lake Sakakawea releases	Depends on relative releases between Fort Peck and Sakakawea, more likely to reduce risk of nest inundation on shoreline	No	Medium
Temperature Control, Fort Peck	No	No	No	No	No	Low
Sediment Augmentation at Fort Peck	No	No	No	No	No	Low
Passage at Intake	Yes	No	No	No	No	Low
Upper Basin Propagation	Yes	No	No	No	No	Low

Action	In Pref. Alt.?	Geographic overlap*	Direct effect on bird habitat	Direct effect on bird reproduction or survival	Constraints on bird actions (other than budget)	Uncer-tainty
Drawdown Lake Sakakawea	No	Yes, Lake Sakakawea	Decrease in overall shoreline availability, but sufficient habitat may remain, depending on topography and population size. Increase to extent of inundation when reservoir fills.	No	No	Medium
Alter Flow Regime at Gavins Point, spawning cue	No, but potential for flow test after 9 years	Yes, Gavins Point, Lake Sakakawea, Lake Oahe	Spawning cues of sufficient length and duration create ESH. Lower pulses may erode ESH. Above-normal releases provide additional reservoir shoreline habitat.	Rises beginning in mid-late May may inundate nests. Birds may be able to renest after peak of pulse, depending on timing and subsequent releases	Use of storage could limit ability to implement flow modifications specifically to create ESH	High
Alter Flow Regime at Gavins Point, low summer flows	No	Yes, Gavins Point, Lake Sakakawea, Lake Oahe	Decreased flows in summer increase availability of existing ESH. Decreased releases from Gavins may result in inundation of nests on reservoir shorelines.	Low flows may increase foraging habitat availability and improve chick survival; if releases must be increased, nests or chicks may be inundated.	If water stored during low flows is released in the fall at discharges >35 kcfs, ESH construction, modification, or vegetation removal may be impeded	Medium
Temperature management, Fort Randall	No	Yes, Fort Randall Reach and Gavins Point Reach	No	Might improve prey availability/quality for plovers or terns	No	Medium
Interception and Rearing Complexes	Yes	No	Limited evidence of opportunistic use of existing sturgeon habitat projects for nesting by terns	Possible positive impact if birds nest in areas associated with IRCs	No	Medium
Spawning Habitat	Yes	No	No	No	No	Low
Propagation Lower Basin	Yes	Yes	No	No	No	Low

Actions for pallid sturgeon create few conflicts or additional constraints (aside from budget allocation) on bird management actions. Storage used for a spawning cue flow would be unavailable for a specific ESH-creating flow modification. Any lowered summer flow for fish, as with those designed for birds, could result in held-back water that would need to be released in the fall; if releases exceed ~35kcfs from Gavins Point they may preclude or interfere with ESH creation, modification, or vegetation removal activities (fall releases of sufficient magnitude or duration may create ESH).

3.3 Monitoring

Annual monitoring of habitat and species performance metrics, and as-needed monitoring of action effectiveness experiments and of unusual events will be required to adaptively manage plovers and terns. Monitoring is necessary for tracking program performance relative to targets and identifying trends that indicate a need for changes to management; it also provides some of the information needed to develop and maintain accurate models (e.g. fledgling production relative to habitat availability; changes in ESH availability as a function of river flow). Monitoring requires flexibility and responsiveness to ensure timely and consistent data collection in a highly variable system. As habitat and populations on the Missouri River have the potential to change rapidly, monitoring for performance metrics must occur annually. Information needs that are not addressed through the monitoring program may need to be addressed through focused research.

The following priorities have been suggested for ESH and bird monitoring. Monitoring should:

1. Provide information to continue advancing the habitat and population models for decision support;
2. Provide information for the evaluation of action effectiveness, including the population response;
3. Track the habitat and population performance metrics annually to determine whether targets are being met;
4. Provide information for assessing incidental take;
5. Be cost effective and practical to implement; and
6. Be comparable with previous monitoring programs to the extent possible while meeting objectives 1-5.

Continued use of the models requires the ability to:

1. Estimate population size, change, and density over time and space
2. Estimate fledgling productivity by habitat condition and over time and space
3. Estimate survival and dispersal over time and space
4. Quantify management action effects and 'take' annually

5. Estimate observation error which may vary by year and segment

Information needs for action effectiveness and model development may also be addressed through research, but some information, such as survival or dispersal data requires multiple years of data collection to estimate parameters and additional years to improve accuracy, including such monitoring annually may provide sufficient value over shorter-term research to justify the associated expenses. Tradeoffs will exist between cost effectiveness and information breadth and quality. Initial and ongoing analyses of the statistical power of a monitoring program and the value of information provided will assist with decisions about how to allocate resources to monitoring and other needs.

3.3.1 Monitoring of hydrology and habitat metrics

Hydrological metrics (reservoir releases and pool elevations for Lake Sakakawea, Lake Oahe, Lake Francis Case and Lewis and Clark Lake; flow at Sioux City) are monitored and reported daily by USACE Water Management and provide information for estimating reservoir habitat availability, adjusting ESH estimates, determining incidental take risk and providing historical inputs to use in ESH model validation.

ESH is monitored by acquiring satellite imagery of all riverine habitat during the nesting season. Imagery is classified to land cover type, which can then be used to estimate area of ESH (dry and wet sand with less than 30% vegetation cover) and vegetated sandbar. These estimates must be adjusted to standardized and maximum July flows for quantification of standardized and available habitat. Ideally, multiple acquisitions are made, including in May during nest initiation and in July during peak chick production, to more accurately estimate metrics.

ESH quantification has been limited to estimating habitat quantity rather than quality. Aside from percent vegetation, no other habitat characteristics are considered in the quantification. Work initiated in the EA to develop a protocol for estimating quality of habitat based upon land cover and landscape features at relevant scales will be evaluated for use in AM. Quality assessments would allow for more accurate predictions of bird population dynamics and better allocation resources to habitat construction or modification. As ESH is quantified with satellite imagery and archived, it can be retroactively reassessed if improvements are made in the quantification and quality assessment protocols.

Periodic assessments of channel form using LiDAR and bathymetric surveys are valuable for determining discharge-area relationships needed to accurately estimate standardized and available ESH from imagery collected at different flows and to predict the effects of planned flow releases on habitat availability. Assessments of sediment load should also be conducted. While annual collection of this data may not be necessary, significant changes to channel form, warrants additional data collection. This may be considered periodic monitoring rather than research, in order to regularly update the ESH discharge-area models and provide information for improving the ESH dynamics model.

Reservoir habitat is not currently monitored beyond hydrological metrics. Research on metrics for reservoir habitat beyond the hydrological metrics described above would help determine if different or additional metrics should be used to quantify reservoir habitat for predicting bird productivity.

3.3.2 Existing program for monitoring of population metrics and associated challenges

Population monitoring requires adult surveys and monitoring of plover nests and chicks on both riverine and reservoir habitat. Adult counts are needed for estimating population size and growth rate, fledge ratios, and population density. As such, count accuracy is vital, but challenging for mobile species that can be spread across large areas, especially on reservoir shorelines, and fly to forage away from nesting sites.

From 1993-2016, the adult population of terns and plovers has been determined by conducting an adult census, an attempt to completely count all adult least terns and piping plovers observed during the third week in June. It is assumed that both of the species are settled on the breeding grounds by that time. There are limitations in trying to accurately count all adult birds on the system, however, due to movement of adult birds, and so the adult count is augmented on sites where the number of adults counted is less than two times the number of active nests and broods at that site. The timing of the adult count – the third week in June – also raises some concerns. The USGS in their analysis of the USACE Tern and Plover Monitoring Program (TPMP; Shaffer et al. 2013) found that peak adult numbers varied by species, by segment and by year, yet none of that variability is factored into the adult census methodology. Since the total number of adults is a key component in calculating the fledge ratio, the USACE should evaluate alternative methods to determine the total number of adults for the monitoring program.

Fledgling counts are required for estimating fledge ratios and density-productivity relationships. Fledge ratios have been used by the USFWS to assess take of least tern and piping plover eggs, chicks, and adults by factors influenced by but not directly attributable to the USACE (predation, human disturbance, abandonment, and erosion), and to assess take of piping plover chicks as a result of insufficient forage in river reaches affected by hypolimnetic releases or on created habitats. The use of fledge ratios in assessing take in the future will be addressed in the Incidental Take Statement accompanying the new BiOp. Fledgling monitoring generally has higher detection and accuracy than adult monitoring (Shaffer et al. 2013), as chicks can be more easily observed and counted prior to fledgling, but requires repeated visits to determine whether chicks survive to fledge. The USACE method of determining fledglings combines counting actual fledglings (chicks able to fly) and assumed fledglings (plover chicks observed in the 21-24 day age group and tern chicks observed in the 16-20 day age group, but not seen as fledglings). However, the ability to observe chicks and determine fledglings is weakness of the TPMP. The cryptic coloration of chicks makes them difficult to observe, and with a 7-10 day return interval for monitoring, some chicks are never observed. In addition, it is difficult to ascertain whether the fledglings observed at a site are chicks that just fledged, fledglings previously observed on site, or chicks that fledged elsewhere and are using the site as a stopover area. The USACE should evaluate alternative methods to determine the total number of fledglings at a site.

While not a direct performance metric for AM, monitoring of nests and broods has also been conducted to assess and avoid take in coordination with water management. Monitoring of nests and broods can provide some information as to the degree of predation, human impacts, and other causes of egg/chick mortality, and improves accuracy of fledgling counts. Such information is useful for understanding observed population dynamics and to trigger and assess effectiveness of population protection actions, but causes of mortality cannot always be determined and nest detection can be low, particularly for failed nests. Accurately determining nest fate relies on the ability of the crew to find the nest and revisit it frequently enough to determine the outcome. The USGS analysis of the monitoring program identified problems related to the ability to find nests and determine nest fate, including the late start of the monitoring program (typically mid-May), the frequency of nest visits (typically 7 – 10 days), and the ability to detect nests at any given site (Shaffer et al. 2013). The monitoring program needs to be flexible enough to adapt to changes in habitat availability and increase crew size accordingly in order to more effectively survey sites and reduce the return interval. The program also needs to address the shortfall in monitoring early season nesting activity.

Accuracy of the monitoring program varies depending on habitat area that must be surveyed, population density, habitat type and age, and experience of monitoring crews. Thus accuracy can vary by year and by segment, and with the exception of Shaffer et al. 2013, has not been quantified in the past. Recommendations to address this challenge are under consideration and future versions of the AM Plan will include any refinements to monitoring procedures.

The monitoring program must be robust to changes in budget or staffing availability, or prioritized such that a base level of monitoring can always be performed at an adequate level. Fluctuations in level of effort and quality of monitoring, such as may occur when funding, equipment or personnel resources are limited, affect both near-term decision making and longer-term assessment of trends and hypothesis assessment.

The predictive habitat and population models will be used to assess the effects of estimated monitoring error and bias on assessment of population objectives. Adjustments may be identified and applied to target metrics to accommodate known limitations in the monitoring program [details to be determined following updates and/or changes to the monitoring program]. They will also be used to assess proposed changes to the monitoring program to evaluate robustness to changing habitat conditions and funding/staff availability.

Periodic review of the monitoring program (e.g. on a 5-year basis) will occur to assess adequacy. If necessary, improvements should be made while keeping in mind that changes to protocols affects the ability to compare data collected before and after the changes are made. Similarly, if methods of collecting information more quickly or cost-effectively become available, they should be explored, but potential impacts to assessment caused by changes to monitoring protocols should be taken into account before changes are made.

3.3.3 Options for changing the population monitoring program

Development of this AM plan, including changes in the piping plover targets, monitoring priorities, and use of the AM models provide an opportunity to re-evaluate the Tern and Plover Monitoring Program (TPMP), which has several challenges outlined in the previous section. Going forward, several options are being considered to improve the monitoring program following the priorities and model data needs listed at the beginning of section 3.3.

Option 1: piping plover monitoring program with a bird banding and re-sighting focus to estimate the piping plover breeding population and fledgling population

This option includes a monitoring program with marked birds (chicks and adults), spatial sampling, error estimation, and productivity represented by fledglings and their recruitment to the breeding population. Use of a marked population and spatial sampling will provide additional data to estimate annual movement, recruitment, and survival (metrics for model parameterization).

The focus on breeding adults at nests will provide an idea of the proportion of piping plover nests loss (including incidental take) during a field season but not directly measure overall take.

Note: Least terns will be monitored following the Post-delisting Rangewide Monitoring Protocol for Interior Least Terns (USFWS; in draft).

The program would estimate:

- **Population size**–estimated annually with open population models
- **Population change**–estimated using annual population size estimates
- **Population density**–estimated using annual population size estimates and estimates of emergent sandbar habitat
- **Productivity** –population of fledged young estimated using open population models and marked fledglings

Requirements:

Banding the population

- Segments (reservoir & river segments) include Lake Sakakawea, Garrison River, Lake Oahe, Fort Randall River/ Lewis & Clark Lake, Gavins Point River.
- 50-100 adult piping plovers marked per segment annually.
- 100-200 piping plover chicks marked per segment annually.
- Five banding teams cover all segments.

Spatial sample

- Classify segments of each segment as low, medium, or high use by nesting plovers.
- Select a portion of habitat in each segment to visit.
- Monitoring crews locate nests and place trap cameras at nests in segments.
- The same crews later re-sight birds; personnel numbers are about the same as historically used for the TPMP survey.

TPMP Option 1 Methods:

1. Stratify sampling units. In week one, survey a set number of high/medium quality sampling units 3 times (M,W,F) and survey a set number of low quality sampling units 2 times (Tues, Thu). In week two, survey a different set of high/medium and low quality sampling units. Repeat the pattern so that in week 3, crews are back to

the same set of units surveyed in week 1; and in week 4, crews are back to the same set of units surveyed in week 2. On the river segments, 2 crews of 2-3 people are required. On the reservoir segments, 3 crews of 2-3 people are required.

Table 32. Sample outline of monitoring schedule by week and unit for river segments.

river segment example					
Week 1	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Crew 1 (2 people) cover 4 sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units
Crew 2 (2 people) cover 4 sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units
Week 2					
Crew 1 (2 people) cover 4 sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units
Crew 2 (2 people) cover 4 sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units	2 low sample units	2 hi/med sample units
Repeat through the nesting season; i.e. in week 3 –crews return to week 1 sample units, in week 4 – crews return to week 2 sample units, etc. for a total of 8 sample units monitored throughout the breeding season.					

Table 33. Sample outline of monitoring schedule by week and unit for reservoir segments.

reservoir segment example					
Week 1	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Crew 1 (2 people) cover 10 sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units
Crew 2 (2 people) cover 10 sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units
Crew 3 (2 people) cover 10 sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units
Week 2					
Crew 1 (2 people) cover 10 sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units
Crew 2 (2 people) cover 10 sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units
Crew 3 (2 people) cover 10 sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units	5 low sample units	5 hi/med sample units

Repeat through the nesting season; i.e. in week 3 –crews return to week 1 sample units, in week 4 – crews return to week 2 sample units, etc. for a total of 60 sample units monitored throughout the breeding season

2. Locate nests at designated sampling units, GPS the nest location, and place “trap cameras” (such as the Kodak PixPro video cameras) at nests with a full clutch for a minimum of 30 minutes.
3. Identify adults on nests (marked and unmarked); do not re-sample nests where adults have already been videotaped.
4. Starting in mid-June crews start carrying digital cameras & take pictures of fledglings in addition to setting trap cameras. Record the number of marked and unmarked fledglings.
5. Population size is estimated by segment and sample period using a mixed logit-normal mark-resight model.
6. Stratification may change annually; should sample at least 25% of each study segment.
7. Crews are not carrying scopes, grid searching, tracking eggs or chicks.
8. Nest success, egg numbers are not tracked.
9. Incidental take estimates would be limited, since nest success is not tracked.

Option 2: piping plover monitoring program without a bird banding and re-sighting focus

Includes a monitoring program with spatial sampling, error estimation, and productivity represented by observed fledglings. Use of spatial sampling will provide additional data to estimate observation error.

The focus on monitoring nests will provide an idea of the proportion of piping plover nests loss (i.e. ‘take’) during a field season.

Note: Least terns will be monitored following the Post-delisting Rangewide Monitoring Protocol for Interior Least Terns (USFWS; in draft).

TPMP Option 2 Methods:

1. Stratify sampling units and sample using the same monitoring schedule as described in Option 1.
2. During each visit, find, mark (GPS), and count nests. Conduct repeat (3) visits within a time-period. Repeat this process throughout the breeding season.

3. Age-ratios could be used to assess recruitment for populations of unmarked birds; assuming constant detection, annual changes in age-ratios (hatch year : after hatch year individuals) can reflect changes in productivity.
4. Starting in mid-June, TPMP crews count the number of fledgling-aged chicks and the number of adults on each surveyed segment.
5. Measurements of estimation error will be possible due to repeat site visits.
6. The Minimum Breeding Population (MINBPOP) will be calculated to determine adult numbers (in lieu of an adult "census"). The number of breeding plover pairs is estimated from the daily sum of active nests plus all previously hatched nests plus nests failed during incubation within the previous 5 days. This estimate represents the minimum number of breeding pairs that used each sampling unit and provides a relative distribution of breeding pairs on each unit within each reach.
7. Benefits of this method include:
    a. estimates of population size with error
    b. estimates of productivity with error
    c. Shorter intervals between nest searches mean less opportunity for nests to fail without being discovered and increased opportunity to locate nests that ultimately produce hatchlings.
    d. Shorter intervals also lead to fewer errors in nest fate determinations and in assigning causes of nest failure.
    e. Shorter intervals may also result in increased chick observations, which could improve fledgling estimates.
8. Drawbacks of this method include:
    a. 'other' demographic estimates (e.g. movement, recruitment, survival) not possible
    b. limited ability to understand 'why' population changes are occurring
    c. limited ability to assess management action effects with some certainty
    d. like the previous method, not all incidental take will be documented
    e. index of productivity is based on observation of chicks and fledglings
    f. double-counting adults and chicks will continue to be problematic

Other monitoring options are being considered and the monitoring protocol will be finalized in the final AM Plan.

3.3.4 Additional species monitoring

Depending on the final design of the monitoring program, additional information may be needed about species demographics, dispersal, and/or habitat use. Supplemental monitoring programs, research, or collaboration with other programs could be used to supply the needed information. The MRRP can benefit from cooperation with other programs that mark and/or resight birds in wintering habitat and other breeding areas.

3.3.5 Action effectiveness monitoring and research

The types of additional monitoring required for action effectiveness depends upon the action and the degree to which existing monitoring is sufficient. Systematic actions such as flow modifications require monitoring data on a different scale than site-specific actions which may only require information from a small number of sandbars within a single reach. Some management hypotheses can be evaluated with existing monitoring, but others may need supplemental or more focused monitoring in specific areas. For example, bird use and fledgling success on constructed sandbars compared to naturally-created sandbars can be assessed using the same ESH monitoring and bird productivity monitoring data collected for evaluating system-wide performance metrics, but may require sandbars to be added to the sampling design used for routine monitoring. Other information needs for routine monitoring may include:

- Habitat-forming flow releases: additional imagery and delineation of habitat availability directly after flow release (especially for fall flow releases); elevation surveys to determine elevation profiles of created sandbars; field surveys to track evolution of created sandbars.
- Lowered nesting season flow releases: ensure habitat quantification captures availability during release; assessment of ESH area before and after flow and after fall evacuations of extra storage to evaluate effects on erosion.
- Sandbar augmentation and modification: elevation surveys and other field observations to evaluate effectiveness, longevity, and evolution of modifications, comparison of wet to dry sand ratio pre and post modification.
- Vegetation management: Line intercept sampling on sandbars using a BACI designed experiment. See line intercept protocol Attachment #4, Appendix G; Spatial analysis using land cover classifications should be used when available but may have limitations in detecting changes due to imagery resolution
- Predation management/human restrictions: Focused monitoring (e.g. increased use of cameras) of selected locations where actions are implemented, in contrast with controls, to detect effects of actions on nest success.

The need for action effectiveness monitoring diminishes with time as information is collected and uncertainty decreases. The uniqueness and value of additional information, in relation to the monitoring cost, should be assessed before determining additional monitoring requirements. E.g. high flows happen rarely and under unique conditions, so additional information would likely be valuable for most releases, and worth some cost to understand the relative value of flow actions compared to construction and any resulting impacts. In contrast, the effectiveness of sandbar construction projects is fairly well understood. Effectiveness assessment of routine, non-experimental construction could be done at little to no cost through existing monitoring.

3.3.6 Events requiring additional monitoring

Natural events provide valuable information for evaluating management actions and for understanding natural variability. Of particular interest include reservoir releases out of the normal range and their effects on habitat dynamics and bird productivity. Monitoring would include geomorphic assessments like those described above for tracking action effectiveness and bird responses. Survival and dispersal data will be especially valuable during unusual conditions (such as very high or low habitat availability, coupled with habitat conditions in other breeding areas).

Actions conducted for pallid sturgeon management that affect plovers and terns are primarily flow modifications (see Section 3.2.5). Their effects on ESH dynamics and fledgling production will be monitored and assessed in the same way as flow modifications conducted specifically for birds. The effects of spawning cue releases on ESH would provide valuable information for the ESH model. The effects of a spawning cue pulse after mid-May on nesting success are uncertain; additional monitoring during and shortly after the flow may be warranted.

3.3.7 Monitoring and research to improve models and action planning/design

Focused studies geared to specific predictive modeling information needs should be regularly assessed and incorporated into the monitoring and research program. For example, the ESH models would benefit from the following studies:

- Investigation of alternative timeframes over which conditions are averaged to determine which provides the most accurate and useful (these are not necessarily the same) basis for the ESH models.
- Monitoring of typical, unusual, and experimental flows would provide needed data that, with statistical and regression analyses, provides a means to update the flow-ESH relations and refine estimates of variability and error.
- High-fidelity studies of sandbar morphodynamics already undertaken in the Gavins Point reach should be revisited and extended to include the other reaches. The resulting data provides a) an improved understanding of underpinning processes of sandbar growth and decay, b) a basis for enhancing the stage-area relations, and c) a basis for establishing multi-dimensional models of bar processes to initially supplement and eventually replace the existing models.

The bird population models would benefit from studies such as the following, in addition to surveillance information on adult and fledgling numbers and demographic rates, as described above:

- What habitat quality characteristics affect plover reproduction and chick survival?
- What are the differences in reproductive performance among geographic locations, if any? What are the management implications?
- Does plover site fidelity change as habitat degrades? Does site fidelity have implications for decisions such as where to construct a sandbar or which sandbars should be treated for vegetation or mechanically modified?
- What constitutes an adequate forage base? Do changes to plover condition based on food quality/availability affect fledge ratios or survival?
- What effect does variability in water elevation, including power peaking, have on plover prey abundance and availability and resulting fledgling production?

The value of potential studies can be addressed by estimating the cost savings provided by reduced uncertainty and improved accuracy in predictive models used to calculate habitat and other management needs. Uncertainty compels managers to manage in ways that hedge against worst-case scenarios; more accurate and precise estimates of likely outcomes leads to more efficient management.

3.4 Implementation

Implementation of management actions for the birds is generally described in the preceding sections. Some evaluations may be ongoing during implementation, as described in the following section. [Note: further discussion of the implementation step may be provided in the final AM Plan].

3.5 Evaluation

The Evaluation step is primarily conducted by the Technical Team, which coordinates with the Bird Team to obtain information and identify analytical needs. The Technical Team’s analyses begin as monitoring data becomes available in fall. The Fall Science Meeting is the venue to review initial outcomes of the previous year’s management actions, monitoring, and research, and to identify specific analytical topics of interest to the Management Team, Bird Team, and MRRIC Bird WG. The Technical Team conducts routine annual analyses as described in this section, assesses topics identified as priorities by the other teams, and presents results in the Draft AM Report. As illustrated in (Figure 16) the Draft AM Report is reviewed in the AM Workshop, revised, and released as a final draft in the spring. This process and the AM Report is the primary means for developing and communicating the technical information for the MRRP, but additional evaluation tasks may arise at other points in the year for topics needing immediate assessment or for longer-term assessments that cannot or do not need to be completed during the annual cycle. Annual analyses include evaluation of status and conditions, hypothesis evaluations, and model updates and validation. The process allows for inclusion of ancillary information and assessment of unexpected outcomes.

3.5.1 Evaluation of habitat status relative to targets

ESH targets are expressed as a quantity of standardized ESH, to be met 3 out of 4 years, and as a distribution over time of available ESH, as described by the proportion of the most recent 12 years in which available ESH should exceed specified acreages. Both standardized and available ESH are specified by median and 95% confidence intervals. The medians provide the target requirements, but the confidence interval allows for variability around that goal driven by the uncertainty in future flows and variability in species response. Species-habitat dynamics are not perfectly known, so more or less ESH than the median estimate may be needed to meet demographic targets. Observed acreages that fall outside the confidence interval should result in more intensive changes to action plans than acreages that fall within the confidence interval. There are four possible outcomes (Figure 46) when comparing observed ESH to targets, each suggesting a course of action:

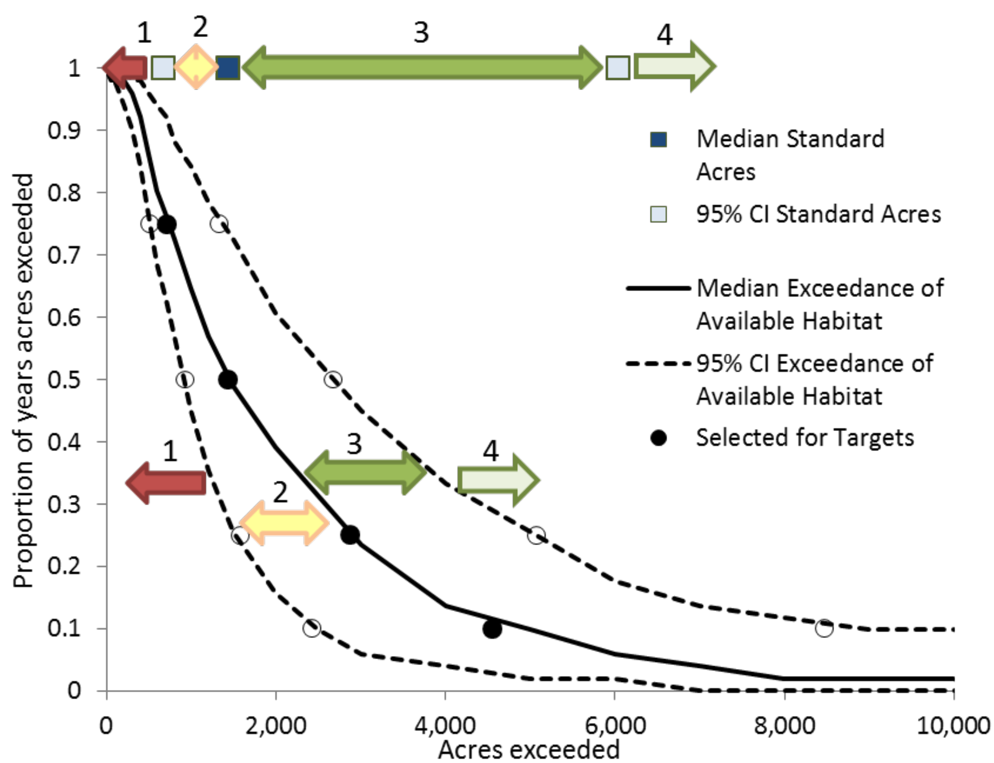


Figure 46. Standardized (squares) and available acreage exceedance targets (circles) with confidence bounds (light blue squares, dashed lines). Observed habitat acreages can fall within four numbered regions relative to the acreage bounds, as described in the text.

1) The acreage is below the lower confidence bound. It is very unlikely that populations have enough ESH to meet objectives and the pace of habitat creation must increase.
2) The acreage is below the median and above the lower confidence bound. While it is possible that population dynamics will meet objectives, habitat creation to increase ESH to median levels is needed.
3) The acreage is above the median and below the upper confidence bound. In this case, it is possible but not certain that more habitat is available than necessary to meet population objectives. Habitat should be maintained with new habitat creation focused on ensuring acreage does not drop below the median.
4) The acreage is above the upper confidence bound. It is very likely there is more habitat than is necessary to maintain the desired species status. Habitat creation is not needed, though existing ESH should be maintained.

For available habitat, the comparison to targets is similar, but requires evaluation of habitat availability over 12 years to create the exceedance curve. That curve is compared to the target and the associated confidence intervals in the same way as the standard acreage (Figure 46). Exceedance curves take time to respond to change in management practices due to the longer time frame. The upper end of the exceedance curve (10% exceedance) may only be met following flows high enough to create habitat.

ESH targets are defined for the Northern and Southern Region and should be evaluated for each region separately (Table 34). In Figure 47 and Figure 48, ESH data from 2006-2015 are compared to the standardized ESH targets and the target exceedance for available ESH. Median standardized ESH targets were exceeded from 2012-2015 for the Northern Region and for 2007-2008 and 2012-2015 for the Southern Region. The timeframe of 3 out of 4 years exceeding the median target was met in 2014 and 2015 for both regions. The habitat availability target has been met for both regions (the observed exceedance line is to the right of the median target line.) Observed ESH compared to habitat availability targets is above target for all percent exceedance metrics (Figure 48).

Table 34. Target and observed available habitat exceedance proportions and acreages (2006-2015). Targets are met if the observed acres exceeded are greater than the median target acres, within each row, for each region. Likewise, the observed exceedances are greater than the target exceedances. Shaded cells indicate the target is met.

Southern Region				Northern Region			
Target exceedance	Observed acres exceeded	Median target acres exceeded	Observed exceedance	Target exceedance	Observed acres exceeded	Median target acres exceeded	Observed exceedance
75%	540	**370**	90%	**75%**	503	**210**	90%
50%	1627	**720**	50%	**50%**	763	**630**	70%
25%	4695	**1370**	50%	**25%**	2900	**1420**	40%
10%	4880	**2320**	30%	**10%**	3057	**2230**	30%

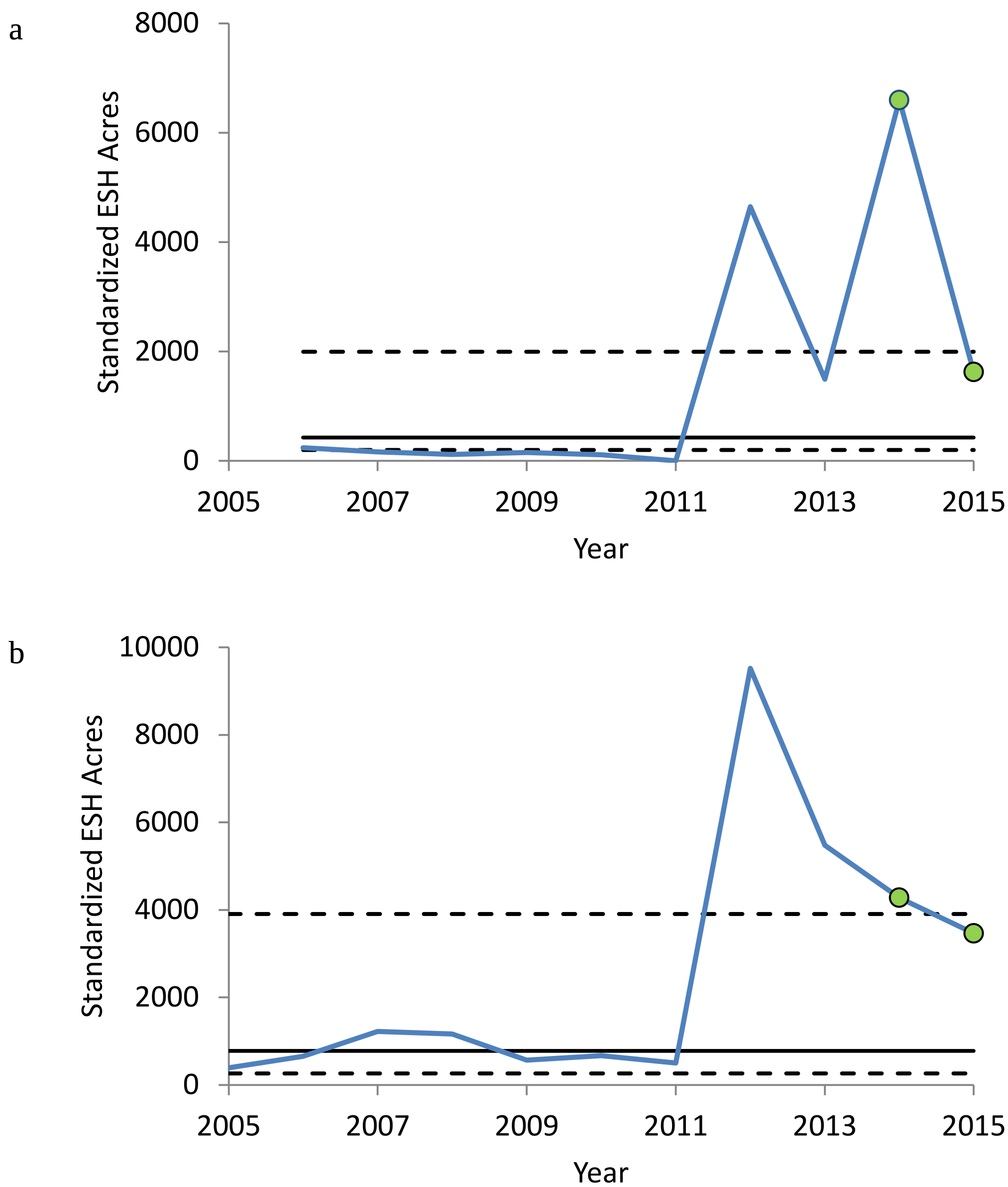


Figure 47. Observed standardized ESH (blue line) from 2006-2014 relative to targets (median, solid black line; 95% confidence interval, dashed lines) for a) the Northern region and b) the Southern region. Green circles indicate years that the time frame of 3 out of 4 years exceeding the median target is met.

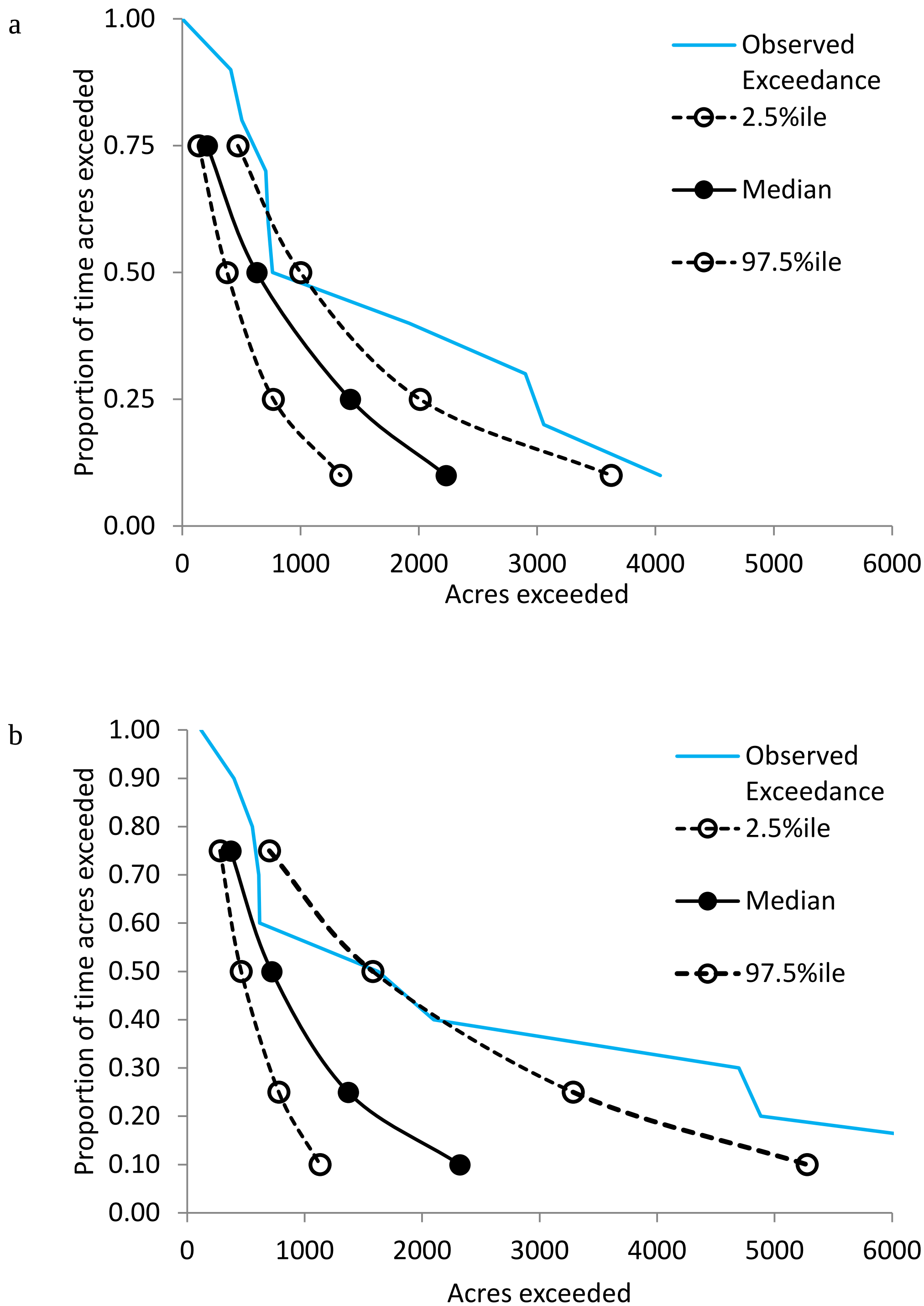


Figure 48. Observed exceedance of available ESH (blue) from 2006-2015 relative to target exceedance distributions (median, solid black line; 95% confidence interval, dashed lines) for a) the Northern region and b) the Southern region. Circles indicate the 75%, 50%, 25% and 10% exceedance criteria specified in the targets. Note that only 10 years of data are available; a 12-year rolling window of data will be used once 12 years of data are available. The observed exceedance meets the median targets for habitat availability if the blue line is to the right of the solid black line.

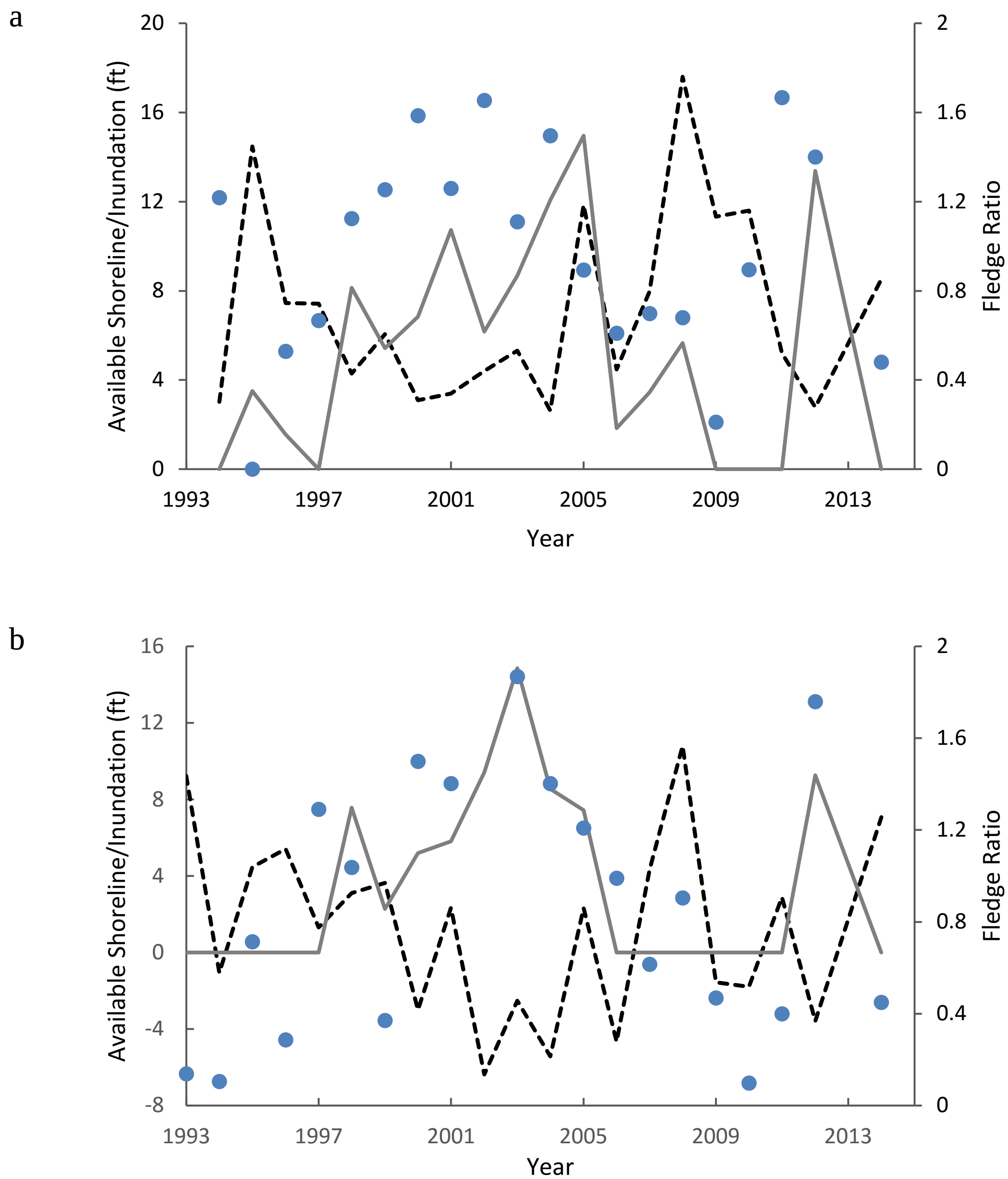


Figure 49. Metrics of available shoreline (solid gray lines, high values are good), inundation during the nesting season (dashed black line, low values are good) and observed fledge ratios (blue circles) for a) Lake Sakakawea and b) Lake Oahe. Fledge ratios on reservoirs were not estimated in 2013.

While there are no targets set for reservoir habitat, tracking the associated metrics is useful for understanding bird population dynamics on reservoirs and how they are affected by management decisions. Figure 49 shows reservoir habitat metrics by year for 1993-2014 for each reservoir, with observed plover fledge ratios. Observed fledge ratios tend to be higher for high values of the available shoreline metric and low values of the inundation metric. Figure 50 shows the relationship between reservoir shoreline habitat metrics and whether or not plover fledge ratios meet their target. Patterns in reservoir shoreline water elevations and resulting fledgling production vary between the two reservoirs, as Lake Sakakawea is more affected by inundation during the nesting season and Lake Oahe by changes in water elevation between years.

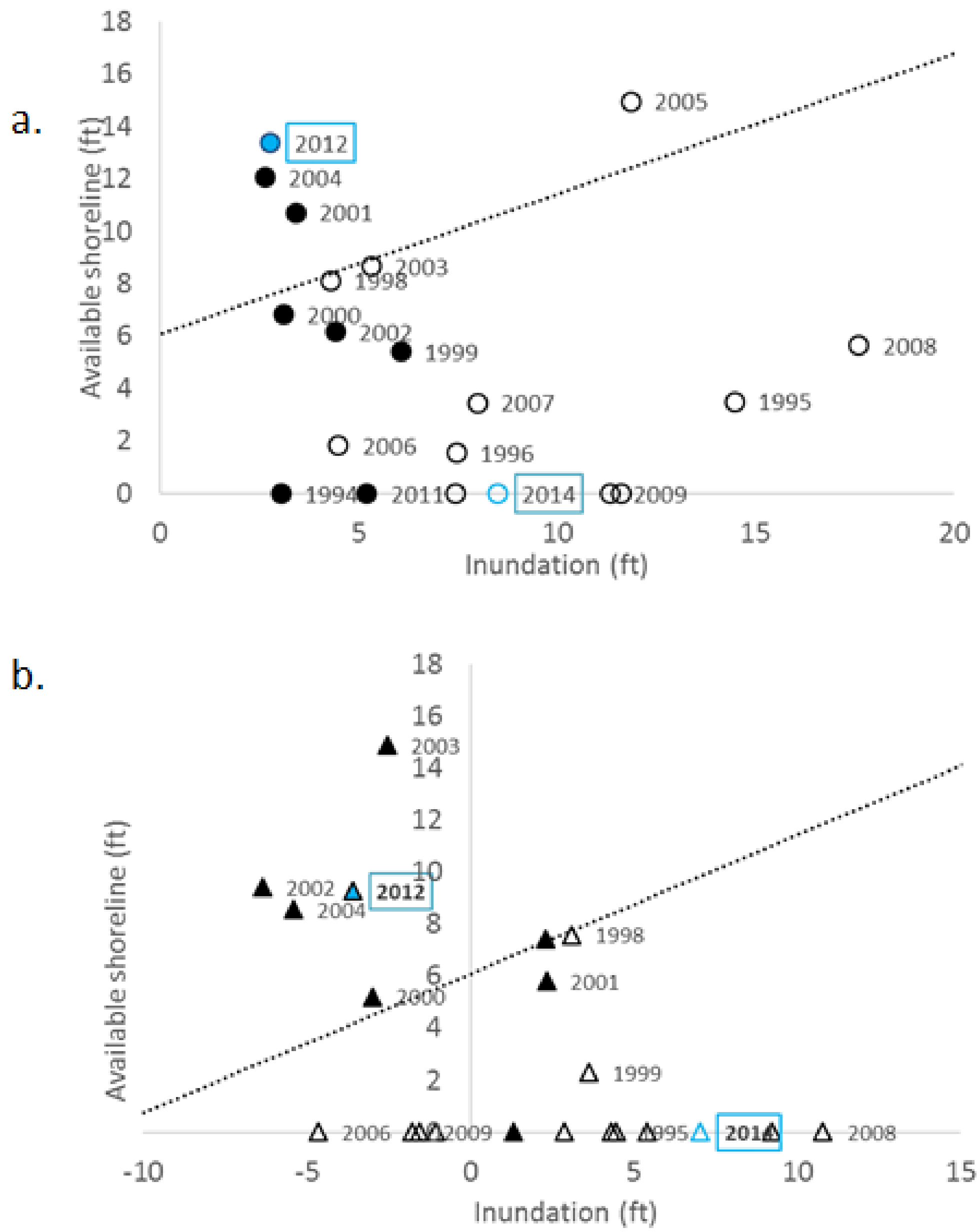


Figure 50. The relationship between reservoir habitat metrics (available shoreline and inundation) and whether the fledge ratio target of 1.14 is met (filled shapes) or not met (unfilled shapes) for a) Lake Sakakawea and b) Lake Oahe for 1993-2014. Recent years are highlighted in blue (fledge ratios were not estimated on reservoirs in 2013). Note that some labels have been omitted for legibility. The dotted line indicates combinations of the two metrics predicted by the model to meet the fledge ratio targets; data points above and to the left of the line are expected to meet the targets and data points below and to the right of the line are not.

3.5.2 Evaluation of population status relative to targets and objectives

The population sub-objectives for birds require that the MRRP 1) maintain the geographic distribution of plovers, 2) maintain a resilient population, 3) maintain population growth that is at least stable, and 4) maintain the success of breeding pair levels that support population growth. Rather than a quantitative target of a number of adults, criteria were set for long-term population persistence (low quasi-extinction risk). Persistence is supported by population growth rates that are at least stable over time and fledge ratios that allow the population to be at least stable, given current survival estimates. Therefore assessment of population status requires assessment of observed fledgling production, trends in population size over time and assessment of population resiliency under current and proposed management conditions through modeling.

3.5.2.1 *Evaluation of fledge ratio and population growth rate*

It is most straightforward to evaluate sub-objectives 3 (growth rate) and 4 (fledge ratio) by directly comparing observed rates and running averages with targets (Figure 51). Adjustments may be required to account for variability in estimated observation error, in order to compare population sizes from year to year to calculate growth rate. Adjustments may also be required to account for differential detection of adults and fledglings to more accurately calculate fledge ratios.

Inter-annual variability in population sizes, growth rates, and fledge ratios is to be expected in any population, particularly birds nesting in naturally variable habitat. In some cases, a single-year deviation from meeting objectives is an early sign of a downward trend that could result in jeopardy, while in others it represents natural variability in an otherwise stable or growing population. Assessment of species status needs to be able to recognize early signs of population decline while not causing overreaction to natural variability. Thus assessment of species status include assessment of the most recent year but also a measure of the metric over a 3-year running geometric mean (for population growth rate) or arithmetic mean (for fledge ratio). These metrics should be interpreted in the context of overall habitat and species status and trends, scientific understanding, and ancillary information.

3.5.2.2 *Evaluation of population trajectory and resilience*

Population resiliency can be assessed through model projections over a 50-year time frame, based on current conditions and management practices, to estimate whether the population under the specified conditions is expected to meet the persistence criteria (remain above the quasi-extinction threshold of 50 adults in each region in more than 95% of model replicates). It is challenging, however, to realistically project current management conditions over a 50-year time frame, and such assumptions of management consistency do not reflect ongoing AM that would be expected to improve management outcomes over time.

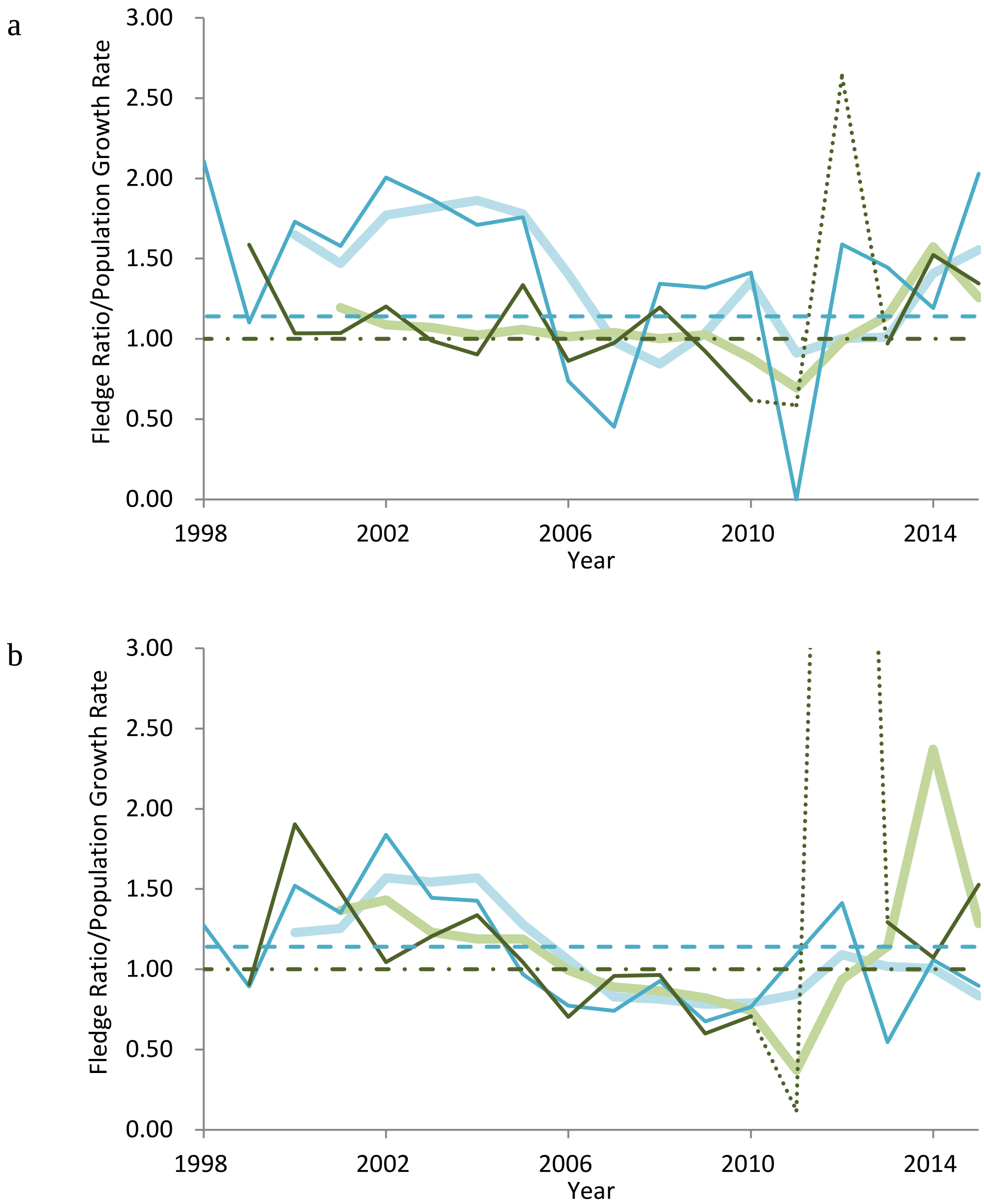


Figure 51. Plover population growth rate ($\lambda = N_t/N_{t-1}$) (green) and fledge ratio (blue) annual values (thin lines), 3-year running geometric mean of growth rate (thick green line) and 3-year running average fledge ratio (thick blue line) from population monitoring 1998-2015 for a) the Northern Region and b) the Southern Region. Years with especially low and high population growth rate (2011-2012; dotted lines) reflect the effect of high flows that did not allow breeding in 2011. As few nesting birds were observed in 2011, calculated population growth reflects the absence then return of birds to nesting areas in addition to changes in population size due to reproduction and mortality. Dashed lines indicate targets.

An alternative is to model a scenario in which the persistence criteria are just met, and evaluate the current and near-future (5-10 year) population status against those projections. The greater the overlap between the target and projected future population distributions, the greater the likelihood that targets will be met without "over managing" the system. For example, population projections beginning in Year 1, with enough habitat availability to meet ESH targets, provide a distribution of population sizes that should be met in the next five years in order to be on track for long-term viability (e.g. Figure 52). This approach acknowledges that population trajectories are more important that single-year population status (e.g. a small, but growing, population with abundant habitat is more likely to persist than a larger population with limited habitat in the long run) and that there are time lags in population response to changes in available habitat.

While an absolute population target cannot be defined for all circumstances, a target population trajectory for the next 5-10 years, given current circumstances, *can* be defined. The degree of overlap between the target population distribution and the distribution expected from planned management actions can be quantified to assess the likelihood of success. For example, an overlap of 85% between the target distribution and the management scenario distribution would be preferable to an overlap of only 50%. If the management scenario distribution is lower than the target distribution, it is unlikely that the habitat and population targets will be met. If the management scenario distribution is greater than the target, there is increased likelihood that the targets will be met, but also that more resources will be used than are strictly necessary.

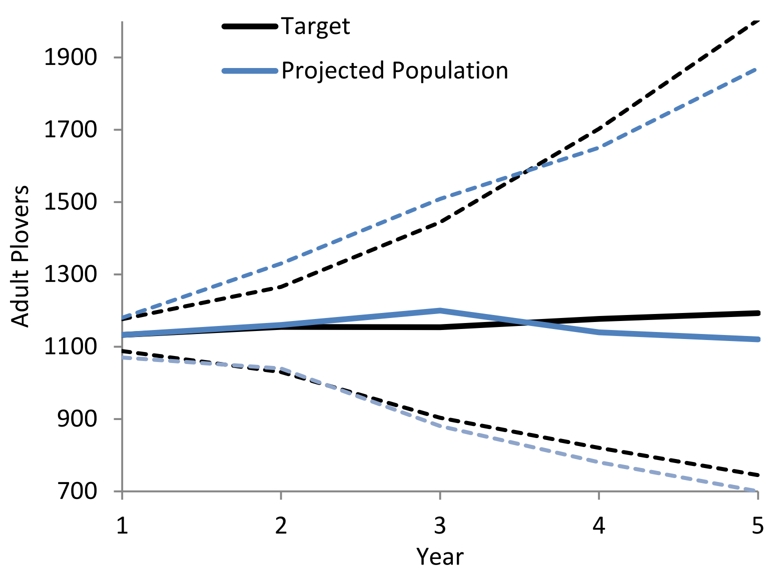


Figure 52. Hypothetical comparison of projected population sizes under a management scenario (blue lines) with a population trajectory that meets the target (black line). Solid lines are median values of 5,000 model replicates; dashed lines are 95% confidence intervals.

3.5.2.3 *Accounting for metapopulation and non-breeding habitat dynamics*

The Missouri River tern and plovers populations are not closed; birds born or previously breeding in other areas may immigrate to breed on the Missouri River, and vice versa. All plovers and terns breeding on the MRMS winter elsewhere. Conditions during migration and at wintering and other breeding habitats affect individual bird condition, annual survival and dispersal, and thus affect MRMS population dynamics. It is important to distinguish these effects from effects of MRMS management actions.

By examining the status and trends of both fledge ratios and population size and growth rates, and incorporating ancillary information (e.g. knowledge of conditions and demographics in other habitats), growth rates that are not in pace with fledge ratios—suggesting changes in survival or dispersal—can be identified and, if possible, attributed to changes on or off the Missouri River. Explanations for discrepancies can be taken into account for management planning. Long-term changes off-river affecting Missouri River populations may require adjustments to target criteria or objectives at the policy/Oversight level. Future metapopulation modeling will incorporate this information as it becomes available in order to improve management decisions.

3.5.3 Overall Evaluation of Status and Management Needs

A holistic assessment of the status and trends of bird populations relative to habitat is half of the foundation for decisions regarding whether actions should be implemented, where, and with what intensity (Figure 40). ESH targets provide guidelines for a resilient population in the long term; the needs of the population in a given year depend on population size relative to habitat availability (population density) and population trends.

A matrix summarizing the status and needs of plovers and ESH (Table 35) provides a heuristic for assessing and communicating the current habitat and species status and recommended overall pathway of management (e.g. continue, increase, or decrease current rates of habitat creation; corresponding rates of habitat maintenance may also be indicated) resulting from that status. To meet objectives, populations must be growing or stable (first two rows of table) and above the lower bound of the ESH targets (second through fourth columns). Outside of that range the population may be on track to meet objectives, unlikely to meet objectives, or potentially in reversal (was meeting objectives but no longer is).

Population Status	**Emergent Sandbar Habitat Status**			
	Acreage < Lower Bound	**Lower Bound < Acreage < Median**	**Median < Acreage < Upper Bound**	**Upper Bound < Acreage**
GROWING POPULATION **FR and λ > target**	On track to meet objectives *Status:* Small population OR density dependence less than expected *Need:* Continue pace of habitat creation	Meeting objectives *Status:* Moderate population, not habitat limited *Need:* Continue habitat creation at current or slower pace	Meeting objectives *Status:* Moderate to large population, not habitat limited *Need:* Maintain existing acreage and quality	Exceeding objectives *Status:* More birds and much more habitat than needed *Need:* Maintain habitat quality
STABLE POPULATION **FR and λ ≈ target**	Unlikely to meet objectives *Status:* Small to moderate population, becoming habitat limited *Need:* Increase rate of habitat creation	Meeting objectives *Status:* Moderate population, habitat may become limiting *Need:* Continue pace of habitat creation	Meeting objectives *Status:* Moderate to large population *Need:* Maintain existing acreage and quality	Exceeding objectives *Status:* More birds and more habitat than needed *Need:* Maintain habitat quality
DECLINING POPULATION **FR and λ < target**	Will not meet objectives *Status:* Small to large population, very habitat limited *Need:* Rapidly increase rate of habitat creation	Unlikely to meet objectives *Status:* Moderate to large population, habitat limited *Need:* Increase pace of habitat creation	Potential reversal *Status:* Large population returning towards equilibrium *Need:* Continue pace of habitat creation and maintain habitat	Reversal *Status:* Large population returning towards equilibrium OR density dependence much higher than expected *Need:* Maintain habitat quality, consider maintaining acreage

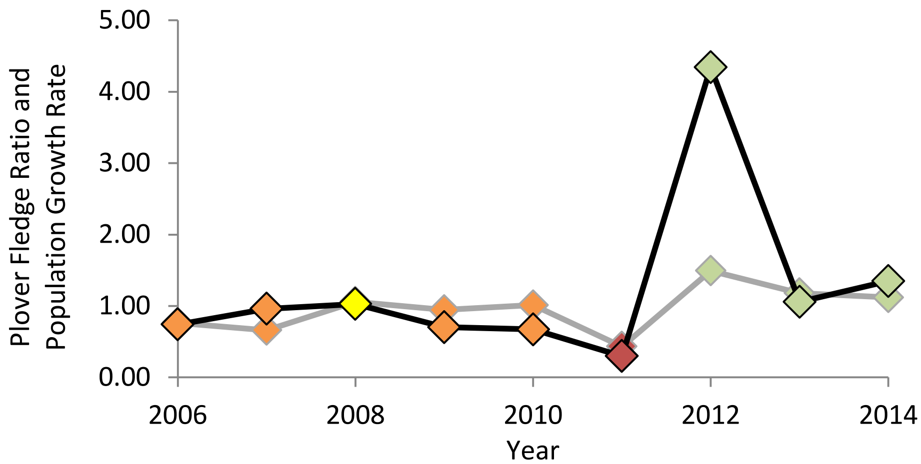
Table 35. Status-and-needs matrix for ESH and birds. The population status and habitat action needs depend on whether the population is growing, stable, or declining based on growth rate (λ) and fledge ratio (FR) and the ESH acreage relative to targets. Bold text indicates the status relative to the targets. The cell color summarizes the status and needs: dark green = objectives are being met and current management (habitat creation rates) should continue; light green = management objectives are exceeded and management can be reduced; yellow = species may be on or near the path to meet objectives, but management increases may be necessary; orange = objectives are not being met and unlikely to be met and management must increase; red = objectives will definitely not be met and strong increases in management must occur.

The status-and-needs matrix makes several important assumptions for simplification:

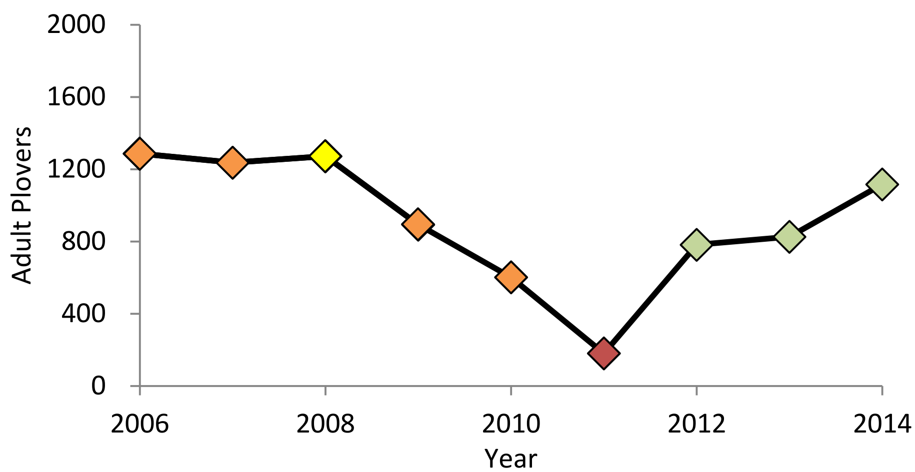
- Plover populations grow or decline based on population density (the number of adults/acre), according to the best available science about density dependence in plover populations. That is, growing populations are at low densities (first row of matrix), declining populations are at high densities (third row) and stable populations (second row) are at moderate, equilibrium densities. ESH acreage targets are built upon those assumptions. If density dependence is substantially different than that estimated when calculating ESH targets, unexpected outcomes may occur. This possibility is noted twice in the matrix: a population growing when ESH is less than the lower bound of the habitat targets is either quite small (low density) or the population can grow at higher densities than expected. Similarly, a population declining when ESH is above the upper bound of target acreage is either very large (high density) or density dependence is higher than expected. Such possibilities may occur within other cells in the matrix as well. When evaluating status, a check of recently observed productivity related to density should be made to ensure population dynamics are within the bounds of this assumption. If there is a deviation over multiple years, then management decisions need to account for a possible bias and ESH targets may need to be re-evaluated.
- The relationship between growth rate (λ) and fledge ratio (FR) is roughly consistent over time. This is only true as long as survival and emigration/immigration are also consistent over time (annual variability is expected, but the distribution of rates is expected to be stationary). If overwinter survival declines, emigration increases, or immigration increases, the calculated equilibrium fledge ratio may not support equilibrium population growth. The reverse is also true. If such variations occur, the population status would not fit in a single row of the matrix. In those cases, fledge ratio should determine where the status of the species lies, as that is most directly affected by MR management actions (i.e. management actions primarily address reproductive success, and cannot address conditions of overwinter habitat, which affect survival, or conditions in other breeding areas, which affect dispersal).
- Growth rate and fledge ratios are generally in sync. In reality, there is usually a time lag for changes in fledge ratio to be reflected in changes in population size, particularly when reversals occur. A declining population that has begun to grow again may have fledge ratios above equilibrium but growth rates below equilibrium for a year or two until the increase in fledglings is reflected in the population size. The same is true for growing populations that begin to decline.

See Section 3.5.11 (unexpected outcomes) for more discussion of handling observations that fall outside habitat or population dynamics as they are currently understood.

As long as the simplifying assumptions are taken into account, the status-and-needs matrix provides a shortcut for determining which path of action should be taken with a holistic understanding of both habitat and species status and trends. It also can be used to summarize and illustrate species status over time (Figure 53). Use of the matrix does not replace more detailed technical analysis and interpretation of habitat and population trends and forecasts. Quantitative modeling and assessment determines how much management and which action should take place. At a minimum, the acreage required to achieve or maintain habitat goals with a desired level of confidence is needed prior to making decisions. Tables generated from the ESH models simplify this process (see Fischenich et al 2016). If targets are not being met, the process and decision criteria to ensure shortfalls are corrected are described in Section 3.6.5.



a.



b.

Figure 53. Evaluation of status over time for a) plover fledge ratio (gray lines) and population growth rate (black lines) and b) plover population size. Symbol color indicates status relative to status and needs matrix (see Table 346 for definitions.)

3.5.4 Evaluation of management conditions

The evaluation of management conditions is the other half of the foundation for decisions, providing the necessary information on what actions are possible. Management conditions define the constraints on actions in a given year (Table 36). Management conditions of standardized acres, vegetated habitat, and population density determine whether habitat creation, vegetation removal, and predator control, respectively, would be effective and how much benefit would likely be gained (Section 3.2.2.3). Information on storage and tributary flows determines whether flow modification actions are feasible, their expected effectiveness, and opportunity for ESH construction or maintenance. Budget and logistics determine the capacity for most non-flow actions. Constraints related to storage, flows, and budget must be determined in the context of the entire program including operation for authorized purposes, pallid sturgeon management actions, research, and other costs.

Table 36. Summary of management condition constraints and opportunities relative to management actions.

Management Condition Management Action	Standard ESH acres	Vegetated sandbar acres	Storage	Planned releases	Tributary flows and downstream stage	Bird population density
In Preferred Alternative						
Mechanical construction	Amount of construction based upon current status relative to targets	High vegetated acreage may restrict suitable area for new bars	Increasing storage increases need for river habitat in north	Can only build if cfs < 35,000		Higher priority for building when density is higher
Sandbar augmentation and modification	Limited by extent and condition of available ESH	Sandbars with late successional vegetation less suitable for modification		Can only build if cfs < 35,000; can only modify what is above current flows		Use when bird density is moderate to high
Flows to avoid take				Releases set in May to accommodate downstream needs and forecasts	Accommodate downstream flood risks with lower releases; increases afterwards increase inundation risk	
Vegetation management		Limited to extent of vegetated acres		Only possible if stage is lower than vegetated habitat		

Predation management	May not be practical if acreage high	Vegetation increases need for predation management				Use when density >~X
Human restrictions						
Not in Preferred Alternative						
Habitat-creating flow	Most effective when combined acreage < X		Storage > 42 for spring release; > 35 SL for fall release	TBD	Flow less than 71 kcfs at Omaha, 82 kcfs at Nebraska City, or 126 kcfs at Kansas City	Most needed when density is moderate to high
Lowered nesting season flow	Moderate acreage (X<acreage<Y)		If water must be evacuated, low flows are unlikely (storage > ??)	Low flows more likely when below full service (specifics)	Accommodate water supply and navigation needs	Use at moderate to high population densities

3.5.5 Incorporation of new information

Research that is conducted over the course of the year is summarized in the annual AM report. MRRP-funded research will typically be reported upon in the Fall Science Meeting and the Annual AM workshop. Relevant non-MRRP research findings will also be discussed in the report when available, with consideration given to the level of QA/QC and peer-review or related evaluations such findings have undergone and to the design and strength of studies (For example, a study conducted over a single year with a small sample size would generally not be given as much weight as a multi-year study with larger sample sizes, particularly if the results of the studies are contradictory. For an example of a weight-of-evidence approach, see Diefenderfer et al. 2016.)

Occasionally, new or unexpected information might become available that has the potential to significantly alter some aspect of management under the MRRP and which is not captured in the annual AM science process. This may be a matter of timing (urgent findings which miss the AM reporting cycle) or because the information was not identified by the Technical or Bird Teams. Such information would be vetted and addressed through the process described in Section 6.2.5. Important insights emanating from the vetting process would be incorporated into the AM process in the same way as other monitoring and assessment results.

3.5.6 Evaluation of key relationships and science questions

Beyond determining system status, monitoring and research provides information for evaluating the critical uncertainties and management hypotheses (Section 3.1.2.5, Table 19). The assessment of evidence for hypotheses should be revisited annually to incorporate any new findings. The level of support for management hypotheses, as evaluated by the Technical Team should then be considered by the Bird Team when determining priorities for WP updates.

In addition to the critical uncertainties and management hypotheses, the physical and biological relationships underlying the conceptual and numerical models should be evaluated regularly. For example, the hypothesis that plover fledgling production is a function of habitat availability and population density underlies the model predictions, objectives and targets, and is the focus of the majority of management actions. New monitoring data collected each year adds information for routine analyses, following the EA (Buenau et al. 2014); e.g. Figure 54, and indicates where in the estimated density-productivity function the system currently falls. Updated analyses are reported annually and results are applied to ongoing modeling (see Section 3.5.7). Most analyses can be done quickly and consistently across years using established scripts in statistical software (e.g. R), though these approaches should be evaluated periodically and may need adjustments if monitoring protocols change.

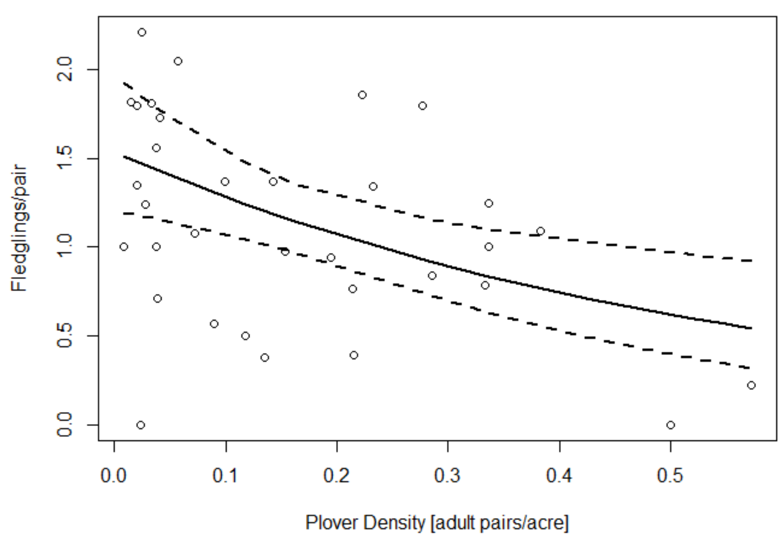


Figure 54. Example of an evaluation of key relationships. Results of best-fit model relating plover density to fledge ratio in annual assessment of density dependence in plover population. Points indicate fledge ratios in individual reaches and years, solid line is median prediction of model, dashed lines are 95% confidence intervals.

For questions that can be addressed quantitatively, the degree of uncertainty can be quantified and used to track the learning process as new information is added. New understanding may allow questions to be refined, or answered conclusively enough that they need no longer be evaluated as frequently. The potential for long-term change in system drivers suggests that hypotheses should be confirmed or re-confirmed over longer time periods. Additional science questions and management hypotheses may also be identified if new situations arise.

3.5.7 Evaluation of action effectiveness

The effects of management actions, particularly those with high uncertainty, can be assessed by predicting outcomes, monitoring the effects of action implementation, and then evaluating predicted vs. observed effects. An example of evaluating a habitat forming flow test is below.

Pre-implementation assessment: Decisions regarding implementation of habitat-forming flows will be based on application of the ESH models to: 1) forecast the outcome of each of several potential releases (e.g. lower magnitude/longer duration vs. higher magnitude/shorter duration) given the ambient ESH acreage, resulting in an expected value and distribution of ESH created, along with likelihood that target acreage will be reached or surpassed, and 2) assess the value of information from potential releases based on uncertainty assessment. Hydrological models and forecasts of flows, including the range of flows evaluated in the AOP, are used to 1) calculate a likelihood that the flow releases would have to be terminated early due to downstream conditions, and if so, the range of actual implemented flows that would result, and 2) assess relevant HC metrics across range of potential releases, with distribution of expected outcomes of impact or benefit and risk of exceeding critical thresholds. These assessments should include any of the relevant new decision rules (not used in the EIS evaluation) outlined in Section 5.8. Relevant models would also be run to assess synergistic or detrimental impacts of flow action on pallid sturgeon.

Potential benefits of a creation flow would be weighed against risks and discussed during the Work Plan engagement process (Section 2.4.4). Relevant risks include the likelihood and severity of HC impacts (individually and/or cumulatively) and the likelihood of early termination due to downstream flood constraints. A number of structured processes for decision making exist (see Section 2.4.5.2), and one or more of these processes would be employed to support the necessary decision. In time, the nature of the uncertainties may decline and/or risk tolerance may rise to the point that other decision rubrics may apply. For example, projected outcomes could be converted to indices and weighted towards overall assessment: <e.g. ESH created * likelihood of full implementation + value of information + synergistic benefits (including HC benefits)/sum of HC impacts>. A ratio in excess of some threshold (e.g. 3.0) may be required in order to proceed with the flow action.

Monitoring, after-action assessment and reporting: Monitoring of actual flow and HC outcomes would typically occur before, during and following implementation, depending on the specific issues being monitored (see Section 5.5.5). Monitoring of standardized ESH acreage is made on an annual basis in June and July, except for more detailed studies of ESH in sub-reaches. After-action assessment and reporting includes:

- A comparison of observed and projected hydrology at decision-relevant gages, with an explanation of any observed deviation and its relevance.
- A comparison of observed and projected HC impacts at decision-relevant locations. If there are deviations, can they be explained by deviations from expected hydrology? If not, are there errors/uncertainty in the HC models that should/can be addressed? (Models should be rerun with observed hydrology to distinguish between causes of error.)
- A comparison of observed and projected ESH outcomes for the reach and at any decision-relevant locations. If there are deviations, can they be explained by deviations from expected hydrology and/or normal range of variability? If not, are there errors/uncertainty in the ESH models that should/can be addressed? (Models should be rerun with observed hydrology to distinguish between causes of error.)
- Depending on the results of the above steps, outcomes either support existing models (dynamics occurred well within expectations, quantifiable to a Z-score) or provide information for challenging/updating models and other information. For ESH models, monitoring protocols should provide information that is always used through a protocol of verifying/updating the ESH models. Such procedures may also be developed for HC or sturgeon models as appropriate.
- Learning outcomes are quantified through estimates of reduction of uncertainty.

3.5.8 Evaluation of cross-program effects

Any observed effects of pallid sturgeon actions on birds, positive or negative, will be noted in the Science Update process. The anticipated effects of pallid sturgeon actions on birds (Table 31) are hypotheses that can be evaluated like the management hypotheses for bird actions. Biologically significant effects that increase or reduce the likelihood of meeting demographic or ESH targets may indicate that programmatic decision criteria and/or tradeoff assessments (see Section 2.2.2) should be reviewed to ensure they reflect new understanding of synergistic or negative interactions.

Similarly, effects of reservoir operations or other activities not specifically tied to bird or pallid sturgeon management should be noted and evaluated as part of the ongoing EA.

3.5.9 Model updates and validation

A primary mechanism for capturing and applying learning is incorporating new information collected during the previous year, if appropriate, into the models. This includes a) assessments based on monitoring data updated on an annual basis (e.g. habitat-productivity analyses, Section 3.5.6), b) information from research studies or short-term additional monitoring (e.g. geomorphic assessments following flow events) and c) information from external studies deemed to be of sufficient quality and relevance.

Routine updates of ongoing assessments based on monitoring data are straightforward. New data follows the same format and can generally use the same processing procedures, statistical methods and code. These assessments should be evaluated periodically to ensure they reflect up-to-date understanding and methodologies. Changes to the monitoring program or data management system may require some updates to procedures or analytical scripts. Incorporation of information from different studies or collected with new methodologies is more challenging. Case-by-case decisions must be made regarding whether new information should replace or be combined with previous information.

Updating model parameters with new information is straightforward to implement and is documented in the annual report, with annual modeling reflecting new information. These evaluations will be conducted by the Technical Team, but the Technical Team may consult with the Bird Team and/or Management Team about the use of additional information and should report on the effects of the changes being made as relevant to decision-making.

New information may allow for structural changes to the models (e.g. modeling ESH at finer scales), requiring additional time to develop, code, and test changes. In such cases, comparison of old and new model results (using otherwise the same parameters) should also be reported, to provide understanding of the consequences of the changes to model structure and function and the decisions informed by modeling.

Model validation procedures test model accuracy and precision by comparing model predictions with observations that were not used to parameterize the model. For example, adult counts were used to predict fledglings/pair/acre relationships for the plover model but not to predict population growth rates themselves within the model. Predicted and observed population growth rates can be compared as a form of model validation. Multiple levels of validation are useful for assessing model accuracy and identifying where error occurs:

- Comparison of observed and predicted standardized and available ESH, using actual flows (tests ESH model accuracy)
- Comparison of observed and predicted standardized and available ESH, using modeled flows (tests ability to predict future ESH dynamics, when flows are unknown, given model accuracy and distributions of modeled flows)
- Comparison of observed and predicted fledge ratios and population sizes, using observed ESH (tests accuracy of population models alone)
- Comparison of observed and predicted fledge ratios and population sizes, using predicted ESH (tests overall ability of model suite to predict population dynamics)

An example of model validation for the 2nd and 4th types of comparison, using data from 2005 to 2014, is shown in Figure 55. Model accuracy will vary depending on the time frame used; consistent time frames (e.g. 5 years) should be used for reporting and should be decision-relevant.

Models are statistically validated by comparing projected (model results) and observed (monitoring data) values for several parameters based on standard deviation scores (z; Tyre et al. 2000; Sheskin 2007), such that

$$z = \frac{X - \mu}{\sigma},$$

where X = observed value (e.g., population size estimate from monitoring data), μ = projected value (e.g., average projected population size estimate), and σ = standard deviation (e.g., standard deviation of model projected population sizes). This score is a measure of distance from the mean in standard deviation units, and is normally distributed with mean = 0 and variance = 1. The more similarity between projected and observed values, the closer the z-score is to zero, resulting in more evidence that model results are accurate. If the model is overprojecting the observations, then the z-scores will be negative. If the model is underprojecting the observations, then the z-scores will be positive. Statistical significance of z-scores is then tested using P-values, assuming that model results and monitoring or habitat data differed if $0.05 > P > 0.95$.

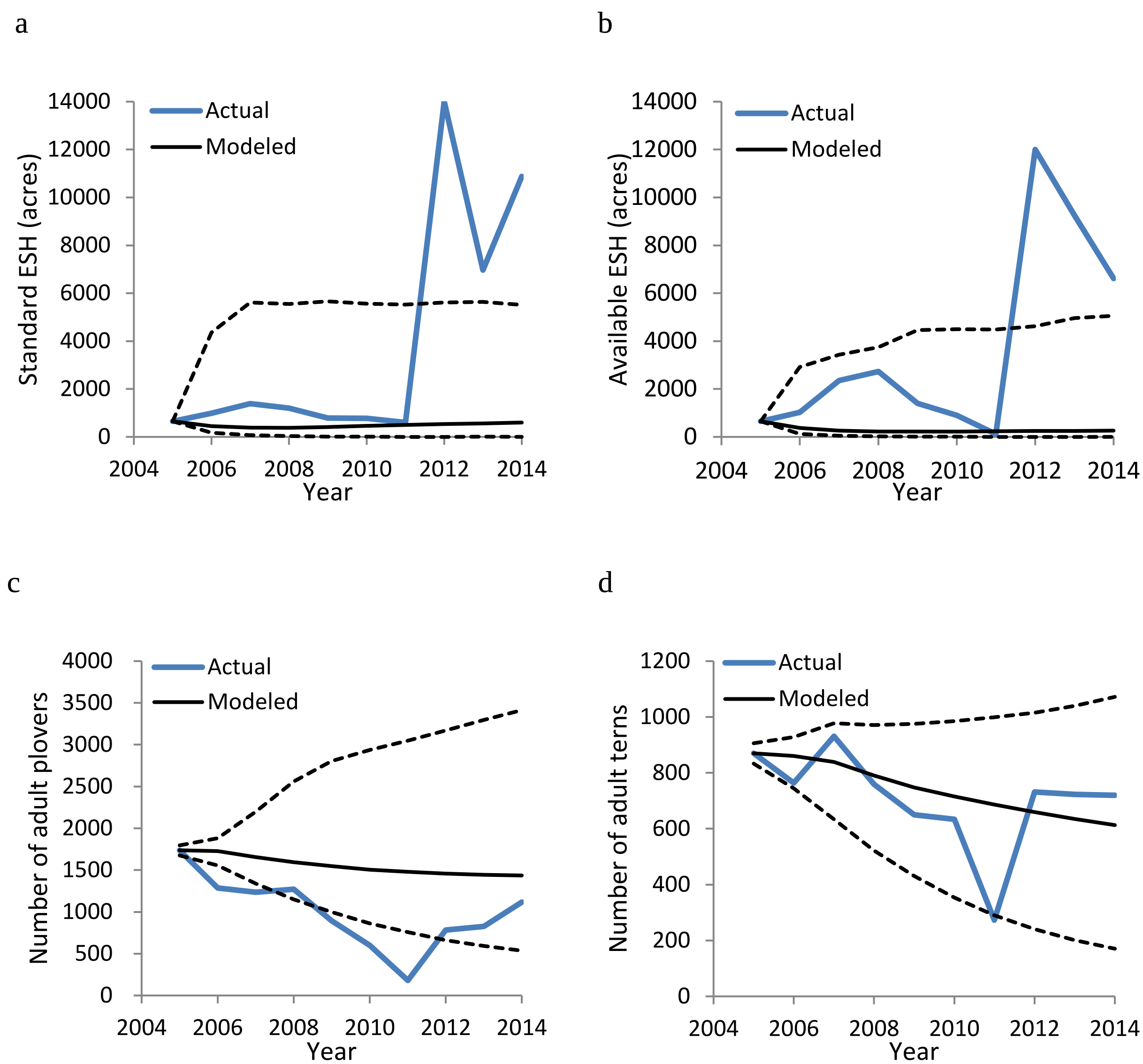


Figure 55. Example of model validation for 2005-2013 for a) standard ESH and b) available ESH modeled using predicted flows (validation type 2 above) and c) plover adults and d) tern adults using predicted ESH (validation type 4 above). Solid black lines indicate the median prediction of 5,000 model replicates; dashed black lines indicate the 95% confidence interval. Thick blue lines are observations.

3.5.10 Ancillary information

Additional information that is qualitative or site-specific also reflects learning and should be captured and synthesized. Examples of ancillary information include: observations about habitat quality on individual sandbars that could be addressed with management actions; local events such as storms that negatively impact bird survival and overall performance; observations of birds nesting in unusual locations; or patterns of ESH erosion. Such information should be quantified and systematically reported along with monitoring data in annual reports. Other information sources can be included if appropriately vetted (see section 6.2.5). Such information can be used to adapt local management actions, help explain patterns in monitoring data (e.g. multiple local factors could result in unusually high or low productivity in a reach), and identify questions and hypotheses for future research and analyses. The quality of ancillary information will vary and may be subject to bias due to how factors are observed (e.g. a lack of observations during bad weather when fieldwork cannot be conducted) and should be assessed when data is collected and/or compiled. Ancillary observations may indicate the need for more systematic monitoring of factors not previously monitored.

3.5.11 Unexpected outcomes

Unexpected outcomes occur when observed habitat or population dynamics fall outside of the range of behavior predicted by the models or otherwise anticipated from the understanding of the system. Examples include: ESH eroding or depositing much more or less than predicted given flows that occurred; bird populations continuing to grow when habitat is limited and population density is high, or conversely populations that are declining despite an excess of suitable habitat. Unexpected outcomes have three possible explanations:

6. Error in mechanisms of the models and/or foundational hypotheses: key driving factors are not represented, or represented in a functionally incorrect way that cannot predict observed dynamics.
7. Error in parameterization of models: the models have the correct mechanisms, but were parameterized in ways that cannot predict observed dynamics—i.e. the parameters are wrong or do not adequately cover the range of potential inputs.
8. A combination of mechanistic and parameterization error.

These errors have several possible sources:

- Insufficient or poor quality data were available for testing hypotheses and parameterizing models;
- Data were analyzed incorrectly;
- Fundamental processes have changed and older data used to test hypotheses and parameterize models no longer reflect conditions (e.g. climate-driven changes in hydrology; long-term changes to sediment budget; changes to bird survival because of migration or winter conditions, or disease, or other factors not captured in the models);
- Some combination of 1-3.

No model is completely accurate. Models used in this AM process explicitly incorporate and project uncertainty. Minor to moderate deviations of observations from projected outcomes are expected—adherence of real populations to median population projections would be highly unlikely. The degree of deviation, as calculated through the model validation process, and the direction of error are of more concern. Large deviations, and those consistently higher or lower (biased), should trigger assessments of why such error occurs.

If an explanation for error cannot be found or corrected, consistent biases in model projections should be identified so that management decisions can respond accordingly. For example, if population projections are biased high compared to observations, more conservative actions (i.e. higher rates of habitat construction) should be considered to compensate until models can be improved. Meanwhile, model validation and associated analyses can be used to identify areas of critical uncertainty and potential error that need to be addressed through research or enhanced monitoring.

3.6 Decisions and planning contingencies

Routine decisions for plover and tern management include when to act, how to act, how much of an action to implement, and how to conduct research and monitoring. These decisions must be made in a programmatic context, incorporating pallid sturgeon management needs and human considerations. They are also made within the current planning context: i.e., which actions are available for use under the ROD. This section includes decisions which have been identified as part of the Preferred Alternative as well as actions that have been evaluated but not included in the Preferred Alternative. Decision criteria have been developed for both categories to represent the AM process across alternatives evaluated in the MRRMP EIS.

The following sections, as well as the descriptions of actions in Section 0, provide guidelines and decision triggers for management action implementation. Decision criteria and triggers provide a pre-specified roadmap to follow and allow for general estimation of the relatively likelihood of specific actions occurring in practice. However it must be recognized that the Missouri River system is too complex and variable to pre-specify every contingency in a way that would optimize the effectiveness and efficiency of on-the-ground management. Predictive models aid in the evaluation and selection of management options; their use in this context is described below. Models, too, cannot account for all available information and situational constraints. Judgment and current scientific understanding must be applied when using decision criteria and triggers.

As described in Sections 3.5.2 and 3.5.3, decision-making relies upon the identification of management needs and management opportunities for the next 3-5 years. This information determines the scope of decisions to be made.

3.6.1 Decision making process

The annual decision-making process in described in full in Section 0, with a brief summary focused on bird management provided here. Following the evaluation phase and the release of the Draft Annual AM Report, the Bird Team meets to develop a list of priorities for updating the multi-year Work Plan. Activities for the current FY are already set, and budget has been established for FY+1. The Bird Team may identify adjustments to the plans for FY+1, but their focus is on specific planning for FY+2 and general planning, including estimates of budget needs, for FY+3 and FY+4.

Using information provided from the Technical Team and guidance on program direction, the Bird Team develops a ranked list of priorities. While aware of the anticipated budget and competing uses of funding, water, and other resources, the Bird Team focuses on identifying plover and tern management needs without attempting to balance programmatic needs. In this way they can identify the optimal pathways to meeting bird objectives, allowing the Management Team to make the decisions needed to balance programmatic needs. The Bird Team would typically identify a suite of actions, including more actions than may be required to meet the targets, and identify any key dependencies among the actions, so that the Management Team can consider alternative approaches when formulating the draft Work Plan. The Bird Team may also identify more than one management option (i.e. alternative strategy); this is most likely to occur when a flow action is proposed as an alternative to construction of ESH, as tradeoffs will need to be considered and contingency plans identified in case the flow cannot be implemented.

The Management Team uses the prioritized lists from the Bird, Fish and HC Teams to allocate resources and identify which actions can be implemented, while taking budget and HC factors into account. If flow modifications outside of routine operations are being considered, the Management Team may make recommendations and MRBWMD decides upon reservoir operations with consideration of those recommendations. The updated Work Plan is then released, reviewed, and finalized according to the process identified in Section 2.4.4.

Some decisions must be made in near real-time rather than during the annual cycle. Activities such as habitat modification techniques and predation control may need to be responsive to conditions on the river; while they are anticipated and planned for in advance, details of their implementation will be made by implementation staff during the construction or nesting seasons. Real-time decisions regarding flow modifications for habitat or flow management to reduce take are made by MRBWMD.

3.6.2 Information for making decisions

The Annual AM Report includes descriptions of the habitat and species status and needs (Section 3.5.3) and management conditions (Section 3.5.4) which provide a starting point for what is needed and what is possible in upcoming years. The report also includes updated assessments of management action effectiveness that the Bird Team will consider. In addition to this information, the Technical Team provides modeling of potential management options as decision support tools.

3.6.2.1 *Model projections of management options*

Depending on the set of available management actions, there may be more than one means of meeting bird objectives and targets, including different actions or different implementation of actions in time or space. The most effective and efficient combination may not be readily apparent, particularly when interactions and natural variability are taken into account. Predictive models can help to determine the optimal combination and intensity of each management action. Incremental benefits of additional management actions or increased effort can be compared with the incremental costs and impacts. In cases where available management options are not expected to meet targets, models can also be used to estimate the impact in future years of short-term shortfalls. This information can be used at the programmatic level to estimate future resource needs and priorities. Once a set of management options has been identified, the predictive models are used to project the expected distribution of habitat and population outcomes for each management option and a “do nothing” baseline comparison. These projections indicate which alternative comes closest to the target trajectory.

A hypothetical example comparing two management actions with the target trajectory and a do-nothing scenario is shown in Figure 56. The scenarios approximate a resource-limited case. Option A uses limited funding to build habitat, but maintaining the target acreage is not possible. Option B uses a flow release to create habitat when conditions allow (prior to year 3) and uses resources to maintain as much of that acreage as possible. Bird populations fare better in the first three years with Option A, but then begin to decline. The population in Option B is not on path to meet targets until year 4 but has habitat and population trajectories very near the target scenario by year 5.

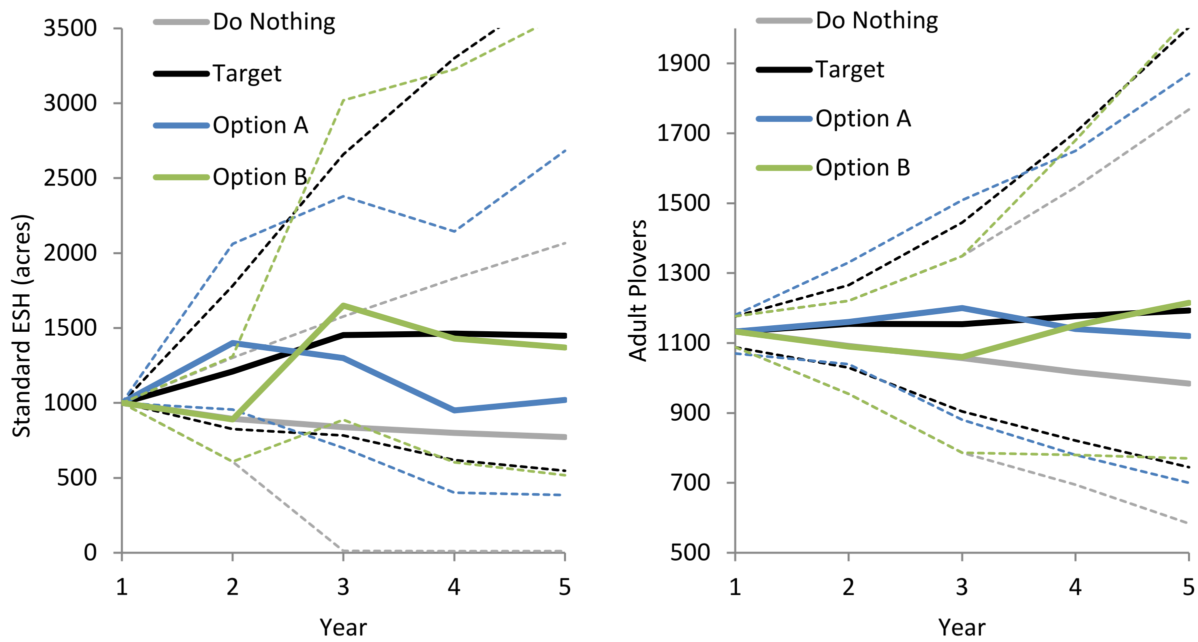


Figure 56. Model projections of a) standard acres and b) adult plovers for two hypothetical management options, compared to a target trajectory and doing nothing. Solid lines are median results of 5,000 model replicates. Dashed lines are 95% confidence intervals.

While this invented scenario is a simplification, it illustrates the importance of using models to compare outcomes across multiple time scales. The use of confidence intervals is also important: while it is expected that the plover population will do better with Option A or B than doing nothing, there is a large overlap in the confidence intervals and it thus cannot be known for certain that one scenario would outperform another in real-life application. The probability of success, however, will likely be different and such probabilities should be explicitly stated and used in the decision making process. All comparisons used for the basis of decisions are probabilistic and must be interpreted in the context of acceptable levels of certainty and risk.

3.6.3 Management action decisions

Most decisions about which actions to implement, when, where, and how are multi-factor decisions. While quantitative criteria can be developed (e.g. how much ESH to create to have a specified likelihood of meeting the target, according to the models), most decisions cannot be simplified to single criteria or triggers. In this section we outline the considerations for implementing management actions. These include flow modifications analyzed in the MRRMP EIS but not included in the Preferred Alternative. The considerations are given as a series of questions that should be answered prior to making a decision. Quantitative criteria for individual factors and multi-criteria decision analysis tools to weight multiple factors can be developed if more quantitative and formal tools are determined to be helpful. Additional tools could be formalized through the AM process if deemed useful.

Evaluations of HC factors related to implementing flow modifications for birds are described in more detail in Chapter 5 and referenced but not reproduced here.

3.6.3.1 *Decisions about how to create habitat*

The Annual AM Report includes estimates of the amount of ESH, if any, that needs to be created. Once the need has been determined, the decision scope is outlined by answering these questions:

- What is the capacity for implementing mechanical ESH creation in the next 1-5 years, taking budget, logistics, possible flow releases, and other constraints into account?
    - What habitat distribution is expected to result if construction were fully implemented?
    - What habitat distributions would be expected if construction could not occur in specific years due to fall releases > 35 kcfs? If budget was not sufficient in one year? Etc.
- Are flow actions to create ESH part of the current set of actions?
    - If yes, how likely is it that reservoir storage will allow for habitat-forming releases in the next 5 years?
    - What habitat distribution is expected to result from a release?
    - If no flow action is available, under what circumstances would a flow test be considered?

While neither future budget nor reservoir storage and releases can be known with certainty, the 5+ year time frame allows for more thorough considerations of timing, including whether more intensive near-term management may be needed to buffer against any reduced ability to act in the future.

If there is a choice between whether to implement flow actions or mechanical creation or how to combine the two, the following questions should be answered:

- *How much ESH is currently present?* Flow releases to create ESH provide the greatest benefit when ambient ESH area is low, as more ESH is created for any given flow release. If large amounts of ESH are available, flow releases may provide little or no benefit.
- *What is the degree of need for ESH?* If larger amounts of habitat are needed, flow creation may be more effective, especially if costs of construction are prohibitive. For

smaller shortfalls in ESH, benefits gain from flows may not outweigh potential risks or conflicting water use.

- *What is the degree of need for the bird population?* Lower risks to the bird population and some other objectives favor the use of habitat construction rather than flow releases, if feasible.
- *Are there competing uses of storage that might preclude habitat-forming releases?* The ability to meet multiple use needs including sturgeon management actions and HCs should be weighed along with benefits to ESH.
- *What are the anticipated human considerations effects?* Estimated impacts and benefits from a habitat-forming flow should be considered (see Chapter 5 for more detail.)
- *Are there synergistic uses of flow actions?* Flows that meet multiple purposes receive higher priority than those that only create ESH.
- *What is the likelihood of flows allowing construction?* High releases may preclude construction.
- *What is the likelihood that the flow release will be successfully implemented?* Planning for a flow, and then being unable to implement it, causes a delay in overall habitat creation.
- *Are there learning opportunities from implementing a flow release? What is the expected value of the information?* Initially most flow releases will provide uniquely valuable information, but some may provide more critically needed information than others and are opportunities for active AM.
- *Are there learning opportunities from implementing construction? What is the expected value of the information?* While there is less uncertainty about construction, learning opportunities may arise that would prioritize construction over flow creation.

Answers to these questions provide a qualitative decision basis and aid in documenting decisions. More specific criteria and/or quantitative criteria may be developed in the future.

Decision and collaboration level: The Management Team decides whether to implement construction or recommend flows (or both, over the multi-year Work Plan). If flows are recommended, Water Management at the Oversight level must make the decision and informs and review actions with MRRIC as described in Section 2.4.2.

3.6.3.2 *Decisions about constructing habitat*

Mechanical construction also requires additional decisions of how much to build within each reach, and at what specific locations.

- *How much ESH is needed to meet targets in each reach?* Habitat targets are specified separately for the north and south regions (Garrison in the north and Fort Randall and Gavins Point in the south), so the ESH needed for each region can be determined. ESH availability may or may not be in sync between regions, so priority may be given to one region over another.
- *What is the population status in each region?* Assessments of population density, fledge ratios, and population growth rates within each region should be assessed to determine if one region should receive more habitat creation effort. Demographic targets are prioritized over meeting ESH targets.
- *Are there constraints that limit ESH construction in any reach in the next 1*-5 years? Construction activities for the current FY are already contracted during the decision making cycle; if it appears that construction may not be possible, e.g. due to higher fall releases, additional construction should be planned for future years to compensate. Logistical considerations may result in construction that is suboptimal from a target perspective but still beneficial.

The numerical models can be used to predict the expected outcome of different construction strategies. Moreover, the agencies may agree to accept the risk of constructing to a level less than target in a given year (due to budget constraints, for example), or to build more than needed to meet targets as a hedge against the risk that conditions in that or future years might limit availability. Such strategies, however, may be inefficient and more costly over longer time periods.

Decision and collaboration level: The Bird Team and associated implementation staff decides where to construct ESH, in coordination with states, tribes, and other agencies as needed.

3.6.3.3 *Decisions about how to create habitat through flows*

Decisions about when and how to implement habitat-forming flows (should they be included in a ROD and ensuing revisions to the Master Manual) would be driven by ESH need and HC-focused decision criteria. Multiple options for creating ESH may be available and should be assessed with the following questions, supported by modeling:

- *What is the expected amount of ESH created by a potential flow release?* Flows of higher magnitude and/or longer duration create more ESH. Constraints on magnitude and duration are included in the action definition. The amount of ESH prior to the flow release will also affect the amount created, and the amount available during future nesting seasons will depend upon the intervening flows.
- *What is the expected bird response to a potential flow release?*
- *What are the expected effects on pallid sturgeon?*
- *What are the expected impacts to HCs?* See Chapter 5

- *What are the expected benefits to HCs?* See Chapter 5
- *Under what conditions would flow modifications be reduced or stopped during implementation?* See Chapter 5

Adjustments to the timing of flow releases (which years, and when during the year) can be used to reduce expected impacts and increase expected benefits. Tradeoff analyses may be necessary to support these decisions and are described in Chapter 5.

Decision and collaboration level: If flow modifications are recommended by the Management Team, MRBWMD must make the decision about how to implement flows and informs and review actions with MRRIC as described in Section 2.4.2.

3.6.3.4 *Decisions about modifying existing habitat and vegetation removal*

Deciding to modify existing habitat (sandbar augmentation/modification and/or vegetation management) is largely a case-by-case decision based upon observations at individual sandbars.

- *Is early-successional vegetation present and above water after the breeding season ends?* Vegetation removal is more efficient at early successional stages, so in most cases removal is warranted to preserve the useful lifetime of ESH.
- *Are there constraints on the use of vegetation removal techniques at a location?* Regulations or HCs may affect the use of vegetation removal at some sites.
- *Is foraging habitat limiting on sandbars that have suitable nesting habitat?* Consider reshaping to provide more foraging habitat.
- *Can low-elevation sandbars be built up to provide nesting habitat that is less vulnerable to inundation?* Consider augmentation or overtopping to provide habitat with less inundation risk.
- *Has predation or human activity been prevalent on a sandbar, impacting bird productivity?* Consider *not* maintaining habitat that may be attractive to nesting birds but results in high mortality due to recurring disturbances. Vegetation removal may reduce risk from some predators, but not all.

Decision and collaboration level: The Management Team decides on the budget available for habitat modification, as informed by the Technical, Bird, Fish and HC Teams. Implementation staff decides on location, methodology, design and contracting based upon identified best practices. MRRIC is informed through the work plan.

3.6.3.5 *Decisions about whether to lower nesting season flows*

Lowered summer flows expose more ESH and thus can be used to increase habitat availability to meet targets, especially when enough ESH cannot be created. The amount of lowering required to have a beneficial effect depends on how much ESH is available and its elevation. Some flexibility to manage lower flows during the nesting season exists within the current technical criteria in the Master Manual. Factors for these decisions include:

- *How much standardized ESH is currently present?* If there is very little ESH available and little additional habitat to be exposed, the benefit of reducing flows may not outweigh impacts. If there is abundant habitat and population density is low, lowered flows have little benefit. Benefits are maximized at low-moderate amounts of ESH with high population densities.
- *How well have habitat availability targets been met in recent years?* A higher need for meeting habitat availability target supports lowering nesting season flows.
- *What are the projected flows absent additional modification?* The availability of ESH given projected flows may be sufficient to meet needs without further modification. Comparison of the expected flows to downstream needs informs how much flexibility there may or may not be to alter flows.
- *Are there synergistic use of lowered flows?* Flows that meet multiple purposes (e.g. benefits to pallid sturgeon; benefits to conserving water in reservoirs) receive higher priority than those that only create habitat.
- *How will reservoir populations be affected?* If the sub-populations nesting on reservoir shorelines are doing well, short-term impacts from holding back water in the reservoirs will have low impact on long-term viability of the northern population.
- *Are there competing uses of storage that might preclude habitat-forming releases?* See Chapter 5
- *What are anticipated human considerations impacts?* See Chapter 5

Decision and collaboration level: Collaboration on lower nesting season flows within current Master Manual criteria follows the AOP process and would be included in the WP as time permits. If lowered summer flows as a deliberate, planned activity are added to the ROD, adjustments to the Master Manual may be required to accommodate more substantive flow management. To modify the action, a high level of collaboration would occur and those decisions would be made at the Oversight level (see Section 2.4.6.5).

3.6.3.6 *Decisions about predation management*

Deciding to implement predation management is largely a case-by-case decision based upon history and observations at individual sandbars and landscape characteristics, though overall population density can help rate the risk of predation and value of management.

- *Has predation been observed on a sandbar/segment in the past?*
- *Is there evidence for predation occurring during this nesting season?*

- *Is the population density above thresholds where predation is more likely?*
- *Do landscape features (vegetation cover, nearby trees) support predators?*
- *Is the sandbar attached to shore in the anticipated range of flows during the nesting season?*

Decision and collaboration level: The Bird Team estimates the degree of predator control needed as informed by the Technical Team's projection of population density. Implementation staff decide on amount and locations based on ongoing monitoring during the season.

3.6.4 Decisions related to experiments and research activities

Opportunities for experimental implementation of management actions can be exercised to develop more productive, efficient, and cost-effective means of achieving the bird objectives. Learning can be accelerated by implementing an action in different ways (e.g. testing and monitoring of different sandbar designs) or implementing actions to broaden the available data, allowing for more definitive hypothesis testing (e.g. implementing flows across a range.) This may include *not* implementing an action that may be otherwise recommended if the information to be gained is sufficiently important. Decisions about experimental design and research implementation are based on the following considerations:

- *What data gaps need to be addressed? What hypotheses require more evidence?* Regular evaluation of evidence for management hypotheses will identify the need for research and the specific questions that should be addressed.
- *What is the expected value of the information?* Learning resulting in greater gains in the efficiency and effectiveness of management should be prioritized. Modeling can help quantify potential benefits of research or experiments.
- *Are there additional benefits to experimental implementation?* Projects may help answer other science questions, enable other research, or provide HC benefits.
- *Does the experimental design increase the likelihood or magnitude of HC impacts?* The potential for impacts not normally associated with an action, or an increase of known impacts, should be evaluated and additional monitoring/analysis, if needed, identified in advance.
- *Are there conflicts or constraints that may preclude completion of the experiment?* For multi-year experiments, the ability to complete the project may be more or less certain or require tradeoffs with other activities. Some experiments may conflict, especially those that include flow modifications.
- *What additional monitoring of outcomes will be necessary, for how long, and for what cost?* In some cases, it may be possible to assess the outcome of experimental actions with the existing monitoring program; in other cases more

focused and/or intensive monitoring or monitoring of additional factors may be required, possibly for multiple years.

Other research activities not directly connected to management actions (e.g. studies of bird foraging ecology, dispersal, etc.) should receive similar consideration:

- *What data gaps need to be addressed? What hypotheses require more evidence?* Regular evaluation science questions and biological hypotheses will provide the information necessary to identify the need for research and the specific questions that should be addressed.
- *What is the expected value of the information?* Learning resulting in greater gains in the efficiency and effectiveness of management should be prioritized. Modeling can help quantify potential benefits of research or experiments.
- *Are there conflicts or confounding factors that may interfere with research or limit application of findings?* Not all factors can be anticipated, but planned management actions or reservoir releases may affect the ability to perform research, to carry out the full length of the intended study, or to interpret the results.

Identified experimental and research actions will be prioritized based upon these criteria and balanced with other management and research needs for funding and implementation.

Decision and collaboration level: Collaboration on research and experimental management actions will vary depending on the nature of the activity. Collaboration on research activities will generally be through an annual needs elicitation (to which the MRRIC may respond), the Fall Science Meeting and the Annual AM Workshop. Decisions regarding which studies to fund will lie with the ISP Manager, subject to the R&D budget provided in the Program. The Management Team proposes the R&D budget in the draft Work Plan, but that figure is subject to approval and appropriations. Collaboration on experimental implementation of management actions would generally be consistent with any other implementation of that management action (see specific action descriptions for examples) and go through the Work Plan process. Decisions would generally be made by the Management Team with input from the Technical, Bird, Fish and HC Teams, with consideration of any MRRIC recommendations. Decisions regarding flow tests would be made by the MRBWMD.

3.6.5 Decision criteria for when targets are not met

The definition of targets in Section 3.2.3 includes the quantitative criteria and time frames for meeting targets. There are a number of reasons that the program could fail to meet targets over the specified time frames. Steps to solve the problem are associated with each potential reason. The AM process is forward-looking and will attempt to anticipate and remedy shortfalls before they occur with the use of predictive modeling and adjustments to management actions in the Work Plan. In the case that problems are not anticipated, or remedies cannot readily be implemented under existing program operation, constraints, or priorities, the criteria described below outlines decisions or decision processs that need to occur. While requirements for specific management actions following failure to meet targets have not been established, decision criteria have been or will be developed to facilitate the decision making process and ensure the relevant scientific information is available and in useful form. These decision criteria do not pre-specify the outcomes of decisions, only that the decision process be initiated with sufficient time to address the problem and followed through to a determination of necessary adjustments to the Work Plan or the AM Plan. While the process may determine that no adjustments will be made, the decision criteria ensure that relevant information is taken into account and the decision was made at the correct level(s).

The diagnostic process would be initially conducted by the Technical Team to identify current or anticipated problems and their causes to the extent possible based on monitoring and other program information; the Bird Team would review the diagnosis and identify solutions to be approved by the Management Team or elevated to the Oversight level. Generally, the Oversight level is responsible for deciding whether or not to remove constraints on action implementation, add actions, or change objectives or target criteria based on policy decisions (e.g. as opposed to updating target values based on new data). Some changes would also require additional NEPA analysis and/or formal consultation with the USFWS (Section 2.4.5). Changes to implementation processes or criteria for existing actions within established constraints, or science-based adjustments to target values may not require Oversight approval.

Figure 57 illustrates the series of diagnostic questions for determining why targets are not being met and steps to take to remedy the problem and improve future performance. Problems are listed starting with questions based on scientific understanding and moving to questions about program design and acceptance of risk. It is possible that there may be more than one problem at any given time, but it may be necessary to correct some problems before addressing others (e.g. must be able to fully implement habitat creation guidelines before determining if the creation criteria are sufficient.) Each question and associated recommendation for resolution are described in more detail below Figure 57.

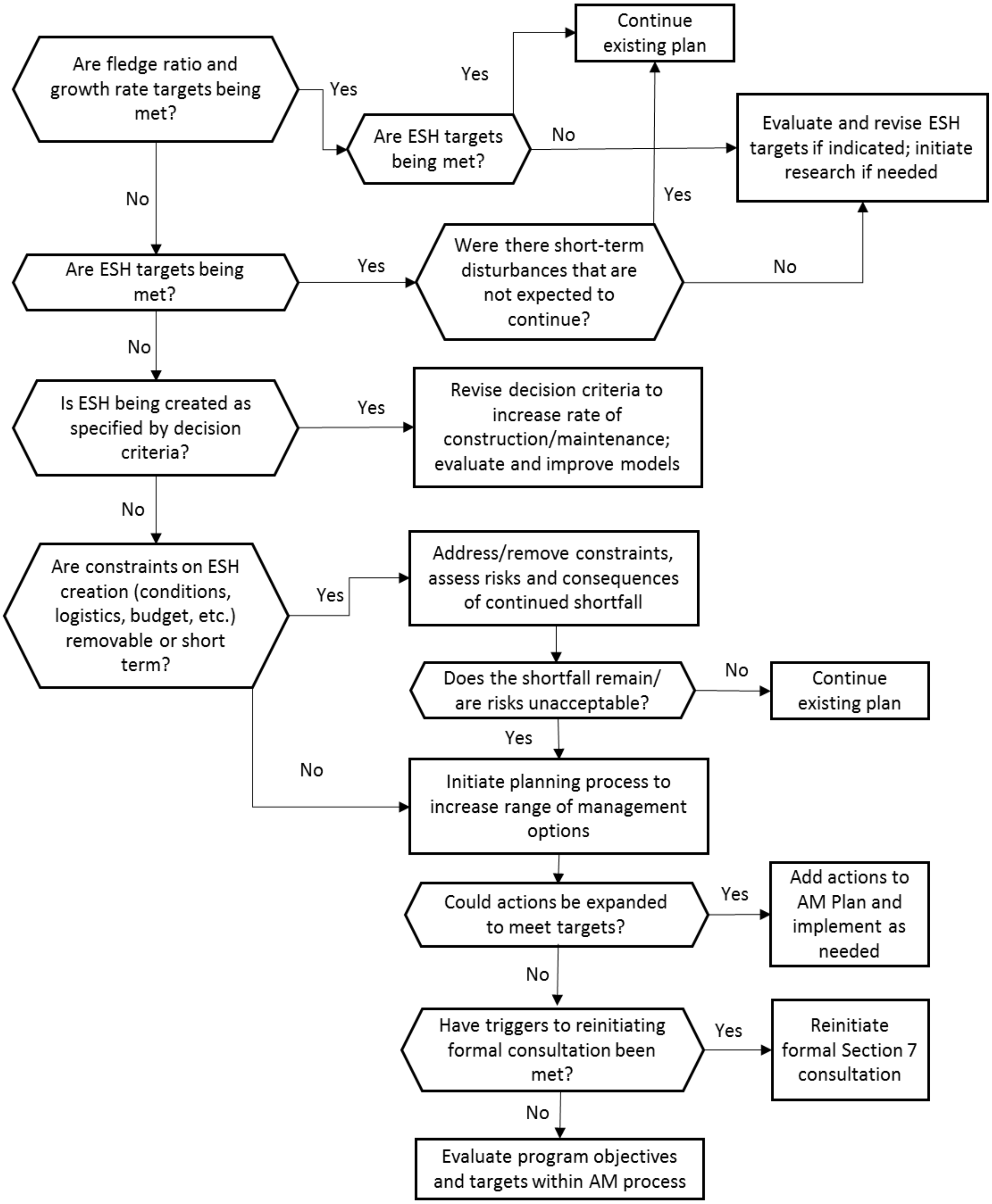


Figure 57. Diagnostic decision tree for a) determining why bird targets are not being met, and b) identifying recommended corrective actions.

1. *Are fledge ratio and growth rate targets being met?*
   a. *Criteria:* Fledge ratio growth and population growth time frames as specified in targets (3-year arithmetic and geometric means, respectively).

   b. *If yes*, the existing program is sufficient and should be continued. However, it is also possible that demographic targets are being met but ESH targets are not. If this occurs over multiple years (to account for time lags in population responses) then ESH targets may be higher than than they need to be and should be assessed and revised if appropriate. **Action: continue program, revise ESH targets if information suggests they are higher than needed to meet demographic targets.**
   c. *If no*, continue to question 2.
2. *Are ESH targets being met?*
   a. *Criteria:* Median standard ESH target is met 3 out of 4 years; available ESH target meeting exceedance criteria over 12-year time frame.
   b. *If yes:* ESH targets may not be high enough either due to insufficient data when targets were set, or because conditions have changed. Targets should be updated with new information; if new information is not available, additional research or monitoring to improve targets should be identified. It is also possible that unusual circumstances (disturbances) lowered demographic rates despite sufficient habitat. If circumstances are identified and not expected to persist, ESH targets may be retained. **Action: evaluate controlling factors, disturbances, and ESH targets; revise ESH targets if the shortfall is not caused by short-term disturbances, initiate additional research if needed to inform models and target calculations.**
   c. *If no:* continue to question 3.
3. *Is ESH being created as specified by decision criteria and model estimates?*
   a. *Criteria:* Meeting habitat creation guidance for 4 out of 5 years (construction rates estimated by model to have 60% chance of meeting targets; criteria for implementing flow actions if available).
   b. *If yes:* Habitat creation guidance criteria is structured to provide sufficient habitat to meet targets given uncertainty in geomorphological understanding and future flows. If habitat is insufficient in the long term after levels of habitat creation specified by the criteria have been met or exceeded, then the models have bias that needs to be corrected and/or assumptions about the hydrograph is incorrect (e.g. flows are in the highly erosive range more often than in the past due to changes in management, basin runoff, or changes in channel morphology and sediment budgets.) Construction estimates can be adjusted to accommodate bias/uncertainty until models can be improved. **Action: Adjust habitat creation criteria to accelerate construction. Evaluate models for sources of bias in habitat estimates; initiate additional research if needed to improve models.**
   c. *If no:* continue to question 4.

4. *Are the factors constraining ESH creation (conditions, logistics, budget, etc) removable or short-term?*
    a. *Criteria:* Constraints are short-term if not expected to occur more than 1 out of 5 years
    b. *If yes:* Constraints and/or conflicts are not allowing the current set of actions to be conducted to the necessary extent. If constraints can be removed by changes to practices, water management, regulations, or changes in priority, than the problem may be resolvable without changes to the set of actions available for use. Other limitations may be known to be limited in term and not expected to recur. **Action: Remove constraints and assess risks and consequences of continued shortfall by any combination of remaining or anticipated future constraints.** Continue to Question 5.
    c. *If no:* continue to Question 6.
5. *Do shortfalls remain/are risks unacceptable?*
    a. *Criteria:* Risk acceptability varies over time, by interest group, and circumstantially. The MRRP will seek to identify (and periodically update) appropriate criteria through the AM process.
    b. *If yes:* The current set and definitions of management actions is not sufficient to meet targets. A broader scope of existing actions and/or the addition of new actions will be necessary to meet objectives. **Action: Initiate planning process to increase range of management options (see sections 2.4.5 and 3.6.6)**
    c. *If no:* continue to question 6.
6. *Can the set of or specifications of actions be expanded to meet targets?*
    a. Results of tradeoff analysis and NEPA processes (as appropriate) indicate actions may be added or expanded in scope
    b. *Criteria:* Specific criteria not identified at present. Criteria development will be a consideration during the transitional period between the DEIS and establishment of the ROD.
    c. *If yes:* add actions to AM Plan, develop necessary decision criteria, and implement as needed and appropriate
    d. *If no:* continue to Question 7
7. *Have conditions for reiniating formal consultation been met?*
    a. *Criteria:* Formal consultation may be reinitiated if "new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion" (USFWS 1996)[1]. That is, the proposed action evaluated by the Biological Opinion included the current targets and associated decision criteria; if

[1] This criteria for reinitiating formal consulation is most relevant to failure to meet targets. There are three additional criteria listed in Section 3.6.7.3.

not met, the USFWS must determine whether the previous consultation is still sufficient.

b. *If yes:* **Action: reinitiate formal consultation under Section 7 of the ESA.**

c. ***If no:*** **Action: revisit program objectives and targets within Oversight Level with support from the Bird Team and Technical Team.**

3.6.6 Decisions to add, change, or remove management actions

Decisions to change how actions are implemented or to add new actions can be triggered by a) new evidence for action effectiveness, b) new evidence indicating expected impacts that precluded an action are sufficiently unlikely, c) regulatory changes that allow additional/broader actions or d) evidence that targets cannot be met with existing actions, thus requiring consideration of expanding the set of available actions.

The decision to add actions is supported by tradeoff analysis, balancing evidence for action effectiveness and for HC impacts and benefits (see Section 2.4.5.2). Cost-effectiveness should also be considered, though the toolbox approach described in Section 3.2.1 includes maintaining a range of management actions for use, even less efficient ones, when the most cost-effective options may not be implementable.

If targets cannot be met using actions currently in the ROD and no additional constraints upon their use can be reduced or removed, addition of actions outside of the ROD should be considered before evaluating targets or reinitiating formal Section 7 consultation (Figure 57). This process also requires trade-off analyses or other structured decision techniques (Section 2.4.5.2).

Criteria for changing individual actions are included in Section 0. The process for adding actions, particularly flow management actions, is described in Section 2.4.5. Actions may also be adjusted during implementation, though they may only be increased in magnitude during implementation to the extent that the action was defined within the programmatic EIS or site-specific assessments. Increase in action specifications for future uses outside of what has previously been analyzed in the EIS would require additional analysis and a decision document before implementation.

Decisions to stop an action during implementation can be triggered by approaching identified HC thresholds (see Chapter 5) or indications that an action is no longer effective or needed. Decisions to reduce the scope of an action or not use it in the future may occur if there is sufficient weight of evidence that an action is not effective or following an evaluation of HC impacts (see Chapter 5). The decision to remove an action from future consideration requires cost-benefit determinations under a variety of scenarios that weigh the use of the action against other alternatives. Low cost, low impact actions may be retained even if less effective than other actions, as they may be useful in cases where resources or conditions do not allow more effective action.

3.6.7 Decisions to change metrics and targets

The process to change metrics and targets depends on the type of change required. Updates to metrics and target values (using the same criteria) are science-based and expected to keep pace with new information with regular updates. Changes to target criteria and or objectives are largely based on policy, risk tolerance, and values and expected to be infrequent. These processes and the information or events that trigger them are described below.

3.6.7.1 *Updates of habitat and fledge ratio targets*

Target values (e.g. acres of ESH, fledge ratios) are developed using the ESH and population models and, consequently, reflect the current level of quantitative understanding. As management, monitoring and research continue, the models will be updated to reflect learning and provide more accurate estimates of habitat and population dynamics, habitat requirements by nesting birds, and population persistence. Periodically, ESH targets should be recalculated to reflect updated information—i.e. every 5 years for incremental changes or more frequently if there are major updates or revisions to models. Note that most changes to either the population model (e.g. survival rates) or the habitat or hydrological models would change calculated ESH targets. ESH targets should be recalculated often enough to allow learning to improve management outcomes, but not so frequently as to hinder reasonable planning and assessment processes. These updates can correspond with broader periodic programmatic reviews. Large increases in information—for example, completion of a research study that allows for significant model improvements—may justify interim updates, pending agreement at appropriate decision levels. Decisions follow the process outlined in Section 2.4.2.

Similarly, new information about demographics, particularly survival rates, would indicate that the fledge ratio target would need to be updated. This value should be periodically assessed and interim updates may be warranted following significant science findings.

It is important to note that these updates are to the quantitative value of the targets for the existing target criteria, not changes to the criteria themselves. These changes are informed by the data available, are not policy- or value-based, and are expected to occur more frequently than changes to the criteria themselves.

For the periodic updates to targets as described above, the Technical Team provides the information about revised target values to the Bird Team, who in turn include request the for adjustment in their recommendation to the Management Team. Updates to the values are approved by the Management Team, who informs the Oversight level of the change and resulting changes to the Work Plan. This update does not require Oversight approval. If either the Bird Team or the Management Team declines to recommend updating the targets, or recommends/approves an updated value that differs from the recommendation of the Technical Team, the original proposal is presented at the next MRRIC meeting along with the basis for the deviation (see the "chain of custody" discussion in Section 2.4.6.1). Agency leadership may consider this information and render a final decision regarding the targets. The MRRIC may make a recommendation regarding the adjusted value.

3.6.7.2 *Revisions to metrics*

Increased scientific understanding may also result in changes to how habitat or populations are measured in the context of objectives. This includes changes to how the fledge ratio or habitat quantification is defined. Changes to metrics may be necessary if either scientific understanding has changed such that the assumptions underlying the metrics are no longer accurate, or if the monitoring program is unable to capture the metric sufficiently and cannot feasibly be improved. As with the quantitative values of targets this does not necessarily reflect a change in the criteria themselves. The Technical Team and Bird Team, individually or together, may recommend a change to metrics to be decided upon at the Management Team level.

3.6.7.3 *Revisions to objectives and target criteria*

The species objectives and target criteria (unlike their numerical values) are policy decisions based upon agreements of acceptable levels of risk and priorities and applicable regulations. These decisions can be informed by modeling and other scientific information (such as metapopulation dynamics), but are fundamentally values-based decisions made at the Oversight level. Objectives and targets should be re-evaluated periodically or if risk tolerance, management priorities, and/or regulations change significantly. The following target criteria are subject to this level of decision:

1) Population persistence criteria: the quasi-extinction threshold, probability of quasi-extinction, and time frame. Higher quasi-extinction thresholds, lower probabilities, and longer time frames reduce risk to the population and increase management requirements (see Buenau 2015 for examples.) Lower thresholds, higher probabilities, and shorter time frames increase risk to the population and reduce management requirements.

2) Time frames for meeting targets: the definition of the targets allows them to be missed on occasion as long as targets are met in most years (i.e. 3 out of 4 years for standard ESH targets and for 3-year averages for demographic targets.) This allows for short-term disturbances (e.g. high flow years that limit nesting) as part of the natural variability of the river. They allow for limited shortfalls in management but not persistent limitations. Changing the frequency that targets must be met will change the level of risk to the population.
3) Confidence bounds: upper and lower confidence bounds trigger larger adjustments to management activities when habitat acreage falls outside rather than within them. These bounds are probability-based but fundamentally a decision based on risk tolerance, and can be adjusted. The lower bound indicates what likelihood of failure to meet population objectives must be met before more intensive habitat creation needs to occur (potentially at higher cost and/or pre-emption of other priority activities.) Increases to the lower bound reduce the risk of failure to meet objectives, while increasing costs and other impacts. The upper bound indicates the point at which too much habitat is being created relative to what is likely needed, and the costs or other impacts are higher than necessary. Lowering that bound places high value on keeping costs and impacts low, with increased risk of not meeting population objectives.

Changes to objectives are a more fundamental step and may be triggered by regulatory or other policy changes (e.g., to USACE authorities) or broad changes in scientific understanding, e.g. how the Missouri River subpopulations of plovers relate to the larger population. They may also require adjustment to reflect any driving factors outside of USACE control that limit the ability to manage the Missouri River subpopulations, such as factors affecting survival or physical condition when birds are using winter habitat.

An inability to meet targets may trigger re-evaluation of target criteria and objectives (Section 3.6.5). However this step should be taken only after other solutions have been attempted and if it has been determined that no adjustments to the program could be made that would meet the targets. Changes to objectives or target criteria may require reinitiation of formal consultation.

4 Adaptive Management of Pallid Sturgeon in the Missouri River

This chapter is organized according to the steps of the AM cycle introduced in Section 1.1.5:

1. Assess (Section 4.1), which provides goals and objectives for pallid sturgeon, and also summarizes the EA (Jacobson et al. 2015a, 2015b, 2016a, 2016b; Delonay et al. 2016b);
2. Plan and Design (Section 4.2), which summarizes metrics and decision criteria for Level 1 and Level 2 components, and describes the design of Level 3 actions (including hypotheses, action descriptions, objectives, expected benefits, metrics, experimental design, decision criteria, and Level 3 contingent actions);
3. Implement (Section 4.3) describes the current schedule for implementation of Level 1, 2 and 3 actions. This schedule will be further revised over time.
4. Monitor (Section 4.4), which summarizes the metrics used for monitoring each Level 2 and 3 action currently under consideration;
5. Evaluate (Section 4.5), which summarizes the evaluation approaches used for each Level 2 and 3 action; and
6. Decide (Section 4.6), which summarizes the decision criteria for each Level 2 and 3 actions.
7. Section 4.2 also incorporates much of the material from the Lower Missouri River Pallid Sturgeon Framework, Targets and Decision Criteria (USFWS and USACE 2015, USFWS 2015a, USFWS 2016). This chapter is associated with several appendices:

A. Appendix C contains details of the design of Level 1 and 2 actions.

B. Appendix D describes the protocol to be used for population monitoring, and the structure of the population model that's closely associated with the population monitoring

C. Appendix E [*in progress*] lists other monitoring protocols not contained in Appendix C.

D. Appendix F contains detailed cost estimates for Level 1 and Level 2 science components.

Relative to birds, there is a greater level of uncertainty about the most appropriate management actions to maintain and recover pallid sturgeon populations in the Missouri River. Therefore, the approach described in this chapter involves a greater investment in research to reduce critical uncertainties that affect management decisions, and in rigorous monitoring of well designed pilot actions (Level 2) to evaluate their effectiveness.

4.1 Assess

4.1.1 Goals and management objectives for pallid sturgeon

In 2013, the USFWS (written com., September 12, 2013 [Draft Species Objectives, p. 1]) developed the following fundamental objective for pallid sturgeon in the Missouri River:

Fundamental Objective: Avoid jeopardizing the continued existence of the pallid sturgeon from the U.S. Army Corps of Engineers actions on the Missouri River.

The USFWS notes that this objective is consistent with species recovery goals (U.S. Fish and Wildlife Service, 2014) but specific to Missouri River management actions.

In 2013, the USFWS also proposed the following two sub-objectives (both measurable), which must be attained to ultimately achieve the stated "fundamental objective". The intent of the sub-objectives is to provide direction in the short term, provide objectives meaningful for AM, and focus efforts on the desired short term outcomes while keeping the fundamental objective in mind. Although attaining a self-sustaining population is the desired outcome of the Revised Pallid Sturgeon Recovery Plan (USFWS 2014), described below under sub-objective 2, we may be decades away from such an objective being very meaningful. If natural recruitment were achieved in 10 years, it could take 20 to 30 years before progress toward the self-sustaining population objective could be assessed. Modeling can give projections and insights into the probability of achieving the fundamental objective under proposed and implemented actions. The two sub-objectives provide guidance for the actions, monitoring and research required to support the fundamental objective over the longer term.

Sub-objective 1: Increase pallid sturgeon recruitment to age 1.

Metrics: primary metric is catch rates of age 0 and age 1 pallid sturgeon; secondary metrics include model-based estimates of abundance of age 0 and age 1 pallid sturgeon, and the survival of hatchery and naturally reproducing fish to age 1.

Target: TBD. The short-term target is to demonstrate measurable recruitment to age 1, and hopefully increasing levels of recruitment over time. Recruitment is emphasized in sub-objective 1 since wild-spawned young-of-year (YOY) or juvenile pallid sturgeon have not been captured in the Upper Missouri River upstream of Lake Sakakawea, and have been captured only rarely in the Lower Missouri River (Jacobson et al. 2016a). Until 2015, there had been no documented captures of genetically identified, wild-spawned pallid sturgeon free embryos, larvae, or YOY in the lower river (U.S. Fish and Wildlife Service, 2014). Recent data indicate that limited recruitment is happening in the Lower Missouri River, but not at a level sufficient to maintain the population (U.S. Fish and Wildlife Service, 2014; Jacobson et al. 2016a). Multiple factors can potentially be limiting recruitment (see Appendix B, Figures B.9, B.10 and B.11).

The long-term target for recruitment (i.e. necessary levels and frequency of recruitment over time) will be informed by the EA (Jacobson et al., 2016a) and collaborative population model (Section 4.1.2.3 and Appendix D of this plan), following the necessary monitoring, model validation, and supporting research. Defining the long term target is not critical in the near-term as the immediate priority is to establish measurable recruitment. Possible targets could include a modeled egg to age-1 survival rates sufficient to result in growth and sustainable population size.

Sub-objective 2: Maintain or increase numbers of pallid sturgeon as an interim measure *until sufficient and sustained natural recruitment occurs.*

Metric: Population estimates for pallid sturgeon for all size and age classes, particularly for ages 2 to 3 to assess recent trends in recruitment; catch rates of all pallid sturgeon by size class (to maintain legacy data). Age classes will be estimated as an output metric of the population model that will be validated through recaptures of tagged fish. There are challenges in quantifying a population size for age 2-3 year old pallid sturgeon as there is a lot of overlap in the lengths of fish aged 2 to 5 years. Further work is required to refine population metrics, which may include estimating a population size for a subset of the length frequency distribution.

Target: TBD. Possible targets could include: 1) positive population growth rates (i.e., lambda (λ) > 1) of pallid sturgeon age 2 and older; 2) estimated survival rates of all size/age classes sufficient to provide a stable population of pallid sturgeon age 2 and older; and 3) acceptable probabilities of persistence and recovery over a 50 to 100 year time frame (utilizing population models). For example, the Lower Missouri Framework (USFWS and USACE 2015) described two preliminary decision criteria for halting population augmentation: 1) when population monitoring demonstrates a self-sustaining population in excess of 5000 adult fish in each management unit; and 2) when the threat of extirpation is less than 5 percent in 50 years, or as based on new criteria introduced through the Basin-wide Stocking and Augmentation Plan. The criteria recommended in USFWS and USACE (2015) are similar to those in the Revised Recovery Plan for the

Pallid Sturgeon for reclassifying pallid sturgeon from endangered to threatened status (UFSWS 2014, pg. 54):

> "Pallid Sturgeon will be considered for reclassification from endangered to threatened when the listing/recovery factor criteria are sufficiently addressed such that a self-sustaining genetically diverse population of 5,000 adult Pallid Sturgeon is realized and maintained within each management unit for 2 generations (20-30 years). In this context, a self-sustaining population is described as a spawning population that results in sufficient recruitment of naturally-produced Pallid Sturgeon into the adult population at levels necessary to maintain a genetically diverse wild adult population in the absence of artificial population augmentation. Metrics suggested to define a minimally sufficient population would include incremental relative stock density of stock-to-quality-sized naturally produced fish (Shuman et al. 2006) being 50-85 over each 5-year sampling period, catch-per-unit-effort data indicative of a stable or increasing population, and survival rates of naturally produced juvenile Pallid Sturgeon (age 2+) equal to or exceeding those of the adults (see Justification for Population Criteria below [in USFWS 2014] for details). Additionally, in this context a genetically diverse population is defined as one in which the effective population size (Ne) is sufficient to maintain adaptive genetic variability into the foreseeable future ($Ne \geq 500$), conserve localized adaptions, and preserve rare alleles."

In addition to the fundamental objective and associated sub-objectives, there are a set of proposed actions to be implemented on the Missouri River, which are the means of achieving the fundamental objectives and sub-objectives. The timelines for these actions serve as a backstop to ensure that the rate of implementation of management actions on the Missouri River is not hindered by an inability to learn from applied science efforts. In effect, they define necessary levels of implementation at a point in time for each hypothesis, and must be met unless the learning from applied science efforts demonstrates that the in-river actions associated with that hypothesis are unnecessary.

4.1.1.1 *Geographic scopes of the Effects Analysis, MRRP-EIS and this AM Plan*

The geographic scope of the Pallid Sturgeon EA was larger than the scope of the MRRP-EIS and this AM Plan. The area considered in the EA included the Upper Missouri River mainstem from Fort Peck Dam to the headwaters of Lake Sakakawea, the Yellowstone River upstream of the confluence with the Upper Missouri River for an unspecified distance, the Lower Missouri River mainstem from Gavins Point Dam to confluence with the Mississippi River at St. Louis, tributaries used by pallid sturgeon, and an unspecified distance downstream in the Mississippi River (Figure 58). The distance downstream in the Mississippi River is unspecified because presently available information (2015) is ambiguous about the extent to which Missouri and Mississippi river populations mix through migrations and dispersal. Recent information suggests that adult pallid sturgeon originating in the Missouri River are frequently found in the middle and upper Mississippi River (Porecca et al. 2015).

This geographic scope was constrained in part by the decision-making authority of the USACE and in part by present understanding of the geographic distribution of pallid sturgeon. Literature and ongoing research from outside this defined area was utilized where it helped to inform hypotheses evaluated in the EA. The reservoirs and inter-reservoir reaches (from Lake Sakakawea to Lewis and Clark Lake) were excluded from the effects analysis based on the assumption that these habitats are unlikely to support reproductive populations of pallid sturgeon. Figure 59 shows the area that is the main focus of research into potential management actions to recover the pallid sturgeon population in the Upper Missouri River.

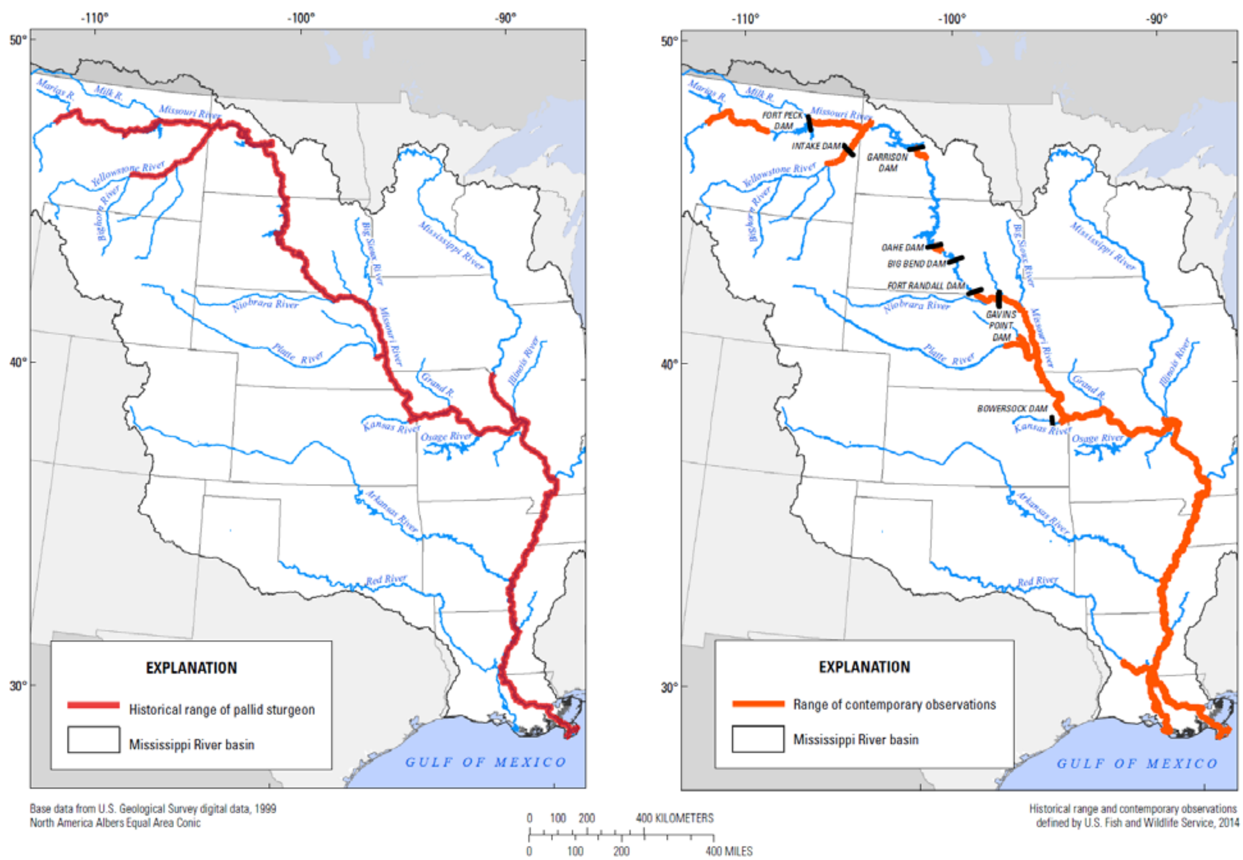


Figure 58. Historical range and present-day occupancy of the pallid sturgeon and scope of the Missouri River included in the EA. Present day occupancy shown on the right side map includes the stretch of the river above Gavins Point Dam and below Fort Randall Dam, which is not included in the defined area of the Lower Missouri River. Pallid sturgeon may be found in reservoirs but do not prefer these habitats. Source: Figure 2 in Jacobson et al. 2016a

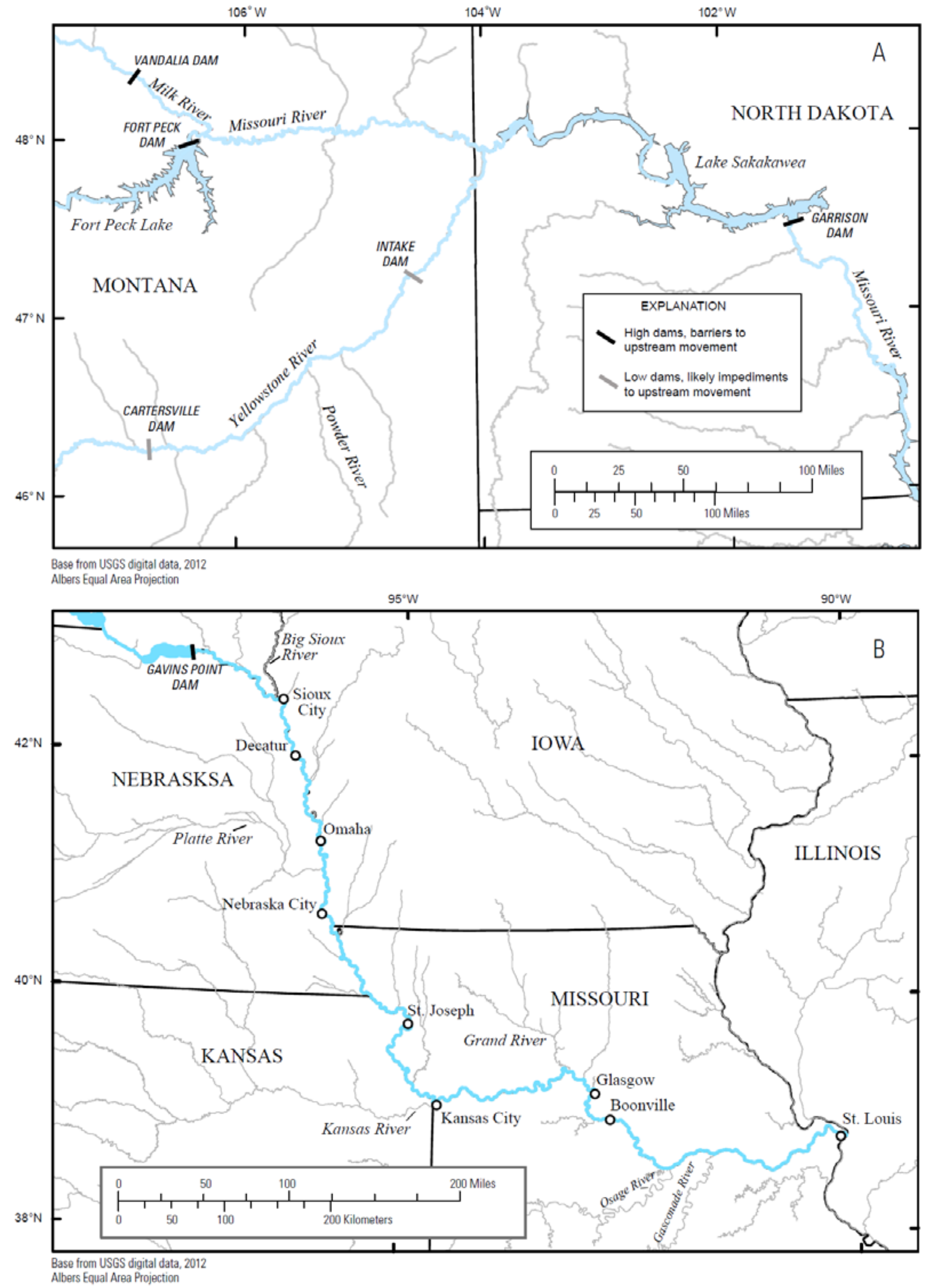


Figure 59. Map of the upper (A) and lower (B) river complex, showing the Yellowstone and Missouri Rivers, major tributaries, and reservoirs. Black lines are absolute barriers; gray lines are likely barriers, including run of river weirs.

Management of Missouri River pallid sturgeon has historically occurred over four Recovery Priority Management Areas or RPMAs, and is now organized around four

Management Units (described in section D.1.3 of Appendix D, and Figure D.1). The area upriver of Fort Peck Reservoir (former RPMA 1) is outside of the geographic scope of the MRRP. The geographic scope of the MRRP (and this AM Plan) includes those portions of the Missouri River encompassed by the portion of the Great Plains Management Unit (GPMU) below Fort Peck Lake, the Central Lowlands Management Unit (CLMU), and the portion of the Interior Highlands Management Unit (IHMU) above the confluence of the Missouri and Mississippi Rivers (MRRMP-EIS, Section 1.8.1), corresponding to the historic RPMA's 2-4 (Figure D.1). The USACE has jeopardy responsibilities for pallid sturgeon under the ESA in these three RPMA's. The Yellowstone River is the only tributary included in the geographic scope of the MRRP-EIS, due to its importance to pallids in RPMA #2, and the effects of the Intake Dam. The Platte River has been utilized by pallid sturgeon and information from the Platte River is relevant to an understanding of pallid sturgeon populations in the Lower Missouri River, but the Platte River is not wihin the geographic scope of the MRRP and the AM Plan. As occurred during the EA, literature and ongoing research from outside the geographic area defined for the MRRMP-EIS (e.g., upstream of Fort Peck Dam) may be utilized where it helps to inform the evaluation of hypotheses and potential management actions.

4.1.2 Key findings from Effects Analysis and more recent work

4.1.2.1 *Purpose and methods of the EA*

The concept of an EA is rooted in the requirement within the ESA to evaluate the effects of actions proposed by federal agencies on listed species or designated critical habitat, using the best available science. Murphy and Weiland (2011) advocated for a rigorous approach to EA that consists of three primary steps carried out once the problem has been formulated with the definition of the proposed action, the area affected, and a conceptual model of the physical and biological relationships relating actions to species outcomes. The first step is to collect reliable scientific information, including observations about the stressor and the range of stressor conditions and information on population sizes and trends. The second step includes assessment of the data, including using quantitative models to integrate existing information and identifying and representing uncertainties. The third step is to analyze the effect of the actions on the species to determine costs and benefits and identify alternatives.

This section summarizes the completed Phase 1 of the EA process and documented in Jacobson et al. (2016a) and Fischenich (in review). The primary and relevant products of the EA are summarized in the following reports and models:

- Summaries of existing data/information reflecting the state of science for the species and their habitats to identify the effects of system operations and actions on species populations and their habitats (Jacobson et al., 2015a)

- Conceptual Ecological Models (CEMs) to guide quantitative models (Jacobson et al., 2015b)
- Hypotheses addressing critical uncertainties (Jacobson et al., 2016b)
- Quantitative models for forecasting the effect of different alternatives on species performance. Modeled processes include reservoir operations and hydraulic conditions (Fischenich, in review), habitat availability (Fischenich et al. 2014, in revision), and species demographics (Appendix D of this Plan)

The EA provides an integrated assessment of the potential benefits of management actions for pallid sturgeon in the Missouri River, and documents uncertainties in that assessment. As the models presented in the EA are improved they will become focal points for data assimilation, hypothesis generation, experimental design, and evaluation of management actions. These models are intended to eventually be used to make projections of habitat availability and population responses under different combinations of actions, and to develop species/habitat targets under the MRRMP. The EA is an on-going process that can be used to further refine strategies to address the uncertainties and hypotheses identified as part of the EA. To date, this process has involved the EA team, independent scientists on the ISAP and ISETR, as well as representatives from MRRIC and its committees. The EA process can be used to address various forms of “new information”, including both unexpected results derived from science efforts within the AM program, as well as novel findings from outside the program (see sections 2.5.4 and 6.2.5). Syntheses of new information could lead to changes in existing hypotheses, the retrieval of hypotheses from the hypothesis reserve (Figure 60) or the addition of new hypotheses.

4.1.2.2 *Overall conceptual model*

Conceptual ecological models (CEMs) illustrate population dynamics at the population level, and show the linkage between management actions, ecological factors, and biological responses (Jacobson et al. 2015b). The generalized population-level conceptual model in Figure 61 was adapted from Figure 3 in Jacobson et al. 2015y. This conceptual model demonstrates the conditions, processes, and potential management actions that affect survival at critical life-stage transitions. In Figure 61, squares represent different life-stages with arrows in the direction of development. Life-stage transitions are influenced by the survival probability (diamonds) and the conditions, processes, and management actions influencing survival (ovals and icons). The conceptualized river in the middle of the graphic demonstrates the use of the river mainstem or its tributaries during different life-stages (Wildhaber et al. 2007).

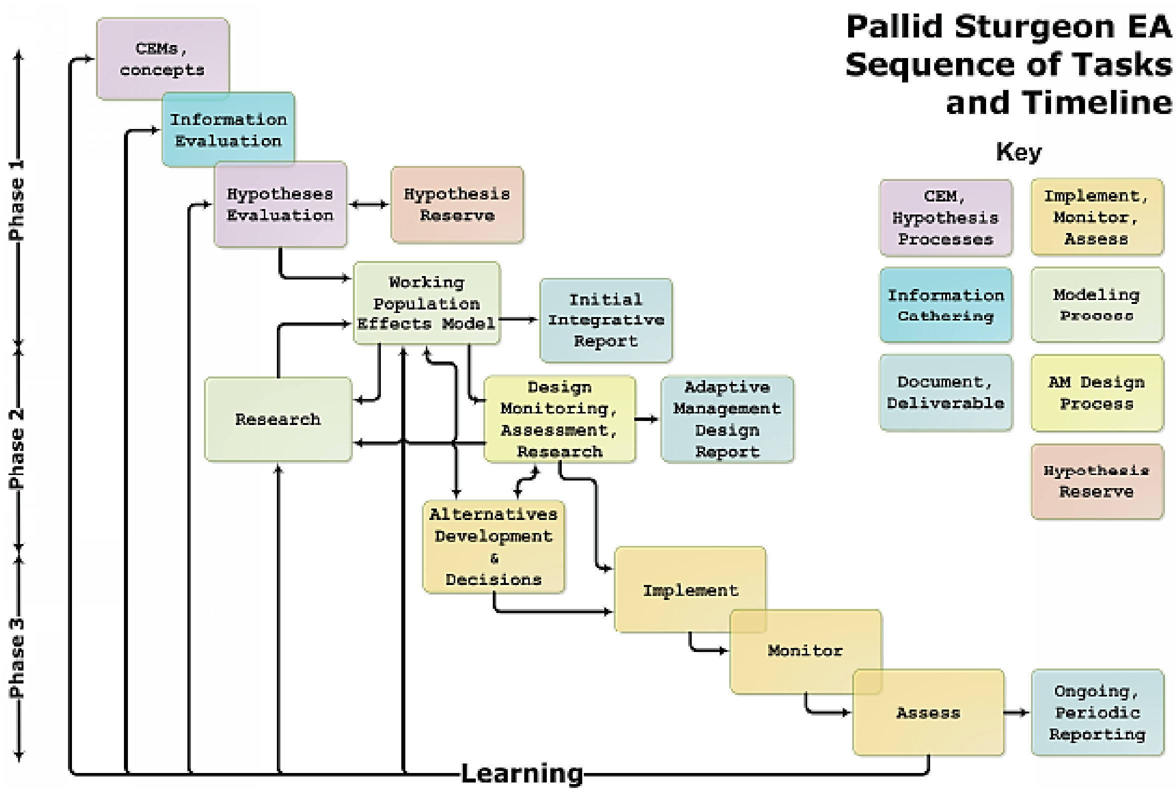


Figure 60. Phases 1, 2, and 3 envisioned for the EA process (Jacobson et al., 2016a).

The two classes of management actions represented in the figure are channel management and restoration, and reservoir engineering and operations. Channel management and restoration options include channel reconfiguration, interception and rearing complexes, spawning habitat creation, bank stabilization and in-river structures to alter velocities or flow paths. Reservoir engineering and operations include operating rules (e.g., flow pulses, drawdown), passage structures, and structures or actions to improve water quality (e.g., temperature, sediment, oxygen).

Life-stage component CEMs were developed by Jacobson et al. (2015b) to illustrate the driver-stressor relationships influencing survival of that life-stage transition. These life-stage transition survival probabilities correspond to the diamonds in Figure 61. Survival at each life history stage is a function of the conditions and processes which occur during that stage, which in turn are potentially affected by different management actions. Figure 61 also shows potential stocking activities (which historically have included stocking at free embryo, exogenously feeding larvae / fingerlings / younger yearlings (all < 1 year old), and juveniles / older yearlings) and broodstock collection of spawning adults.

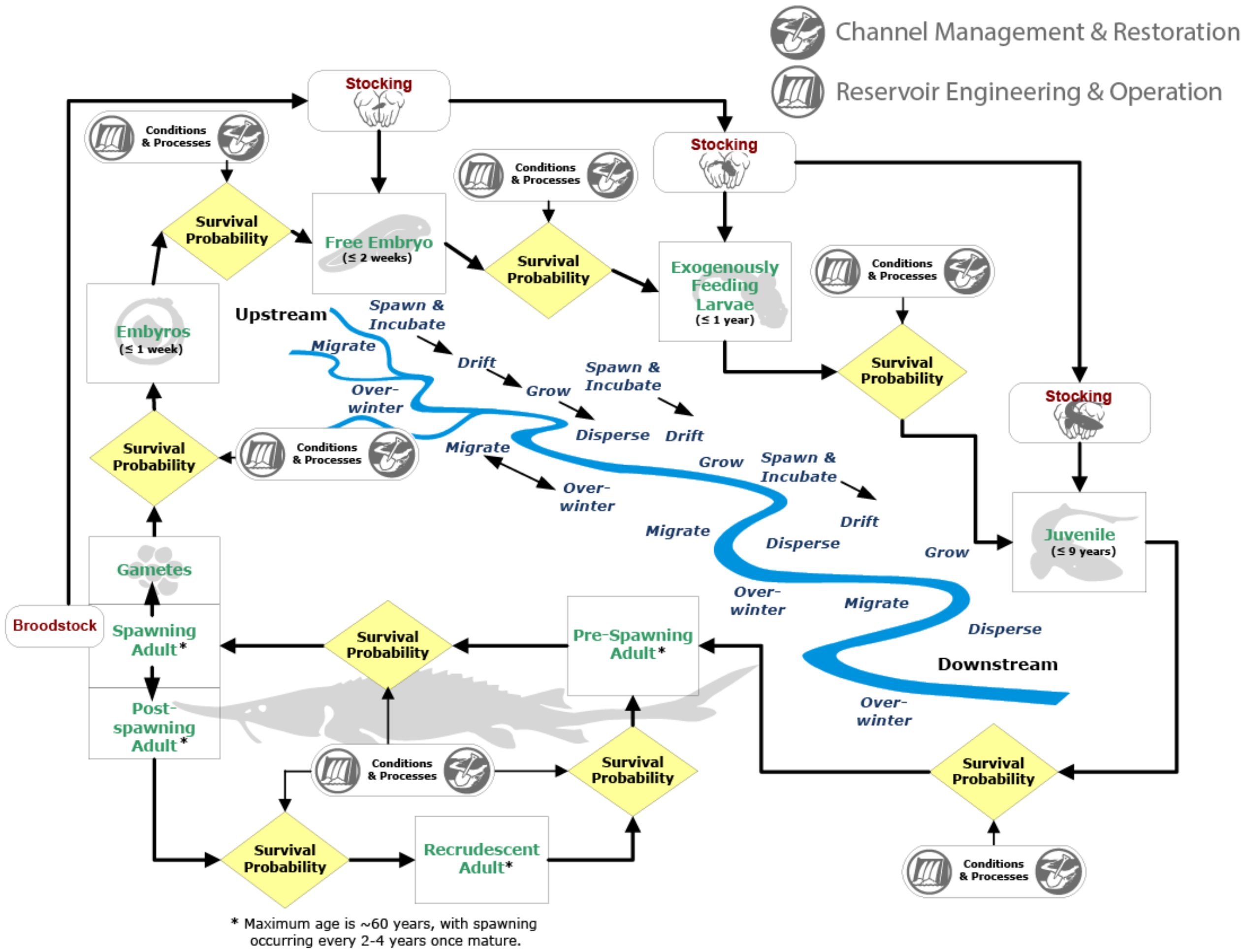


Figure 61. Generalized population-level CEM showing life stages, geographic context of pallid sturgeon reproductive cycle. Fingerlings and yearlings less than 1 year old fit into the “exogenously feeding larvae” life stage.

Figure 62 is an example of a life-stage component CEM. Each pair of columns, from left to right can be considered a cause-effect linkage, with the final rightmost column being the ultimate biotic response (Jacobson et al. 2015b). The classes of factors that were considered include (from left to right in Figure 62): anthropogenic or geologic independent drivers, management and restoration activities, primary ecological factors, secondary ecological factors, primary biotic responses, and ultimately the secondary biotic response of survival of that life-stage (yellow diamond). The conceptual model uses a hierarchical structure of factors, whereby bounding boxes represent broad descriptions of ecosystem factors and are common across all component CEMs, and the colored boxes within each column are more specific factors which may vary depending on the life-stage and location of the component CEM. Hypothetical relationships between the factors were explicitly mapped out in a workshop process involving experts in pallid sturgeon biology and Missouri River processes. Participants at these workshops characterized each relationship by its relative importance and uncertainty. The relative importance ranking used line weight used in Figure 62 (solid, dashed, and dotted lines, where solid represented the highest relative importance), and the uncertainty ranking used line color (black–least uncertainty, blue–moderate uncertainty, and red–most uncertainty). These hypothetical relationships provide the basis for the global hypotheses for the EA (Section 1.4.2).

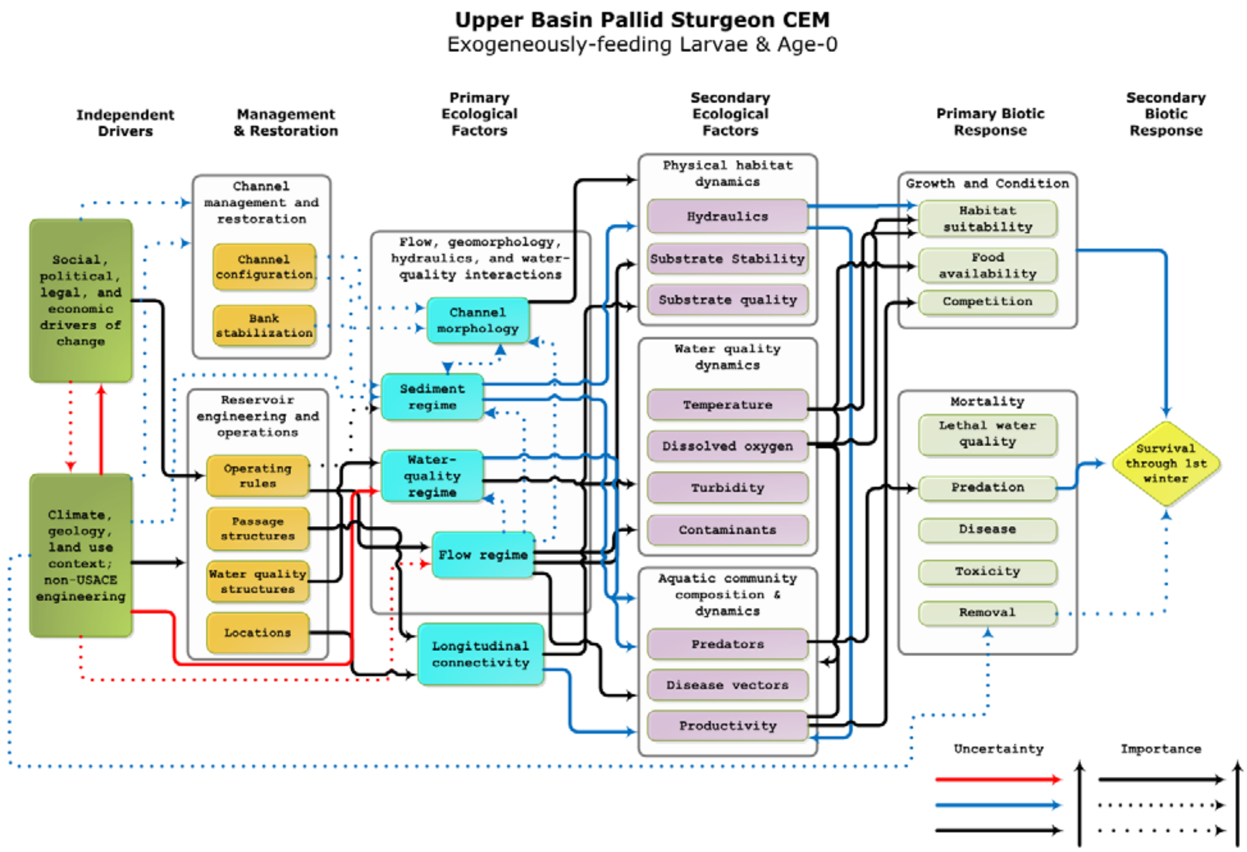


Figure 62. Example of a life-stage component CEM showing the cause-effect linkages leading to survival to the next life-stage (Jacobson et al. 2015b).

4.1.2.3 *Collaborative population dynamics model*

The collaborative pallid sturgeon population model (Jacobson et al. 2016a; Appendix D, section D.4.3) serves as a central tool to organize, assimilate, and evaluate information on Missouri River pallid sturgeon populations. The primary purpose of the model is to evaluate the population-level effect of management actions and provide metrics (e.g., population viability, abundance) that link to fundamental objectives for pallid sturgeon. The description of the model presented here is a snapshot of the current state of the model, which has expanded in scope since the EA was developed. The models are the quantitative statement of hypotheses. Expressing hypotheses in a quantitative form reveals where the most critical uncertainties exist in our understanding of functional relationships (i.e., uncertainties in key inputs to decisions), which helps to prioritize data collection and small-scale experiments. The models also provide a mechanism for extrapolating observed changes at specific life-history stages (from field data) to their long term population consequences, and propagating the inherent uncertainties in life-stage specific survival probabilities (the diamonds in Figure 61). The structure of the model mimics the structure of the revised population assessment program, as described in Appendix D. This will provide benefits in both directions: essential empirical data for model calibration, testing and application; and use of the model to design the most cost-effective data collection procedures, explore alternative hypotheses, and evaluate the long term consequences of current and proposed actions for fundamental and sub-objectives.

The development of the stage-based collaborative model has several advantages over previous age-structured models (e.g., Reynolds and Tyre 2011, Steffensen et al. 2013a, Wildhaber et al. 2015. First, the collaborative model explicitly models all life-stages. Specifically, there are several early life history stages that participants believed required their own conceptual ecological models, including gametes, embryos, free embryos, exogenously feeding larvae, and age-0 fish. The collaborative population model faithfully represents the work of the participants who developed the component CEMs. Second, the collaborative model has a flexible model structure template to model several populations (i.e., upper river, lower river, and sub-populations if identified) at varying spatial resolutions. Previous models were constrained to either the upper and lower basins with most effort in the lower basin and a strong bias towards the lower basin population (Jacobson et al. 2015b). Finally, the development of the collaborative model occurred through a transparent process involving input from potential users using open-source software with public-domain source code and open accessibility to an online version. This tool will evolve and be modified to meet the AM process needs and the community of scientists engaged in understanding pallid sturgeon population dynamics.

The geographic extent of the current model is limited to segments of the lower and upper Missouri River (Figure 58). These two parts of the Missouri are subdivided into bends representing the spatial grain of the population model. River bends are defined as three continuous habitats (channel cross-over, inside bend, outside bend) and vary in number and size from the lower to upper basin[1]. Bends are used as a spatial organization for the model, to accommodate movement of fish among bends in the model, and because bends are the sampling units for the Pallid Sturgeon Population

[1] Lower: 317 bends, in river km, mean=4, min=0.2, max=19; in river mi mean=2.5, min=0.1, max=11.8; Upper: 157 bends, in river km, mean=2.3, min=0.6, max=8; in river mi mean=1.4, min=0.4, max=5;

Assessment Program (PSPAP). The current temporal extent (duration of model runs) is user defined and can be up to 50 years with a monthly time step.

The model requires basin-specific demographic rates and values (e.g., survival, fecundity, sex ratio) and values for state variables (e.g., number of hatchery fish, number of natural fish) to simulate population dynamics. Uncertainty is associated with most of these inputs, though the number of stocked fish is known precisely. Inputs are derived from literature and from experts within the basins. The population model is initialized by drawing demographic values and rates from distributions. Next, state values (i.e., number of hatchery or natural origin fish) are drawn from distributions. Age structure is then initialized given the abundance and demographic rates drawn. For example, if 4000 natural origin fish were stochastically selected, those fish are then allocated to an age class given their cumulative probability of surviving, yielding the typical exponential decay in number of fish with age. Model initialization makes an assumption of population equilibrium as in past modeling studies (Steffensen et al. 2013), which basin experts agreed was reasonable. This assumption takes into account the fact that, even in the absence of recruitment, population declines are expected to be relatively small for a long-lived fish with high sub-adult and adult survival.

Current model implementation outputs the origin and fate of individual fish (i.e., natural, hatchery, mortality) for each time step over the years simulated. When multiple stochastic replicates are simulated, values can then be post-processed to forecast values like pseudo-extinction probabilities. Additional post-processing includes a function to simulate a robust design capture-recapture program so that the model can be used to inform population monitoring designs (discussed in section 4.4 and Appendix D).

The ultimate objective for the population model is to evaluate management actions propagated through the pathways described in the CEMs. There are many gaps in biological understanding linking primary and secondary biotic responses. Current model implementation accepts demographic rates; however, direct effects of primary biotic responses are uncertain or unknown. These uncertainties and unknowns aside, the model framework development is focused at further development of the capacity to evaluate primary biotic responses in two approaches. The first approach modifies the demographic rate distributions as a function of a primary biotic response. For example, the current model represents demographic rates in terms of a baseline survival rate, the uncertainty in that survival rate, and potential changes in the survival rate as a function of other factors (e.g., amount of food available for exogenously feeding larvae in interception and rearing habitat). The mathematical form of these functions is described in Appendix D, section B.4.3.3.

Sensitivity analyses of parameters in the collaborative population dynamics model confirmed that early life-stage survival values were the most uncertain and have the most leverage on population dynamics. Further, the EA team used the model to explore how the persistence of pallid sturgeon in the Missouri River varied with different levels of stocking. Parameter estimates generated from the modeling included estimates of early life-stage survival rates needed to sustain a population under current stocking rates. These numbers provide benchmarks to evaluate stocking and ongoing refinement of survival rates. The early life-stage survival rates also represent a key parameter uncertainty in the model (gamete, embryo, free embryo, exogenously feeding larvae, age-0) because there are limited data on these probabilities. Another source of uncertainty is the spatial dynamics including flow cues as a trigger for movement and flow modifications for drift of free embryos. An additional complicating factor (not included in the model) is hybridization between pallid sturgeon and shovelnose sturgeon (Jacobson et al. 2016a), albeit hypothesized genetic consequences on population demography are not well understood. The model's structure and proposed applications are closely aligned with the proposed revisions to monitoring of pallid sturgeon populations, as described in Appendix D.

4.1.2.4 *Initially modeled hypotheses and process for examining additional hypotheses*

The filtering approach used to determine the 21 hypotheses that were the focus of conceptual and quantitative modeling (Upper River - Table 37, Lower River –Table 38) was a stepwise process starting with the implicit hypotheses from the component CEMs. A series of workshops were used to filter these hypotheses, link these hypotheses to management actions, and determine if these actions were within the USACE authority and jurisdiction (Jacobson et al. 2016b).

Jacobson et al. 2016b defined several categories of hypotheses (Table 1 in their report). *Global* hypotheses are a set of possible, biologically important hypotheses, relevant to population dynamics that are derived from the CEMs (see Appendix B). These implicit hypotheses are depicted by the arrows between cells in the CEM. These were filtered by the EA team to a set of 40 *candidate dominant* hypotheses that were identified by experts as being important in pallid sturgeon population dynamics. Through a series of workshops and a modified Delphi process, this list was filtered to 23 *working dominant* hypotheses based on input from experts (Jacobson et al. 2016b). This list is meant to include plausible, most biologically relevant hypotheses without regard to specific management or mitigation actions. These working dominant hypotheses were then linked to management actions resulting as many as 176 potential linkages, but when consolidated across life-stages led to 53 hypotheses. The list was further reduced through an expert survey to a list to 30 *working* management hypotheses. Finally, the set of working management hypotheses was filtered by the USACE MRRP for actions that were within the agency's authority and jurisdiction resulting in the 21 initially modeled hypotheses selected for modeling in Phase 1 of the EA.

As learning occurs through the AM cycle, the list of hypotheses may expand and contract beyond the initially modeled hypotheses. In anticipation of this, a hypotheses reserve will explicitly manage the broad suite of hypotheses developed through the EA and highlighted in the CEM. Using this concept, hypotheses can be brought forward or moved back into reserve as information and understanding directs. The hypotheses reserve concept includes: 1) hypotheses that are not deemed important to investigate at this time; 2) have high uncertainty and require further investigation; and/or 3) are outside USACE authority (see Jacobson et al. 2016b for examples).

The annual AM process described in Chapter 2 will bring forth new findings that lead to adjustments, additions or rejections of the existing set of hypotheses. In addition, the new information process (described in Section 2.5.4) provides a mechanism for bringing forward new information that is analyzed by a technical team in a "joint fact finding" process. This analysis could lead to hypotheses being brought forward from the list of reserve hypotheses, or new action hypotheses being formulated, which would then be included in the AM Plan, and further considered by the Technical Team and Management Team.

The new information process is well illustrated by efforts currently underway for the issue of declining fish condition, which involved the following steps:

- A problem with fish condition was observed by biologists with the Nebraska Game and Parks Commission (NGPC) during efforts at broodstock collection in the Lower Missouri River in the spring of 2015. NGPC biologists submitted an issue paper to the USFWS and USACOE in January 2016.

- The NGPC evidence on this issue was then reviewed by the Chief of the Threatened and Endangered Species Section of USACE and the Missouri River Coordinator of the USFWS. They agreed that this issue merited further investigation, and developed a charter (Bonneau and Kruse 2016) for a joint fact-finding team (coordinated by the EA team for pallid sturgeon) to investigate the fish condition issue. The charter for the investigation (Bonneau and Kruse 2016) involves a detailed review of the evidence that pallid sturgeon are in poor or declining condition (including patterns across space, time, size, age and wild vs. hatchery fish), the potential for negative effects on reproduction and survival, the likely causes of observed patterns that have potential impacts on reproduction and survival, and the recommended next steps (including both science efforts and potential remedial actions).

- A joint fact-finding team conducted a 6-month investigation into the problem, following the terms of reference of the charter. The draft report of joint fact-finding team (Randall et al. 2016) confirmed the existence of the pattern of declining condition from 2012 to 2015, found variable levels of fish condition in the same locations, and observed a higher percentage of fish in low condition within the Lower Basin (particularly in the section of river between Omaha and Kansas City). The draft report proposed various hypotheses to explain the observed patterns, including reduced carrying capacity, changes in the amount of suitable habitat following the 2011 flood, changes in prey base, intraspecific and interspecific competition, and changes in fitness. Randall et al. (2016) recommended a systematic evaluation of these alternative hypotheses in the AM Plan through such activities as continued monitoring of movement and non-lethal measures of fish health across contrasting regions and fish histories; research on diet, bioenergetics, food webs and habitat changes to test alternative hypotheses; necropsies of stored carcasses, and (possibly, following a reduction in the number of possible hypotheses) carefully designed and monitored changes in propagation strategies and/or other management actions.

- The ISAP reviewed the draft report of Randall et al. (2016), and made various recommendations (webinar September 29, 2017), including applying different methods of analysis to assess whether the apparent decline in condition might be an artifact of an increasingly older population and the particular methods of analysis that were employed in Randall et al. (2016).

- Subsequent work (R. Jacobson, USGS, presentation to MRRIC on November 15, 2016) used four different approaches to analyzing the data, and confirmed declines in fish condition in the Lower Basin, but not in the Upper Basin.

- The draft report will be revised, subjected to internal and external peer review, and published in 2017, first as a USGS technical report and later as a journal paper, with all of the data and methods provided. The peer-reviewed recommendations from the report will be considered for inclusion in the AM Plan and annual work plan by the Fish Team and the Independent Science Program.

Beyond the 21 EA hypotheses, there may be additional factors affecting pallid sturgeon recovery which will need to be considered in developing management actions and experimental designs (e.g., fitness of pallid sturgeon, hybridization of pallid sturgeon and shovelnose sturgeon; climate change (USFWS 2016)), but for which clear linkages to USACE authority and jurisdiction are lacking. When developing designs for management actions within USACE authority and jurisdiction, it is very important to anticipate the influence of these additional factors on the potential effectiveness of management actions, and the ability to evaluate action effectiveness. Genetics information from field sampling will be informative on which genotypes appear to be surviving better than others. Spawning habitats should be designed to reduce (not increase) hybridization of pallid and shovelnose sturgeon. Trends in hybridization over time should be tracked, so that they don't confound field and model based estimates of the effects of various management actions. Finally, higher year to year variability in flows due to climate change (USACE 2016) could create more variation in catch per unit effort estimates of age 0 fish, making it more difficult to detect the effects of IRCs. It is vitally important for information on pallid sturgeon to be shared and communicated (throughout their range, regardless of who collects these data), as data outside of the scope of the MRRP may still have implications for actions within USACE authority and jurisdiction (see section 6.3 Data Management).

4.1.2.5 *EA findings, critical uncertainties, potential actions and decision trees*

The key findings and potential routing for each of the initially modeled hypotheses are summarized in Table 37 (Upper Missouri River) and Table 38 (Lower Missouri River). Fundamental information gaps (high uncertainty) compromise the ability to quantify many of the hypotheses of pallid sturgeon population dynamics. For some of the 21 hypotheses, the available information is from theoretical deduction, inferences from sparse empirical datasets, or expert opinion. The degree of uncertainty and risk associated with each hypothesis (risks to both pallid sturgeon and human considerations) will guide the level and sequence of experimentation (i.e., Level 1 vs Level 2, see Table 39). Hypotheses with the highest levels of uncertainty and risk will first be explored through research, mesocosm experiments, opportunistic field experiments or gradient studies. Specific management actions can be taken for hypotheses with less uncertainty and risk, from limited implementation as field-scale experiments (Level 2) to full field implementation (Level 3). This process of hypothesis routing is further developed into Level 1, 2, and 3 actions in Section 4.2. Regardless of the information gaps, key outputs from the EA were conceptual models and hypothesized functional relationships that could help assess the effects of management actions on pallid sturgeon life-stage survival.

The population model developed in the EA can be used to assess sensitivity of life-stage specific demographic rates, assess some hypotheses related to stocking decisions, and explore a limited number of management scenarios. However, information gaps prevent linkage of flow and channel reconfiguration actions directly to population responses.

Aside from the population dynamics model described in Section 4.1.2.3, two other types of models were developed for the EA to evaluate hypotheses. These included one-dimensional advection/dispersion models to assess drift dynamics of free embryos (Fischenich, in review), and 2-dimensional hydrodynamic models for functional habitat assessments to provide an understanding of how the availability of functional habitat varies jointly with flow regime and channel reconfigurations. Models are available for both the upper and lower river. These models will be used to assess the effects of management actions on the survival of drifting free-embryos in the upper river, and for assessing the effects of flow and channel-reconfigurations on interception and habitat availability in the lower river.

Table 37. Findings from Effects Analysis for Upper Missouri River hypotheses.

Action Location	Action	Num ber	Management Hypothesis	Findings	Potential Routing
Upper Missouri River	Alter Flow Regime at Fort Peck	1	Naturalized flow releases at Fort Peck will result in increased productivity through increased hydrologic connections with low-lying land and flood plains in the spring, and decreased velocities and bioenergetic demands on exogenously feeding larvae and juveniles during low flows in summer and fall.	Theoretical support but inadequate data to model and forecast population response	Research on bioenergetics, hydrodynamic models, comparative field experiments
		2	Attractant flow releases at Fort Peck will result in increased reproductive success through increased aggregation and spawning success of adults.	Theoretical support, inference from other sturgeon species, but inadequate data to model and forecast population response	Research, monitor responses to events, possible pulsed flow experiment
		3	Reduction of main stem Missouri River flows from Fort Peck Dam during free-embryo dispersal will decrease main stem velocities and drift distance, thereby decreasing mortality by decreasing numbers of free embryos transported into headwaters of Lake Sakakawea.	Potential effective action, subject to contingent information	Research to resolve anoxia, use of Yellowstone, interstitial hiding, retarded drift
	Temperature Control, Fort Peck	4	Warmer flow releases at Fort Peck Dam will increase system productivity and food resource availability, thereby increasing growth and condition of exogenously feeding larvae and juve-niles.	Theoretical support but inadequate data to model and forecast.	Research on bioenergetics, hydrodynamic models, comparative field experiment
		5	Warmer flow releases from Fort Peck Dam will increase growth rates, shorten drift distance, and decrease mortality by decreasing free embryos transported into headwaters of Lake Sakakawea.	Potential effective action, subject to	Research to resolve anoxia, use of Yellowstone, interstitial

				contingent information	hiding, retarded drift
	Sediment Augmentation , Fort Peck	6	Installing sediment bypass at Fort Peck will increase and naturalize turbidity levels, resulting in decreased predation on embryos, free embryos, and exogenously feeding larvae.	Theoretical support, but laboratory data equivocal; no specific models	Research on predation of eggs, embryos, free embryos
Yellowstone River	Passage at Intake	7	Fish passage at Intake Diversion Dam on the Yellowstone River will allow access to additional functional spawning sites, increasing spawning success and effective drift distance, and decreasing downstream mortality of free embryos and exogenously feeding larvae.	Potential effective action, subject to contingent information	Implementation underway. Complement with robust monitoring and evaluation
Upper Missouri and Yellowstone	Upper Basin Propagation	8	Stocking at optimal size classes and in optimal numbers will increase growth rates and survival of exogenously feeding larvae and juveniles.	Potential effective action, subject to hatchery capacities	Implemented, validate with monitoring, assessment. Research on optimization
		9	Stocking with appropriate parentage and genetic diversity will result in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.	Theoretical support, no specific data, models to forecast for pallids	Research on linking parentage and population viability
Lake Sakakawea	Drawdown, Lake Sakakawea	10	Drawdown of Lake Sakakawea will increase effective drift distance, decreasing downstream mortality of free embryos and exogenously feeding larvae.	Potential effective action, subject to contingent information.	Research to resolve anoxia, use of Yellowstone, interstitial hiding, retarded drift

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Table 38. Findings from Effects Analysis for Lower Missouri River hypotheses.

Action Location	Action	Number	Management Hypothesis	Findings	Potential Routing
Lower Missouri River	Alter Flow Regime at Gavins Point	11	Spring flow pulses from Gavins Point will provide aggregation and spawning cues for reproductive pallid sturgeon, resulting in increased spawning success.	Theoretical support, inference from other sturgeon species, but inadequate data to model and forecast population response	Research, monitor responses to events, possible pulsed flow experiment
		12	Naturalized flows from Gavins Point dam will increase productivity and food availability for age-0 pallid sturgeon through improved connectivity with channel-margin habitats and low-lying floodplain lands, increased primary and secondary production, and increased growth, condition, and survival of exogenously feeding larvae and juveniles.	Theoretical support, inference from hydrodynamic models, but data inadequate to model, forecast population response	Research on bioenergetics, comparative field experiments, possible pulse flow experiment.
		13	Naturalized flows from Gavins Point Dam will decrease energetic requirements of age-0 pallid sturgeon through decreased velocities, resulting in increased growth, condition, and survival for exogenously feeding larvae and juveniles.	Theoretical support, inference from hydrodynamic models, but data inadequate to model, forecast population response	Research on bioenergetics, comparative field experiments, possible pulse flow experiment.
		14	Decreased flows in late May and June from Gavins Point Dam will result in decreased velocities and dispersal distance, resulting in increased survival of pallid sturgeon free embryos.	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Research into drift dynamics
	Temperature management, Gavins Point	15	Increased temperatures in May from Gavins Point will provide aggregation and spawning cues for reproductive pallid sturgeon.	Theoretical support, inference from other sturgeon species, data equivocal about magnitude of change, population response	Research, monitor responses to events
Lower Missouri River	Channel Reconfiguration	16	Channel reconfiguration to increase quality and availability of spawning habitat will increase successful	Theoretical support, support from sturgeon species,	Research in spawning dynamics, comparative

Action Location	Action	Number	Management Hypothesis	Findings	Potential Routing
			fertilization, incubation, and hatch of pallid sturgeon.	hydrodynamic models, but data are equivocal as limiting factor and population response	field experiment
		17	Channel reconfiguration to increase food-producing habitats will increase growth and survival of age-0 pallid sturgeon, through increased channel complexity and improved bioenergetic conditions to increase prey density (invertebrates and native prey fish).	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Implemented in part, comparative field experiment, validate with monitoring, assessment
		18	Channel reconfiguration to increase availability and quality of foraging habitat will increase survival of age-0 pallid sturgeon, through increased channel complexity and minimized bioenergetic requirements for resting and foraging.	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Implemented in part, comparative field experiment, validate with monitoring, assessment
		19	Reconfiguration of the channel to promote interception of drifting free embryos from the thalweg and transport to supportive channel-marginal habitats will increase survival of free embryos to exogenously feeding age-0.	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Possibly implemented in part, validate with monitoring, assessment, comparative field experiments
	Propagation Lower Basin	20	Improved stocking strategies by optimizing stocked size classes will improve age-0 to age-1 survival of hatchery-origin pallid sturgeon.	Potential effective action, subject to hatchery capacities.	Implemented, validate with monitoring, assessment. Research on optimization
		21	Improved stocking strategies by optimizing genetic diversity will improve population viability for pallid sturgeon.	Theoretical support, no specific data, models to forecast population response	Implemented, validate with monitoring, assessment. Research on linking parentage and population viability

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Potential management actions were also identified and include flow management, temperature management, sediment augmentation, passage at Intake Dam, propagation, stocking, and the construction of interception and rearing complexes (IRCs), spawning habitat, and food and foraging habitat. These actions were selected using a scientific filter (do they benefit the species?), a human considerations filter (are impacts acceptable?), and a feasibility filter (can actions be feasibly implemented?). Further filtering of management actions occurred through the MRRMP process, as described in Chapter2 of the DEIS).

Key outcomes and uncertainties from the EA can be conceptualized in a decision tree framework that highlights the possible management actions or additional hypotheses and monitoring (Jacobson et al. 2016a), which can assist the *evaluate* and *decide* stages of the AM process (Sections 4.5 and 4.6 of this plan). Decision trees are shown below for the Upper Missouri and Yellowstone rivers (Figure 63) and for the Lower Missouri River (Figure 64). The decision trees illustrated in Figure 63 and Figure 64 follow the same format and graphical representation. Key uncertainties related to a subset of the key hypotheses being evaluated in the AM Plan are depicted by yellow diamonds and potential actions are depicted by blue boxes. The initial uncertainty, posed as a question, is listed in the top-left corner. The yes/no answer to this question is connected by arrows which either lead to another uncertainty (question) or a potential action. The directionality of subsequent decisions follows the life-stages in sequence, which would be the most systematic approach to understanding recruitment failure. Useful information can be generated outside of the sequence as well. For example, using age-0 shovelnose sturgeon as a surrogate species may generate insights about food limitations of pallid sturgeon and allow for an emphasis on other hypotheses. Appendix F contains decision trees with added detail and explanation, which accommodate all of the hypotheses considered in the EA, as well as recent advances in understanding. These detailed decision trees are an important input to the prioritization of Level 1 and Level 2 science activities (Table 39), also described in Appendix F.

The Upper Missouri-Yellowstone rivers decision tree (Figure 63) focuses on hypotheses related to drift and dispersal. The effects of fragmentation are clearest, and the available drift/dispersal distance and hypothesized inhospitable headwaters of Lake Sakakawea pose a distinct constraint on recruitment. The ability to overcome these constraints has bearings on the efficacy of potential management actions including flow management, temperature management, and drawdown of Lake Sakakawea at Garrison Dam. The first uncertainty is whether sediments in the headwaters of Lake Sakakawea are anoxic and lethal to developing embryos. If this is confirmed, then the next uncertainties are whether pallid sturgeon are able to migrate and spawn in the Yellowstone River and whether spawning occurs >500 km upstream (an approximation of required drift distance). If pallid sturgeon do not migrate a sufficient distance up the Yellowstone

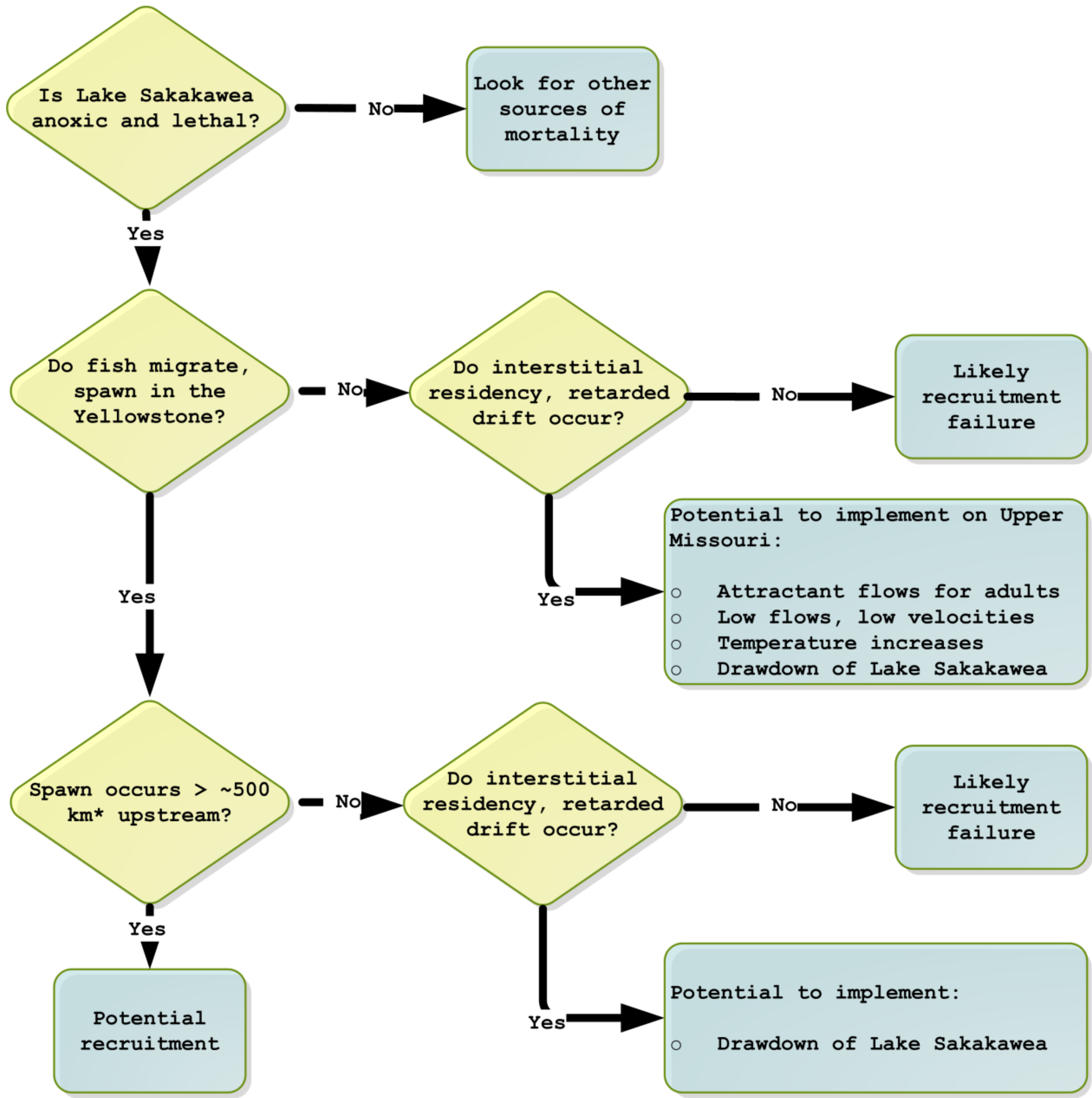
River, then the uncertainty is whether retarded drift (interstitial hiding and other mechanisms) occurs. If it occurs, then potential actions include flow management (attractant flows for adults, low flows to slow rate of movement of embryos), temperature management (increased temperature to increase development rates), and drawdown of Lake Sakakawea (or other, as yet unidentified, means of addressing the anoxia). If pallid sturgeon choose to spawn primarily in the lower Yellowstone River then recruitment failure appears likely, as there is not sufficient drift distance before Lake Sakakawea. If pallid sturgeon migrate to the Yellowstone River but do not spawn at a distance far enough upstream from Lake Sakakawea, the uncertainty is again whether retarded drift (interstitial hiding) occurs. The potential action is drawdown of Lake Sakakawea (or otherwise addressing anoxic headwater conditions). Finally, if pallid sturgeon are attracted to migrate up the Yellowstone River, are able to pass Intake Diversion Dam in sufficient numbers, and are attracted to migrate and spawn far enough upstream in the Yellowstone River watershed, potential recruitment may occur and other management actions may be unnecessary. The level of drawdown of Lake Sakakawea contemplated in Figure 63 has not been determined. It would need to be sufficient to provide a biological benefit in terms of drift distance, while still being consistent with authorized purposes. A much larger drawdown of Lake Sakakawea would provide greater drift distance but would not be consistent with current operations. Taking advantage of natural variations in water conditions (e.g., a series of low water years in which reservoir levels naturally decline) could be very informative for determining the survival of free embryos under conditions with greater drift distance.

Figure 63 shows a complex set of alternative future scenarios. Focusing research studies and AM experiments on key decision nodes (i.e., the diamonds in Figure 63) can simplify the decision process by rejecting some hypotheses and thereby eliminating certain branches on the decision tree. Such advances help to clarify that some actions are very unlikely to be successful, which helps to focus management attention on the remaining actions with potential benefit, and reduces the number of possible future scenarios. Learning is not instantaneous. Various forms of variability (e.g., year to year variations in flows, temperatures and reproductive spawners; spatial and temporal variability in the distribution of free embryos within each year) require multiple years of observations to separate the signal from the noise, and draw reliable conclusions. Therefore, though information from pallid sturgeon studies will be analyzed and reported annually, major decisions on actions are likely to proceed based on several years of accumulated and carefully confirmed findings.

Interstitial hiding was a hypothesis that emerged through the expert opinion process. Prior to the summer of 2015, immediate drift was also never observed directly in pallid sturgeon; immediate drift was inferred but not documented. USGS studies have provided good evidence regarding drift rates, and further studies are planned (Patrick J.

Braaten, USGS, pers. comm.). Emerging evidence suggests that pallid and shovelnose embryos are not retained within the substrate, in contrast to lake sturgeon (Delonay et al. 2015 conference presentation). However, these results have not yet been peer reviewed and published. Until these USGS studies have been peer reviewed and published, the interstitial hiding hypothesis is retained in the AM Plan, given somewhat less emphasis, and enhanced with the idea of retarded drift to encompass myriad other factors that could also affect net dispersal rates. Passage at Intake will result in approximately 400 km of drift (less than the rough guideline of 500 km in Figure 63), so the degree of retarded drift is important. These issues are discussed further in section 4.2.5.2 with respect to Intake Dam.

In June and July 2016, a large group of collaborating agencies and scientists conducted the Missouri River Pallid Sturgeon Free Embryo Drift Study, which is described here: https://www2.usgs.gov/blogs/csrp/. The study involved dye-studies to test assumptions in hydraulic models, the release of nearly 700,000 free embryos 2 miles downstream of the Milk River, and detailed monitoring of the movement and dispersal of these free embryos, guided by advection-dispersion models that were recalibrated based on the dye studies. The results of this experiment will yield insights on the proportion of free embryos that are able to find suitable rearing habitat and avoid the anoxic zones at the upper end of Lake Sakakawea, and provide improved tools for predicting the rate of movement and dispersion of both water and free embryos. This information is critical to determining the required dispersal distance for free embryos, and addressing key decision nodes in Figure 63.



* 500 km distance upstream is a coarse guideline because it would provide about 9 days for drift and development under purely passive drift assumptions.

Figure 63. Diagram of a decision tree for addressing contingent information for drift and dispersal related management actions in the Upper Missouri and Yellowstone rivers. In this diagram, drawdown of Lake Sakakawea (lower right) is to a level consistent with authorized purposes. The diamond in the upper left refers to the headwaters of Lake Sakakawea. Information exists to partially answer some of the questions in the diamonds, as discussed in the text. A more detailed decision tree, including other actions such as augmentation, is contained in Appendix F (Figure F2). Source: Jacobson et al. 2016a.

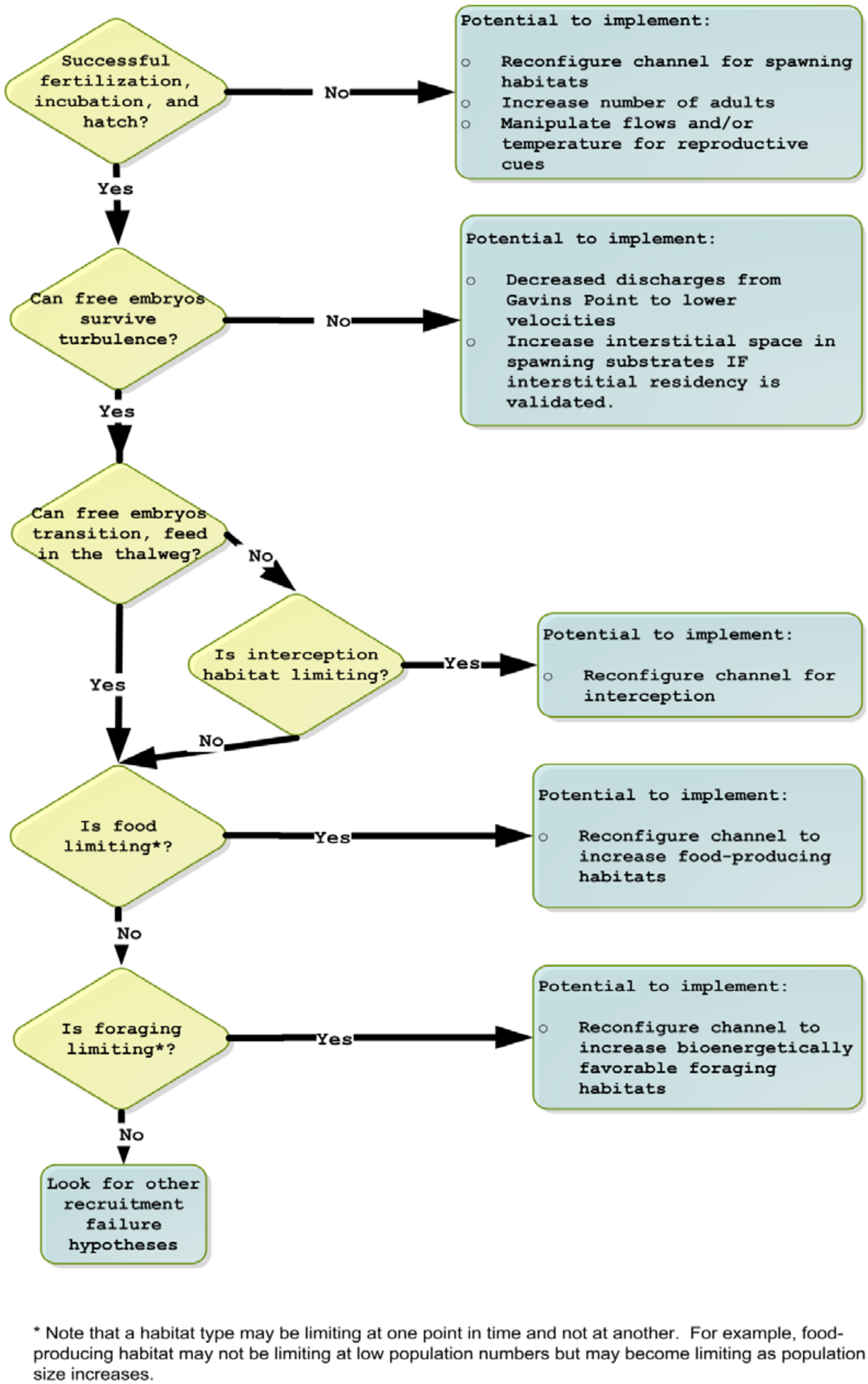


Figure 64. Diagram of a decision tree addressing contingent information in the Lower Missouri River. Modified from Jacobson et al. 2016a.

For the Lower Missouri River decision tree (Figure 64), uncertainties center around how pallid sturgeon use the Lower Missouri River, tributaries, and the Mississippi River. This has bearing on the efficacy of potential management actions including flow and temperature management (Gavins Point Dam); manipulating spawning substrates to increase aggregation, reduce hybridization and improve reproductive success; , and channel reconfiguration to construct foraging and food habitat and interception and rearing complexes. The first uncertainty is whether fertilization, incubation, and hatch can be demonstrated. If this cannot be established, potential actions include flow and temperature management from Gavins Point Dam for reproductive cues, channel reconfiguration for spawning habitat, and increased stocking to generate more adults. If successful fertilization, incubation, and hatch can be demonstrated, then the next uncertainty is whether velocities and turbulence are lethal to drifting free embryos. If velocities and turbulence are lethal to drifting free embryos, then potential actions are flow management (decreased discharge), and manipulating spawning substrates to allow greater access of free embryos to interstitial spaces. If free embryos can survive turbulence, then the next uncertainty is whether free embryos being transported in the thalweg will starve unless they can settle into supportive, channel-margin habitats, or if instead they can transition to first feeding, find food, and grow to the point where they are mobile enough to seek habitats on their own. If free embryos cannot transition or settle into supportive habitats, IRCs could be constructed. If IRCs are not limiting, and free embryos can transition or feed in the thalweg, the uncertainty is whether food is limiting. If food is not limiting, then other recruitment failure hypotheses need to be considered. If food is limiting, foraging and food habitat could be achieved through channel reconfiguration. Completing science studies in parallel rather than in sequence can accelerate the learning process about the different diamonds in each decision tree.

4.2 Plan and Design

4.2.1 Pallid sturgeon framework

On November 2, 2015, the USFWS provided the USACE with a Planning Aid Letter (USFWS 2015a) confirming support for a document called "Lower Missouri River Pallid Sturgeon Framework, Targets and Decision Criteria" (USFWS and USACE 2015). This document provides guidance for actions to be included in the Missouri River Recovery Management Plan Environmental Impact Statement (MRRMP-EIS), and its structure has been used to guide the section of this AM Plan dealing with actions to be implemented in the Lower Missouri River (section 4.2.6). Though an equivalent document has not yet been generated for the Upper Missouri River, we have applied a similar structure to discussions of actions to be implemented in the Upper Missouri River (section 4.2.5). Chapter 2 of the MRRMP-EIS provides guidance on the rationale for including some actions in the alternatives to be analyzed (for both the Upper and Lower Missouri River), while excluding others.

Since the AMP is intended to provide the means of evaluating the effectiveness of actions described in the MRRMP-EIS, and the Pallid Sturgeon Framework (USFWS and USACE 2015) describes those actions, the Framework is a foundational document. Key principles underpinning the Framework are as follows (extracted from USFWS and USACE 2015):

- Given the lingering uncertainties regarding the scope and scale of the management actions necessary for the USACE to avoid jeopardizing the continued existence of pallid sturgeon, a strategy reliant upon a progressive AM program is the most effective way to manage risks to the pallid sturgeon.
- The Framework is expected to accelerate the identification of recruitment bottlenecks, resulting in a more strategic and focused implementation of appropriate management actions. This approach has the added benefit of minimizing impacts to stakeholders and avoiding unnecessary implementation costs.
- The artificial propagation program would be continued throughout the Framework's implementation as guided by the USFWS Basin-wide Stocking and Augmentation Plan, and improvements to that program related to genetic concerns, disease, stocking size, etc., would be pursued consistent with that plan.
- Implementation of management actions at Level 3 (described below) for each hypothesis would be required within a specified timeframe, provided the hypotheses associated with the action are not rejected by that time.
- At any time during the Framework's implementation, it may become apparent that: 1) a particular action is not needed, 2) a proposed action requires modification to be effective, or 3) that some new action not previously evaluated is required.

4.2.1.1 *The four levels of the framework*

The Framework consists of four levels of activity, as described in Table 39: research (Level 1); in-river testing (Level 2); scaled implementation (Level 3); and implementation at the ultimate scale required (Level 4). The lower river refers to the mainstem Missouri River downstream of Gavins Point Dam, including the influences (to the extent they are relevant) of upstream reservoirs like Fort Randall and Lewis and Clark Lake, influences of major tributaries, and some portion of the Middle Mississippi River. While originally developed for the Lower Missouri, the concepts are equally applicable to the Upper Missouri.

As information is developed from Level 1 and 2 studies or through monitoring of effectiveness of management actions, the Framework's decision criteria will be used to determine when and what action should follow. Decisions might include:

a) accepting that the scientific information supports the hypothesized action and:

1. moving to the next most important science question pending for each big question; or:
2. moving to implementation of higher-level (i.e. Level 2, 3 or 4) actions;

b) determining that the scientific information does not support the hypothesized action and:

1. refining the hypothesis and continuing scientific investigations; or
2. rejecting the hypothesis and promoting an alternative hypothesis that better explains observed information.

c) to begin implementing at Level 3 because a time limit for a hypothesized action has been reached and results remain equivocal (studies at Levels 1 and 2 might continue concurrently)

Table 39. Pallid sturgeon framework for the lower Missouri River (same as Table 6)

<table>
<tr><td>Level 1: Research</td><td rowspan="2">Population Level Biological Response IS NOT Expected</td><td>Studies without changes to the system (Laboratory studies or field studies under ambient conditions)</td></tr>
<tr><td>Level 2: In-river Testing</td><td>Implementation of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response.</td></tr>
<tr><td>Level 3: Scaled Implementation</td><td rowspan="2">Population Level Biological Response IS Expected</td><td>In terms of reproduction, numbers, or distribution, initial implementation should occur at a level sufficient to expect a meaningful population response progressing to implementation at levels which result in improvements in the population. The range of actions within this level is not expected to achieve full success (i.e. Level 4).</td></tr>
<tr><td>Level 4: Ultimate Required Scale of Implementation</td><td>Implementation to the ultimate level required to remove as a limiting factor.</td></tr>
</table>

Level 1 and 2 studies are directly tied to those uncertainties and management hypotheses highlighted in the EA that, if resolved, could significantly affect the implementation of management actions. They can continue concurrently with Level 3 efforts (to better understand cause-effect mechanisms), but are generally intended to inform future actions at Level 3. Although Level 2 studies have learning as a primary objective, they can also provide measurable and meaningful benefits to pallid sturgeon populations and, in such cases, would be counted toward targets in the same manner as Level 3 actions. Criteria for accepting or rejecting specific hypotheses, for assessing the results of scaled experiments, and for moving from Level 1 to Level 2 or Level 2 to Level 3 actions are described in section 4.2.4.

Chapter 2 of the MRRMP-EIS provides the rationale for which actions are currently included or excluded from Level 3 implementation in the EIS. Actions excluded from Level 3 implementation may still be the focus of investigations at Levels 1 and 2.

4.2.1.2 *Current status of actions, relative priority of Level 1 investigations, and overview of decision criteria*

Table 40 shows the current status of actions under consideration for both the Upper and Lower Missouri River, in terms of the 4-level framework in Table 39, based on the EA, the MRRMP-EIS and the Lower Missouri River Framework. In addition, Table 40 shows the relative priority of Level 1 investigations. As illustrated in Figure 41 and discussed in section 3.2.1 (Bird Framework), an action may change in scope, be removed from consideration, or be added as a potential action even though it was not part of the EIS or part of the Selected Alternative (with the required review processes).

Figure 65 provides an overview of the decision criteria for moving actions from Level 1 through Levels 2, 3 and 4, as well as for abandoning or revising certain actions. Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. Appendix C provides a detailed listing of all Level 1 and 2 science components and associated decision criteria. For those science components prioritized for the first five years after the ROD, decision criteria are summarized in Table 43 for the Upper Missouri and Table 44 for the Lower Missouri.

The descriptions of experimental designs for L3 actions in Section 4.2.5 (Upper Missouri) and Section 4.2.6 (Lower Missouri) are examples based on the current understanding of which actions may be included in the MRRMP-EIS. It is possible that actions at Levels 2 to 4, which are not currently included in the MRRMP-EIS, are currently planned for investigation at Level 1. Investigations at Level 1, if favorable, might ultimately lead to implementation at implementation of actions at Level 2 or Level 3. If such Level 2 or Level 3 actions are determined to be outside the scope of the alternative selected in the ROD then a supplemental NEPA process would be required before implementation (section 2.2.5).

Table 40 Current status of actions under consideration for both the Upper and Lower Missouri River, and relative priority of investigations at each level.[1] Details of the formulation of alternatives and the rationale for decisions on these alternatives will be included with the release of the Draft EIS in December 2016.

Action location	Action	Current level of implementation and relative priority			Comments
		Level 1	Level 2	Level 3	
Upper Missouri River	Alter Flow Regime at Fort Peck	Low	Depends on results of Level 1		Continue to investigate biological benefits with better information on interstitial residency and movement rates of embryos at Level 1. Not currently included in Preferred Alternative, but one possible outcome of research studies and AM experiments (see Figure 63).
	Temperature Control, Fort Peck	Low	Depends on results of Level 1		Continue to investigate biological benefits at Level 1. Not currently included in Preferred Alternative, but one possible outcome of research studies and AM experiments (see Figure 63).
	Sediment Augmentation at Fort Peck	Low	Depends on results of Level 1		Continue to investigate at Level 1. Not currently included in Preferred Alternative.
Yellowstone River	Passage at Intake	High	High	High	This action and associated evaluations of effectiveness have been determined to be a high priority by the USFWS in coordination with the USACE and Reclamation for the Upper Missouri[2].
Upper Missouri and Yellowstone	Upper Basin Propagation	High	High	High	The Recovery Team and participating federal agencies are considering several potential changes to the propagation program, including the number, age and genetics of stocked fish, and stocking locations. The new information analysis of the fish condition (section 4.1.2.5) may lead to additional EA hypotheses concerning propagation. The experimental designs described in section 4.2.5.1 of the AM Plan are applicable to multiple potential action hypotheses. Included in Preferred Alternative. Amount of augmentation could be decreased significantly in the next Basin-wide Stocking and Augmentation Plan

[1] Detailed alternative formulation and decision rationale will be included with the release of the Draft EIS in December 2016

[2] For further information please see the Final EIS and ROD for the Lower Yellowstone Intake Diversion Dam Fish Passage Project (USBOR and USACE 2016a, 2016b)

Action location	Action	Current level of implementation and relative priority			Comments
		Level 1	Level 2	Level 3	
Lake Sakakawea	**Drawdown, Lake Sakakawea**	Low	Depends on results of Level 1		Continue to investigate biological benefits with better information on interstitial residency and movement rates of embryos at Level 1. Not currently included in Preferred Alternative, but one possible outcome of research studies and AM experiments (see Figure 63).
Lower Missouri River	**Alter Flow Regime at Gavins Point**	Medium-High	Medium-High after 9-year period post-ROD, depending on results of Level 1 studies	Medium-High after 9-year period post-ROD, depending on results of Level 1 and Level 2 studies	Spawning cue flows will be a high priority Level 1 investigation. Naturalization of the flow regime at Gavins Point will be a medium priority Level 1 investigation. Not currently included in Preferred Alternative, but might be implemented as a test flow following 9 years of study post-ROD (see Figure 64 and section 4.2.6.6).
	Temperature management, Fort Randall	Low	Depends on results of Level 1		Not currently included in Preferred Alternative, but one possible outcome of research studies and AM experiments (see Figure 64).
	Channel Reconfigu–ration	High	High	High	Construction of habitat to support early life history survival (e.g., Interception and Rearing Complexes, Spawning Habitats) is included in the Lower Missouri Framework. Included in Preferred Alternative.
	Propagation Lower Basin	High	High	High	As described above for the Upper Missouri River. The experimental designs described in section 4.2.6.1 of the AM Plan are applicable to multiple potential action hypotheses. Included in Preferred Alternative.

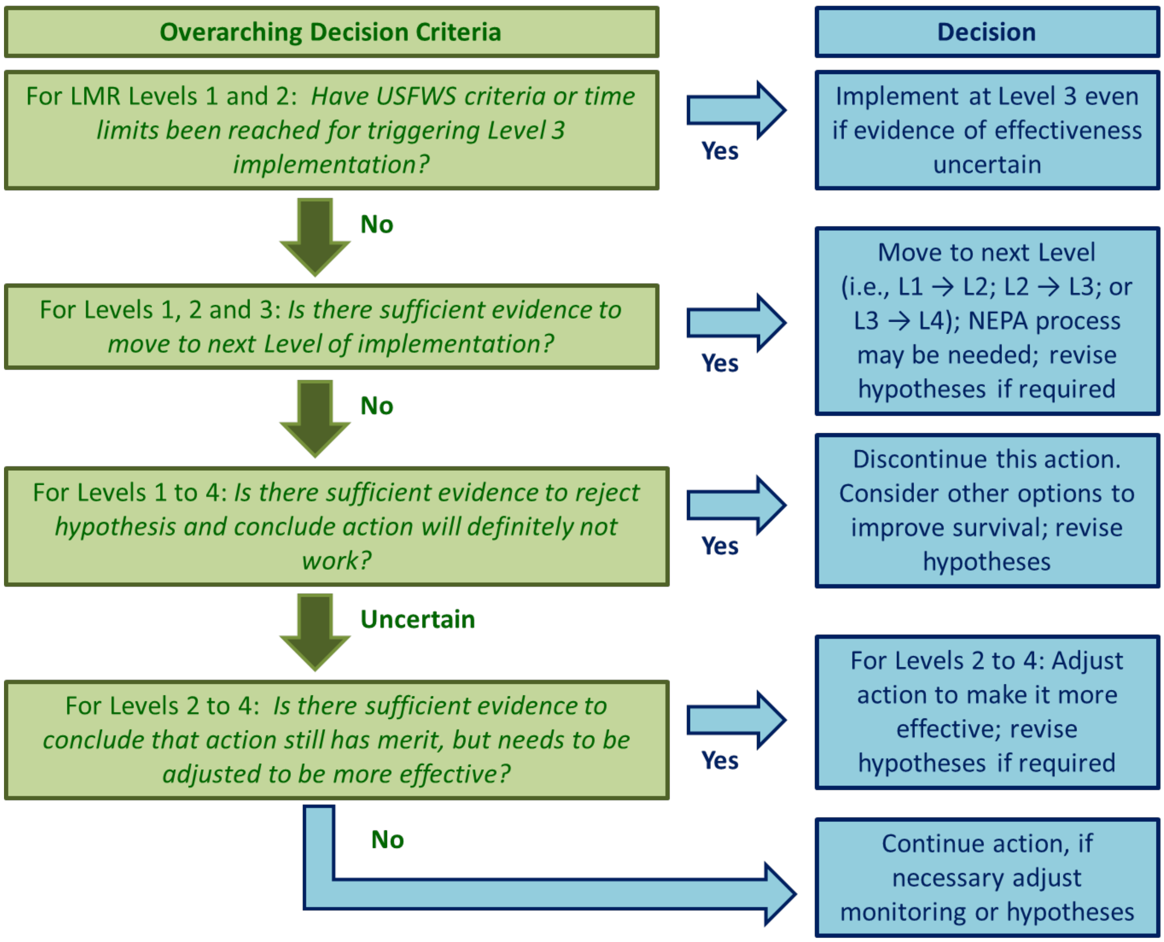


Figure 65 Overview of the decision criteria for various decisions in the Pallid sturgeon framework. The top green box refers to the decision criteria in Table 41 and Table 42. The remaining green boxes refer to the evidence and decision criteria in Appendix C, Table 43, Table 44 and Table 53. The blue box second from the bottom ("Discontinue this action, consider other options to improve survival") is illustrated by the decision trees in Figure 63 and Figure 64

4.2.1.3 *Level 3 Actions, Targets and Decision Criteria:*

Requirements for Level 3 were developed collaboratively by the USACE and USFWS and reflect both best available science and policy considerations. Implementation of management actions at Level 3 for any limiting factor would commence at the earlier of two triggers (to allow quick response to information): 1) within two years of affirmative results from Level 1 and/or 2 studies indicating an action is needed for a limiting factor (see decision criteria in section 4.2.4 and Appendix C), or 2) the established time limits in Table 42 have been reached, and the results of studies/tests at Levels 1 and 2 of the associated hypotheses still remain equivocal.

There is a tradeoff between taking action and decreasing uncertainty. To help find an appropriate balance, USFWS and USACE (2015) defined a series of five questions as a proposed checklist to guide decisions to advance to implementation at Level 3 for any of the hypotheses identified by the EA (Table 41). Work at Level 1 will help to answer questions 1, 2, 3 and 5. The decision criteria described in Appendix C (and summarized in Table 43 and Table 44 for components prioritized for the first five years post-ROD) will help in deciding whether or not to move hypotheses from Level 1 to Level 2. Level 2 in-river tests of actions will be particularly helpful for providing empirical evidence to address question 4; strong experimental designs will be required to provide compelling evidence. If all five questions can be answered "Yes", advancement to Level 3 implementation would be triggered. If an affirmative answer to four of the five questions exists and either question 1 or question 2 is equivocal, implementation of Level 3 management actions would be triggered within two years (unless the hypothesis is rejected in that timeframe). It may be possible to answer question 2 (e.g., the amount of spawning, feeding or rearing habitat required for age-0 fish) without knowing which of these factors are most limiting recruitment to age-1. In this chapter we provide a more detailed hierarchy of questions to evaluate the effectiveness of Level 2 and Level 3 actions, which are summarized in sections 4.5 (Evaluate) and 4.6 (Decide).

Table 41. Supplemental lines of evidence strategy for triggering Level 3 implementation. See above text.

	Question	Y	U	N
1	Is this factor limiting pallid sturgeon reproductive and/or recruitment success?			
2	Are pallid sturgeon needs sufficiently understood with respect to this limiting factor?			
3	Do one or more management action(s) exist that could, in theory, address these needs?			
4	Has it been demonstrated that at least one kind of management action has a sufficient probability of satisfying the biological need?			
5	Have other biological, legal, and socioeconomic considerations been sufficiently addressed to determine whether or how to implement management actions to Level 3?			
	Criteria for Level 3 implementation			
	1 - A "Yes" to all five questions triggers Level 3 implementation			
	2 - A "Yes" to four of five, with an "Uncertain" for either #1 or #2 triggers a two-year clock to either reject the hypothesis or implement at Level 3			

The USFWS and USACE (2015) defined time limits for implementation of Level 3 actions and their scope, expressed as targets (Table 42). These time limits are intended as a determination to proceed if the evidence for or against particular actions remains equivocal (i.e., a decision could be made to either abandon or proceed with actions at Level 3 prior to these time limits). The targets for IRCs were subsequently revised by the USFWS (2016). The time limits were set by the USFWS based on a recognition of the tradeoff between two objectives: 1) learning what actions are likely to be effective (which requires more time for Level 1 work); and 2) the need to take actions to benefit the species even if uncertainty remains about the effectiveness of such actions. As knowledge is gained from Level 1, 2 and 3 actions, the timeframe for implementation may be adjusted, targets may be changed, management actions may be refined, and hypotheses may be dismissed. The "rules" by which these decisions will be made are outlined in the decision criteria for the respective management hypotheses, subject to the overarching governance and decision process laid out in Chapter 2 of this AM Plan.

Table 42. Summary of time limits for implementation and scope of actions.

Action Category	Time Limit*	Minimum Scope	Maximum Scope
Population augmentation (Level 3)	Immediate	Current stocking rate as directed by USFWS Basin-wide Stocking and Augmentation Plan	Variable over time as directed by USFWS Basin-wide Stocking and Augmentation Plan
IRC habitat development (Levels 2 to 4)	Stage 1: study phase (years 1-3 post-ROD)	Build 2 IRC sites per year (paired with control sites), adding 33,000 ac-d/yr of suitable habitat, using staircase design[1]. Assess potential for refurbishing existing SWH sites as IRCs	
	Stage 2 – continue study phase (years 4-6 post-ROD)	Build 2 IRC sites per year (paired with control sites), adding 33,000 ac-d/yr[1] of suitable habitat. Refurbish SWH sites in addition to study sites (rate TBD).	
	Stage 3 - Level 3 implementation (years 7-10 post-ROD)	Continue assessing IRC sites and refurbishing new SWH sites, adding at least 66,000 ac-d/yr[1] of suitable habitat. Determine required rate of Level 3 implementation based on stages 1 and 2.	
	Stage 4 – Level 4 implementation	Remove IRC habitat limitations to pallid sturgeon survival by implementation at Level 4.	
Spawning habitat[2] (Level 2)	2 years	1 spawning site	See decision tree in Figure 78
Spawning cue flows (Level 2)	9 years	Requirement for spawning cue flows (and appropriate scope) depends on the outcome of Level 1 monitoring and modeling studies during years 1-9. [3]	

Notes to Table 42

1. Units of ac-dy/year are calculated based on how the flow regime and channel configuration result in cumulative days of availability of suitable habitat during the growing season. Progression through each stage of IRC habitat development is contingent on outcomes and hypothesis tests (USFWS 2016); efforts could be halted if evidence shows IRCs are not successful. Experimental design for IRC sites is described in section 4.2.6.3 and Appendix E. Refurbishment of SWH sites into IRCs is described in section 4.2.6.4.

2. Anticipated as a Level 2 pilot projects focused on developing and evaluating high-quality spawning habitat. Spawning habitat implementation will be guided by the decision tree in section 4.2.6.3 (Figure 78). The evaluation of spawning areas will be based on comparing attraction, egg survival, and hatch to existing spawning areas (see section 4.2.6.5).

3. See evidentiary framework in Table 48, section 4.2.6.6. Bird impacts and status, reservoir levels, and HC impacts will inform decisions regarding spawning cue flows below Gavins Point Dam in any particular year.

4.2.2 Tradeoffs between different learning strategies

As noted in the previous section, there is a tradeoff between taking action and decreasing uncertainty. Taking actions at Level 3 or 4 without strong evidence of their effectiveness may be costly, and may use resources which could have been better allocated. On the other hand, there are constraints on how much can be learned from retrospective studies of past data, analyses of the current system, laboratory experiments and mesocosm experiments. Delaying Level 3 or 4 actions that have potential benefits could delay the recovery of pallid sturgeon. The AM strategy needs to find the appropriate balance between three risks: 1) premature implementation of ineffective actions, which wastes resources; 2) excessive delay in implementing actions which would have helped the population; and 3) implementation of multiple concurrent actions without an ability to determine which actions are most effective, which makes future management adjustments more difficult.

The AM Plan embodies a fast pace of learning, by implementing many nondependent Level 1 components concurrently or nearly concurrently rather than sequentially (as explained in Appendix C). Too many concurrent activities could however be overwhelming and inefficient. Therefore, the AM Plan also prioritizes some components to be implemented during the first five years post-ROD, and defers others for consideration beyond this period (as explained in Appendix F). Concurrent implementation of multiple components will require a substantial investment in early and carefully planned research. Level 1 science components jointly provide complementary lines of evidence that cumulatively affect decisions to implement field experiments at Level 2.

4.2.3 Recommended learning strategy for AM Plan

In developing a learning strategy for the AMP, we have adopted the following principles:

- Wherever possible conduct L1 research concurrently to accelerate learning, consistent with the criteria for prioritization described in Appendix F.
- Combine all lines of evidence from L1 research to determine level of support for and form of design of L2 experimental management actions.
- Use L2 actions to test action effectiveness and to develop experimental designs that would be applicable at both L2 and L3;

- For L3 actions already underway (e.g., propagation) use L1 and L2 actions to confirm that these actions are working as intended, to better understand cause and effect, and to determine if L3 actions need to be adjusted.
- In evaluating L2 actions and associated hypotheses, seek to maximize spatial and temporal contrasts within the constraints of both feasibility and authorized purposes, so as to develop the clearest possible inferences from L2 actions.
- Design L1 and L2 research to efficiently transition to Level 3 based on learning, rather than exceeding time limits.
- Ensure that Level 2 experiments do not risk negative effects on either pallid sturgeon or human considerations.

4.2.4 Overview of Level 1 and 2 Components and Decision Criteria

Table 4 and Table 5 list the 12 big questions and 21 associated hypotheses for pallid sturgeon. For each big question, science components have been developed for Level 1 and Level 2 (see definitions in Table 39). Appendix C of this document provides a detailed explanation of each study component, while this section provides a tabular overview of those activities prioritized for the first five years after the ROD (see Appendix F for further details on the prioritization criteria that were used). Study components are classified as:

- **Engineering/technology:** studies needed to a) develop technology to measure pallid sturgeon responses to a management action (for example, new telemetry technology, new population modeling approaches) or b) develop engineering approaches to achieving the management action (for example, engineering designs capable of increasing interception of drifting free embryos).
- **Biological screening:** studies to screen a management hypothesis and better determine the magnitude of potential benefit of a management action. For example, biological screening could describe a study to determine whether growth or survival of age-0 pallid sturgeon is food limited. If so, studies would proceed to quantify functional relations between the management action and the population response; if not, the management hypothesis might be placed in reserve until the biological relevance was established.
- **Level of biological effect:** studies to quantify the functional relationship between levels of management action and biological response, for example, to determine how much survival increases for an increment of increased food-producing habitat. The functional relations that come from understanding levels of biological effect are critical to modeling and projecting the effects of management actions on the species.

In addition, biological-screening and biological-effect studies are classified by approach. Because the sturgeon life cycle is complex and critical parts of it involve very small fish in a fast, deep and turbid river, improvements in scientific understanding are likely to require a combination of approaches. Approaches range from laboratory studies, which provide highly controlled, but unrealistic conditions, to field-gradient studies, which typically lack experimental controls and replication, but take place under realistic conditions.

- **Laboratory experiment** – controlled experiment at laboratory scale, typically involving randomization and replication for statistical rigor. Includes experiments to determine fundamental biological rates – for example, embryo development rate as a function of temperature – and behavioral experiments like drift studies in racetrack flumes.
- **Mesocosm experiment** – experiments outside of the strict controls of laboratories, but at less than field scale. Examples include experiments in controlled stream or pond environments. These conditions are incrementally closer to field conditions compared to laboratory experiments, but lack the full dynamism of the field example and typically involve somewhat less statistical rigor and precision of measurements compared to laboratory experiments.
- **Field-gradient experiment** - using existing gradients of hydrologic, geomorphic, and biotic conditions to identify and/or quantify biological effects. These experiments often substitute space for time, or for treatment level. They take advantage of existing conditions and offer to provide results under realistic conditions, but often lack replication and statistical rigor. Gradient studies require care to reduce or eliminate interacting variates.
- **Monitoring/assessment** – as used in this document, monitoring/assessment denotes data collection of physical and/or biological data, but not necessarily in a hypothesis-testing or adaptive-management framework (field experiments – next category – include hypothesis-driven monitoring/assessment in an AM framework). Monitoring often provides critical contextual or covariate information, for example water quality or discharge, or population indices or metrics.
- **Modeling** – numerical experiments with computational models to test sensitivity of habitats or population dynamics to changing parameter values and to explore system dynamics. An example is using a well-calibrated population model to test population responses to variable stocking levels.
- **Field experiment** – manipulative field experiment to quantify responses to management actions and to test hypotheses. Examples would be pulsed-flow experiments to elucidate effects of spawning cues, or controlled experiments on varied channel reconfigurations to document effects on foraging habitat availability. Although these are planned experiments, they fit the definition of "quasi-experiment" because they typically lack randomization, replication, and/or independence of treatments.

Appendix C provides a detailed description of all Level 1 and 2 science components, as well as the decision criteria for evaluating their outcomes. Table 43 and Table 44 (for the Upper Missouri and Lower Missouri, respectively) provide a summary of the Level 1 and 2 components that are prioritized for the first five years after the ROD, based on the preferred alternative in the MRRP-EIS, and the prioritization process described in Appendix F. These tables summarize the metrics to be obtained by the work within each component, the criteria to be applied in decisions regarding progress to the subsequent component or level of investigation, and the degree of confidence in these decisions given the metrics to be provided by each component and the complexity of the component study. These tables are based on current understanding of research needs, and will need to be periodically revised, including after the ROD.

Table 43. Overview of highest priority Level 1 and 2 science components for the Upper Missouri, anticipated to be completed within the first five years of the Record of Decision (ROD) (subject to budget and resource constraints). Appendix C contains a complete list of all Level 1 and 2 components, and Appendix F describes the prioritization process. Components listed in Appendix C but not in this table could be implemented beyond the 5-year, post-ROD period. Metrics and decision criteria with associated degrees of certainty for the working management hypotheses are summarized from Appendix C. Categories for Degree of Certainty: 1 = Definitive, 2 = Statistically rigorous, 3 = Indicative but not authoritative, 4 = Expert judgment of multiple lines of evidence required. BQ = Big Question, L = Level, C = Component (e.g., BQ1/L1/C2 is Big Question 1, Level 1, Component 2). Work under BQ6 subject to Recovery Team discussions and Propagation Strategy. Hypotheses are from Table 1 in Jacobson et al. 2016a.

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty *	Concurrent / Dependent Components
Big Question 1 – Spawning Cues: Can spring pulsed flows from Fort Peck synchronize reproductive fish, increase chances of reproduction and recruitment?				
Associated Hypotheses: **H2.** Attractant flow releases at Fort Peck will result in increased reproductive success through increased aggregation and spawning success of adults.				
BQ1/L1/C1-- Design study: complementary passive telemetry network	Detectability of telemetry tags by network receivers, variation of tag detectability with discharge-related characteristics, tag cost, tag reliability.	IF fish movements past strategic locations are successfully detected, THEN deploy a larger network of telemetry receivers to help evaluate sturgeon response to flow.	1	C1-C2 all concurrent. Also with design of lower basin telemetry network (Table 39 - BQ1/L1/C1)
BQ1/L1/C2 – Field study: opportunistic tracking of reproductive behaviors	Degree of association of reproductive behaviors and successful spawning with monitored hydrologic characteristics.	IF there are moderate to strong associations between hydrologic characteristics and reproductive behavior, THEN this provides stronger evidence for L2 studies. However, IF successful reproductive behavior is observed in the absence of the hypothesized hydrologic characteristics AND is	4	C1-C2 concurrent

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty *	Concurrent / Dependent Components
		sufficient to have a population-level effect THEN this provides evidence against hypothesis H2.		
Big Question 2 – Food and Forage: Can naturalization of the flow regime from Fort Peck contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?				
Associated Hypotheses: **H1.** Naturalized flow releases at Fort Peck will result in increased productivity through increased hydrologic connections with low-lying land and flood plains in the spring, and decreased velocities and bioenergetic demands on exogenously feeding larvae and juveniles during low flows in summer and fall.				
No science components prioritized for first five years after ROD for BQ2 and H1. Postpone work on BQ2 until work on BQ5 is completed.				
Big Question 3 – Temperature Control: Can water-temperature manipulations at Fort Peck contribute significantly to increased chance of reproduction and recruitment?				
Associated Hypotheses: **H4.** Warmer flow releases at Fort Peck Dam will increase system productivity and food resource availability, thereby increasing growth and condition of exogenously feeding larvae and juveniles. **H5.** Warmer flow releases from Fort Peck Dam will increase growth rates, shorten drift distance, and decrease mortality by decreasing free embryos transported into headwaters of Lake Sakakawea.				
During first five years after ROD, focus on science components within BQ3 that are supportive of investigations under BQ5.				
BQ3/L1/C2b - lethality of Lake Sakakawea to age-0	2b – Spatial and temporal extent and variability of conditions lethal to benthic larval fish in Lake Sakakawea.	IF results indicate that Lake Sakakawea is not limiting, THEN this provides more support for Level 2 experiments.	3	C2b, C3b and C4b all concurrent
BQ3/L1/C3b – Field studies: validating advection / dispersion model	3b – Spatial and temporal distributions of larvae and surrogate flow tracers to determine larval retention.	IF results indicate that free embryos can be retained in the Fort Peck segment THEN this provides more support for Level 2 experiments.	3	C2b, C3b and C4b all concurrent
BQ3/L1/C4b – Mesocosm studies: developing quantitative temperature-recruitment relationships	4b – Temperature-dependence of pallid sturgeon developmental rates.	IF data on developmental rates and other evidence indicates that drift/dispersal is not limiting, THEN this provides more support for Level 2 experiments.	4	C2b, C3b and C4b all concurrent

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty *	Concurrent / Dependent Components
Big Question 4 – Sediment Augmentation: Can sediment bypass at Fort Peck contribute significantly to increased chance of reproduction and recruitment?				
Associated Hypotheses: **H6.** Installing sediment bypass at Fort Peck will increase and naturalize turbidity levels, resulting in decreased predation on embryos, free embryos, and exogenously feeding larvae.				
No science components prioritized for first five years after ROD for BQ4 and H6. Postpone work on BQ4 until work on BQ5 is completed.				
Big Question 5 – Drift Dynamics: Can combinations of flow manipulation from Fort Peck, drawdown of Lake Sakakawea, and fish passage at Intake Dam on the Yellowstone River increase probability of successful dispersal of free embryos and retention of exogenously feeding larvae?				
Associated Hypotheses: **H3.** Reduction of mainstem Missouri flows from Fort Peck Dam during free-embryo dispersal will decrease mainstem velocities and drift distance, thereby decreasing mortality by decreasing numbers of free embryos transported into headwaters of Lake Sakakawea. **H7.** Fish passage at Intake Diversion Dam on the Yellowstone River will allow access to additional functional spawning sites, increasing spawning success and effective drift distance, and decreasing downstream mortality of free embryos and exogenously feeding larvae. **H10.** Drawdown of Lake Sakakawea will increase effective drift distance, decreasing downstream mortality of free embryos and exogenously feeding larvae.				
BQ5/L1/C1a,b – Modeling / engineering study: drift dynamics and effects of anoxia	1a – Integrated model linking hydrodynamics, water temperature increases, developmental rates, and population dynamics. 1b – Spatial/temporal variation of anoxia in Lake Sakakawea. <u>Overall</u>: length of free-flowing river under drawdown and flow scenarios; frequency of occurrence	Complete C2 regardless of C1 outcomes. IF model results show that biologically significant movement of the anoxic zone is substantial across management scenarios, THEN this provides more support for L2 drawdown management actions.	1	C1, C2, C3 and C4 completed concurrently
BQ5/L1/C2a,b - Screening: anoxia-dependent recruitment limitation	2a - Spatial / temporal extent and variability of anoxia in Lake Sakakawea. 2b – Spatial distributions of suitable spawning habitat upstream of Intake Dam.	IF results indicate that anoxic zones are patchy, dispersal into Lake Sakakawea is not necessarily fatal AND suitable spawning habitat exists to take advantage of greater passage, THEN this provides more support for L2 drawdown management actions, and potentially other actions.	1	C1, C2, C3 and C4 completed concurrently
BQ5/L1/C3 – Field studies: validating temperature, drift, and	Spatial and temporal distributions of larvae and surrogate flow tracers to determine larval retention.	IF drift experiments show that advection is significantly different than predicted in passive transport models, THEN this provides more	2	C1, C2, C3 and C4 completed concurrently

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty *	Concurrent / Dependent Components
recruitment relationships		support for L2 drawdown management actions.		
BQ5/L1/C4 – Mesocosm experiments: Larval dispersal rates	Virtual velocity of free embryos as a function of time, temperature, and developmental stage in relation to channel complexity.	IF results provide robust relationships among abiotic variables, developmental stages, and dispersal rates AND results of C1-3 indicate anoxia is patchy and retardation mechanisms can be identified and quantified, THEN use this information to inform design of L2 studies.	4	C1, C2, C3 and C4 completed concurrently. All mesocosm studies designed concurrently.
Big Question 6 – Population Augmentation. Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?				
Associated Hypotheses: **H8.** Stocking at optimal size classes and in optimal numbers will increase growth rates and survival of exogenously feeding larvae and juveniles. **H9.** Stocking with appropriate parentage and genetic diversity will result in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.				
BQ6/L1/C1 - Engineering studies: feasibility hatchery needs, facilities, operations	Costs and measures of likely survival for a range of propagation facility designs.	IF alternative designs are expected to produce population benefits at a reasonable cost, THEN this provides more support for L2 management experiments	4	C1-C3 done concurrently
BQ6/L1/C2 - Retrospective study: survival linked to hatchery operations	Number and survival probabilities for stocked pallid sturgeon by stocked size, hatchery of origin, location of release and health history.	IF results indicate that changes in propagation facility operations could increase survival, THEN this provides more support for L2 management experiments. IF results indicate that more fish releases are required to estimate survival probabilities, then review alternative designs for BQ6/L2/C4.	3	C1-C3 done concurrently
BQ6/L1/C3 - Simulation models: population sensitivity to size, health, genetics	Probability of quasi-extinction, instantaneous growth rates, and sensitivity measures under various model scenarios.	IF results indicate that population dynamics are sensitive to changes in augmentation practices AND the information provided by previous components shows the need for L2 studies THEN this provides more support for L2 management experiments	4	C1-C3 done concurrently

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty *	Concurrent / Dependent Components
BQ6/L2/C4 – Manipulative field experiments: varying size, location of stocking	Estimated number and survival probabilities for stocked pallid sturgeon by stocked size and age, hatchery of origin; fish condition; water year conditions, and release location.	IF results indicate that survival is sensitive to size or age at stocking, THEN proceed to L3 implementation.	4	Decision criteria met for all three BQ6/L1 studies

Table 44. Overview of highest priority Level 1 and 2 science components for the Lower Missouri, anticipated to be completed within the first five years of the Record of Decision (ROD) (subject to budget and resource constraints). Appendix C contains a complete list of all Level 1 and 2 components, and Appendix F describes the prioritization process. Components listed in Appendix C but not in this table could be implemented beyond the 5-year post-ROD period. Metrics, and decision criteria with associated degrees of certainty for the working management hypotheses are summarized from Appendix C. Categories for Degree of Certainty: 1 = Definitive, 2 = Statistically rigorous, 3 = Indicative but not authoritative, 4 = Expert judgement of multiple lines of evidence required, BQ = Big Question, L = Level, C = Component. (e.g., BQ1/L1/C2 is Big Question 1, Level 1, Component 2). Work under BQ6 subject to Recovery Team discussions and Propagation Strategy. Hypotheses are from Table 1 in Jacobson et al. 2016a.

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty*	Concurrent / Dependent Components
Big Question 1 – Spawning Cues: Can spring pulsed flows synchronize reproductive fish, increase chances of reproduction and recruitment?				
Associated Hypotheses: **H11.** Naturalization of the flow regime at Gavins Point Dam will improve flow cues in spring for aggregation and spawning of reproductive adults, increasing reproductive success.				
BQ1/L1/C1-Design study: complementary passive telemetry network and biological modeling of potential population benefits	1a) Detectability of telemetry tags by network receivers, variation of tag detectability with discharge-related characteristics, tag cost, tag reliability. 1b) Power analysis to determine how many tagged adults required to detect various differences in level of spawning. Development of population model to model potential population benefits of spring pulsed flows as a function of frequency of implementation. 1c) Modeling analysis to determine required level of spawning to support a sustainable population	IF fish movements past strategic locations are successfully detected, THEN deploy a larger network of telemetry receivers to help evaluate sturgeon response to flow.	1	BQ1/L1 – C1, C2 done concurrently
BQ1/L1/C2 – Field study: Opportunistic tracking of reproductive behaviors	Degree of association of reproductive behaviors and successful spawning with monitored hydrologic characteristics.	IF there are moderate to strong associations between hydrologic characteristics and reproductive behavior, THEN this provides stronger evidence for L2 studies. However, IF successful reproductive behavior is observed in the absence of the hypothesized hydrologic characteristics AND is sufficient to have a population-level effect THEN	4	BQ1/L1 – C1, C2 done concurrently

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty*	Concurrent / Dependent Components
		this provides strong evidence to reject the hypothesis H11.		
Big Question 2 – Temperature Control: Can water-temperature manipulations at Fort Randall and/or Gavins Point contribute significantly to increased chance of reproduction and recruitment?				
Associated Hypotheses: **H15.** Operation of a temperature management system at Fort Randall Dam and/or Gavins Point Dam will increase water temperature downstream of Gavins Point, providing improved spawning cues for reproductive adults.				
BQ2/L1/C1 – Modeling study: water temperature management options, Gavins Point and Fort Randall	Absolute water temperatures and changes relative to historical values downstream of Gavins Point Dam and Fort Randall across various temperature control implementations, cost effectiveness.	IF temperatures are significantly lower than historical values, THEN this provides more support for other L1 studies.	2	Prerequisite for other L1 studies
Big Question 3 – Food and Forage: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?				
Associated Hypotheses: **H12.** Naturalization of the flow regime at Gavins Point Dam will improve connectivity with channel-margin habitats and low-lying flood plain lands, increase primary and secondary production, and increase growth, condition, and survival of exogenously feeding larvae and juveniles. **H13.** Naturalization of the flow regime at Gavins Point Dam will decrease velocities and bioenergetic demands, resulting in increased growth, condition, and survival for exogenously feeding larvae and juveniles. **H17.** Re-engineering of channel morphology in selected reaches will increase channel complexity and bioenergetic conditions to increase prey density (invertebrates and native prey fish) for exogenously feeding larvae and juveniles. **H18.** Re-engineering of channel morphology will increase channel complexity and minimize bioenergetic requirements for resting and foraging of exogenously feeding larvae and juveniles.				
BQ3/L1/C1 - Screening: limitations of food or forage habitats	Indicators of starvation or impending death of age-0 sturgeon based on stomach contents (empty/full) or physiological indicators (lipid content).	IF results indicate bioenergetic constraints, THEN this provides more support for L2 experiments.	3	BQ3/L1 -C1, C2, and C3 done concurrently
BQ3/L1/C2 – Engineering study: Technology development for IRC sampling, modeling, measurement	Density, transport, and flux of food items (chironomid larvae) and estimates of age-0 survival rates in prospective IRCs obtained through measurement and modeling.	IF results demonstrate a spatial relationship between food and forage habitats AND food flux is a significant factor in growth and survival within and among IRCs, THEN this provides more support for L2 experiments.	2	BQ3/L1 -C1, C2, and C3 done concurrently
BQ3/L1/C3 - Field studies: food and forage habitat gradients	Depths, velocities, substrate, and spatial complexity of habitat, as well as whether habitats are occupied by food items	IF results demonstrate a systematic spatial relationship between habitat characteristics and selection by food sources and age-0	3	BQ3/L1 -C1, C2, and C3 done concurrently

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty*	Concurrent / Dependent Components
	(chironimids) and foragers (age-0 sturgeon).	fish, this provides more support for L2 experiments.		
BQ3/L1/C4 - Mesocosm studies: quantitative habitat-survival relations	Depths, velocities, substrate, and spatial complexity of habitat, as well as relative growth rates and survival as a function of habitat characteristics.	IF results demonstrate a systematic relationship between habitat characteristics and growth/survival, THEN this provides more support for L2 experiments.	1	Complete this component unless BQ3/L1/C2 provides alternative methods of estimating survival in the field
BQ3/L2/C5 - Design studies: effect of channel reconfigurations on IRCs	Relative performance of designs, measured as areas of functional habitat, using linked hydraulic and biological models.	IF demonstrated ability to increase habitat components benefiting growth and survival without unacceptable risks to other authorized purposes, THEN proceed to C6 field experimentation.	4	Develop concurrently with BQ3/L1 studies
BQ3/L2/C6 - Manipulative field experiments: effect of channel reconfigurations on IRCs	Area of food-producing habitat, area of foraging habitat, catch per unit effort of age-0 sturgeon, stomach contents, and lipid content.	IF results support the hypothesis that channel reconfigurations can provide increased functional habitats, THEN move to L3 implementation.	4	Described in section 4.2.6.3
Big Question 4 – Drift Dynamics: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to decreased direct mortality and increased interception of free embryos into supporting habitats?				
Associated Hypotheses: **H14.** Alteration of the flow regime at Gavins Point Dam can be optimized to decrease main stem velocities, decrease effective drift distance, and minimize mortality of free embryos. **H19.** Re-engineering of channel morphology in selected reaches will increase channel complexity and serve specifically to intercept and retain drifting free embryos in areas with sufficient prey for first feeding and for growth through juvenile stages.				
BQ4/L1/C1 - Technology development: surrogate particles, particle tracking applied to IRCs	Recovery rate of marked particles in tracer studies and strength of model predictions for particle fate (combination of 1D and 2D models).	IF methods can provide strong inference on transport pathways, THEN this provides more support for L2 experiments.	1	C1-C6 done concurrently with L1 IRC studies under BQ3
BQ4/L1/C2 – Field studies: Resilience, stamina in turbulent flows	Survival of free embryos related to measures of fluid stress, including turbulent intensity and shear.	IF survival is sensitive to range of river velocities, turbulence, or shear during dispersal, THEN this provides more support for L2 experiments.	3	C1-C6 done concurrently with L1 IRC studies under BQ3
BQ4/L1/C3 - Field studies: free embryo exit paths	Proportion of surrogate particles (real or computational) that exit the thalweg and are retained in IRCs under	IF advection of surrogate or digital particles varies substantially with discharge or channel configuration,	4	C1-C6 done concurrently with L1 IRC

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty*	Concurrent / Dependent Components
	various channel geometries.	THEN this provides more support for L2 experiments.		studies under BQ3
BQ4/L1/C4 – Field studies: age-0 survival and complexity across flow gradients	Catch per unit effort of free embryos and measures of channel complexity relevant to interception hydraulics.	IF there are moderate to strong associations between advection metrics and channel configuration options, THEN this provides more support for L2 experiments.	4	C1-C6 done concurrently with L1 IRC studies under BQ3
BQ4/L1/C5 – Field studies: Free embryo transport to Mississippi River	Estimated number and survival of age-0 to juveniles hatched in the Missouri that reach the Mississippi River, relative to the number and survival of those that remain in the Missouri River.	IF the population of Missouri free embryos recruiting in the Mississippi River is NOT high enough to sustain the Missouri population, THEN increase effort to intercept free embryos in the Missouri River.	3	C1-C6 done concurrently with L1 IRC studies under BQ3; C5 dependent upon feasibility assessment
BQ4/L1/C6 – Modeling studies and field experiments: embryo dispersal tracking	Distributions of free embryos or other tracers, over time and space, as the constituents disperse downstream over a range of opportunistic flows.	IF field tracking data validate the outputs of drift models over a range of opportunistic flows, THEN proceed to proceed with L2 field experiments.	4	C1-C6 done concurrently with L1 IRC studies under BQ3
BQ4/L2/C7 - Engineering study: designs for interception experiments	Range of engineering designs that meet practical hydraulic needs and contribute to interception of drifting free embryos, and their cost.	IF designs provide evidence that IRCs contribute to growth and survival of age-0 pallid sturgeon, without unacceptable risk to other authorized purposes, THEN proceed to C8 manipulative field experiments.	4	Follows BQ4/L1 work
Big Question 5: Spawning Habitat. Can channel reconfiguration and spawning substrate construction increase probability of survival of eggs through fertilization, incubation, and hatch?				
Associated Hypotheses: **H16.** Re-engineering of channel morphology in selected reaches will create optimal spawning conditions -- substrate, hydraulics, and geometry -- to increase probability of successful spawning, fertilization, embryo incubation, and free-embryo retention.				
BQ5/L1/C1 –Field study: functional spawning habitat, Yellowstone River	River depth, velocity, substrate, and habitat stability of documented spawning habitat, and reproductive responses of adults and embryos.	IF there is sustained moderate to strong spawning habitat selection that contrasts strongly with Lower Missouri River results, AND the results agree with spawning habitats quantified for other sturgeon species, THEN this provides more support for spawning habitat designs that mimic Yellowstone spawning.	3	C1-C3 concurrent

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty*	Concurrent / Dependent Components
BQ5/L1/C2 – Retrospective study: habitat condition gradients LMOR	River depth, velocity, substrate, habitat stability of documented spawning habitat, and reproductive responses of adults and embryos.	IF there is sustained moderate to strong spawning habitat selection that contrasts strongly with Yellowstone River results, THEN this provides more support for spawning habitat designs that mimic Lower Missouri spawning.	3	C1-C3 concurrent
BQ5/L1/C3 - Mesocosm studies: spawn conditions, behaviors	Hatch rate as a function of different combinations of depth, velocity, substrate, and hydraulic variables, with water quality and fish behaviors as covariates.	IF results provide quantitative criteria for abiotic (and biotic) variables influencing spawning behavior from aggregation of adults to hatch of embryos, THEN proceed to L2 field experiments.	3	C1-C3 concurrent C3 concurrent w other mesocosm studies
BQ5/L2/C4 - Engineering studies: sustainable design	Design performances, measured as ability to create the hydraulic and substrate conditions developed in components 1-3. Evaluate appropriate segments for spawning habitat using combined advection dispersion and population model	IF designs are judged capable of achieving functional spawning habitat while minimizing adverse effects to other authorized purposes, THEN proceed to C5 manipulative field experiments.	1	Build on learning from L1 C1-C3 studies
BQ5/L2/C5 - Manipulative field experiments: spawning habitat	Use of spawning sites compared to other areas; Hatch rate, as determined by catch per unit effort of free embryos or alternative techniques. See section 4.2.6.3.	IF created spawning patches are functioning as intended to improve spawning success, THEN proceed to L3 implementation	4	Build on learning from L1 C1-C4 studies
Big Question 6: Population Augmentation. Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?				
Associated Hypotheses: **H20.** Stocking at optimal size classes and in optimal numbers will increase growth rates and survival of exogenously feeding larvae and juveniles. **H21.** Stocking with appropriate parentage and genetic diversity will result in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.				
BQ6/L1/C1 – Engineering studies: feasibility hatchery needs, facilities,operations	Costs and measures of likely survival for a range of propagation facility designs.	IF designs are expected to produce population benefits at a reasonable cost, THEN this provides stronger support for L2 studies	4	C1-C3 done concurrently
BQ6/L1/C2 - Retrospective study: survival linked to hatchery operations	Number and survival rates for stocked pallid sturgeon by stocked size, hatchery of origin, and health history.	IF results indicate that changes in propagation facility operations could increase survival, THEN this	3	C1-C3 done concurrently

Question, Level and Study Components	Key Metrics	Simplified IF - THEN Decision Criteria	Degree of Certainty*	Concurrent / Dependent Components
		provides stronger support for L2 studies		
BQ6/L1/C3 – Modeling study: population sensitivity to size, health, genetics	Probability of quasi extinction, instantaneous growth rates, and sensitivity measures under various model scenarios.	IF results indicate that population dynamics are sensitive to changes in augmentation practices AND the information provided by previous components are not sufficient to make specific implementation decisions, THEN this provides stronger support for L2 studies	4	C1-C3 done concurrently
BQ6/L2/C4 - Field study: varying size, location of stocking	Differential survival as a function of size/age at stocking and other variables. See section 4.2.6.1	IF results indicate that survival is sensitive to size at stocking, and that changes are warranted in current practices THEN proceed to adjust L3 implementation.	4	Build on results from L1 studies

The following two sections (4.2.5 and 4.2.6) describe some of the details of those Level 3 Actions which are either currently being implemented (e.g., propagation), or have been proposed for implementation in the near to medium term through policy determinations (e.g., spawning habitat, interception and rearing habitat, spawning cue flows). Appendix K provides a summary of metrics used to detect the effectiveness of various actions, as well as metrics used for tracking the status and trends of the pallid sturgeon population.

4.2.5 Details on Level 3 Actions (and associated Level 2 Components) for Upper Missouri River

This section provides more details on each of the Level 3 actions included in the MRRMP-EIS, describing the scope of the action, as well as the associated hypotheses, objectives, metrics, experimental designs, decision criteria, and contingent actions (if the outcomes are different from those anticipated). The EA recognizes the impacts of fragmentation in the Upper Missouri River imposed by dams which pose barriers to upstream migration of adults and of limited drift/dispersal distances of embryos. As well, recent analyses of anoxic conditions in Fort Peck Lake have been used to argue that such conditions in Lake Sakakawea would also be lethal to drifting free embryos, thereby potentially limiting natural recruitment. Currently, the wild pallid sturgeon population in the Upper River is dominated by old-age individuals.

Upper River Big Questions relate to management actions that are hypothesized to increase natural recruitment (see Table 40 and Table 43). The Level 3 actions described here are based on the scientific considerations and policy determinations that have been made to focus implementation on actions that are either proposed (fish passage at Intake Diversion Dam) or are currently being implemented (population augmentation). A detailed summary of all Level 1 and 2 actions is contained in Appendix C. It is possible that over time, other potential actions may move from L1 feasibility analyses to L2 or L3 implementation (Figure 65).

4.2.5.1 *Population augmentation*

4.2.5.1.1 *Introduction*

This introduction provides an overview of issues associated with population augmentation for both the Upper and Lower Missouri River. Since 1998, population augmentation (stocking) of pallid sturgeon has occurred at a level intended to have a measurable effect on the population. Three federal hatcheries (Gavins Point National Fish Hatchery, Garrison Dam National Fish Hatchery, and Neosho National Fish Hatchery) and three state hatcheries (Blind Pony State Fish Hatchery, Miles City State Fish Hatchery, and Bozeman Fish Technology Center) are involved with propagation of Missouri River pallid sturgeon. Pallid sturgeon have been stocked into four Resource Priority Management Areas (RPMAs), now reorganized into four Management Units (Appendix D; Figure D.1).

Population augmentation is designed to ensure genetic diversity using local and wild broodstock collection (Pallid Sturgeon Recovery Team 2008). In 2014, hatcheries stocked a combined 24,309 fingerling and yearling-sized pallid sturgeon from the 2013 and 2014 year classes into the RPMAs (draft MRRMP-EIS). In the last 10 years (M. Colvin, unpub. hatchery operations data), releases from hatcheries have either been fingerlings (spawned in spring and released in fall; released 50 to 110 (mean 90) days post-spawn in RPMA 2, now part of the Great Plains Management Unit) or yearlings (spawned in spring and released in spring of the next year; 260 to 500 (mean 360) days post-spawn in RPMA 2)[1]. Fingerlings released in RPMA 4 are 50-70 days older on average for both categories. There have been occasional releases of age 2 or older fish, but these are quite rare now. Historically, year to year variation in releases of yearling equivalents has been relatively high with ongoing challenges in meeting propagation targets in the Lower Missouri River, specifically in RPMA 4 (Figure 66). A contributing factor related to these challenges has been a lack of availability of genetically strong adult pallid sturgeon. There is also year-to-year variation in the locations of stocking across the Missouri River (Figure 66 and Figure 67).

[1] In terms of the generalized conceptual model in Figure 60, *fingerlings* and *yearlings < 1 year old* fit into the life stage of "exogenously feeding larvae", while *yearlings > 1 year old* correspond to the start of the "Juvenile" life stage.

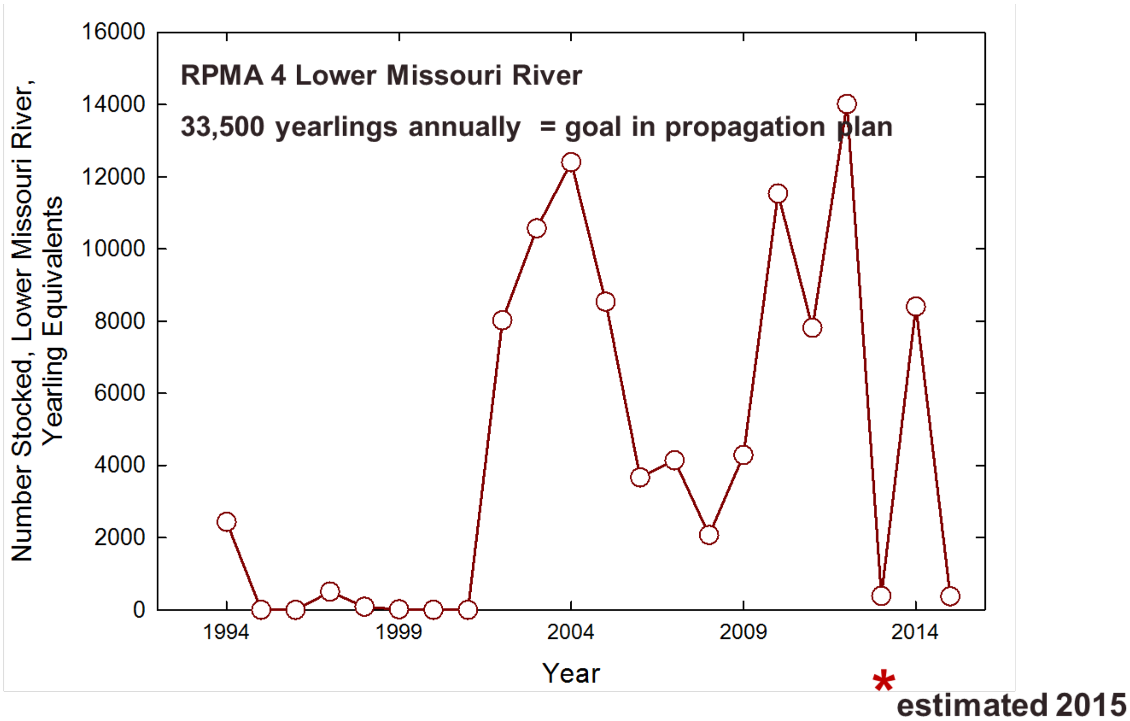
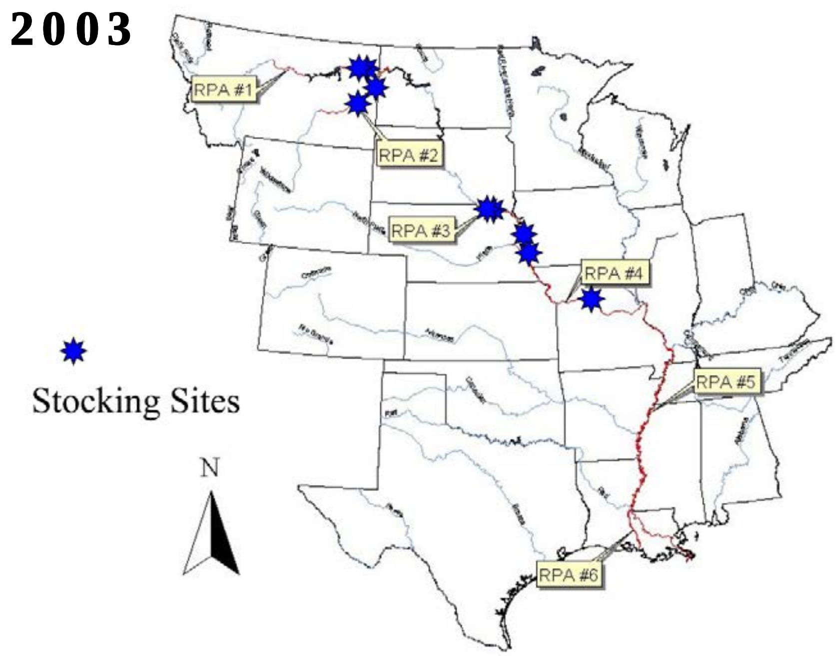


Figure 66. Stocking history for pallid sturgeon in the Lower Missouri River (summary of yearling equivalent stocking data for RPMA4). The 2015 value is a preliminary estimate.

A variety of marking methods have been used to identify hatchery fish in subsequent recoveries (Krentz et al. 2005). The Passive Integrated Transponder (PIT) tag is typically implanted in fish larger than 160 mm since tag losses are known to increase as the size of fish and experience of tagging crew decreases. Smaller juveniles (that cannot be PIT tagged based on size) are marked with an elastomer tag (visual) or coded wire tag (CWT) or by scute[1] removal which has been incorporated within the past several years. Genetic records are now kept for all releases so genetic identification of recaptured fish can identify the year class of release. If a fish is recaptured without a PIT tag, one is inserted (if the fish is large enough) for future identification.

Reviews of stocking data have been used to inform stocking plans (e.g., USFWS 2007). Importantly, a Pallid Sturgeon Basin-wide Stocking and Augmentation Plan will be developed over the coming year by the Pallid Sturgeon Recovery Team and participating federal agencies due to concerns related to fish health/disease, genetics, stocking size, numbers/carrying capacity, stocking practices, etc. This plan is expected to evaluate monitoring, hatchery use, genetics, propagation, database management and research in the context of recovery concerns for Pallid Sturgeon.

1 Scutes are armor-like structures on the sides and back of pallid sturgeon



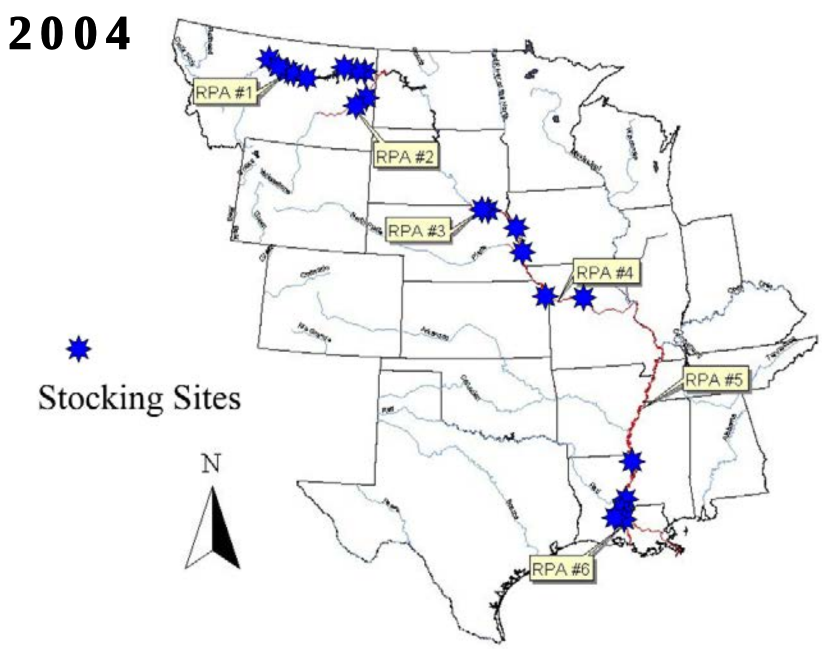


Figure 67. Location of stocking sites for pallid sturgeon across its range in 2003 and 2004 (Krentz et al. 2005). RPA = Recovery Priority Area.

Changes to current stocking practices that are recommended in the stocking and augmentation plan will need to be integrated into this AM Plan. This AM Plan defers to existing or future governance structures for decision making which recognize that the Upper Basin and Middle Basin Working Groups and Pallid Sturgeon Recovery Team alongside participating agencies have established roles in the conservation and recovery of Pallid Sturgeon that may influence actions that relate to AM. For instance, while the authority and responsibility for hatchery management lie with the USFWS for those facilities operated by the USFWS, other entities (e.g., Montana Fish Wildlife and Parks) are responsible for hatchery operations. However, the USFWS has the responsibility for oversight of all pallid sturgeon propagation efforts, including providing direction on rearing and stocking strategies, genetics, stocking targets, etc. through the forthcoming Basin-wide Stocking and Augmentation Plan. Much of the existing information collected in the Missouri and Yellowstone rivers has been due in part to collaborative efforts among agencies.

This AM Plan further recognizes that a number of key documents have been developed to provide guidance for the population augmentation program and a framework for routine and non-routine decision making. Among others, these documents include the Pallid Sturgeon recovery plan (USFWS 2014), Rangewide Stocking and Augmentation plan (Jordan 2008), as well as the Genetics Management (Heist et al. 2013) and Propagation Plans for the Upper Basin (USFWS 2005). Moreover, the Pallid Sturgeon Population Assessment Program (PSPAP) provides important inputs to decision making by collecting data on survival, movement, distribution, and habitat use, ultimately for the purpose of assessing population abundance, length frequencies, age distribution, geographic distribution, survival, growth, genetic representation, fish fitness (i.e., condition), habitat use, and carrying capacity. Figure 68 illustrates the annual decision process and information inputs for population augmentation in the Upper Basin.

The following sections focus on the fate of fish after leaving the hatchery (in terms of ultimate changes to the population), and are meant to illustrate examples of how alternative actions can be systematically and rigorously evaluated. In the context of AM, many level 1 and 2 science activities and some level 3 and 4 activities related to propagation are or will be funded by the USACE to help avoid jeopardy of Pallid Sturgeon. These actions are intended to be complimentary examples to work of the USFWS around hatchery practices and broader activities of the Recovery Team and Working Groups. Although the details of related governance and decision making have not been confirmed (see Chapter 2), the expectation is that decision authorities related to propagation actions would still be retained within the USFWS and Recovery Team.

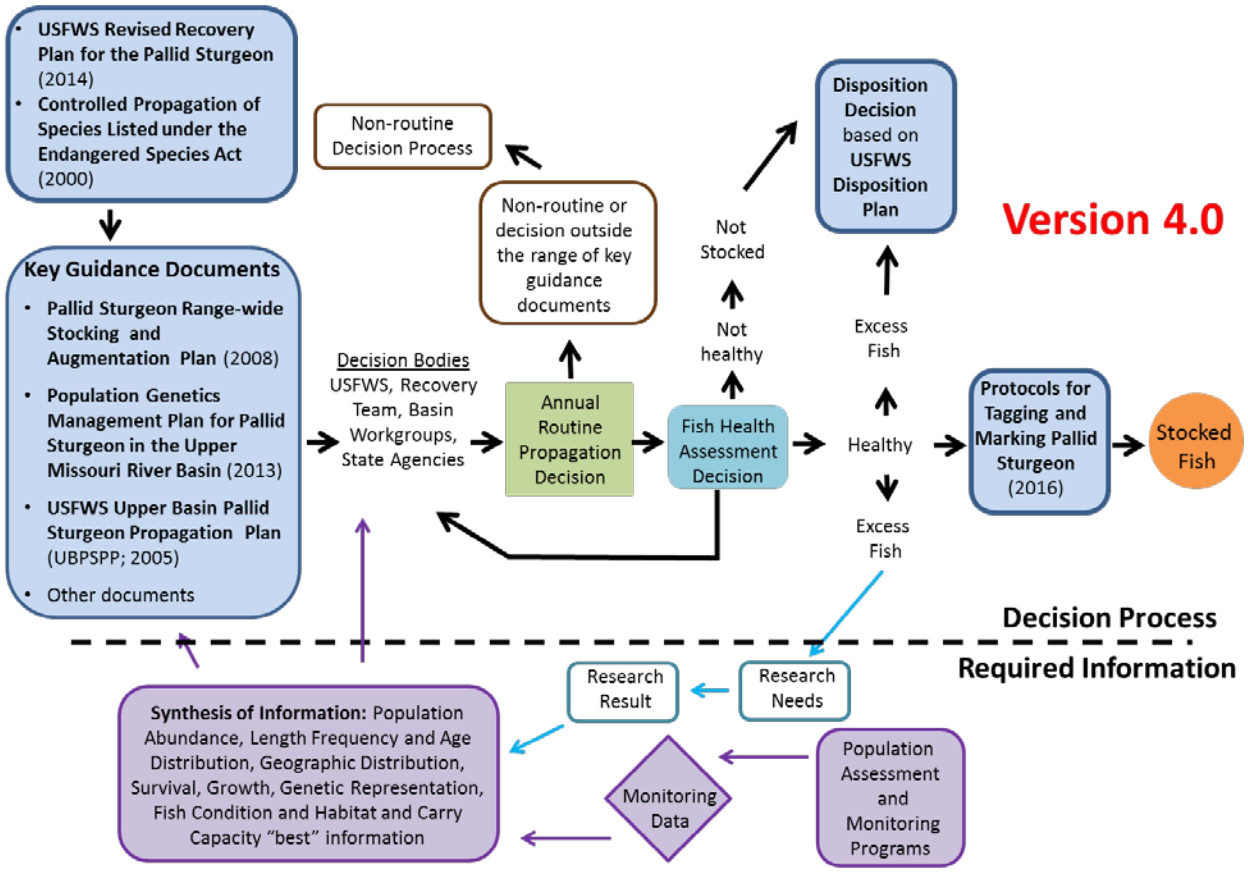


Figure 68. Annual decision making process, supporting documents, and information requirements for population augmentation in the Upper Basin. Source: USFWS "Adaptive Decision Making Process Associated with the Pallid Sturgeon Population Augmentation"

4.2.5.1.2 *Hypotheses*

The following management hypotheses from the EA are relevant to population augmentation in the Upper Missouri River:

- H8. Stocking at optimal size classes and in optimal numbers will increase growth rates and survival of exogenously feeding larvae and juveniles.
- H9. Stocking with appropriate parentage will increase genetic diversity and health of the population (as opposed to individuals) resulting in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.

These hypotheses are intended to assist in clarifying evaluations of population level effects for a range of propagation actions including alternative sizes and numbers of releases (which relates to carrying capacity), locations, and genetic diversity/parentage. There are a wide range of perspectives and a strong basis of scientific evidence around population augmentation. These perspectives and the evidence need to be debated and discussed further through the Recovery Team and the USFWS which we expect would be clarified in the forthcoming Basin-wide Stocking and Augmentation Plan. The AM Plan recognizes that those discussions may lead to a different set of propagation strategies, which will need to be carefully designed, implemented, monitored and evaluated. Recent findings on deteriorating fish condition in the Lower Missouri River indicate that fish condition of adult Pallid Sturgeon has been declining, starting in 2013 with increasing declines in 2014 and 2015 (Steffensen and Mestl 2016, Randall et al 2016). A variety of hypotheses have been proposed to explain this pattern, which include a recognition of possible limits on the carrying capacity for pallid sturgeon, and intraspecific competition. If evidence supports this hypothesis, there are potential implications for the number of fish that can be stocked. Hence, the systematic and rigorous evaluation of propagation strategies is crucial and needs to remain a consistent attribute of all strategies, even if the strategies themselves are different from what appears in the current AM Plan (e.g., hatchery releases are increased, decreased, or modified from the status quo).Below we describe an example experimental design that relates to testing the effect of release locations in the Upper River due to the potential influence of proposed passage improvements at Intake Diversion Dam and the anoxic environment in the headwaters of Lake Sakakawea which has the potential to affect survival of hatchery fish. These hypotheses are linked to evaluations of other hypotheses and their related actions (i.e., Big Question 5, H7 and H10). The metrics and analytical methods used to test these hypotheses are outlined below. Hypotheses and possible designs around actions involving numbers of release, size at release, and genetic diversity are described in Section 4.2.6 (Lower River Level 3 actions), which could similarly be applied in the Upper River.

Although other information gaps and specific hypotheses have been identified as potentially important to address in the Upper River (e.g., skinny fish due to reduced carrying capacity relative to number of fish stocked and changes in prey base / predators), they have not been identified as priority hypotheses affecting propagation actions at this time. Additional EA hypotheses may emerge from the new information process (see Section 6.2.5). If additional EA hypotheses emerge, it will be important to have L1 activities to develop rigorous experimental designs and L2 activities for testing those designs.

4.2.5.1.3 *Action Description*

Propagation actions have been ongoing for some time at a level intended to benefit the population (i.e., Level 3). As noted, a Basin-wide Stocking and Augmentation Plan is forthcoming, so the implementation of propagation measures required under the MRRP and partially funded by USACE will require close coordination with the Pallid Sturgeon Recovery Team and Upper Basin Workgroup to ensure this AM plan supports and in consistent with the Stocking and Augmentation Plan. Some additional and concurrent Level 1 and Level 2 components may be considered to better understand how well current methods of propagation have affect population outcomes and to explore alternative approaches which might improve Level 3 actions (see Appendix C).

Propagation actions are generally similar for the Upper River as for the Lower River. Sections 4.2.6.1 and 4.2.6.2 describe management experiments involving stocking fish at variable numbers, sizes, and/or manipulating other hatchery factors to examine the influence on early life survival. The proposed focus of a Level 2 study would be on improved monitoring to understand the influence of location of stocking on early survival, while holding as many other factors as constant as possible (e.g., genetic diversity, size at release, hatchery origin) and accounting for other factors that naturally vary year to year (e.g., water conditions). The AM Plan acknowledges that survival estimates for different size classes are currently available and the purpose of this and any additional monitoring would be to provide comparable data across the Upper and Lower Rivers that can inform population modeling in support of AM (see Appendix D). Any experimental design or adjustments in the location of stocking would need to be coordinated with the Working Groups responsible for managing pallid sturgeon releases and aligned with the stocking goals in the stocking and augmentation plan for the management area.

4.2.5.1.4 *Objectives and Expected Benefits*

While population augmentation is *necessary* for recovery of the pallid sturgeon, it is not *sufficient* because the ESA requires a self-sustaining population. While both the Upper and Lower River have had difficulties in meeting propagation targets, the objective of this Level 2 management experiment would be to identify release locations that improve survival of free swimming larvae in the Upper River with the ultimate purpose of supporting natural recruitment. More specifically, these actions are expected to provide evidence about the influence of upstream distance and habitat differences (e.g., due to passage structure at Intake and anoxic environment in Lake Sakakawea) on survival of hatchery releases. Estimates of survival probabilities would be entered into the population model to determine the ultimate impacts of actions on the Upper Missouri River populations, and also to help in refining objectives / experimental design.

4.2.5.1.5 *Metrics*

Assessing the effect of stocking location requires understanding the fate of marked hatchery releases in the Upper River, and ultimately the number that survive to age 2. Hence, this action and most other propagation actions are closely tied to the population monitoring program described in Appendix D. Specific metrics associated with releases include hatchery of origin, number, size, timing, stocking location (or River Mile), site and parental cross, and water conditions (e.g., water temperature, velocity, discharge, turbidity, substrate). Upon recapture, key metrics include habitat/location of sample (or

River Mile), sampling method and intensity, number collected, size and age, hatchery of origin, fish condition (length/weight), and water year conditions (to help explain survival probabilities). These data can be used to generate key metrics for analyses, such as proportion of recaptures from different release groups, catch efficiency, and ultimately survival probabilities between early years of life (these methods are described in more detail in section 4.2.6.1.3).

4.2.5.1.6 *Experimental Design*

This example of a management study is primarily intended to examine the effect of release locations on early survival of hatchery fish between Rivers (e.g., Yellowstone and Upper Missouri Rivers) and across River Miles (e.g., upstream and downstream release locations on each River). We are aware that other examinations of stocking site and river (Yellowstone vs. Missouri) has and continues to be evaluated in the Upper Basin via survival analyses (by Jay Rotella at MSU), but these studies were not available at the time of writing. Other important factors that need to be controlled or accounted for include genetic diversity, hatchery of origin, number and size of releases, disease (e.g., ranavirus, iridovirus, fin curl, *Polypodium hydriforme*), and water conditions across years.

Monitoring the fate of hatchery releases would require establishing spatial contrasts across the Upper Missouri River basin. This monitoring would need to be part of the broader population monitoring program including efforts targeted at free embryos that would hypothetically be produced through natural spawning in the Yellowstone River and have the potential to drift into the anoxic zone of Lake Sakakawea (see Appendix D). On the Yellowstone River spatial contrasts would include using consistent release locations upstream and downstream of the Intake Diversion Dam with a sufficient distance between locations to ensure that habitat influences are independent of these release locations. Likewise, Upper Missouri River spatial contrasts would include release locations at upstream and downstream locations which should likely be close to past stocking sites.

Temporally, it would be important to monitor sites close to the release location shortly after release to examine whether local conditions affect metrics of fish response relative to other sites with different local conditions. It is expected that monitoring would need to occur across the spatial network for a number of years, which would depend on the number of marked fish that are released. Available stocking information and low capture efficiencies suggest that the number of marked releases may currently be too low to detect an effect in a reasonable time frame. Power analyses would assist in better identifying the number of releases that are required. Given the proposed fish passage at Intake, it would also be important to establish a temporal baseline at upstream and downstream locations before passage construction occurs to help evaluate whether the structure has any additional effect on early survival.

If smaller fingerlings are used, fish would require elastomer markings to identify hatchery of origin. An additional mark would be required to distinguish among release locations for individuals with the same parentage that are released at different sites. Upon recapture, destructive sampling of a sub-sample of individuals may be required to assess genetics (unless technological improvements allow non-destructive genetic sampling) and PIT-tags would be added once they have reached a sufficient size. If larger fingerlings or yearlings are used, fish would be marked with PIT-tags. As noted in Section 4.2.6, variants of a Cormack-Jolly-Seber (CJS) or more complex models would be used to estimate survival of the release groups using multiple recapture occasions. Standard analysis-of variance (ANOVA) methods could also be used to evaluate differences in fish metrics across release groups (e.g., comparison of relative proportions of release group sampled or comparison of fish condition across spatial contrasts noted above). There would be challenges in interpreting some of these data across sampling locations, however, since capture efficiencies can only be estimated upon 2 successive captures. For instance, without repeated captures it will not be possible to estimate if fish are absent from a sample because they died elsewhere in relation to their release location or are simply absent because they are using a different habitat.

4.2.5.1.7 *Decision Criteria*

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. Comparisons of relative or absolute measures across spatial contrasts/locations would help determine the biological benefits of release locations (i.e., different rivers and different upstream distances). As noted above, estimates of survival probabilities of release groups across years would provide more robust evidence about potential benefits. However, as fish mature and move throughout the Upper River basin it would become increasingly difficult to isolate the effect of release location from other factors. In contrast, data that are closer in time and space to the actual release locations would be less reliable (i.e., provide only a relative measure of observation), yet would be more strongly related to the effects of release location. As such, there will be a need to evaluate multiple response measures over time and across spatial locations in combination with modeling results and expert judgments to assess whether different hatchery release locations have effects on early life survival. Once better information has been gathered, Level 3 actions can be adjusted in combination with improved knowledge about optimal numbers/carrying capacity, size, hatchery operations, and genetic diversity of the releases from the propagation program.

4.2.5.1.8 *Level 3 Contingent Actions*

See Section 4.2.6 for a summary of uncertainties and contingencies related to propagation.

4.2.5.2 *Passage at Intake Dam on Yellowstone River*

4.2.5.2.1 *Introduction*

The Bureau of Reclamation (Reclamation) operates Intake Diversion Dam on the Yellowstone River 70 miles (112 km) upstream of the confluence with the Missouri River. Construction of this structure was completed in 1909 as a 12-foot high wood and stone dam to divert water from the mainstem into an irrigation canal that runs parallel to the River and provides a dependable water supply for adjacent lands. Since its construction, the Dam has impeded upstream migration of native fish and poses a partial or complete barrier to different species (Reclamation and USACOE 2015).

In recent years, the U.S. Department of the Interior, Bureau of Reclamation and the U.S. Army Corps of Engineers have been jointly evaluating proposed modifications to Intake Diversion Dam that would reduce entrainment (related actions have already been completed) and improve fish passage. Evidence suggests that the dam poses a barrier to upstream migration of pallid sturgeon (Reclamation and USACOE 2015). As such, improvements to fish passage are expected to assist in the recovery of pallid sturgeon in the Upper Missouri River basin by providing access to up to 165 miles (264 km) of habitat in upstream reaches of the Yellowstone River. Historically, Pallid sturgeon have been documented about 112 miles (180 km) upstream of Intake at times of year when spawning was known to occur (Brown 1955; 1971 as cited by Walsch 2015). The hydrology, thermal conditions, and sediment regime in the Yellowstone River are seen as providing habitat conditions that are suspected to be supportive for pallid sturgeon. As well, additional drift distance may better allow for larval drift and recruitment, although mean velocities on the Yellowstone are as much as 2 times higher than those on the Upper Missouri for equivalent June flow exceedance.

The USACE is a joint lead agency for improvements to Intake since this action was identified as a Reasonable and Prudent Alternative (RPA) in the USFWS 2003 Amended Biological Opinion. As such, the USACE is working with Reclamation and others to ensure that modifications are effective and the population response of pallid sturgeon is well documented. In 2016, Reclamation released the final EIS and ROD, which summarize the impacts of the proposed action (and alternatives to it) on environmental and human resources (USBOR and USACE 2016a, 2016b). Appendix E of the EIS (USBOR 2015) is a “Monitoring and Adaptive Management Plan”, focusing on monitoring the effectiveness of fish passage to reduce uncertainties related to biological performance, and ultimately improve passage operation over time. The Intake EIS (USBOR and USACE 2016a) is a separate document from the MRRMP-EIS.

Given this context, any actions that are implemented by the USACE would need to be closely coordinated with the Bureau of Reclamation and others (e.g., Pallid Sturgeon Recovery Team and Upper Basin Workgroup). Additional studies and/or actions beyond what are described here may be required or come to light resulting in changes to the experimental design and related needs for information (e.g., possibly applying the refined advection/dispersion model). Moreover, due to the lawsuit on the implementation of passage around Intake Dam, there is considerable uncertainty regarding the type of action that may be implemented and its related timing. As a result, the different Level 2 study components described below depend somewhat on which course of action is eventually pursued.

4.2.5.2.2 *Hypotheses*

The following management hypothesis is directly relevant to improvements in fish passage at Intake Diversion Dam:

- H7. Fish passage at Intake Diversion Dam on the Yellowstone River will allow access to additional functional spawning sites, increasing spawning success and effective drift distance, and decreasing downstream mortality of free embryos and exogenously-feeding larvae.

Stemming from this hypothesis are five broad monitoring questions that will clarify the success of passage at Intake and its ability to help achieve the recovery goals in the Upper Basin (see Section 4.1.1):

- Do motivated spawners and downstream adult migrants successfully move past Intake?
- How far upstream do motivated spawners migrate?
- Does successful aggregation and spawning occur?
- Do free embryos successfully move downstream past Intake?
- Is recruitment successful and sufficient to meet population targets?

The unique in-river movements, life history stages, and agency responsibilities for monitoring suggest the need for five study components to provide answers to these and more specific underlying questions (discussed below in Section 4.2.5.2.3). Answers to these questions would be further linked to a series of related decisions that might be required to improve passage and ultimately assist in achieving recovery goals (discussed in Section 4.2.5.2.7).

As noted by the summary of priority Level 1 and 2 study components under Big Question 5 (Table 43), this hypothesis is also linked to other actions related to Missouri River flows, drift distance, drawdown of Lake Sakakawea and mortality of free embryos and exogenously feeding larvae. These linked hypotheses would be explored through the Level 1 and Level 2 actions summarized in Table 43 and Appendix C. As noted below, there are also linkages to propagation and developing an understanding about whether passage improvements have any effect on survival of hatchery releases.

4.2.5.2.3 *Action Description*

Due to the uncertainty in knowing the type and timing of action that might be implemented at Intake, there is further uncertainty in knowing what other actions might be most appropriate to implement as part of the MRRP AM Plan. The preferred alternative in the final EIS for Intake is to implement a bypass channel to support passage of adults and free embryos. Other alternatives that were considered include existing channel modifications, dam removal, as well as no action (which could be a near-term outcome if a decision were delayed or implementation of the preferred alternative were deferred for more than 5 years).

If passage improvements occur, a variety of study components would be undertaken to assess the influence of fish passage improvements at Intake on the Upper River population of pallid sturgeon. These components are framed around the five broad monitoring questions presented above and would need to be tailored further depending on the passage alternative that is eventually implemented:

- **Component 1 (C1):** Monitor physical conditions as well as a group of telemetry-tagged adult pallid sturgeon to understand compliance and effectiveness of upstream and downstream passage, as well as the specific behaviors and movement of adults around Intake.
- **Component 2 (C2):** Track movements of telemetry-tagged adult pallid sturgeon to understand their movements in the Yellowstone River, upstream of the fixed telemetry stations positioned around Intake.
- **Component 3 (C3):** Track aggregations and spawners upstream of Intake to understand whether spawning occurs.
- **Component 4 (C4):** Track the movement and fate of free embryos and larvae downstream through Intake to understand potential impacts on mortality.
- **Component 5 (C5):** Post-spawn monitoring of free embryos / larvae to evaluate the success of spawning and hatching by documenting the presence of free embryos and natural recruitment.

Table 45 provides more detail around these study components. These components are strongly inter-related, and require coordination across the different agencies responsible for monitoring. Reclamation has the primary responsibility for monitoring related to Intake Diversion Dam and the passage channel. The USACE has responsibilities for monitoring to support AM of the MRRP. Component 1, 2, and 3 would require tracking the same group of telemetry-tagged adult pallid sturgeon as the monitored sub-sample of the population in the Yellowstone River, based on a future study design for passive telemetry in the Upper River (see Table 43, BQ1/L1C1 and Appendix C). These study components would parallel monitoring in the Lower River in response to spawning habitat creation and spawning cue flows (see Sections 4.2.6.5 and 4.2.6.6). Capture, implantation, and intensive passive tracking protocols developed by the USGS would be used to document adult movements, passage at Intake, migration to spawning sites, aggregations of adults, and spawning itself (as described in Delonay et al. 2016a and other references cited therein). Component 4 would require sampling embryos and determining their fate in the lower Yellowstone River (upstream of Lake Sakakawea) in the same way that would be conducted in the Lower River, using a sampling design that supports the broader population monitoring program, the details of which have yet to be finalized (see Appendix D).

The details and integration of these study components depends on the passage alternative that is eventually implemented. For instance, if a bypass channel or existing channel modifications were implemented, then all study components would be appropriate. However, if dam removal were implemented then components 1 and 4 would be more focused on monitoring river conditions at the location of Intake instead of monitoring the performance of Intake’s physical structures. Lastly, if fish passage were not provided or if there were an extended period with no passage, then an adult transplant experiment above Intake (catch and haul) could be conducted in combinations with study components 2-5. If the risks from capture, handling and transport are judged to be acceptable (to be discussed with the Recovery Team), then it may also be beneficial to translocate a group of reproductive adults to locations upstream of Intake dam prior to construction to evaluate whether spawning habitats exist and successful spawning can occur. This experiment and the resulting data would provide insights into the effectiveness of passage, identify biological constraints, and potentially lead to other actions that might help to avoid jeopardy and move towards recovery goals in the Upper River.

Table 45. Summary of the study components and related details to assess effectiveness of Intake Diversion Dam[1].

Monitoring question	More detailed monitoring questions	Monitoring details	Monitoring responsibilities
Q1. Do motivated spawners and downstream adult migrants successfully move past Intake?	• Q1A: Are the target physical criteria (e.g., depth and velocity) for passage of pallid sturgeon being met? • Q1B: Are the target biological criteria (e.g., number of motivated spawners moving upstream past Intake) being met? • Q1C: Are fish able to approach and navigate the bypass? • Q1D: Is the speed of upstream / downstream movement of adults unimpeded? • Q1E: Does passage lead to injury, stress, or mortality of adult pallid sturgeon migrating downstream?	Various study designs have been proposed by the Bureau of Reclamation which differ across passage alternatives (see Reclamation 2016). These designs include monitoring of the physical criteria/conditions of the selected alternative (e.g., bypass channel, rock ramp) during a baseline period with a proposal for less intensive monitoring after a period of learning. A set of telemetry stations would also be established at strategic locations to track the upstream and downstream movement of telemetry-tagged fish at, below, and above Intake (i.e., 3-6 locations including one mile downstream, one mile upstream, and at various locations around Intake depending on the selected alternative).	Primarily the Bureau of Reclamation since this study component is focused on evaluating the effectiveness of passage at Intake. The USACE would have some responsibilities for monitoring in the first year of operation, as referenced in Reclamation (2016).
Q2. How far upstream do motivated spawners migrate?	• Q2A: Do spawners migrate sufficiently far upstream to provide enough drift distance to support development of free embryos?	The location and number of fixed-station telemetry receiver sites have yet to be determined and are linked to the design of the broader telemetry network in the Upper River (see Table 43, BQ1/L1C1 and Appendix C). Once movement and spawning has been detected upstream of Intake, advection/dispersion models and in-river monitoring (Q4) would be used to estimate whether free embryos are likely to drift into Lake Sakakawea.	The USACE would install and maintain a passive telemetry network and more intensive boat-based tracking upstream of Intake.
Q3. Does successful aggregation and spawning occur?	• Q3A: Are spawning locations of suitable quality? • Q3B: Do spawners aggregate in sufficient numbers to initiate spawning? • Q3C: Is spawning successful?	This study would employ a similar design as will be used to assess spawning in the Lower River (see Sections 4.2.6.5 and 4.2.6.6). Monitoring would involve tracking telemetered spawners that migrate upstream of Intake. Data collection would involve opportunistic measurements of in-river conditions as spawning aggregations and spawning occur, physical conditions at identified spawning locations, recapturing females to confirm egg release, and sampling to detect	The USACE would maintain and operate mobile telemetry gear to track spawning events.

[1] For further information please see the Final EIS and ROD for the Lower Yellowstone Intake Diversion Dam Fish Passage Project (USBOR and USACE 2016a, 2016b)

		embryos in locations immediately downstream of spawning locations.	
Q4. Do free embryos, larvae, and young-of-year successfully move downstream past Intake?	• Q4A: Can embryos, larval, and young-of-year sturgeon move downstream without impacts on survival (i.e., due to impingement and entrainment)? • Q4B: Are sources of impact on survival of embryos due to physical conditions /structures at Intake (i.e., over dam, through side channel, entrained in canal)?	Strategies to monitor free embryos and larvae are broadly similar across passage alternatives (see Reclamation 2016). If upstream spawning has been confirmed and there is sufficient lead time, larval nets would be deployed at select locations in-river, near the headworks, in the main canal, and downstream of Intake to ensure larvae are successfully passing downstream.	Primarily the Bureau of Reclamation since this study component focuses on understanding the effectiveness of passage improvements at Intake.
Q5. Is recruitment successful and sufficient to meet population targets?	• Q5A: Does successful spawning result in recruitment? • Q5B: Is the level of recruitment sufficient to meet population targets?	Details on locations, gear type, and effort to successfully monitor free-embryos/larvae are described in Appendix D. The intent would be to assess whether natural recruitment occurs by sampling embryos/larvae at locations downstream of the spawning site and Intake Diversion Dam and tracing genotypes to parents that spawned upstream. If natural recruitment is detected, this information would be used in the pallid sturgeon population model to evaluate how passage improvements affect population trajectories.	The USACE would monitor embryos / larvae at downstream locations in the Yellowstone River to understand whether natural recruitment is occurring and track progress towards population recovery goals.

4.2.5.2.4 *Objectives and Expected Benefits*

The ultimate objective of this study component is to assess progress towards USFWS goals and objectives for pallid sturgeon (section 4.1.1) as well as recovery goals described in USFWS (2014), through the population's response to improvements in fish passage at Intake, and whether this action is sufficient to support natural recruitment in the Upper Missouri River. More specifically, this study will provide information on upstream movements of adults and downstream movement of embryos past Intake, the location of adult aggregations and spawning sites, and the likelihood that free embryos will drift into Lake Sakakawea. By sequentially answering the above monitoring questions, decision makers will be able to better discern the biological outcomes of passage improvements, leading to more timely and targeted adjustments in recovery actions (see Section 4.2.5.2.7).Given a limited set of Level 3 actions in the Upper River at this time, this information would also be essential for informing decisions around implementation of management actions in other parts of the basin (e.g., flow, temperature, or sediment manipulations at Fort Peck, drawdown of Lake Sakakawea).

4.2.5.2.5 *Metrics*

Monitoring metrics will be specific to the five study components described above. Data collection will involve sampling at two spatial scales for different purposes by agencies with different monitoring responsibilities: (1) monitoring by the Bureau of Reclamation (Reclamation 2016) in the immediate vicinity of Intake Diversion Dam to assess the effectiveness of fish passage improvements and compliance with USFWS criteria for physical and biological success (see Thabault no date), and (2) monitoring by USACE upstream and downstream of Intake Diversion Dam to evaluate progress towards pallid sturgeon population recovery goals and avoidance of jeopardy. There will also be a need to coordinate data collection around these metrics with other study components within the MRRP since there are strong linkages to monitoring at other locations for other actions (e.g., telemetry to assess spawning success for both passage improvements at Intake in the Upper River and spawning habitat creation and spawning cue flows in the Lower River). A summary of metrics by study component includes the following (also listed in Appendix K):

- **Component 1 (C1):** water velocity and water depth at cross-sections within structures and around Intake, timing of arrival and number of motivated spawners, numbers of adults passing upstream/downstream of Intake; speed and route of adult passage upstream/downstream of Intake (e.g., existing irrigation canal, bypass channel, over weir), survival of adults upstream/downstream of Intake, condition of upstream/downstream migrating adults (i.e., injury/stress);

- **Component 2 (C2):** number/sex of individuals, timing and distance of upstream migration, genetics of spawners;
- **Component 3 (C3):** measures of fish aggregation and spawning behavior (e.g., male:female ratio), number and location of spawning sites (i.e., through telemetry/acoustic video), site characteristics of spawning locations (e.g., water year conditions, velocity, water temperature, suspended sediment, substrate, cross-section profile), confirmation of egg release through recapture of female spawners;
- **Component 4 (C4):** number (survival) of embryos at locations immediately upstream and downstream of Intake, location of downstream passage past Intake/sources of mortality (e.g., over dam, through side channel, entrained), number (survival) of free embryo and young-of year passing downstream of Intake; and
- **Component 5 (C5):** water conditions during downstream drift of embryos, numbers of embryos/free embryos collected at downstream locations on the Yellowstone River, genetics of embryos, survival of free embryos calculated from calibrated advection/dispersion model runs as a proportion that should be retained in the free-flowing river at first feeding, rate of natural recruitment, probability of population persistence over a 50-year timeframe based on projected outputs from the pallid sturgeon population model.

4.2.5.2.6 *Experimental Design*

In the near term, these monitoring components would be focused on testing the response of improved passage on adult spawning in the upper Yellowstone River and drift of free embryos downstream, as well as compliance of the selected alternative at Intake with physical and biological success criteria that have been articulated by USFWS. Longer term monitoring across a broader spatial scale would be required to assess the population response to passage improvements. Below we discuss some of the more specific sampling design, spatial, and/or temporal contrasts related to the above study components.

Component 1 (C1): As noted in Reclamation (2016), there are a variety of potential passage alternatives that could be implemented at Intake. For some alternatives, it may not be possible to meet physical success criteria under all flow conditions. Yet as noted in Section 4.2.5.2.7, there is a need for decision makers to be able to detect failures in passage structure at Intake if physical and/or biological criteria are not being met. Hence, the location, timing, and duration of monitoring physical conditions at Intake needs to both assess compliance with the physical and biological success criteria, as well as have the ability to clarify where the passage structure might be failing and what might be required to improve its design. For passage alternatives that are being considered, an acoustic Doppler current profiler (ADCP) would be deployed at appropriate cross-sections to monitor depth and velocity during the spawning season. The location and timing of monitoring are described in Reclamation (2016) and are intended to capture variation in physical and hydraulic conditions. The intention is to initially monitor conditions for a baseline period (1-3 years), with effort scaled back in intermediate (3-6 years) and longer (6+ years) time frames.

Components 1, 2, and 3 (C1, C2, C3): These study components require installing telemetry tags on the same group of pallid sturgeon ranging in size and reproductive condition using passive telemetry protocols developed by the USGS (Delonay et al. 2016a and other references cited therein). Low population abundance and cost will limit the number of fish that can be tagged; too small a sub-sample of individuals would limit opportunities to make inferences about population-level benefits and affect the length of time monitoring is required to assess the benefits of passage improvements. Tagging would also require that individuals of reproductive age are not being used in the propagation program, though genetic sampling would be required to trace parentage of embryos sampled at downstream locations. Overall, careful consideration would need to be given to decide on the appropriate number of fish tagged each year as a sub-sample of the spawning population and then monitor consistent numbers from year to year (to be determined through the telemetry monitoring study identified in Table 43, BQ1/L1C1 and Appendix C).

There will also be challenges in detecting a population level effect due to the low number of individuals that can be expected to use the Yellowstone River upstream of Intake. Data since 2006-2007 indicate that roughly 85 to 90% of telemetered fish in the Upper River use the Yellowstone, while in 2011, a year with high flows, only 35% used the Yellowstone River. On average, only 12-15% of tagged adults have been known to make the long migration up to Intake, representing about 5 fish, only 1-2 of which are typically female. Successful spawning requires an aggregation of more than 5 males at a single location to encourage a female to spawn. Hence, there may be a need for many years of monitoring (e.g., 10-15 years) to evaluate whether aggregations can occur in sufficient numbers at enough locations to initiate natural recruitment. In the absence of natural movement there may be a benefit of using shovelnose sturgeon to test for the effectiveness of passage or to conduct more manipulative experiments with pallid sturgeon to encourage upstream spawning in sufficient numbers (i.e., trap and haul).

The most reliable way to track fish is to install fixed telemetry stations at strategic locations to provide spatial continuity along the Yellowstone River, with an emphasis on locations from Intake to Cartersville dam, the next upstream barrier to migration (see example locations in Figure 69). As noted below, finer-resolution telemetry with acoustic tags, potentially 3-d systems, would also be required to provide more information on habitat selection. In the Monitoring and Adaptive Management Plan for the Lower Yellowstone Passage Project (Reclamation 2016), four telemetry stations are proposed around Intake: one mile downstream of the passage channel, one mile upstream of the diversion weir, along the passage channel, and at the headwork structures.

Prior to construction it would be essential to continue consistently monitoring telemetered fish to establish a pre-project baseline of spawners in spawning locations in the lower Yellowstone River (below Intake). This information will provide a baseline understanding about spawning in the lower Yellowstone River and the effects of passage improvements at Intake. Determining whether the selected passage alternative is successful would require a spatial comparison of the number of adult fish upstream and downstream of Intake, which could likely be assessed within a few years. As noted below, however, additional monitoring would be required over a longer timeframe to determine whether aggregation and spawning occurs, embryos are detected downstream, and natural recruitment is subsequently observed.

Component 3 (C3): In addition to the telemetry monitoring discussed above, another consideration will be the need to monitor the physical characteristics of spawning habitats once a spawning aggregation has been confirmed. This information would provide important insights for understanding habitat availability and key features that support spawning in both the Upper and Lower River (see Section 4.2.6.5 and 4.2.6.6). Although there is some historical evidence of spawning upstream of Intake (see Figure 69), the location of spawning could change following passage improvements at Intake. Section 4.2.5.2.5 lists the biological and habitat metrics that would be monitored at those locations following sampling protocols that are referenced in Delonay et al. 2016a. Multi-receiver, 3D telemetry and DIDSON (Dual Frequency Identification Sonar) video would also be used to capture a spawning event. As well, fish would be recaptured to determine if spawning has occurred (i.e., gravid before, no eggs after with a decrease in body weight).

Components 4 and 5 (C4 and C5): These study components would focus on passive detection of free embryos and larvae downstream of spawning events upstream of Intake. In the case of monitoring at Intake, the intent would be to assess whether embryos move past the structure and whether it has an impact on survival using a spatial contrast in sampling, deployed at locations immediately upstream and downstream of Intake when successful spawning has been documented (see Reclamation 2016). To quantify embryo survival it may also help to experimentally release shovelnose sturgeon embryos above Intake Dam to estimate the proportion that get entrained into the irrigation ditch, and to determine whether changes in operations during critical migration period can reduce the rate of entrainment.

Passive detection of free embryos and larvae would also occur in downstream locations on the Yellowstone River (yet to be determined) using established sampling protocols (see PSPAP in Appendix D). Since it will be difficult to acquire direct evidence of recruitment to age-1 and later ages for several years, the intent in the near term would be to examine the size, age, and genetics of sampled embryos associated with a spawning event, alongside application of the advection-dispersion model, to assess if embryos are likely to survive based on spawning location alone. Since a large number of eggs (150,000 to 250,000) can be hatched over a relatively short time frame (3-4 days), the sampling scheme would deploy nets over a short interval (e.g., for 10-15 minutes) multiple times per day to ensure that the sampling protocol does not miss capturing drifting embryos after a spawning event. Post-construction monitoring would need to continue until results indicate whether or not the project has resulted in successful recruitment. A determination of successful natural recruitment would take more than 5 years since some time is required for embryos to develop into free swimming larvae and juveniles of a sufficient age/size to be sampled. However, varied success in passage/spawning and low detection of adults/juveniles may lead to a mix of results and a need to monitor for a longer time frame. Further analyses of these sampling challenges (including statistical power analyses) should be completed as Level 1 research under Big Question 5 (BQ5/L1/C3 in Table 45).

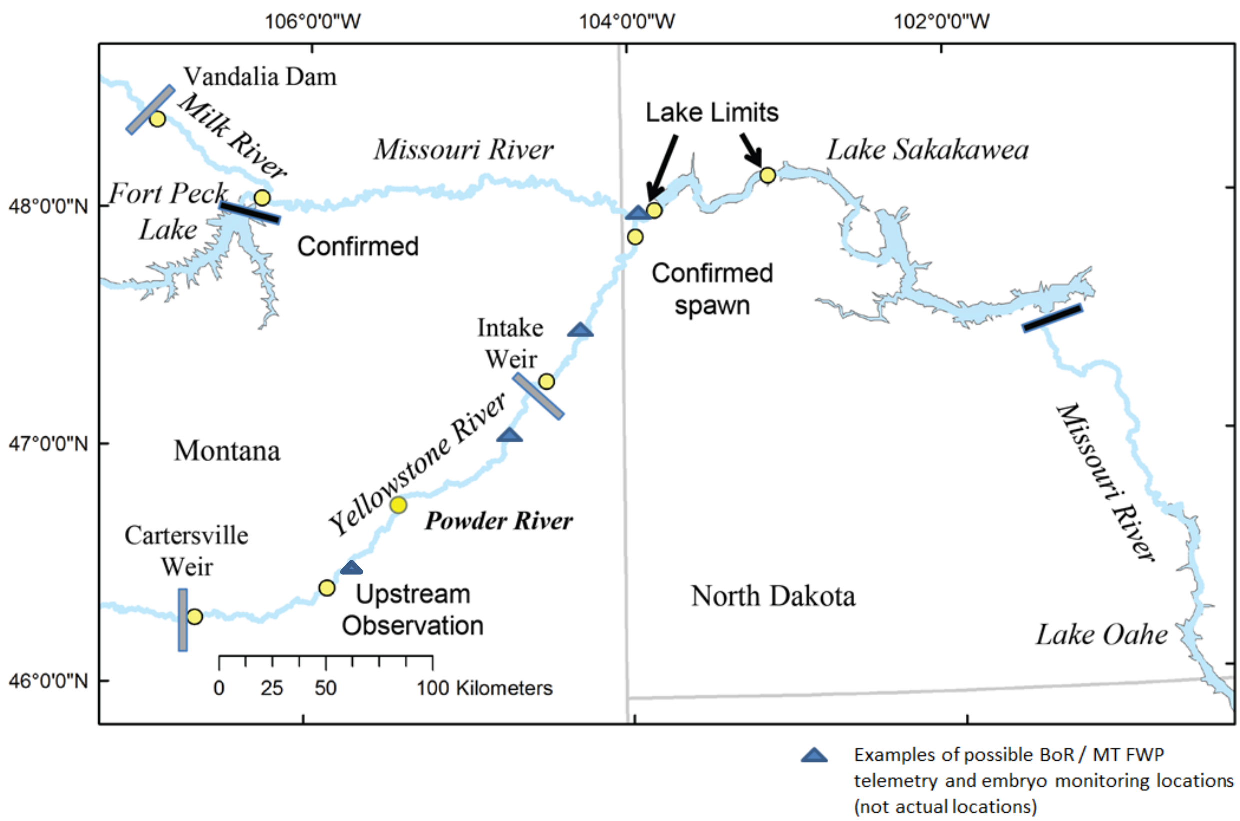


Figure 69. Locations of possible fixed telemetry locations (triangles) to monitor adult pallid sturgeon in the Yellowstone River.

4.2.5.2.7 *Decision Criteria*

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. Although there remains uncertainty about the alternative at Intake that is implemented, there are some consistencies to the study components that would be conducted to understand the effectiveness of passage improvements at Intake (as noted in Section 4.2.5.2.3). There are also some dependencies in answering key monitoring questions that should be evaluated in sequence to understand at which stages in the life cycle there may be a problem with passage improvements. If so, there may be additional decisions that can be implemented to support natural recruitment of juvenile pallid sturgeon and progress towards the USFWS goals and objectives for pallid sturgeon in the Missouri River (section 4.1.1), as well as recovery goals (USFWS 2014).

Table 46 presents the sequence of questions and decision relevance of different monitoring results, for each of the study components presented above. The effectiveness of Intake as a Level 3 action in the Upper Missouri River requires an evaluation of data to assess:

- Do motivated spawners and downstream adult migrants successfully move past Intake?
- How far upstream do motivated spawners migrate?
- Does successful aggregation and spawning occur?
- Do free embryos, larvae, and young-of-year successfully move downstream past Intake?
- Is recruitment successful and sufficient to meet population targets?

The first question requires an assessment of whether the physical and biological criteria for Intake are being met and that these criteria are sufficient to support upstream passage and downstream movement of different pallid sturgeon life stages (see Thabault no date and Reclamation 2016). These criteria include:

- maintaining depth and velocity ranges within specified limits that depend on the selected passage alternative;
- ensuring 85% of adult pallid sturgeon motivated to spawn can migrate upstream during the spawning migration period (April 01-June 15) without substantial delays;
- ensuring upstream passage of juveniles occurs without negative population-level effects;
- minimizing mortality of adult pallid sturgeon during downstream passage to 1% during the first 10 years of project implementation; and
- monitoring of downstream passage of free embryos at the intake screens, in the irrigation canal, and immediately below Intake Dam to assess mortality.

Decision criteria for the remaining questions are unavailable, yet need to be assessed to evaluate progress towards USFWS goals of avoiding jeopardy and moving towards recovery (see Table 46).

Successful natural recruitment would occur if data revealed that: spawners were able to migrate successfully past Intake and sufficiently far upstream; successful aggregations and spawning occurred; Intake provided for safe downstream passage of embryos; and naturally recruited age-o pallid sturgeon genetically linked to the spawners passing Intake were detected in the lower Yellowstone River. To understand whether natural recruitment is sufficient to support population recovery, more robust population monitoring may be required to better quantify the benefits of passage improvements and inform parameter estimates in the population model (see Appendix D). Ambiguity in the results would be expected if answers to the above questions were equivocal (e.g., a limited amount of successful spawning is documented or natural recruitment can only be documented in 1 of 5 years). Additional monitoring would likely be required if results were equivocal, since the data could not be used to defensibly reject any question.

Table 46 Summary of the monitoring questions for Intake and the decision relevance of different answers to these questions.

		Decision relevance of answers to questions		
Question	**Detailed questions**	**No [or]**	**Inconclusive [ ]**	**Yes [or]**
Q1. Do motivated spawners and downstream adult migrants successfully move past Intake?	• Q1A: Are the target physical criteria (e.g., depth and velocity) for passage of pallid sturgeon being met?	Assess compliance with biological criteria (Q1B). If biological criteria are met, re-assess physical criteria, and assess upstream movement (Q2). If biological criteria are not being met, investigate deficiencies in passage provided (Q1C-E).	Collect more data. Re-assess design of compliance monitoring. (e.g., location, frequency, and/or timing of sampling).	Assess compliance with biological criteria (Q1B). If biological criteria being met, investigate distance of upstream movement (Q2). If biological criteria not being met, re-assess physical criteria.
	• Q1B: Are the target biological criteria (e.g., number of motivated spawners moving upstream past Intake) being met?	If number of spawners moving upstream is not sufficient, investigate deficiencies of passage (Q1C-E).	Collect more data. Re-assess design of compliance monitoring (e.g., location, frequency, and/or timing of sampling).	If sufficient number of spawners move upstream, investigate distance of upstream movement (Q2).
	• Q1C: Are fish able to approach and navigate the bypass? • Q1D: Is the speed of upstream / downstream movement of adults unimpeded? • Q1E: Does passage lead to injury, stress, or mortality of adult pallid sturgeon migrating downstream?	If problems are detected, modify the passage structure to improve number of adults moving upstream/downstream. Continue to monitor compliance with biological criteria (Q1B).	Collect more data. Re-assess monitoring of behavior and movement of adults through structure (e.g., location, frequency, and/or timing of sampling).	If no problems are detected, re-assess physical and biological criteria. Monitor distance of upstream movement (Q2).
Q2. How far upstream do motivated spawners migrate?	• Q2A: Do spawners migrate sufficiently far upstream to provide enough drift distance to support development of free embryos?	If migration distance is consistently insufficient, other Level 3 actions in the Upper River may be necessary.	Collect more data. Re-assess design of telemetry network (e.g., location, frequency, and/or timing of sampling).	If migration distance is sufficient, investigate success of aggregation and spawning (Q3). Consider other actions if necessary (i.e., passage at Cartersville).
Q3. Does successful aggregation and spawning occur?	• Q3A: Are spawning locations of suitable quality?	If spawning locations are unsuitable, investigate creation of spawning habitats. Continue to monitor upstream migration (Q2).	Collect more data. Re-assess monitoring of spawning locations (e.g., location, frequency, and/or timing of sampling).	If spawning locations are of suitable quality, investigate aggregations and spawning success (Q3B-C).
	• Q3B: Do spawners aggregate in sufficient numbers to initiate spawning? • Q3C: Is spawning successful?	If aggregations and/or spawning are unsuccessful, consider ways to increase success (e.g.,	Collect more data. Re-assess design of spawning occurrence	If aggregations and spawning is successful, investigate downstream movement past

		increase numbers as hatchery fish mature). Other Level 3 actions in the Upper River may be necessary.	(e.g., location, frequency, and/or timing of sampling).	Intake (Q4) and whether natural recruitment occurs (Q5).
Q4. Do free embryos, larvae, and young-of-year successfully move downstream past Intake?	• Q4A: Can embryos, larval, and young-of-year sturgeon move downstream without impacts on survival (i.e., due to impingement and entrainment)?	If Intake has impacts on survival of juveniles, investigate source of mortality (Q4B).	Collect more data. Re-assess juvenile monitoring of downstream passage at Intake (e.g., location, frequency, and/or timing of sampling).	If juvenile survival is unaffected by downstream passage through Intake, investigate whether natural recruitment occurs (Q5).
	• Q4B: Are sources of impact on survival of embryos due to physical conditions / structures at Intake (i.e., over dam, through side channel, entrained in canal)?	If impacts are not directly related to Intake, investigate other potential sources of mortality (e.g., predators).	Collect more data. Re-assess juvenile monitoring of downstream passage at Intake (e.g., location, frequency, and/or timing of sampling).	Modify structures at Intake to improve downstream passage of juveniles. Re-assess physical criteria for downstream passage at Intake. Continue to monitor impacts on downstream passage (Q4A).
Q5. Is recruitment successful and sufficient to meet population targets?	• Q5A: Does successful spawning result in recruitment?	Investigate sources of potential limitation in recruitment (e.g., distance upstream, passage at Cartersville, number of spawners, quality of spawning habitats, passage efficiency at Intake). Take action to address potential limitations.	Collect more data. Re-assess design of juvenile monitoring (e.g., location, frequency, and/or timing of sampling).	Test genetics of embryos to parentage of upstream spawners. Apply population model. Assess whether natural recruitment is sufficient to meet population targets (Q5B).
	• Q5B: Is the level of recruitment sufficient to meet population targets (95% probability of persistence over a 50-year period)?	Investigate opportunities to enhance natural recruitment. Take action. Continue to monitor (Q1-5).	Collect more data. Re-assess design of juvenile monitoring and/or population model (e.g., location, frequency, and/or timing of sampling).	Maintain beneficial actions to ensure success in achieving recovery goals. Continue to monitor (Q1-5).

4.2.5.2.8 *Level 3 Contingent Actions*

The fundamental scientific uncertainty related to improved fish passage at Intake is whether reproductive adults will find passage around or over Intake Dam and migrate a sufficient distance up-stream for spawning. Resolution of this uncertainty will have a profound effect on the ability to predict whether recruitment is possible in the Upper River. Robust monitoring and assessment should resolve this uncertainty. In the event that Intake is not successful, other uncertainties become more important. For instance, one of those uncertainties relates to biological departures from purely passive transport of free embryos. If free embryos progressively develop the ability to move themselves out of the current or to slow dispersal by interacting with benthic bedforms, then advection/dispersion calculations will overestimate dispersal distance. In that scenario, the other management actions being considered are more likely to have the potential to support natural recruitment. The Missouri River Pallid Sturgeon Free Embryo Drift Study, undertaken in June and July 2016 (and summarized in section 4.1.2) will provide insights into this uncertainty.

As illustrated by the decision trees on information needs that emerged from the EA (see Section 4.1.2.5), a determination of the effect of fish passage at Intake on natural recruitment has a strong influence on the exploration of other Level 3 actions on the Upper Missouri River. For instance, if spawning occurs at locations far enough upstream in the Yellowstone River so that free embryos have sufficient distance to allow for transition to first feeding upstream of Lake Sakakawea, then other Level 3 actions on the Upper Missouri River may not be necessary to recover the subpopulation. In this situation, successful wild recruitment would be required at a level that would increase and sustain population abundance over a sufficient time frame. Alternatively, if Intake fails to result in sufficient natural recruitment, or if results are equivocal (e.g., recruitment does not occur with sufficient frequency), then other Level 3 actions might be required. These actions could include decreases in flows from Fort Peck to decrease downstream transport rates, increases in temperatures from Fort Peck to increase developmental rates, drawdown of Lake Sakakawea to increase available dispersal distance, or some combination thereof. Implementation of these other actions would require evidence from related Level 1 and Level 2 studies to suggest that some combination of actions would improve survival to first feeding in the Upper River (see study components related to Big Question 5 in Table 43).

The contingent nature of Upper Missouri River actions on the success of Intake also affects the timing of other Level 1 science components and Level 2 actions described in Appendix C and summarized in Table 43 (see discussion of learning strategies in Section 4.2.3). The schedule in Figure 69 assumes that various Level 1 activities will occur concurrently, exploring key hypotheses sooner in the absence of definitive results on the biological performance of Intake (i.e., parallel staging). This implementation schedule reflects ongoing and planned research to address hypoxia, interstitial hiding and drift hypotheses in this reach that will have been executed prior to significant monitoring of the Intake passage project.

4.2.6 Details on Level 3 Actions (and associated Level 2 components) for Lower Missouri River

Figure 64 (in section 4.1) presented a decision tree for possible actions to ensure survival and recovery of pallid sturgeon in the Lower Missouri River. A more detailed decision tree for the Lower Missouri is found in Appendix F. The following potential Level 3 actions emerge from these decision trees: population augmentation, creation of interception and rearing complexes (IRCs), creation of spawning habitat, and manipulation of flows and/or temperatures. The remainder of section 4.2.6 discusses each of these actions (with the exception of manipulation of temperatures, which is not yet a candidate Level 3 action, and is discussed for Levels 1 and 2 in Section 4.2.4 and Appendix C).

4.2.6.1 *Level 2 Studies - Population Augmentation*

4.2.6.1.1 *Introduction*

Section 4.2.5.1.1 above provides a summary of current hatchery practices and the decision making processes for propagation, led by the Recovery Team and involving other entities. Those decision making processes will ultimately determine whether there is a need to change the number, biomass, size, age, genetics or location of hatchery fish that are stocked, as well as potential changes to hatchery practices. There remains considerable uncertainty about what actions will be recommended by the Recovery Team. It is important that whatever actions are recommended, that they be rigorously designed, implemented, monitored and evaluated, consistent with AM principles. To illustrate such a rigorous approach, this section describes an example Level 2 management experiment which could be undertaken to improve population augmentation in the Lower Missouri River (section 4.2.6.1.3). This is only one example of many possible actions which could emerge from the Recovery Team, and the actual experimental design will need to be tailored to the selected actions. Section 4.2.6.2 describes future augmentation actions at Level 3 and Level 4, which could potentially be altered as a result of Level 2 management experiments. As the Recovery Team and other entities converge on a propagation strategy, a similar structured approach should be applied to the selected preferred actions.

4.2.6.1.2 *Hypotheses*

The following hypotheses are relevant to this action[1]:

- H20. Stocking at optimal size classes and in optimal numbers will increase growth rates and survival of exogenously feeding larvae and juveniles.
- H21. Stocking with appropriate parentage and genetic diversity[2] will result in increased survival of embryos, free embryos, exogenously feeding larvae, and juveniles.

Testing these overall hypotheses will require a nested set of more detailed hypotheses that are structured to be amenable to specific statistical and modeling analyses, and will need to build on Level 1 analyses of existing data. The term "optimal numbers" in H20 could mean a change up or down from current practices to match current carrying capacity. Genetics (part of H21) is an issue of increasing concern in the Missouri River. More detailed hypotheses related to genetics (and associated metrics) will need to be developed as part of the ongoing work on a Basin-wide Stocking and Augmentation Plan.

4.2.6.1.3 Action Description

Propagation has been ongoing for a long time at Level 3 to increase the abundance of pallid sturgeon in the wild. Unlike some other actions where Level 2 studies are required *before* undertaking Level 3 actions (e.g., spawning cue flows), the purpose of Level 2 studies of propagation is to better understand how well current methods of propagation have been working, and to explore alternative approaches that might better avoid jeopardy.

Level 2 components are envisioned to be field-based experiments that will vary size at stocking and assess differential survival. These Level 2 activities may not be necessary to decide among facilities/operations options if the retrospective evidence that's reviewed and modelled at Level 1 under Big Question 6 (components BQ6/L1/C2 and C3 in Table 44) is sufficiently robust. Moving to Level 2 would be recommended if the data and models indicate a high sensitivity of cost and survival to size at stocking, and more precise parameters for the relationships are needed.

[1] The wording of these hypotheses is exactly the same as propagation hypotheses H8 and H9 described under section 4.2.5.1.2, but have different numbers to distinguish the lower river hypotheses from the upper river hypotheses.

[2] Genetic diversity refers to variability in genotypes comparable to the unaltered, wild population. The assumption is that maintenance of the appropriate genetic diversity will result in increased fitness of individuals and the population. Further research is required to define performance measures and targets for genetic diversity.

This example Level 2 management experiment would involve stocking fish at variable sizes (representing variable hatchery costs), and/or manipulating other hatchery factors (such as the genetics of stocked fish to meet specified objectives for identified metrics) while keeping all other factors as constant as possible. Such management changes have occurred in the past. The intent of this description is to illustrate a well-designed approach which maximizes the ability to detect the signal from implemented actions, while controlling for the noise created by year to year variability in flow and variability amongst hatcheries. Genetics is another factor which could affect the outcomes of this management experiment, and has been included as a covariate to help explain outcomes. If this Level 2 experiment were to proceed (which depends on both the strategy developed by the Recovery Team and the availability of sufficient hatchery fish of the appropriate size), it could be a planned comparison of survival rates and fish metrics between releases as fingerlings or yearlings, accounting for variation in outcomes due to both hatchery differences and the type of water year.

4.2.6.1.4 Objectives and Expected Benefits

The objective of this Level 2 management experiment is to make long term improvements in the cost-effectiveness of propagation practices, or to confirm that current practices are the most appropriate for maintaining and recovering pallid sturgeon populations. Many of the design principles could be applied to other types of actions.

4.2.6.1.5 Metrics

Metrics would include: estimated number and survival probabilities for stocked pallid sturgeon by stocked size and age, hatchery of origin; fish condition; genetics; and water year conditions (as additional covariates to help explain survival rates). Metrics for genetics have not yet been determined, but will be discussed in the development of the Basin-wide Stocking and Augmentation Plan. Candidate metrics might include such measures as the mean observed heterozygosity for multiple polymorphic markers, mean relatedness among individuals, allelic richness, and effective population size (Richard Lance, Environmental Genomics and Conservation Genetics Laboratory, USACOE, pers. comm.).

4.2.6.1.6 Experimental Design

Overall design. This management experiment would need to take place over a number of years and a number of hatcheries to separate out three factors: the local effects of hatcheries (some tend to have higher quality fish than others), the practices applied in each hatchery (e.g., age at release), and the particular circumstances in each water year.

The design will need to take place in the context of the overall propagation strategy developed by the Recovery Team, and consider various practical constraints (e.g., the availability of a sufficient number of hatchery fish, the implications of the experiment for stocking targets and hatchery operations, genetic factors, size constraints on tagging). These practical constraints will inevitably (and appropriately) lead to modifications to the example design described here. A common experimental design for these type of studies is a staggered-entry design similar to the staircase design of Walters et al., 1988, Figure 70; staircase designs are also discussed by Roni et al. 2012 and Bennett et al 2016. For example, hatchery A would start an alternative hatchery management practice in year t1+1; hatchery B would start the alternative practice in year t1+2; and hatchery C would remain a control, applying current practices. The years prior to implementing an alternative hatchery management practice at each hatchery act as controls, to be compared with the alternative treatment. Monitoring after release occurs via the population monitoring program where recaptured fish have their tags read and fish metrics determined. If changes in the genetics of hatchery fish become part of the alternative management practices under consideration in the development of a Basin-wide Stocking and Augmentation Plan, then part of the experimental design would involve tracking metrics of population genetics over time, and also relative to some baseline or target values. Such baseline or target values might be obtainable from historical samples, and by sampling wild populations (Richard Lance, Environmental Genomics and Conservation Genetics Laboratory, USACE pers. comm.).

Results from Level 1 studies and expert opinion would be used to determine the contrast of interest, e.g. releasing fingerlings vs releasing yearlings. Retrospective information will be needed to estimate year-specific effects (e.g., does a wet year impact survival rates different than a dry year?), and hatchery effects (e.g., how different are survival rates for similar fish released in the same year in two different hatcheries?). This retrospective information and the size of effect to be detected between the release groups is then used in a power analysis to determine combinations of how many fish are needed to be released; how many hatcheries are needed; how many years of releases; and how many years of monitoring are needed to reliably detect this effect. Additional fish/hatcheries/years may be added to mitigate the impact of unforeseen impacts of disease or disaster at a hatchery. Planning for implementing such an experiment at hatcheries would also occur (e.g., is there sufficient broodstock, tanks, and water?).

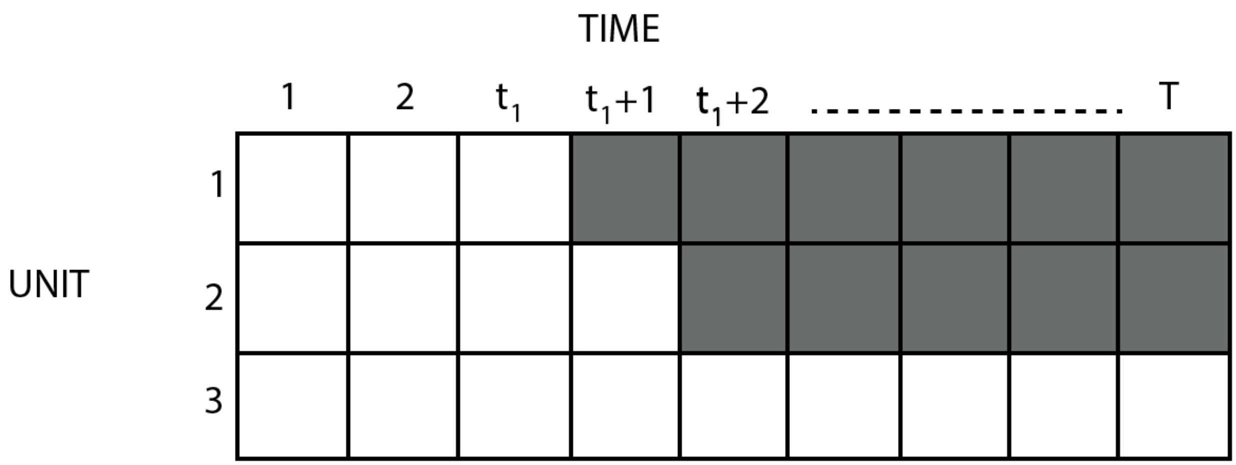


Figure 70. Illustration of a staircase design. Treatments are staged so as to avoid confounding of treatment effects and year effects. Unit 1 is treated in year t1+1; unit 2 is treated in year t1+2; and unit 3 remains untreated. Adapted from Walters et al. 1998.

Released fish will either be individually tagged with PIT-tags (if large enough) or using other marking methods (for smaller fish). Parental genotyping will be done so that a recaptured fish without a PIT-tag can be identified back to the year class and type of release before a PIT-tag is inserted.

Length of the Experiment. The number of years that are required for the implementation of this study should follow the recommendations of the power analyses. It is difficult to determine the time needed for such an experiment, but robustness consideration imply that at least 3 different years of releases over at least 3 hatcheries with an additional 5 years of monitoring may be needed for a total of 8-10 years for the study.

Data analyses. The study results will use the database created as part of the Level 1 retrospective studies under BQ6/L1/C2 and BQ6/L1/C3 (see Table 44).

There are a variety of methods which could be used to analyze the data. Variants of a Cormack-Jolly-Seber (CJS) model could be used to estimate survival of the release groups using the multiple recapture occasions using mark recapture software such as Program MARK. Because monitoring methods have changed over time and will continue to be improved (see Appendix D), more complex statistical models may also be required (e.g., the robust-design model or hierarchical-Bayesian models to allow for information sharing among sparse datasets).

Standard ANOVA methods can be used to evaluate differences in fish metrics across release groups. Power analyses can be used to determine the yearly samples required to determine a change in survival.

Evaluation of standard versus alternative hatchery practices could be based on the survival estimates produces by the CJS model, and whether there are statistical differences in survival. The collaborative population model could be used to project the population consequences of differences in survival probabilities. Because **differences** in survival are of interest, it may not be necessary to fully model emigration from the system as long as it is roughly equal across all release groups. Data will accumulate over time. Interim analyses will be conducted each year after the monitoring for the year is complete.

4.2.6.1.7 Decision Criteria

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. Interim analyses may indicate that the experiment demonstrates a biologically significant benefit (as determined by simulations of long term outcomes) with a high likelihood. This could be used along with other lines of evidence to accelerate changes in hatcheries going forward. The criteria used to determine biological benefit will require further discussion among the Recovery Team, USFWS and other entities. A weight of evidence approach, using multiple criteria based on the above-described field metrics, and model simulations of consequences, is preferred. The Lower Missouri Framework (USFWS and USACOE 2015) mentions two possible criteria related to propagation: the number of adult pallid sturgeon in each management unit (target of 5000), and the threat of extirpation over 50 years (target of less than 5%). Criteria for more specific objectives will be presented in the Basin-wide Stocking and Augmentation Plan for pallid sturgeon.

4.2.6.1.8 Uncertainties and contingency plans

Practical constraints on the study design were summarized above. Uncertainties in the design of this study (and possible contingency plans) include:

- *Insufficient fish to run experiment.* Required sample sizes may be too large given the number of broodstock that are available and reproductively ready. The experiment can still be run with the smaller sample size, but it will require more years of monitoring to obtain sufficient recaptures.
- *Hatchery rearing problems.* For example, disease may remove a hatchery from production. This will reduce the sample size, power, and require additional years of monitoring.
- *Amount of monitoring needed.* The proposed population monitoring plan may not be sufficient (both spatially and intensity) for evaluating this experiment under

realistic numbers of releases and time frame. This would require more intensive monitoring.

- *Survival estimates are not sufficiently precise to be useful.* If survival estimates fail to show reliable inferences (e.g., very wide confidence intervals), an evaluation of the cause is needed. Despite the planned power analysis, the actual survival rates could be different than used during planning, indicating that sample sizes were inadequate.
- *Environmental conditions change from those used in planning.* Environmental conditions may affect survival in unforeseen ways and the experiment may not be a proper reflection of longer-term conditions. For example, a mini-drought may occur during the experiment. Dealing with this uncertainty would require extending the experiment for a longer period of time.

4.2.6.2 *Level 3 studies – Population Augmentation*

4.2.6.2.1 *Action Description*

Population augmentation (stocking) of pallid sturgeon is already taking place at a level having a measurable effect on the population (i.e., Level 3), and will continue. While population augmentation is *necessary* for recovery of the pallid sturgeon, by itself it is not *sufficient* as the ESA requires a self-sustaining population. Augmentation can help severely depleted populations recover numbers of individuals needed to evaluate what works and what doesn't in recovering the population. Additionally, some concurrent Level 1 and Level 2 components are proposed to develop information to improve on the Level 3 implementation (see Figure 71 for an approximate schedule).

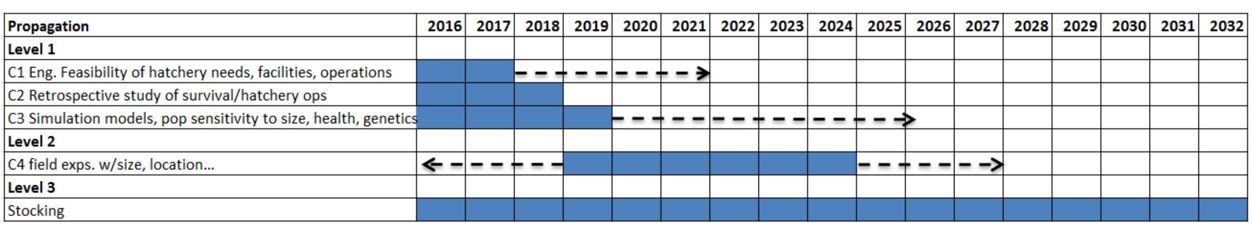


Figure 71. Preliminary timeline of actions related to propagation, as proposed by the USFWS and USACE (2015). Activities and timeline are likely to be revised in response to the new Basin-wide Stocking and Augmentation Plan for pallid sturgeon. Arrows represent flexibility in the timing of implementation.

Supplementation actions will be closely coordinated with the new Basin-wide Stocking and Augmentation Plan for pallid sturgeon being developed by the Pallid Recovery Team because of important concerns related to fish health/disease, genetics, stocking size, stocking practices, etc. Once the Plan is developed, the target values in Table 42 will be adjusted to reflect the role of the MRRP in meeting plan objectives. The target values in the table may best be represented by running averages in addition to or rather than annual minimums or maximums. It is important that the Basin-wide Stocking and Augmentation Plan rely upon the collaborative population model being developed as part of the EA and AM Plan (and in support of the recovery plan). This model can incorporate multiple alternative hypotheses and is specially designed for the MRRP. Other modeling efforts, should they arise, may be viewed as additional lines of evidence, though the preferred approach is to explore alternative hypotheses within a single modeling framework.

4.2.6.2.2 Objectives

The stocking rate and target number of fish stocked is intended to ensure a 95% probability of persistence for the species over a 50-year period, and at least 5000 adult pallid sturgeon per management unit (USFWS and USACE 2015). Short-term objectives are to increase the number of adult pallid sturgeon in the lower Missouri River. Long-term objectives are to reduce and eventually eliminate the need for supplemental stocking by demonstrated wild recruitment at a level sufficient to meet the fundamental objectives and associated sub-objectives (section 4.1.1). Criteria for more specific objectives will be presented in the Basin-wide Stocking and Augmentation Plan. The targets per management unit may be adjusted over time by the USFWS in response to increased knowledge about carrying capacity, effective population size, and other factors.

In addition to the above primary objectives, more specific, means objectives for propagation have been identified and include increased fitness and genetic diversity of released fish (to better match natural genetic variation in the wild population, as discussed in section 4.2.6.1), improved brood stock handling, and adjusting hatchery capacity. Some of these efforts are being addressed through Level 1 and 2 studies. Further work is required to define metrics for genetic diversity.

A key uncertainty of the evaluation process is whether the population model reflects reality, and has scientifically defensible estimates of abundance and survival for different life stages. If the population model does not reflect reality, the performance measures generated by the model will not be meaningful.

Figure 71 shows the timing of implementation of actions related to propagation as suggested by USFWS and USACE (2015). Deviations from that implementation plan will be documented. Implementation at Level 3 is to begin immediately (i.e. continue from present, with recommended changes in propagation from the Basin-wide Stocking and Augmentation Plan) following issuance of the ROD, but there is no specific timeframe identified for transition to a Level 4 action.

4.2.6.2.3 Metrics

The metric for reporting and assessing stocking rates will be yearling equivalents; performance measures will be based on a three-year running average of annual yearling equivalents. Other metrics include: number and survival rates (to age-0, age-1[1], and juvenile stage) for stocked pallid sturgeon by stocked size, hatchery of origin, and condition; catch rates of adult pallid sturgeon; measures of fitness including population genetics; condition factor; levels of disease; and simulations of the benefits of propagation using field-estimated survival rates (e.g., probability of quasi extinction, instantaneous growth rates, and sensitivity measures under various scenarios and parameterizations of the collaborative model, including alternative hypotheses and functional relationships). Metrics are subject to adjustment upon coordination with the Recovery Team on the new Basin-wide Stocking and Augmentation Plan for pallid sturgeon. Population monitoring and modeling approaches are described in Appendix D. A more detailed list of metrics is provided in Appendix K.

4.2.6.2.4 Experimental Design

The hatchery strategy developed through Level 2 studies of propagation (section 4.2.6.1.3) will be implemented for a number of years, with monitoring of the above-described metrics. Estimated survival rates through this Level 3 implementation will be compared to those expected from the Level 2 studies. Evaluations of fish survival rates and rearing practices may lead towards revision of the Level 3 action. As natural recruitment improves, it may be necessary to adjust both stocking levels and stocking strategies.

[1] Age-0 fish become age-1 fish on January 1st

4.2.6.2.5 Decision Criteria

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. Population augmentation may be halted when population monitoring demonstrates that a self-sustaining population in excess of 5000 adult fish exists in each management unit, when the threat of extirpation is less than 5 percent in 50 years, or as based on new criteria introduced through the Pallid Sturgeon Recovery Plan by the Recovery Team (see USFWS 2014). These criteria could include other considerations, such as genetics, fish community health (carrying capacity), habitat availability and hybridization.

Adjustments to the number of fish and their age structure will be based on the results of population modeling and sensitivity analyses using the most up-to-date version of the model available each year. Until the model is sufficiently robust to meet this need, a target of 5000 adult pallid sturgeon in each management unit will serve to guide stocking rates, when the threat of extirpation is less than 5 percent in 50 years, or as based on new criteria introduced through the Pallid Sturgeon Recovery Plan.

<u>Triggers for Moving to Higher Implementation Level</u>: No clear transition from Level 3 to Level 4 exists; implementation at Level 3 will continue until such time as supplemental stocking is no longer required.

<u>Trigger for abandoning population augmentation actions:</u> Population augmentation may be halted when population monitoring demonstrates that a self-sustaining population in excess of 5000 adult fish exists in each management unit, when the threat of extirpation is less than 5 percent in 50 years, or as based on new criteria introduced through the Basin-wide Stocking and Augmentation Plan. These triggers should be evaluated within the pallid sturgeon population model framework, with recognition of the carrying capacity of different sections of the river.

<u>Triggers for adjusting augmentation practices to optimize fitness or genetic diversity:</u> Hatchery practices need to be evaluated to assess the impact on fish health. Measures of genetic diversity must be considered.

4.2.6.2.6 *Level 3 Contingent Actions*

Contingency plans for artificial propagation are limited to those associated with the secondary objectives; adjustments to the propagation program will focus on achieving the necessary fitness and genetic diversity.

4.2.6.3 *Interception and Rearing Complexes (IRCs)*

4.2.6.3.1 *Hypotheses*

The following hypotheses (discussed in the EA) are relevant to this action:

- H17. Re-engineering of channel morphology in selected reaches will increase channel complexity and bioenergetic conditions to increase prey density (invertebrates and native prey fish) for exogenously feeding larvae and juveniles.
- H18. Re-engineering of channel morphology will increase channel complexity and minimize bioenergetic requirements for resting and foraging of exogenously feeding larvae and juveniles.
- H19. Re-engineering of channel morphology in selected reaches will increase channel complexity and serve specifically to intercept and retain drifting free embryos in areas with sufficient prey for first feeding and for growth through juvenile stages.

The EA (Jacobson et al. 2016a) found that there was theoretical support for all of these hypotheses, and from hydrodynamic models, but that data were equivocal as to whether IRC habitat was a limiting factor (Table 38). Testing these hypotheses requires an experimental design with high statistical power, discussed further in section 4.2.6.5.6 on Experimental Design. The Lower Missouri River Pallid Sturgeon Framework (USFWS and USACE 2015; pg. 11), posed some more detailed hypotheses that are somewhat more amenable to field tests:

- *Interception habitat* - Improved or increased interception of drifting free embryos from the thalweg and transport to supportive channel-margin habitats will increase survival of free embryos to exogenously feeding age-0.
- *Food production habitat* - A lack of food limits survival of age-0 pallid sturgeon. [Chironomids are particularly important to benthic-feeding, age-0 pallid sturgeon.]
- *Foraging habitat* - An increase in availability and quality of foraging habitat will increase survival of age-0 pallid sturgeon.

4.2.6.3.2 Action Description

Interception and rearing complexes (IRCs) are areas that meet the functional definitions laid out in the EA Integrative Report. For the purpose of establishing targets and measuring progress, the physical definitions of IRCs are currently identified as follows: 1) food-producing habitat occurs where velocity is less than 0.08 m/s, 2) foraging habitat is defined as areas with 0.5 – 0.7 m/s velocity and 1-3 m depth, and 3) interception habitat has been qualitatively described as zones of the river where hydraulic conditions allow free embryos to exit the channel thalweg (Figure 72). A functional IRC exists where the juxtaposition of the described habitats is such that all three functions are performed and collectively contribute to survival to age-1. These specifications could be adjusted as warranted based on monitoring and evaluation, or new information (see Section 6.2.5), regarding observed utilization of different habitats by age-0 pallid sturgeon. Research is continuing on conditions that create interception hydraulics. Effective interception hydraulics seem to occur where flow expands downstream from a wing dike followed by a relatively long section of river without wing dikes (Figure 72). Creating effective interception hydraulics on the Lower Missouri River may require only modest changes to wing-dike geometries.

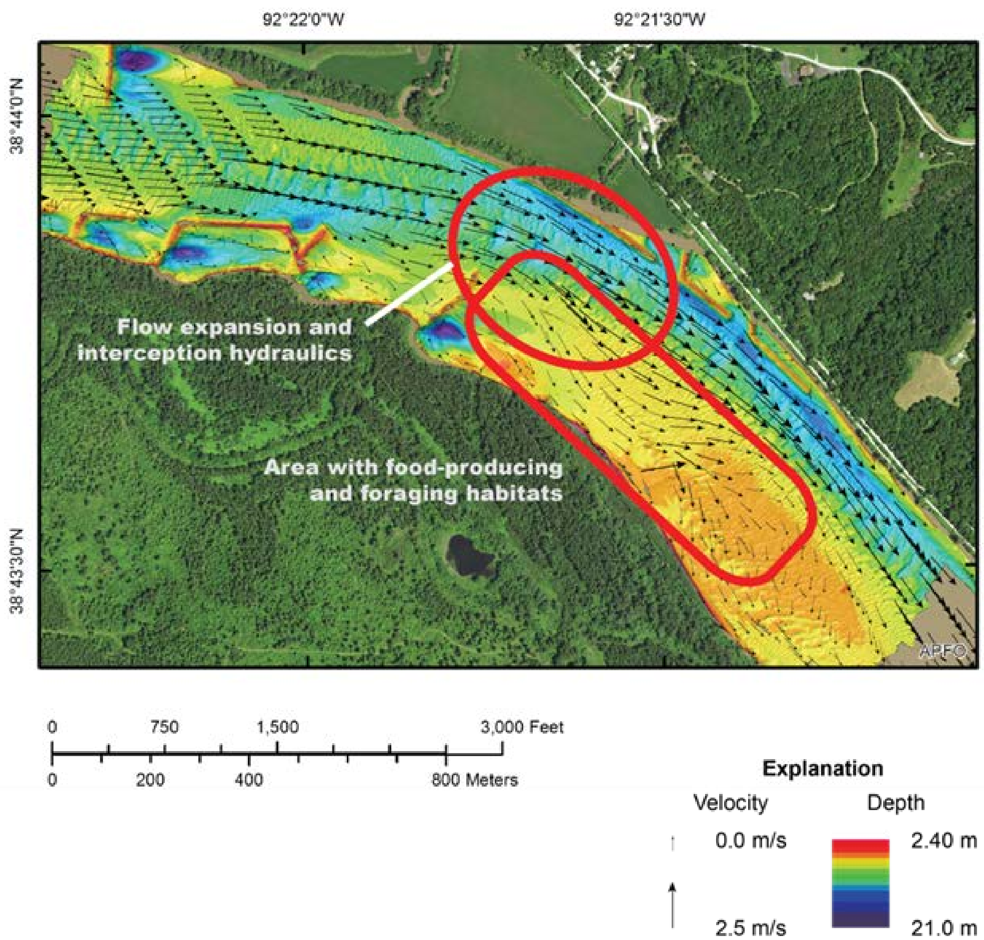


Figure 72 Concept of an interception-rearing complex near river mile 162. Flow expansion is shown by modeled current velocity and direction (arrows) angled away from the channel and towards the right descending bank.

The biologically optimal size of an IRC is not known. The maximum size of individual IRCs is constrained by both channel width and typical bend length. Individual IRCs adjacent to the main channel were estimated to range from 80 to 260 acres in size for the MRRMP-EIS. Constructed side-channel chutes can also provide IRC functions and would likely be somewhat larger. IRCs would be designed and constructed to maintain the navigation channel and minimize any changes to flood heights.

The availability of food-producing and foraging habitats varies with flow, as does the local hydraulic field at any location (and hence the potential for interception and retention). Consequently, IRC habitat is flow-dependent and time-variant and can be affected by both mechanical manipulations of river geometry and flow management actions. For the timeframe addressed by the MRRMP-EIS (approximately 15 years), flow management will not be required to meet any IRC targets associated with Level 3 unless information developed during Level 1 and Level 2 implementation unequivocally demonstrates the need for flow manipulation. Because flow manipulations will not be assessed under the current actions for Level 3 (Table 40), additional NEPA analysis of those actions would be required before implementing changes to flows to improve the performance of IRCs.

Level 1 and 2 activities associated with IRCs focus on: 1) the need for additional IRC habitat, 2) refining the relationship between the habitat components, flow (utilizing current operations), and the biological requirements of each habitat type, 3) the needed habitat characteristics and their spatial and temporal distributions, and 4) determining the effectiveness of various mechanical activities and the potential for flow management actions to contribute to future IRC needs. A proposed sequencing for actions associated with IRCs, developed by USFWS and USACOE (2015), is shown in Figure 73. To the extent possible and where appropriate, Level 1 and 2 activities will incorporate habitat projects which have already been completed. Although the habitat focus has changed from Shallow Water Habitat (SWH), there is likely much that can be learned from existing SWH projects, and it is expected that many SWH projects may address one or more functional components of IRC (as described in Section 4.2.6.4.2).

Level 3 actions include physical manipulation of habitats and structures on the Missouri River to create or improve areas having hydraulic conditions to intercept drifting free embryos combined with food-producing habitats and foraging habitats. Actions might be directed at one or any combination of the three components of IRCs. Examples include adjustments to navigation training or bank stabilization structures, channel widening, floodplain modifications or other adjustments to channel geometry, placement of structures to encourage development of needed habitat or habitat complexity, chute development or adjustments to existing chutes, etc. In addition to development of functional IRCs, management actions will be aimed at ensuring availability of IRC habitats over a wide range of flows as well as the necessary spatial characteristics (distribution, concentration, proportions, etc.,) on the lower Missouri River such that interception, food production, and foraging are not preventing the achievement of the pallid sturgeon fundamental objectives. Increases in the amount of food-producing habitat should help to recover apparent declines in fish condition (draft report by Randall et al. 2016), as discussed in section 4.1.2.4. The timeframe for the implementation of Level 3 actions is shown in Figure 73. Deviations from that implementation plan will be documented.

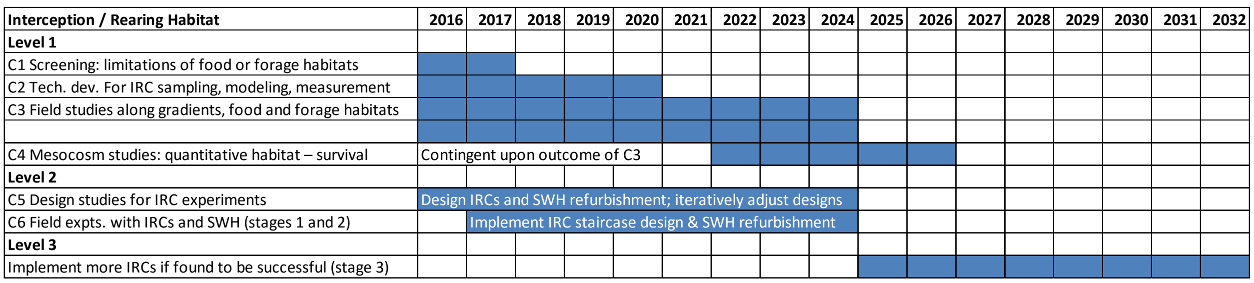
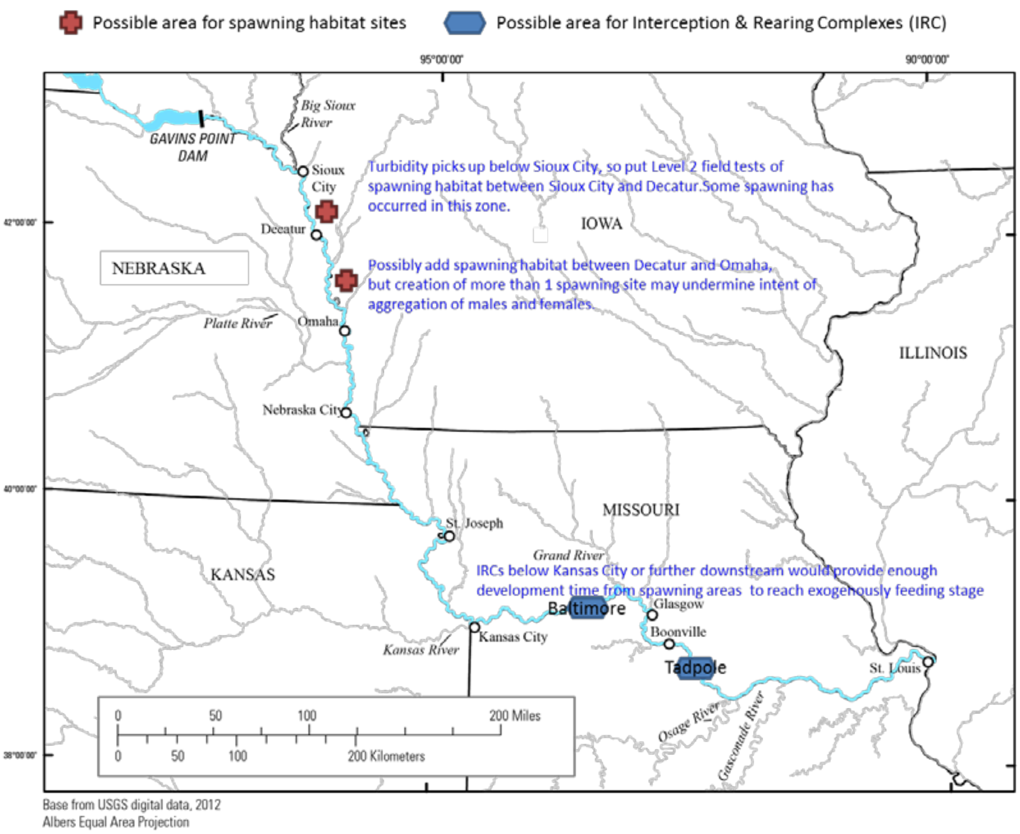


Figure 73. Current timeline for IRC action Implementation. Revised from USFWS and USACOE (2015) to reflect preferred alternative and current targets in Table 42.

The targeted longitudinal distribution of IRCs will be influenced by biological needs as outlined in the EA and supported by results of larval drift modeling as well as other practical considerations. It is anticipated that most IRCs will be created downstream from the Platte River (RM 595), with others below Kansas City to promote sufficient time for embryos to mature into the larval form during the passive drift phase. This assumption (based on current scientific understanding) will be tested and reviewed through Level 1 science efforts during the design phase, using all available information (particularly empirical observations of the distribution of embryos and larvae coupled with improved drift-dispersal models), and evaluating the potential for interception and recruitment upstream of the Kansas River. Currently proposed locations of IRCs are shown on the map in Figure 74, together with the rationale for those locations. The strategy for site selection will be based on considerations of both maximizing survival of exogenously feeding larvae and maximizing learning, according to the experimental design described in section 4.2.6.3.4 Experimental Design, and taking into account the variability in channel conditions. Projects with potential to quickly reduce uncertainties will be emphasized to the extent practicable. New IRC habitat resulting from both Level 2 and Level 3 actions that meets the IRC criteria will be counted as contributing to the targets for Level 3, as described in section 4.2.6.3.5 Metrics and section 4.2.6.3.6 Decision Criteria . Level 3 actions and outcomes are focused on helping to understand and describe future Level 4 actions and targets.



figLMOR_Loco_jacobson.ai Lower Missouri River mainstem and major tributary rivers within the Comprehensive Sturgeon Research Project study areas.

Figure 74. Possible locations of new spawning habitats (red symbols), and Interception and Rearing Complexes (IRCs; blue symbols). The general rationale for these general locations is shown on the map in blue text, with further details in the text of this section.

Long-term (Level 4) targets will be based on the outcomes of Level 2 and Level 3 management experiments, and the integration of multiple metrics on physical habitat and biological performance., The USFWS (2016) established Level 2 targets for IRCs (Table 42; Stage 2) based on two methods: 1) the historical rate of implementation of Shallow Water Habitats (SWH) which was approximately 260 acres per year, converted into roughly 33,000 acre-days per year of suitable habitat; and 2) a model-based estimate of the increased amount of suitable food and foraging habitat (in acre-days per year) at two planned IRC sites (Searcy and Baltimore), which cumulatively equal about 30,000 acre-days per year. These two different methods generated an estimate of the amount of IRC habitat to be constructed each year during Stage 2 of IRC habitat development (33,000 acre-days/year; Table 42), to be supplemented by the refurbishment of SWH into IRCs (described in section 4.2.6.4). Stage 2 will provide insight on the amount of IRC habitat required at Stage 3 / Level 3; Table 42 proposes 66,000 acre-days/year.

The growth period for larval and juvenile pallid sturgeon in the lower Missouri River is generally considered to occur from May (hatch) through October, though there can be considerable variability, with hatching potentially occurring as early as March, and apparent growth (at least in age-1 shovelnose sturgeon) occurring over the following winter. Improving our understanding of the timing of growth in age-0 pallid sturgeon, and the relationships between growth and other variables (e.g., temperature, flow and river geometry) will be one of the priorities of Level 1 work under Big Question 3 (food and forage), and hypotheses H17, H18 and H19.

4.2.6.3.3 *Objectives*

The primary objectives are to: promote the interception of drifting free embryos and age-0 larvae; increase food production and effective foraging for age-0 pallid sturgeon; increase survival probabilities to age-1; and ultimately increase the probability of population survival and recovery in the Lower Missouri River. From a risk avoidance perspective, it's important to ensure that creation of IRC habitats has a net positive effect (e.g., does not reduce the availability of other important habitat types or limit recruitment in the lower Missouri River, either locally or systemically). Secondary objectives are to make progress toward the targeted amount and distribution of IRC habitats, and to ensure that human considerations are protected. The creation of spawning habitat and IRC habitats will be planned in an integrated manner, using experimental designs that reveal the degree to which each of these habitats may be limiting recruitment to age-1.

4.2.6.3.4 *Experimental Design*

The following principles are important for the iterative development of the experimental design and monitoring protocol (building on the general principles described in Appendix G):

- Develop biologically significant effect sizes for each of the IRC decision criteria listed below in sections 4.2.6.2.6 and 4.6.
- Determine acceptable risks of false positives (falsely detecting a benefit of IRC habitats when no benefit actually occurred) and false negatives (not detecting a real benefit); now completed (Appendix E);
- If possible, use past data and possibly intensive pilot sampling to gain insight into spatial and temporal variability in the relative abundance of age-0 pallid and

shovelnose sturgeon within different habitat types, and how relative abundance varies over time and river conditions (variation over time described in Appendix E);

- Conduct statistical power analyses to determine how false positives and false negatives vary with sampling effort, number of IRC and reference sites, and the number of years of monitoring. The power analysis in Appendix E (Figure E4) indicates that acceptable statistical power (near 80%) is generally achievable for an effect size of 75% or higher (the increase in CPUE), 7 to 12 treatment-control pairs, and 7-15 years of monitoring.;
- Use the information from steps 1-4 to refine both the experimental design and existing monitoring protocols (e.g., improving the protocol described in HAMP SOP 2015, and making it more consistent with the robust population monitoring strategy described in Appendix D). A stratified random approach could be used to guide sampling efforts throughout the habitat classification hierarchy to avoid extensive oversampling in habitats where age-0 sturgeon (possible indicator is a size ≤109 mm, though other length-age relationships exist) are not likely to occur, while still ensuring that all habitats are sampled. The monitoring protocol should however recognize that the spatial distribution of age-0 fish can vary considerably with flow; the locations in which age-0 fish are found tend to be correlated with current velocity. For example, age-0 sturgeon were found clustered in near shore and other seemingly protected habitat types during periods of high flow in 2010 and 2011, but were not commonly observed in these habitat types during periods of normal flow (Ridenour et al. 2012). The draft monitoring plan for IRCs in Appendix E considered the above issues, and applies a stratified random sampling approach.
- Development of stocking and sampling strategies which can provide estimates of age-0 survival (e.g., stocking of pallid sturgeon with known genetics at a few days old, estimating survival through mark-recapture)

The design in Appendix E envisions both treatment (IRC) sites and control sites. Control sites should be: representative of areas currently used by age-0 sturgeon, independent of the effects of IRC creation (e.g., it's better to have control sites upstream of treatment sites), in generally similar habitat categories as those used for IRCs, and accepted as providing a fair reference point for estimating the IRC treatment effect on various metrics (described below). In developing designs for IRC sites, different configurations of IRC habitat within a site can be modeled using the particle tracking analysis to determine the best configuration for interception of free embryos.

The choice of experimental design used to assess whether the interception of age-0 pallid sturgeon increased depends on the quality, variability and quantity of existing data on catch per unit effort (CPUE) and the anticipated time for IRC modifications to show an impact following the 2-year period of construction (T. Gemeinhardt, pers.comm.). Some sites identified as IRC sites may have pre-construction data (e.g., Tadpole site has 2014 and 2015 data – see Appendix E); however, other sites may not. For those sites where existing data are present, the analysis could take the form of a Before-After (BA) or Before-After-Control-Impact (BACI) design. It is possible to create several IRC sites with a single control site as this is a simple modification of the BACI design. However, a key attribute of a BA or BACI design is that the impact is immediate. If the impact is not immediate, which would be expected with IRCs due to geomorphic and biological changes over time, then the staircase design (Walters et al, 1998, Roni et al. 2012) is preferable. Site-to-site variability is not important in BA/BACI/Staircase designs as site effects cancel out when the same site is repeatedly measured over time. Differences in the responses of sites to year to year changes (site- year interaction) add noise to the signal from IRC sites, as explained in Appendix E. The draft monitoring plan in Appendix E assumes a staircase design for both statistical and logistical reasons.

Practical consideration of the time required to construct IRC sites also favors a staircase design. Since IRC sites will not be created all at once (construction is currently anticipated to occur over a 7-year period, Appendix E), the staircase design might be useful because all IRC sites would not have to be created in a single year, and interactive effects with time (e.g., water years) can be detected. Power will increase over time as more IRC sites are constructed. The staircase design requires at least one control site, though the current design assumes 12 IRC sites and 12 control sites (Appendix E). Once an IRC is deemed to be effective, it is possible to stop monitoring that IRC site and move field crews to other sites. It will be important to ensure (to the greatest degree possible) that multiple IRC sites are considered to be independent of one another, as well as independent of control sites. Measuring covariates, which might be able to account for a lack of independence, will also be important.

The design described in Appendix E assumes that the construction of IRC sites will not impact either the control sites, or the pre-construction condition of future IRC sites. Strategies to remove such potential confounding include locating control sites upstream of IRC sites, and staging the spatial implementation of IRC sites in a manner that minimizes potential confounding effects.

Staircase designs usually look for changes in mean, but they can be readily adapted to detect changes in trends. For example, a change in trend could be detected by comparing the slope of a regression line with a breakpoint at the date of the restoration activity.

The draft monitoring plan (Appendix E) includes the following classes of response variables:

- stratified random sampling of age-0 pallid sturgeon to generate CPUE (catch per unit effort) at the IRC site level;
- length-frequency distributions at the IRC site level (increased retention and growth in IRCs should cause this distribution to shift to the right compared to control areas), rolled up to the project scale;
- other fitness variables of individual fish (e.g., condition, mass, % of empty/full stomachs, lipid content, genetics), rolled up to the site scale;
- hydroacoustic measurements of hydraulic conditions at IRC treatment bends, both pre- and post-construction, and Missouri River mainstem control bends, used to estimate the amount of suitable habitat before and after construction, and to develop hydrodynamic models of the depth and velocity within surveyed reaches;
- measurements of water depth and velocity; and
- predictive models of CPUE based on physical covariates, as well as the length of time that an IRC site has existed, and its location.

Another consideration is how to treat multiple samples at each site during a year, which may vary for different questions. Depending on the assumption of site closure multiple samples can be handled in an Occupancy or *N*-mixture model.

The power analyses in Appendix E have been helpful in determining the extent of monitoring and sampling intensity at IRC and control sites required to observe an effect on the interception, growth and survival of age-0 sturgeon – including the number of trawls per site, total trawls per year, and the number of years before / after that are needed to detect a certain sized change in CPUE. Sampling information at multiple sites and over multiple years can be used to improve the accuracy of the power analyses in Appendix E, as more years of data will improve estimates of the process (natural) variability and sampling variability in the system. Experimental releases of hatchery-reared, first-feeding pallid sturgeon larvae could be a Level 1 tool-building action used to improve statistical power.

Variation might be reduced, or interpretation might be aided, with suitable covariates such as an index of the number of successful spawning events in that year. Adjustments can be made for the actual number of spawning fish each year as opposed to treating this as a ‘random year effect’ in the analysis. One would expect higher CPUE in IRC areas in years when many eggs are released, all else being equal. Measuring egg production (though difficult and really only feasible for telemetered fish) would be helpful because egg production could be related to many factors, including both management actions (e.g., spawning cue flows and the creation of spawning habitats) and natural factors (e.g., the number of females in a reproductive state, natural spatial and temporal variability in hydrology, abundance of predators). An index of spawning success, as well as relevant flow indices, could be used as covariates in the analysis of response variables to explain some of the year-to-year variation seen. The results may be confounded by changes elsewhere in the system, (e.g., modifications to increase spawning success may lead to an increase in CPUE even if there were no benefit from the IRC work); an index of spawning success can help to reduce such confounding.

Some possible adjustments and refinements to the above experimental design might include:

- **Trawl efficiency**. The Missouri River is a big moving river, and a challenging place to sample fish. Only a small portion of the available habitat is sampled with each pass of a trawl net. It would be very valuable to review past PSPAP and HAMP data sets in which multiple trawls were run in approximately the same location to estimate capture efficiency.
- **Residence time**. It would be valuable to get an estimate of residency time in IRC complexes, possibly using 2D models, or mark-release and recapture of some of the fish. Given the current capture rate, this experiment may not currently be feasible. Improvements in sampling gear might make it more feasible to measure residence time using mark-release methods, but changes to sampling gear must be implemented gradually, as described below.
- **Gear efficiency changing over time.** If CPUE is the response variable, then it is assumed that changes in CPUE are an index to changes in the underlying abundance rather than an artifact of detection efficiency in the gear. A similar concern exists if presence/absence is used. If gear is to be changed, then both sets of gear should be run in parallel for at least two years to estimate the calibration between the two types of gear. Various approaches should be considered to account for the effects of gear efficiency and to improve the signal to noise ratio in the data: apply occupancy models to estimate detection probabilities; do extensive training of field crews on boat and net deployment methods to minimize variability within and among sampling crews; perform repeat sampling to estimate variability among sampling crews; and measure covariates that may be correlated with gear efficiency (e.g., velocity, turbidity, temperature).
- **Periodic resurveys of IRCs.** Re-surveys will be used to update hydrodynamic models as geomorphology evolves, and will indicate whether IRCs are physically sustainable. Hydrodynamic models will also provide insights into the role of the flow regime in providing IRC habitats.

4.2.6.3.5 *Metrics*

The means objectives by which the USACE will be evaluated in meeting their obligations under the BiOp are based on the net increase in “effective” acreage of IRC habitat (in acre-days/yr) listed in Table 42. “Effective” acreage is determined by integrating the developed or available IRC habitat with mean daily flows for May through October, expressed as acre-days. These dates correspond with the period of growth for pallid sturgeon (T>13^0 C). IRC habitat occurs where foraging habitat is collocated with or proximal to and downstream of food-producing habitat, and is intersected with hydraulic conditions that would promote interception and retention of free embryos drifting in the channel (typically in June). Habitat metrics are based on measures of depths, velocities, and substrate, including mean and variance, and potentially complemented with metrics of spatial complexity like diversity indices, patch shape, and patch connectivity. The algorithm for calculating IRC habitat might weight the hydrograph in June higher because of the importance of first feeding to survival. Distribution will be evaluated as deviation from a target distribution.

Calculation of effective acreage will require implementation of 2-dimensional computational hydrodynamic modeling at each IRC reach and at each control reach. The hydrodynamic models will be compiled, calibrated, and validated using accepted engineering standards for data collection and model simulation. The models will be run to simulate distributions of depths and velocities over at least 20 increments of discharge ranging from 90% daily exceedance to 10% daily exceedance. The outputs of the models will be integrated in geographic information systems (GIS) to evaluate the areas of depths and velocities that meet the prevailing definitions of IRC food-producing and foraging habitats that exist at each incremental discharge (Figure 75). The present definitions of food-producing and foraging habitats overlap in part with SWH (Figure 75), but food-producing habitat can be substantially deeper and foraging habitat is both deeper and faster. The physical criteria describing IRCs are provided in section 4.2.6.3.2, Action Description. Additional metrics may be calculated in the GIS to explore more habitat affinities and patch dynamics.

This evaluation step yields area of habitats as a function of discharge. The daily time series of discharges in the reach (either modeled as in the EA or actual discharges measured at nearby stream flow gaging stations) are then used to calculate how much habitat is available, on average, for each day during the growing season, yielding acre-days. Acre-days of habitat will usually be evaluated as average acre-days per year over some number of years. This process provides flexibility to change habitat and growing-season definitions as new information is developed, or possibly to weight certain critical time periods more strongly in the calculation.

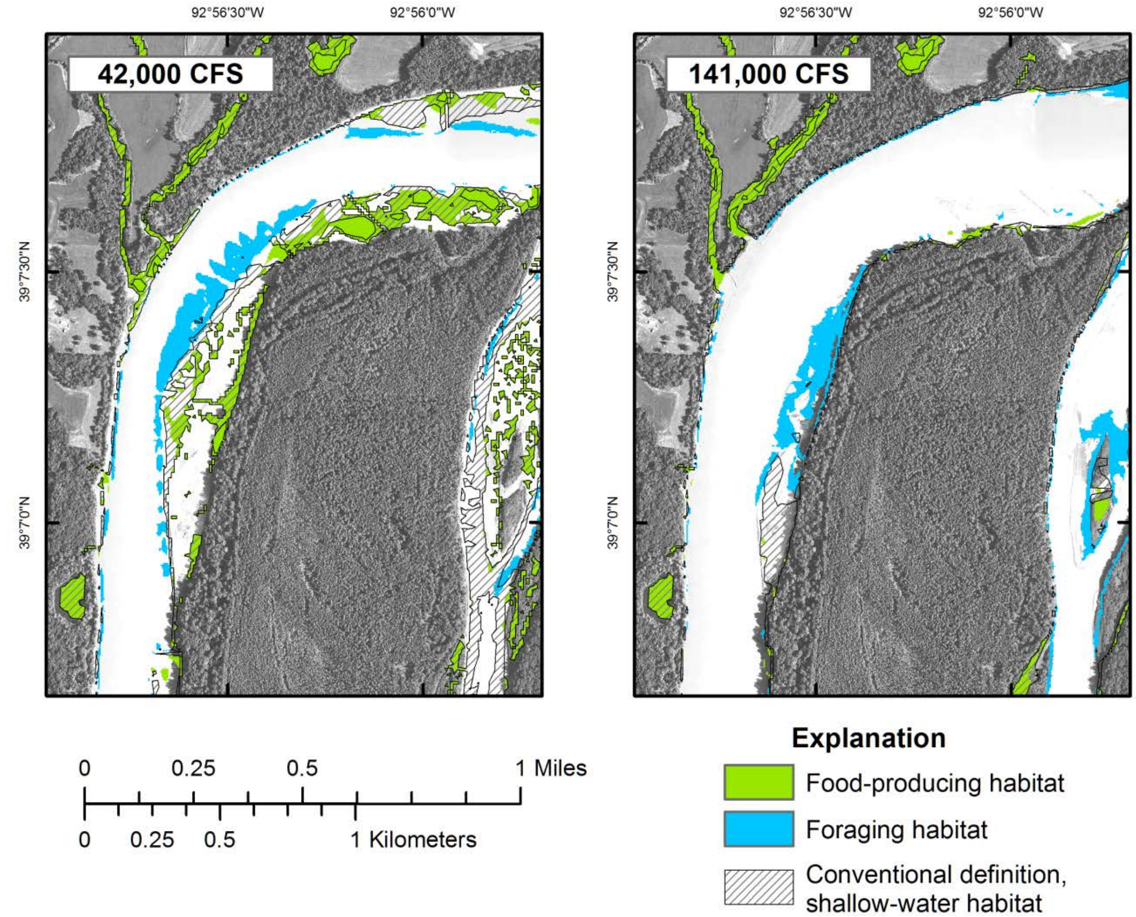


Figure 75 Maps of food-producing and foraging habitats modeled with a hydrodynamic model, river mile 219, Lower Missouri River, at two discharges. Food-producing and foraging habitats are two components of IRCs; conventionally defined shallow-water habitats are shown for comparison. Left side: Habitats at discharge of 42,000 cubic feet per second (cfs). Right side: Habitats at discharge of 141,000 cfs.

Performance of IRC actions will also be based on a subset of metrics addressing the primary objectives outlined above. The effectiveness of projects in promoting interception will be based primarily on CPUE of age-0 sturgeon at project (pre- and post-implementation) and reference sites, as described in Appendix E. Effectiveness in terms of food production will be based on production of food per unit area, survival and indicators of starvation or impending death of age-0 pallid sturgeon (percentages of empty/full stomachs; lipid content). Effectiveness in terms of foraging will be based on gut content and survival of age-0 pallid sturgeon with consideration for bioenergetics requirements of age-0 pallid sturgeon, and possibly the use of bioenergetics models. Survival rates of hatchery-reared first-feeding pallid sturgeon larvae released in the Missouri River may serve as a metric for all three IRC elements. Further Level 1 work is required to determine how mark-recapture techniques could be used to estimate survival rates of released hatchery larvae at various scales (i.e., within IRCs, in the thalweg, across multiple IRCs, to age-1). Hatchery origin or parentage will also be of interest, and may help to explain variability in abundance across hatcheries or genotypes.

These various performance measures will provide multiple lines of evidence for evaluating the habitat and biological benefits of IRCs. Research will explore alternative ways in which these multiple performance measures could be integrated for making decisions on the various phases of development of IRCs (described in Table 42 and USFWS (2016)).

4.2.6.3.6 *Decision Criteria*

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. The targets for implementation (Table 42) afford a straight-forward measure of compliance with the means objectives for IRCs at Level 3. Net increases in habitat will be computed on an annual basis. The intention is to permit flexibility to address needs while promoting learning through Level 2 actions and to address programmatic requirements related to pallid sturgeon. Performance relative to targets will be assessed using a running average of annual lift in effective acre-days of IRC habitat (described above in section 4.2.6.3.5). Acceptable performance is meeting or exceeding the targets in Table 42 based on a three-year running average for at least 4 of every 5 years (80% success rate). Level 3 / Stage 3 targets could be revised based on the outcome of actions at Level 2 / Stage 2.

Additional decision criteria for prioritized Level 1 and Level 2 studies are listed above in Table 44 (with all L1 and L2 studies listed in Appendix C), and below in Table 53 for Level 2/3 studies. If experimental results in Level 2 studies fail to demonstrate an increase in key metrics relative to control areas and pre-treatment conditions, there are several potential responses depending on syntheses of all lines of evidence: IRC designs may need to be adjusted to be more effective; the hypothesis may need to be refined; the hypothesis should be moved into set of the reserve hypotheses; or the hypothesis should be abandoned. If the experimental results support the hypothesis that channel reconfigurations can provide increased food-producing and foraging functional habitats, and increase pallid sturgeon condition, then the decision would be to move toward Level 3 implementation. The four stages of development of IRCs proposed by the USFWS are described in USFWS (2016) and summarized in Table 42.

<u>Triggers for Moving to Higher Implementation Level</u>: The decision to move from Level 3 to full implementation at Level 4 will be based on a systematic relationship between IRCs and increases in growth and survival of age-0 sturgeon that permits modeling of

the needed scope of IRC implementation to meet the fundamental objectives. This judgment should be based on the strength and replicability of functional relationships between abiotic habitat variables describing food and forage habitats, and growth and survival of age-0 sturgeon. In addition, the need for supplemental flow management at Level 3 or 4 would be based on the availability of sound functional relationships between flow conditions, IRC habitat, and growth and survival of age-0 sturgeon.

Timeframes: The timeframes for implementation of IRC habitat work are described in USFWS (2016) and summarized in Table 42.

4.2.6.3.7 *Level 3 Contingent Actions*

Contingency plans for IRCs are mainly associated with the secondary objectives (e.g., structure manipulations will not adversely affect navigation); however, adjustments to the targets, habitat criteria, methods, etc. might be required if performance fails to meet expectations. Analyses of performance across multiple water years and multiple IRC sites may reveal flow management strategies that enhance the performance of IRCs.

4.2.6.4 *Interception and Rearing Complexes (IRCs) via Modification of Existing Shallow Water Habitat (SWH) Projects*

The 2003 BiOp presents a reasonable and prudent alternative (RPA) that contains requirements for the restoration of SWH in the channelized portion of the Missouri River. According to the 2003 BiOp, SWH may be restored through flow management, increasing the top width of the channel (top-width widening), restoring chutes and side channels, manipulation of summer flows, or combinations thereof (USFWS 2000, 2003). Modification of in-channel structures, top-width widening, and creation of chutes and backwaters are SWH restoration measures that have been implemented (USACE 2014). Table 47 provides the numbers, locations and types of SWH construction actions through 2014 (USACE 2014).

Table 47. Number of SWH construction actions by USACE river segment (11 is Ponca to Big Sioux River; 12 is Big Sioux River to Platte River; 13 is Platte River to Kansas River; 14 is Kansas River to Osage River; 15 is Osage River to the Mississippi River).

River Segment	Main Channel Modifications						Off-Channel Projects	
	Dike Notching[1]	Major Modification Actions[2]	Dike Extension	Dike Lowering	Revetment Chute	Channel Widening	Side-Channel Chute	Backwater
Segment 11	--	--	--	--	--	--	--	--
Segment 12	95	123	--	--	--	3	12	9
Segment 13	487	231	--	27	10	--	13	5
Segment 14	788	--	16	36	7	--	13	--
Segment 15	327	--	20	--	3	--	1	--
Total # of Actions	1,697	354	36	63	20	3	39	14

[1]actions include dike notching, type B notching, rootless dikes, revetment notches, and bank notches.
[2]actions include chevron construction and other similar actions

4.2.6.4.1 Hypotheses

Hypotheses 17 to 19, identified in section 4.2.6.3.1 (and discussed in the EA) are relevant to this action. The EA (Jacobson et al. 2016a) found theoretical support for all of these previously referenced hypotheses, and they are further supported by hydrodynamic modeling, but the data were equivocal as to whether IRC habitat was a limiting factor (Table 38). Testing these hypotheses will require a nested set of more detailed hypotheses structured for statistical and modeling analyses, as discussed further in section 4.2.6.4.4 on Experimental Design. Modification of existing SWH projects to test this subset of hypotheses may be more cost-effective compared to building new IRC projects and thereby permit earlier assessments of project performance and corresponding species response. The action-related hypothesis for this action ($H_{SWH \rightarrow IRC}$) is as follows:

> $H_{SWH \rightarrow IRC}$: A subset of Shallow Water Habitat projects can be successfully converted into effective IRC habitats, providing suitable interception, food production and foraging habitats for exogenously feeding larvae and juveniles, which result in higher abundances, stronger growth and better survival of age-0 pallid sturgeon.

4.2.6.4.2 Action Description

IRCs are areas that meet the functional definitions laid out in the EA Integrative Report (Jacobson et al. 2016a). While the proposed criteria for food-producing and foraging habitat components of IRCs are narrower than the previous definition of SWH, significant overlap in the depths and velocities of the three habitat types exist, so existing SWH projects can be modified to provide IRC habitat. A functional IRC exists where the juxtaposition of the described habitats is such that all three functions are performed and collectively contribute to survival to age-1, which is similar to the intended design of many chute projects. There can be a significant time lag, however, between chute construction and the development of desired habitat conditions. In naturally-functioning chutes and side channels, it is common for sediment to be deposited in the entrance and extend downstream. Sedimentation in the chute contributes to reduced velocities and additional deposition within the chute that may limit benthic fish access to the chute. As this process proceeds, the depth, morphology, and velocities in the chute evolve, leading to habitat diversity. Habitat diversity may similarly evolve through widening and lateral migration of the channel if conditions allow it to erode. In some cases, chutes also have the potential to develop excessive depths, higher than desired velocities, and minimal habitat diversity, which could require post-construction modifications including inlet and grade control structures, structures to promote meandering, structures to promote local scouring, etc. to achieve the desired benefits.

The availability of food-producing and foraging habitats within existing SWH projects, specifically chutes, varies with flow and the chute morphology. The location of a chute entrance within a river bend and the configuration and elevation of control structures can influence the ability of chutes to intercept drifting free embryos (and sediment). Consequently, IRC habitat within chutes is both flow-dependent and time-variant and can potentially be improved by both mechanical manipulations of river geometry and flow-management actions. See section 4.2.6.3.2 for more discussion regarding the utilization of flow management to reach level 3 IRC targets.

Level 1 and 2 activities associated with the modification of SWH projects to become well-functioning IRCs focus on: 1) defining the need for additional IRC habitat in different river sections, and how much is required, 2) refining existing empirical relationships among habitat attributes, flow (utilizing current operations), channel morphology, and observed occupancy by age-0 fish, 3) assessing the spatial and temporal distribution of desired habitat attributes, and 4) determining the feasibility of various mechanical and flow-management actions to reconfigure existing SWH projects into functional IRCs. The general timeline for actions to assess and refurbish SWH projects is shown in Figure 73. Level 1 and 2 activities will incorporate habitat projects that have already been completed. Although the focus has changed from SWH to IRCs, much can be learned from existing SWH projects and it is expected that many SWH projects may address one or more functional components of IRCs.

For discussions on Level 3 and 4 IRC activities see 4.2.6.3.2.

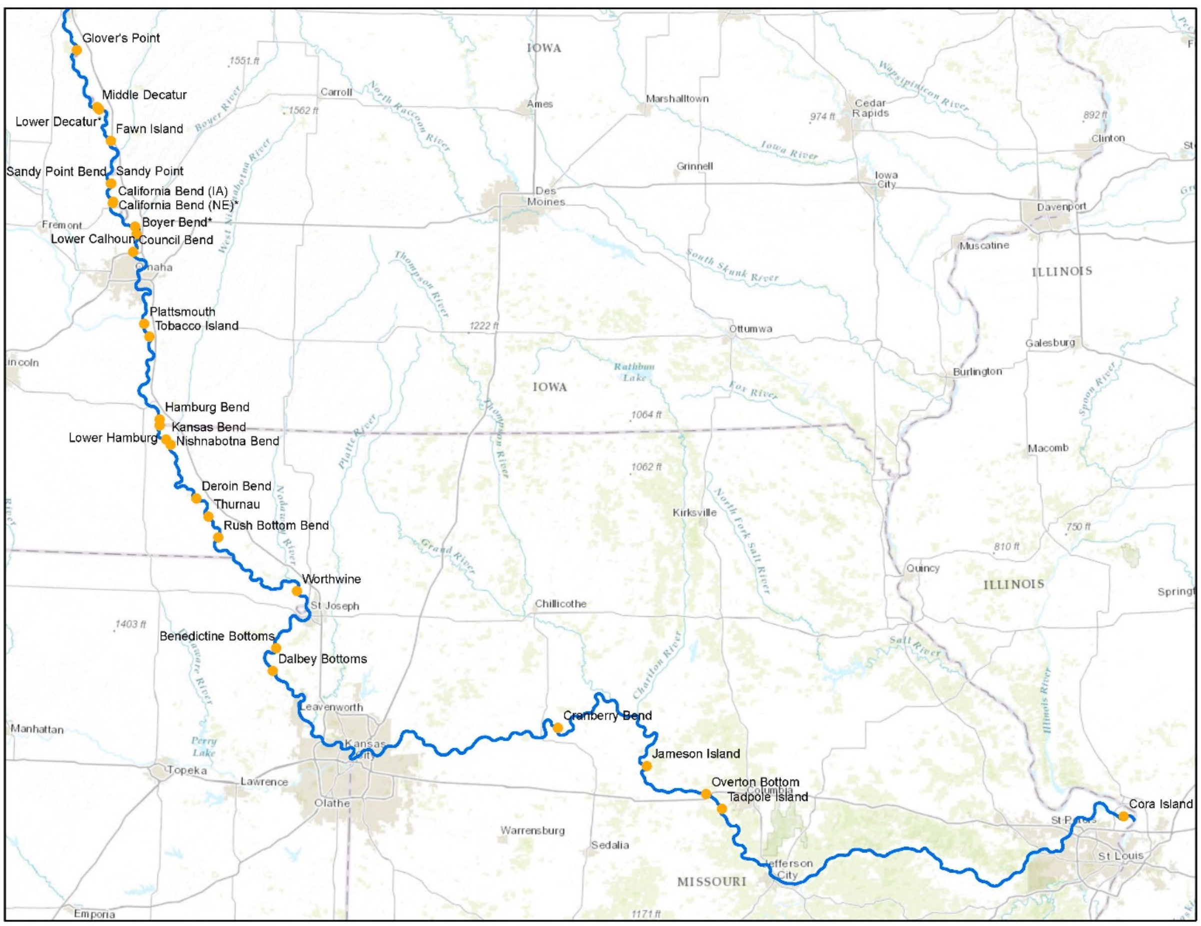


Figure 76. Existing chute locations that may be available for modification to provide IRC habitats.

4.2.6.4.3 Objectives

The primary objectives of modifying existing SWH sites to provide IRC habitat are the same as the objectives identified for IRCs in section 4.2.6.3.3. Significant increases in IRC habitat could be achieved by modifying non-functional or underperforming chute projects. Because in many cases they are allowed to erode and migrate laterally, chutes provide a set of attributes and functions not found in other mainstem SWH projects. Chutes have higher potential to deliver large wood, increase retention of wood, and develop point bars that promote natural riparian vegetation successional patterns. Chutes therefore provide an opportunity to better understand the relationship between physical processes, habitat development, and benefits to pallid sturgeon. It will be important to manage risks and ensure that modification of existing SWH sites generates a net positive effect (i.e., does not reduce the availability of other important habitat types or limit recruitment in the lower Missouri River, either locally or systemically) and does not interfere with the IRC experimental design referenced in section 4.2.6.3.4. Secondary objectives are to contribute to the IRC targets and to ensure that impacts to HCs are minimized.

4.2.6.4.4 Experimental Design

The choice of experimental design used to assess whether existing SWH chute projects can be modified to IRC habitats depends on the quality and quantity of existing data and the anticipated time for chute modifications to yield measurable responses. Some existing chute sites have baseline physical and biological data. Unlike the IRC monitoring proposed above, however, control sites are not available, so the analysis may take the form of a Before-After (BA) design. A key attribute of a BA design is that the impact is immediate. However, habitat changes in response to existing project modifications may take several years. Therefore, comparing the rate and direction of change in the distribution and amounts of suitable food producing and foraging habitats, pre and post construction, within individual chutes may be the most beneficial for determining success at the project scale.

An alternative to a simple BA design would be the following BACI or staircase design:

- Determine the subset of SWH chute projects which could potentially become functional IRC habitats (sites that have no potential for rehabilitation are excluded from the design);
- Randomly divide the subset of sites with rehabilitation potential into treatment and control chutes, and immediately begin (or continue) monitoring physical and biological metrics;
- Design rehabilitation actions for each chute to be treated;

- Implement rehabilitation actions in the treatment chutes, either all at once (BACI design) or gradually over time (staircase design);
- Monitor both treatment and control chutes for an appropriate length of time to assess trends in physical and biological metrics (at least 6 years after implementation of rehabilitation actions);
- Use methods like those described in Wiens and Parker (1995) to compare the trends in physical and biological metrics in treated vs. control sites (the differences between treated and control sites should increase over time in the intended direction if the actions are working); and
- If treated sites show significantly greater improvement in physical and biological metrics than the control sites, then design and implement rehabilitation actions in the control sites, so as to increase the benefits to pallid sturgeon.
- This schema recognizes that control and treatment chutes will likely vary considerably in their inherent hydrologic and geomorphic characteristics, and this divergence will somewhat lower statistical power.

The Nebraska Game and Parks Commission (NGPC) and Missouri Department of Conservation (MDC) have recently proposed an approach for analyzing the availability of habitat in chutes. This method quantifies available age-0 sturgeon habitat within chutes at a specific discharge. Additional information regarding the relationship between flow and habitat availability within chutes at a variety of river stages could be obtained via 2-D modeling. This methodology may prove effective at assessing the evolution of habitat conditions within chutes, and may also allow for comparisons among chutes. This approach could be used to screen existing chutes to identify those that may already be providing significant amounts of IRC habitats, those that require modifications to provide well-functioning IRCs, and chutes that are not likely to provide IRCs. A Chute Assessment and Monitoring Plan will be developed and included as Attachment 2 to Appendix E. This plan will describe the steps necessary to evaluate habitat availability and interception within existing chutes, steps necessary to modify existing chutes to promote IRCs, and a methodology for assessing the progress of modified chutes towards IRCs.

4.2.6.4.5 Metrics

The means objectives by which the USACE will be evaluated in meeting their obligations under the BiOp are based on the net increase in “effective” acreage of IRC habitat (in acre-days/yr) from existing SWH sites. “Effective” acreage will be calculated as described in section 4.2.6.3.5. As described in section 4.2.6.3.5, metrics will be based on measures of depths, velocities, and substrate, including mean and variance, and potentially complemented with metrics of spatial complexity like diversity indices, patch shape, and patch connectivity. Successful rehabilitation of a chute or other habitat unit would be indicated by positive trends in the fraction of the habitat area with suitable habitat characteristics for IRCs, and evidence of desired directions of changes in depths, velocities and substrates according to the site-specific design. Unsuccessful rehabilitation would be indicated by no change (or a decrease) in the fraction of the habitat area with suitable habitat characteristics, and evidence that depths, velocities and/or substrates are not evolving in the desired direction. As for IRCs, increased densities of age-0 fish (as estimated by catch per unit effort) would provide a primary biological performance measure, ideally supplemented by estimates of survival. As discussed in section 4.2.6.3.4, it would be helpful to have an estimate of upstream egg production in that year as a covariate in statistical analyses of before-after, or BACI comparisons, though estimating this covariate will be difficult. Alternatively, a "year effect" could account for year-to-year variations in egg supply.

4.2.6.4.6 Decision Criteria

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. The targets for implementation (Table 42) afford a straight-forward measure of compliance with the means objectives for IRCs at Level 3, computed on an annual basis using 2D hydrodynamic models. Net increases in habitat will be computed on an annual basis. The intention is to permit flexibility to address needs while promoting learning through Level 2 actions and to address programmatic requirements related to pallid sturgeon. Performance relative to targets will be assessed using a running average of annual lift in effective acreage of IRC habitat (described above in section 4.2.6.3.5). Acceptable performance is meeting or exceeding the targets in Table 42 based on a three-year running average for at least 4 of every 5 years (80% success rate).

Additional decision criteria for Level 1 and Level 2 studies are listed above in Table 44, and below in Table 53 for Level 2/3 studies. If experimental results in Level 2 studies fail to demonstrate an increase in key metrics relative to control areas and pre-treatment conditions, there are several potential responses depending on syntheses of all lines of evidence: IRC designs and locations may need to be adjusted to be more effective; the hypothesis may need to be refined; the hypothesis should be moved into set of the reserve hypotheses; or the hypothesis should be abandoned. If the experimental results support the hypothesis that channel reconfigurations can provide increased food-producing and foraging functional habitats, and increase pallid sturgeon condition, then the decision would be to move toward Level 3 implementation.

<u>Triggers for Moving to Higher Implementation Level</u>: The decision to move from Level 3 to full implementation at Level 4 will be based on a validation of a systematic relation

between IRCs and increases in growth and survival of age-0 sturgeon that permits modeling of the needed scope and distribution of IRC implementation to meet the fundamental objectives. This judgment should be based on the strength and replicability of relations between abiotic habitat variables describing food and forage habitats, and growth and survival of age-0 sturgeon. In addition, the need for supplemental flow management at Level 3 or 4 would be based on the availability of sound relations between flow conditions, IRC habitat, and growth and survival of age-0 sturgeon.

Timeframes: Implementation of IRC habitat at Level 3 will occur no later than two years post-ROD. There is no time limit for the transition to Level 4.

4.2.6.4.7 Level 3 Contingent Actions

Contingency plans for modifying existing SWH projects into IRCs are mainly associated with the secondary objectives (e.g., structure manipulations will not adversely affect navigation); however, adjustments to the targets, habitat criteria, methods, etc. might be required if performance fails to meet expectations. Analyses of performance across multiple water years may reveal flow management strategies that enhance the performance of modified SWH projects.

4.2.6.5 *Spawning Habitat*

The action of creating spawning habitat relates to Big Question 5: Can channel reconfiguration and spawning substrate construction increase the probability of survival through fertilization, incubation, and hatch?

4.2.6.5.1 *Hypotheses*

The following hypothesis is relevant to this action:

> H16. Re-engineering of channel morphology in selected reaches will create optimal spawning conditions -- substrate, hydraulics, and geometry -- to increase probability of successful spawning, fertilization, embryo incubation, and free-embryo retention.

Delonay et al. (2016) provide a review on what is known and not known about the spawning of pallid sturgeon in the Missouri River, and the subset of sites for which spawning has been rigorously confirmed. Some key points (Robb Jacobson and Aaron Delonay, USGS, pers. comm.) that are helpful for understanding the inherent challenges in testing hypothesis H16 are as follows:

- Figure 77 shows the distribution of known spawning sites in the lower Missouri River. The spatial distribution of spawning areas in Figure 77 reflects both where females were originally tagged (two groups, one upstream and one downstream) as well as where field observations were able to infer that spawning occurred.

- Spawning is most accurately confirmed by intensively tracking the movement of tagged females, and the release of their eggs, usually between the first week of April and the first week of May. Detection of eggs and embryos downstream is further confirmation of spawning, but this has not been done for most of the sites shown in Figure 77. Males tend to aggregate at spawning areas and then wait for females, but it isn't possible to know the distribution or movement patterns of untagged fish (most tagged fish are females raised in a hatchery).

- Recent observations indicate that juveniles produced from wild parents are returning to the Nebraska portion of the Missouri River, but this area also has fish in poor condition which could delay spawning (section 4.1.2.4). Net sampling of free embryos, genetic identification and back-calculation of presumed spawning locations based on the advection-dispersion model indicate that fish spawned successfully in 2014 around the Sioux City area above the Platte River.

- Tagging permits identification of repeat spawners, which has shown that some females have spawned in the same location in different years, while others have spawned in different locations in different years, sometimes over 100 km apart (Robb Jacobson, USGS, pers. comm.).

- Acoustic telemetry is not always sufficiently accurate to identify the exact location of spawning, due to noise interference from boat vessels.

The EA found that there was theoretical support for hypothesis H16 based on support from sturgeon species and hydrodynamic models, but that data were equivocal as to whether spawning habitat was a limiting factor. It is important to determine whether or not current spawning is successful at existing spawning sites, so as to determine the need for additional spawning habitat, and the attributes of spawning habitat which currently leads to successful spawning. Testing hypothesis H16 will require a nested set of more detailed hypotheses that are structured to be amenable to specific statistical and modeling analyses, discussed further in section 4.2.6.5.6 on Experimental Design.

The spawning habitat hypothesis (H16) is highly uncertain, with multiple hypotheses influencing potential directions and action. The hypothesis with the highest potential to provide rapid learning and insight is that high quality spawning habitat is limiting. Pilot projects (at Level 2) to address this hypothesis can be implemented within a few years and could greatly improve our understanding of the relationship between spawning habitat and successful reproduction.

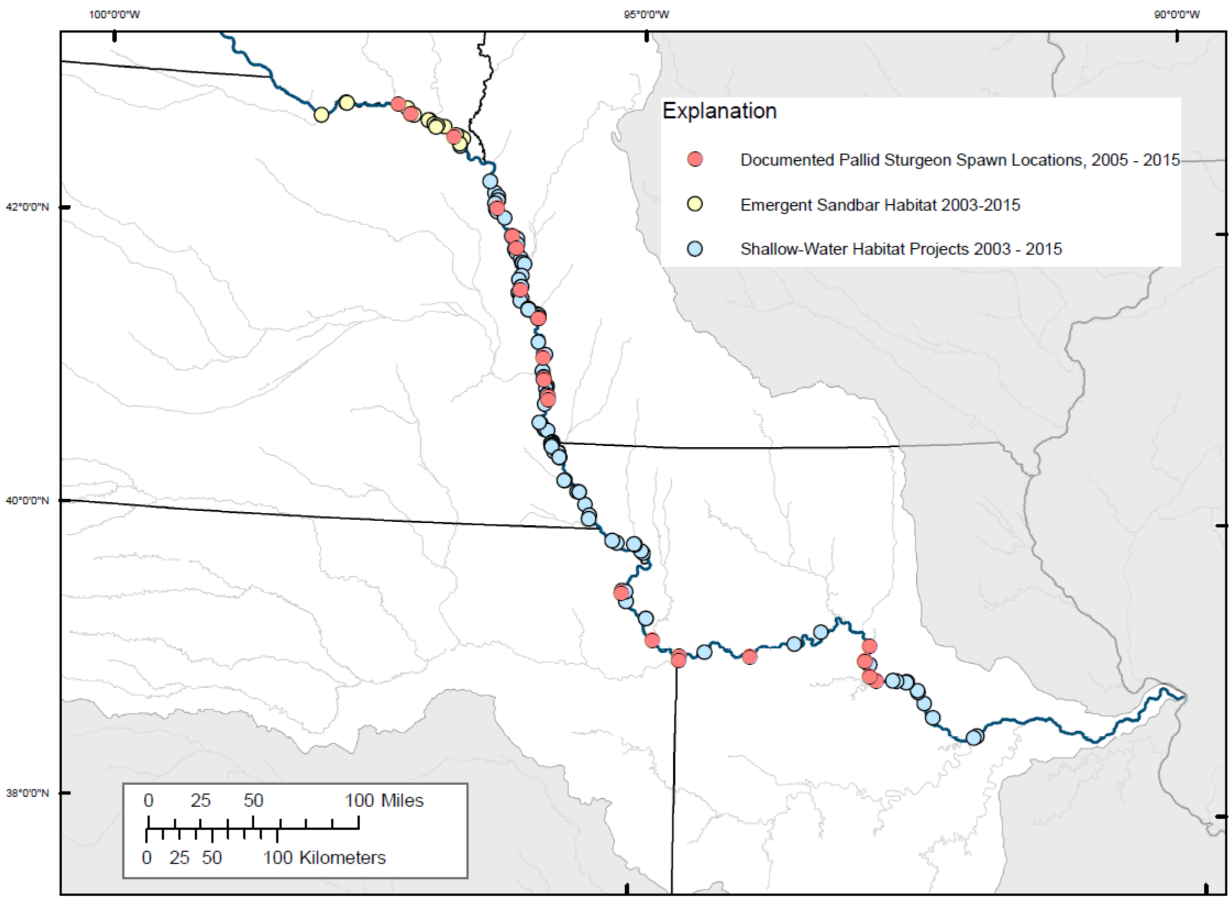


Figure 77. Distribution of known spawning sites in the lower Missouri River.

There are two competing high-level hypotheses regarding spawning habitat concerns: one hypothesis is that additional high-quality spawning habitat is needed, while the opposing hypothesis is that too much poor-quality (i.e. “confusion”) spawning habitat exists on the river, dispersing pallid sturgeon among multiple spawning sites. Because the first hypothesis is much easier to test, the AM strategy will focus on that hypothesis first and pursue the confusion habitat hypothesis only if Level 1 or 2 studies reject the first hypothesis or provide added support to the second. Removal of confusion habitat could be very difficult. A decision tree (Figure 78) has been developed to guide the development of decision criteria related to level 1 through 3 spawning habitat activities. An ideal outcome would be that the development of very high quality spawning habitat will attract fish away from low-quality confusion habitat, and that gradual degradation of confusion habitat will increase the relative attractiveness of high quality spawning habitat. If fish are not attracted to the created spawning habitat, this could mean that either spawning habitat is not limiting, or that the design needs to be adjusted.

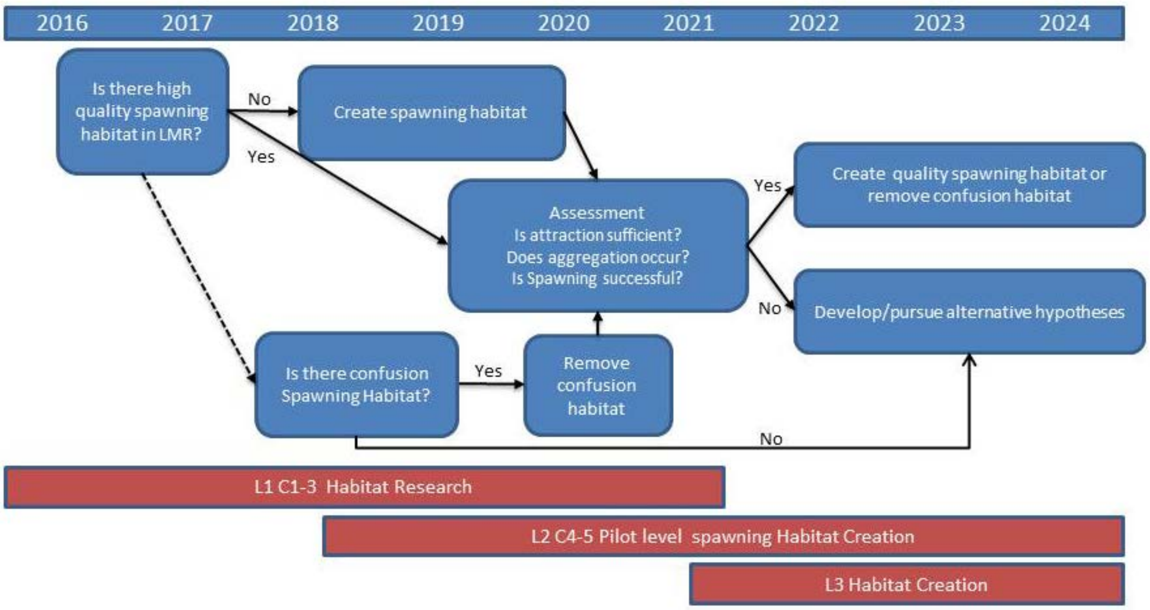


Figure 78. Decision tree for spawning habitat. Source: USFWS and USACOE (2015)

4.2.6.5.2 *Action Description*

We presently do not have sufficient understanding to characterize the necessary actions at Level 3 or determine quantifiable targets for spawning habitat. The focus of Level 1 and 2 will be to reduce the uncertainty regarding spawning habitat characteristics and needs for successful recruitment.

An early emphasis will be to utilize information from the Yellowstone River as the best natural reference condition to inform the design of Level 2 pilot projects on the Lower Missouri River, while also continuing to examine the habitat characteristics of spawning sites on the Lower Missouri. Pilot projects on the Lower Missouri will be monitored for effectiveness based on metrics ranging from observed aggregation to the number of free embryos in the water column (described below in section 4.2.6.5.5 on metrics). Level 3 targets for spawning habitat may be beyond the 15 year timeline under the planning process, depending on the rate of learning from Level 2 activities. If hypothesis H16 is correct (spawning habitat is limiting), costs and impacts on other uses should be relatively low, and construction relatively easy. In contrast, should the confusion hypothesis be true, the costs and potential impacts on other uses are likely to be much greater.

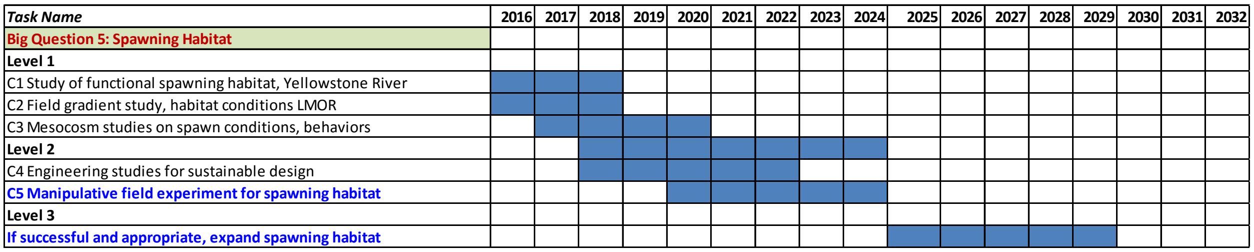


Figure 79. Proposed sequencing of actions and studies for spawning habitat, revised from USFWS and USACOE (2015) to reflect current USFWS priorities and timelines.

4.2.6.5.3 *Objectives*

The objectives of Level 1 studies of spawning habitat are to:

- Determine the characteristics of ideal spawning habitat for pallid sturgeon, based on observations of successful spawning sites on the Yellowstone River (BQ5/L1/C1 in Table 44);
- Assess the habitat characteristics of historical spawning sites on the Lower Missouri River (BQ5/L1/C2 in Table 44); and
- Use mesocosms to experimentally determine how spawning varies with depth, velocity, substrate, hydraulic variables and water quality (BQ5/L1/C3 in Table 44).

Level 2 studies have the following objectives:

- Apply advection dispersion models, population models and engineering studies to determine how to create and sustain the ideal hydraulic and substrate conditions determined from Level 1 studies, and to evaluate appropriate locations (river segments) for creating spawning habitat based on both past utilization and channel / substrate characteristics (BQ5/L1/C4 in Table 44).
- Create at least 1high quality spawning habitat site (Table 42) , and monitor the effectiveness of this action in terms of the *relative use* of this site compared to control areas, and the *relative spawning success*, as determined by hatch rate, catch per unit effort of free embryos and other indicators (BQ5/L1/C5 in Table 44).

Though multiple high quality spawning habitat sites would have benefits from the perspective of experimental design (i.e., a replicated treatment), initially developing just one high quality spawning site appears to be preferable from a biological perspective (i.e., more likely to concentrate males and females at one location and time, reduced risk of hybridization with shovelnose sturgeon, greater ability to target flow manipulations if they are implemented in the future – discussed in section 4.2.6.6). The tradeoffs between a single site versus multiple sites are discussed further under section 4.2.6.5.6 , Experimental Design.

4.2.6.5.4 *Expected Benefits*

If Level 1 and Level 2 studies fulfill their objectives, and Level 2 pilot / proof-of-concept projects show improved spawning success over control areas, it will allow the development of Level 3 designs for a larger scale spawning site (or possibly two spawning sites if it appears that pallid sturgeon naturally aggregate in different areas). If the proof-of-concept shows benefits at a site scale, then scaling up should increase both spawning success and the abundance of pallid sturgeon in the Lower Missouri River.

4.2.6.5.5 *Metrics*

Many of the metrics associated with the creation of spawning habitat are identical to those for the Intake Dam (described in section 4.2.5.2.5). Metrics for spawning habitat creation can be organized around a series of questions:

Has suitable spawning habitat been created and maintained? Habitat will be characterized in terms of suitable depth, velocity, substrate, and derivative hydraulic variables (based on studies of Yellowstone spawning), with covariates relating to water quality and fish behaviors. Pallid sturgeon minimize their energy expenditure by migrating up inside bends, and then traverse across to outside bends when they're ready to spawn. Spawning habitat sites will create cross-over points at appropriate outside bends, using a sill across the river to minimize the amount of sand carried over it, while at the same time ensuring that navigation is not affected. Physical monitoring of these sites will involve ensuring that the desired habitat characteristics are being naturally maintained through natural or managed flow releases. One measure of site quality is to compare measured hydraulic variables with the rate at which unfertilized eggs fall down through the water column to evaluate whether eggs are likely to be deposited in the manipulated habitats. In the Yellowstone River, spawning females selected small patches of gravel between dynamically moving sand dunes, whereas the expectation based on past observations was to see spawning on hard substrates. This variability in habitat selection suggests that providing a range of depths, velocities and substrates within a large site would help to determine habitat preferences at a fine spatial scale. Level 1 mesocosm experiments (BQ5/L1/C3 in Table 44) will also be helpful to determine preferences for spawning habitat.

Are created spawning habitats preferred over other areas? With a fixed telemetry network it should be possible to determine the number of times each reproductively ready female encounters the created spawning habitat site, and how often she encounters other potential spawning sites (i.e., outside bends of rivers). Relative preference can then be calculated based on the ratio of documented spawning events to encounter events, for both created and potential spawning sites. The statistical power to detect this releative preference will be proportional to the number of tagged fish in reproductive condition. To detect differences in habitat selection between a created spawning site(s) and control areas, one would ideally have at least 10 to 20 spawning females in reproductive condition at each location, as well as an approximately equal number of males (Aaron Delonay, USGS, pers. comm.). With fish spawning only every 3 years, and roughly two groups of 40 tagged fish in the upper and lower part of the Lower Missouri (mostly females), attaining such sample sizes is unlikely to occur in most years, particularly if many fish remain in poor condition and delay reproduction. One way in which to increase sample sizes would be to precondition a group of 30-40 adult fish to a reproductive state in a hatchery, and then release them downstream of both treated and control sites with fixed telemetry detectors. The feasibility of such an experiment depends upon the outcome of the Basin-wide Stocking and Augmentation Plan for pallid sturgeon.

Other metrics relevant to this question are measures of fish aggregation and spawning behaviors (for example, optimum male: female ratios in spawning aggregations), and the degree of attraction/specificity of adults to different spawning substrates.

Does successful spawning occur in the created spawning habitats? This question is very similar to Q3 discussed in Table 46 for Intake (Does successful spawning and aggregation occur?), and Q3 in Table 48 for spawning cue flows (Do upstream movements and spawning aggregations lead to documented successful spawning?), and would use similar metrics. Multi-receiver, 3D telemetry and DIDSON (Dual Frequency Identification Sonar) video can be used to evaluate behaviors of reproductive adults on the spawning patches to identify spawning aggregations and egg-release events. The ultimate metric for spawning habitat is hatch rate as a function of habitat availability. Deploying ichthyoplankton nets downstream of sites with apparent spawning is used to capture eggs and embryos to confirm that spawning has occurred. Females can also be recaptured to determine if they have released their eggs. Repeat high-resolution multi-beam maps of the spawning patches during incubation will indicate whether the substrate is subject to burial or erosion, which is likely to result in zero hatch. Monitoring of age-0 fish downstream of spawning habitats will be important; a redesigned PSPAP (Appendix D), including increased numbers of genetically tested age-0 sturgeon, will help to improve evaluation of recruitment.

Is recruitment successful and sufficient to meet population targets? This question depends on the outcome of not only spawning, but also survival of free embryos and feeding larvae over the first year of life. The primary metric is catch rates of age 0 and age 1 pallid sturgeon; secondary metrics include model-based estimates of abundance of age 0 and age 1 pallid sturgeon, and the survival of hatchery and naturally reproducing fish to age 1.

4.2.6.5.6 *Experimental Design*

The experimental design of L2 spawning habitat actions needs to accomplish three things: 1) maximize the effectiveness of newly created spawning habitat; 2) create contrasts over space and time to evaluate the effectiveness of this habitat (test hypothesis H16); and 3) avoid confounding from other potential L2 and L3 actions.

Potential Locations. Spawning habitat would ideally be placed in locations which maximize aggregation of males and females, spawning success, and the survival of spawners' progeny (i.e., embryos, exogenously feeding embryos and larvae). The EA suggested that sites should be located where they would be encountered by reproductive pallid sturgeon at or near the upstream apex of their reproductive migration (Jacobson et al., 2016a). Level 1 studies (especially observations of spawning migrations and locations) and Level 2 engineering and modeling studies (Table 44, Big Question 5) will help to determine the best locations.

Figure 74 shows potential locations for newly created or enhanced spawning habitat between Sioux City and Decatur, and between Decatur and Omaha. The area between Sioux City and Decatur provides a convergence of four attributes: near the upstream apex of reproductive migrations; close enough to Gavins Point Dam to ensure that flow pulses maintain spawning habitat quality; far enough downstream from Gavins Point Dam to allow for the recovery of some turbidity in the river (necessary to reduce predation on embryos); and far enough upstream to allow sufficient drift distances for embryos to mature into feeding stages and utilize IRC habitat much farther downstream (also in Figure 74). Locating spawning habitat downstream, say near Booneville, Missouri, would provide free embryos that would drift into the Middle Mississippi River. While such fish might still potentially return to the Missouri River, they would not be sufficiently mature to utilize IRC habitats in the Missouri River and therefore might have lower survival. Other potential locations for creating spawning habitat include the unchannelized 59-mile reach below Gavins Point.

As stated above, it would be preferable to initially implement only one spawning site. If however, evidence were to indicate that aggregations were occurring naturally in more than one area after creation of the first spawning site, and/or it were possible to use preconditioned hatchery fish for a spawning site selection experiment, then the area between Decatur and Omaha might be another possible location for a future spawning site. A site between Decatur and Omaha would avoid confounding the effectiveness monitoring of two level L2 actions: spawning habitat creation and spawning cue flows. A spawning cue flow (if it were implemented after year 9 from Gavins Point – see section 4.2.6.6) would dissipate downstream, allowing for the utilization of spatial contrasts within the years that such flows occur. If spawning habitat sites were only available between Sioux City and Decatur, and this portion of the river were also subject to a strong signal from an L2 spawning cue flow, then it would be difficult to determine whether a concentration of spawners at these sites were due to the spawning cue flow, the spawning habitat, or both. Providing an additional spawning habitat site further downstream between Decatur and Omaha (an area with a weaker signal from a Level 2 spawning cue flow) would help to reduce the potential confounding of the two treatments (i.e., spawning cue flows and spawning habitat creation).

In their review of Version 3 of the AMP, the ISAP (2015) made the following comment, which suggests it would also be worth considering creating spawning habitat in the upper reaches of the Lower Missouri River:

> A potential justification for focusing on reproductive success in the upper reaches of the lower Missouri River is that embryos produced farther upriver would be more likely to remain in the Missouri River rather than being transported to the middle Mississippi River, depending on flow conditions. And, the role of the Mississippi River in providing rearing capacity for pallid sturgeon that might later migrate into the lower Missouri River to mature and reproduce remains unclear. If that capacity is high, then suitable spawning habitat in most locations on the lower Missouri River could provide valuable contribution to pallid sturgeon recovery. [pg. 19]

Development of spawning sites at Level 2 would logically proceed with a proof-of-concept at one location, and necessary adjustments to the design until success is achieved or the hypothesis is rejected. If success is achieved, and the first site shows evidence of over-crowding, then it would be worth considering expanding the first site prior to building additional sites, so as to maintain aggregation. ,

Are created spawning habitats preferred over other areas? The experimental design would involve the use of a stationary telemetry network to determine the number of *actual spawning events* (i.e., selecting a site for spawning) and the number of *encounters with potential spawning sites*, for both the created spawning habitat and *n* control areas for telemetered fish (every outside bend encountered by a spawning female is a potential spawning site and therefore a control area). The prediction to be tested (consistent with hypothesis H16) is that the ratio of actual spawning events to encounters with potential spawning sites will be significantly higher for the newly created spawning habitat than for the control sites.

Does successful spawning occur in the created spawning habitats? The metrics described above in section 4.2.6.5.5 would be measured at the newly-created spawning site and 3 control sites that were selected for spawning. The prediction to be tested (consistent with hypothesis H16) is that spawning success (assessed by multiple metrics) will be higher at the newly created spawning sites than at the control sites.

Are newly created spawning sites beneficial for the population? By definition, actions at Level 2 are at an insufficient scale to have an *actual* effect on the population (see Table 39), and therefore the effects of Level 2 spawning habitat creation would not be expected to be detected in population monitoring. However, the potential population benefits of this action can be inferred through the use of the collaborative population model. For example, if the probability of site selection and successful reproduction was 5 to 10 times higher at spawning sites than at control sites, one could model the potential population benefit of such an effect.

4.2.6.5.7 *Decision Criteria*

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. The relevant decision for the Level 2 studies associated with hypothesis H16 would be whether to move forward into full implementation, change the experimental patch design, or abandon the spawning habitat quality hypothesis and pursue the confusion habitat hypothesis. Robust statistical results cannot be expected for the preferred metric (hatch rate) because of the difficulties in enumerating this under field conditions. However, the results of other metrics described above should contribute to a lines-of-evidence decision of whether the spawning patches are functioning as intended.

<u>Criteria for Accepting or Rejecting Hypotheses</u>: Lines of evidence discussed above for each question.

<u>Triggers for Moving to Higher Implementation Level</u>: Fish use created spawning habitats in multiple years at a rate significantly greater than control sites; hatching success is greater at created spawning sites than at control sites; the simulated benefits of high quality spawning habitat (based on empirical measurements) suggest that scaling up the action to Level 3 or 4 would have a significant benefit to the pallid sturgeon population.

Timelines: No specific timeline for these hypotheses has been established, though the timelines in the above figures provide a sense of the expected outlay of effort and the sequencing/dependencies of certain activities.

4.2.6.5.8 *Level 3 Contingent Actions*

Information provided through field experimentation will indicate whether channel geometries and/or substrate should be altered to improve performance of spawning patches, and whether additional locations would contribute to spawning success and population growth. Rejection of the "quality habitat" hypothesis would result in pursuit of the alternative "confusion habitat" hypothesis, though the daunting nature of that undertaking has prevented an outlay of the necessary actions to date.

4.2.6.6 *Spawning Cue Flows*

The action of creating spawning cue flows relates to Big Question 1 for the Lower Missouri River: Can spring pulsed flows synchronize reproductive fish, increase chances of reproduction and recruitment? As described in Table 42, the MRRMP-EIS assumes that Level 1 actions would occur after a ROD for up to 9 years prior to the possible implementation of spawning cue flows at Level 3. At the end of this 9-year period, the Technical Team would apply the decision criteria and evidentiary framework shown in Table 48 to determine if it were appropriate to implement spawning cue flows at either Level 2 (test flows to create more contrast, test hypothesis H11 (listed below) and create possible biological benefits) or (if the Level 2 test proves to be successful) at Level 3 (flows to generate biological benefits).

What constitutes a *sufficient contrast of flows* would be determined by objective analysis of the data by the Technical Team at the end of the 9-year period, and peer review of these conclusions by the ISAP (and likely peer review for journal publications). *Successful spawning* is confirmed by: colocation of females and males; multi-receiver, 3D telemetry and acoustic video to confirm egg release events; downstream capture of viable eggs and embryos; and recapture of spawned females that have released eggs. *Unsuccessful spawning* is confirmation of an interruption of any of the steps that lead to successful spawning (i.e., movement, aggregation, egg release, embryo creation).

Table 48 Evidentiary Framework for Flow Observations. This decision aid is intended to determine if sufficient spawning cue flow events occur during the first nine years of implementation post ROD, and to determine if an explicitly managed spawning cue flow should be implemented after the ninth year to test flow hypotheses.

Question	Potential Metrics and Lines of Evidence Based on Observations over 9 years		
	No [or]	Inconclusive [ ]	Yes [or]
Q1. Are there attributes of river flow that are strongly correlated with upstream movement of male and female pallid sturgeon of reproductive age?	Sufficient contrast of flows has occurred over first 9 years to answer this question, and movements of pallid sturgeon have been well monitored, but no significant correlations are apparent between flow and movement. Flows aren't associated with movement.	Insufficient contrast of flows has occurred over first 9 years to be able to rigorously answer this question. Effects of flows unclear.	Sufficient contrast of flows has occurred over first 9 years to answer this question, movements of pallid sturgeon have been well monitored, and significant correlations are apparent between flow and movement, at flow magnitudes that could be released by managers. Flows are associated with movement.
Q2. Are there attributes of river flow that are strongly correlated with immediately subsequent spawning aggregations of telemetered male and female pallid sturgeon of reproductive age?	Wide contrast of flows has occurred over first 9 years (below and above potential spawning flows) and movements of telemetered pallid sturgeon have been well monitored, but no significant correlations are apparent between flow and spawning aggregations. Flows aren't associated with aggregation.	Insufficient contrast of flows has occurred over first 9 years to be able to rigorously answer this question. Effects of flows unclear.	Wide contrast of flows has occurred over first 9 years (below and above potential spawning flows), movements of telemetered pallid sturgeon have been well monitored, and significant correlations are apparent between flow and spawning aggregations, at flow magnitudes that could be released by managers. Flows are associated with aggregation.
Q3. If the answers to Q1 and Q2 were "yes"", do upstream movements and spawning aggregations lead to documented successful spawning?	n.a. [Answers to Q1 and Q2 were "No", so Q3 does not apply. If successful spawning did occur, it was not due to flow-triggered movement and aggregation]	n.a. [Answers to Q1 and Q2 were "Inconclusive", so Q3 does not apply.]	Successful spawning observed at spawning sites (gravid females released eggs in the presence of males), following flow-associated upstream movement and spawning aggregations. Strong evidence that flows support spawning.
Q4. If successful spawning occurs (and answers to Q1, Q2 and Q3 are "yes"), are viable embryos found downstream of the spawning site?	n.a. [Answers to Q1 and Q2 was "No", so Q4 does not apply. If successful spawning did occur, it was not due to flow-associated movement and aggregation]	n.a. [Answers to Q1 and Q2 were "Inconclusive", so Q4 does not apply.]	Viable embryos found downstream of successful spawning events that are genetically related to the males and females observed to be spawning. Very strong evidence that flows support spawning.
Q5. Do successful spawning events occur sufficiently frequently under current water management rules to prevent jeopardy and support recovery?	No. Successful spawning does not occur frequently enough under current water management rules to prevent jeopardy and support recovery.	Inconclusive (e.g., not enough tagged fish to estimate total spawning success)	Yes. Successful spawning occurs frequently enough under current water management rules to prevent jeopardy and support recovery.
Conclusions regarding need for spawning flows after Year 9	No to Q1-Q2: Do not implement spawning flows at Level 2. Inconclusive to Q1-Q2: Implement spawning flows on a trial basis (Level 2) to get enough contrast and answer Q1-Q4. Yes to Q1-Q2 and No to Q5: Possibly implement spawning flows on a trial basis (Level 2), and do research to understand what else is limiting spawning success (e.g., substrate, predation). Yes to Q1-Q2 and Yes to Q5: Rely on natural flows from tributaries to trigger movement and aggregation, and do research to understand what else is limiting spawning success. Yes to Q1-Q4, No to Q5: Possibly implement spawning flows on a trial basis (Level 2), and if successful, continue to do so once every 3 years (Level 3). Continue to monitor movement, aggregation, spawning. Yes to Q1-Q5: Rely on natural flows from tributaries to trigger movement, aggregation, and successful spawning. Continue to monitor movement, aggregation, spawning.		

4.2.6.6.1 *Hypotheses*

The following hypothesis is relevant to this action:

- H11. Naturalization of the flow regime at Gavins Point Dam will improve flow cues in spring for aggregation and spawning of reproductive adults, increasing reproductive success.

The EA (Jacobson et al., 2016a) found that while there was theoretical support for this hypothesis based on inferences from other sturgeon species, that there were inadequate data to model and forecast consequences of this action (Table 38). Earlier, the Independent Science Advisory Panel (ISAP 2011; pg. 1-2) concluded that {italics added}:

> Pallid sturgeon have spawned in the lower Missouri River in all years for which data are available, with and without managed spring pulses. Based on that information, the ISAP concludes that the spring pulse management action, *as currently designed*, is unnecessary to serve as a cue for spawning in pallid sturgeon.

It therefore is important to gain a better understanding of the mechanisms and factors which stimulate spawning in pallid sturgeon.

4.2.6.6.2 *Action Description*

A series of Level 1 and Level 2 studies (described in Table 44 and Appendix C) would be completed prior to implementation of any Level 3 spawning cue flow at Gavins Point. These studies include:

- Designing a passive telemetry network, and associate power analyses to determine how large of a change in spawning would be detectable (BQ1/L1/C1a)
- Statistical power analysis and biological modeling of potential population benefits (BQ1/L1/C1b); and
- Continuation of opportunistic tracking of reproductive behaviors to determine the degree of association of reproductive behaviors and successful spawning with monitored hydrologic characteristics (BQ1/L1/C2).

Opportunistic tracking of pallid sturgeon (BQ1/L1/C2) would involve the following components, in **both** the Upper and Lower Missouri River, as both areas can help to test hypotheses related to spawning cue flows:

- opportunistic monitoring of water discharge, pallid sturgeon movement, and pallid sturgeon location data
- flows, temperature and turbidity measured continuously at multiple locations downriver from Fort Peck and Gavins Point Dams, and on the lower Yellowstone River
- tracking of pallid sturgeon in reproductive condition via telemetry to determine movement patterns, documenting reproductive behavior (aggregation, synchronization, spawning)
- monitoring spawning success by site observations and measuring the production of free embryos (see section 4.2.6.5.5 describing metrics for assessing the effectiveness of spawning habitat creation)
- evaluation of the statistical relationships of flow-regime components (e.g., mean discharge, peak discharge, change in discharge), and covariates (turbidity and temperature) to pallid sturgeon behavior
- for the Lower Missouri River, examination of the influence of flows at both created spawning habitat and at reference locations, since spawning habitat creation could also influence spawning behavior.

As is clear from the evidentiary framework in Table 48, a range of opportunistic flows (low to high) is needed to bracket ecologically ineffective and effective flows. Variation in flows between the Upper Missouri River and the Yellowstone River will provide a strong experimental contrast in the Upper Missouri. Variation in flows between Sioux City to Omaha and Kansas City to St. Charles will provide strong experimental contrast in the Lower Missouri. However, the number of telemetered fish may limit the inferential power of studies undertaken in the Lower Missouri.

A description of a spring pulse sufficient to define a Level 3 implementation, developed in USFWS and USACE (2015) is presented in Table 49. If it were decided after year 9 (post-ROD) to proceed with a Level 2 test of spawning cue flows, the flow attributes in Table 49 would likely be modified based on what has been learned during years 1-9, including the requirements for pallid sturgeon, the benefits of this action, the potential effects of on tern and plover nesting success, and the distribution and magnitude of effects on human considerations. The design of a Level 2 test of spawning cue flows would also require further sensitivity analyses of the effects on human considerations, sturgeon and bird populations.

A maximum frequency of 1 in 3 years was agreed upon by the USFWS and USACE (2015) as an estimate for the purposes of assessing effects on human considerations during the EIS. Decisions on the required frequency of spawning cue flows would depend on the outcomes of the first test of Level 3 flows, together with other evidence from opportunistic monitoring, and simulations from the collaborative sturgeon population model. Level 3 spawning cue flows are currently conceived as bi-modal pulse flows from Gavins Point Dam (Table 49). Options for increasing the variability in the overall pulse height should be explored to more closely mimic the variability that occurred naturally as a means of precluding impacts on sandbar nesting birds.

Table 49. Proposed characteristics of Level 3 spawning cue flows.

The first pulse from Gavins Point would conform to the following guidelines:

- Rise begins on first day after flow to target navigation flows are achieved.
- Peak release from Gavins Point is equal to double the flow to target level release the first day of navigation flow to target levels are achieved from Gavins Point
- Increase to peak by 2,200 cfs per day
- Maintain peak for 2 days
- Reduce pulse by 1,700 cfs/day until releases are back to base flow to target levels

The second pulse is cued by water temperature (**16-18 degrees**) at Sioux City Iowa as follows.

- Checks to implement release increases
    - > 40.0 MAF in System Storage on March 15 storage check
    - Steady release has been set and implemented for 3 days
- Releases from Gavins Point
    - Rise begins on May 18 or later based upon water temperature and implementation of steady release for at least 3 days
    - Increase to peak by 2,200 cfs per day
    - Peak release from Gavins Point is equal to twice the steady release from Gavins Point
    - Maintain peak for 2 days
    - Reduce pulse by 1,900 cfs per day until the steady release flows are reached
- Flood targets will be the full service flood targets increased by the steady release level
    - If the steady release is 31 kcfs and the full service flood targets are 41 kcfs, 47 kcfs, and 71 kcfs at Omaha, Nebraska City, and Kansas City, respectively, the new flood targets will be 72 kcfs at Omaha (31 + 41), 78 kcfs at Nebraska City (31 + 47), and 102 kcfs at Kansas City (31 + 71).

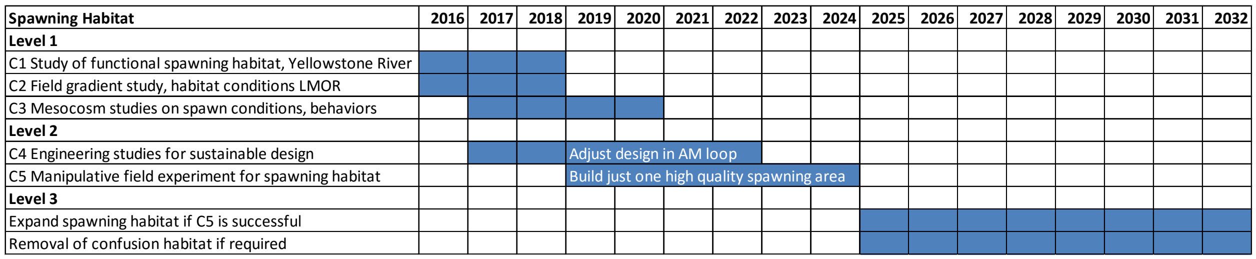


Figure 80. Preliminary sequencing of actions and studies for spawning flow cues, revised from USFWS and USACE (2015) to reflect the preferred alternative and current USFWS priorities and timelines. In the preferred alternative for the MRRMP-EIS, a test Level 2 flow would only occur after 9 years of post-ROD monitoring, and if supported by the evidentiary framework in Table 48.

4.2.6.6.3 *Objectives*

Spawning cue flows are intended to elicit a movement response in gravid pallid sturgeon that results in an aggregation of reproductively ready pallid sturgeon, and thereby improve both reproductive success and recruitment to the population.

4.2.6.6.4 *Expected Benefits*

If the evidentiary framework in Table 48 leads to the conclusion that Level 2 spawning cue flows are warranted, the expected benefits will be a more definitive test of the effectiveness of this action. If the Level 2 experiment in turn shows biological benefits (i.e., movement, aggregation and successful spawning), then Level 3 flows are likely to increase reproductive success, increasing the probability of survival and recovery. Implementation of such flows would need to be done in a manner which had acceptable impacts on both birds and human considerations. The remainder of this section assumes that the evidentiary framework leads to the conclusion that Level 2 spawning cue flows would be implemented after year 9, and that Level 3 spawning cue flows would follow.

4.2.6.6.5 *Metrics*

Many of the metrics associated with spawning cue flows are identical to those for the Intake Dam (described in section 4.2.5.2.5) and for the creation of spawning habitat (described in section 4.2.6.5.5). Success metrics for spawning cues are generally related to fish behavior (reproductive migrations, aggregation and successful spawning with monitored experimental flow pulses) and successful reproduction (hatch rate, capture of free embryos, etc. as discussed above for spawning habitats in section 4.2.6.5). Practical assessment of spawning success in the near-term is extremely difficult, so it will be necessary to rely upon behavioral monitoring. Intensive telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for the degree of association. Reproductive success or failure is inferred by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes, as well as monitoring the abundance of age-0 fish (critical to a determination of recruitment success). If required based on the evidentiary framework in Table 48, monitoring of one test flow at Level 2 would provide important information to supplement the inferences gained from opportunistic monitoring at Level 1, but it would only be one instance of the experiment. Monitoring of a series of Level 3 flow releases over several years would provide more extensive information, from which one could hopefully establish a functional relationship between flow-pulses and the probability of producing viable larvae. The value of repeating flow releases would depend on the outcome of a one-time test.

Another important component of monitoring (for both natural and managed flows) will be determining how the exposure of fish to changing flows and temperatures varies as one moves downstream of Gavins Point. The shape of the hydrograph created by natural or managed flow releases from Gavins Point will be altered as other tributaries enter the Missouri River, and the signal from Gavins Point will be decreased. If pallid sturgeon are affected by a spawning cue flow from Gavins Point, this will likely occur upstream of the Platte River. Sudden decreases in temperature due to changing weather patterns can disrupt pallid sturgeon reproductive migrations which apparently were associated with flow pulses (Robb Jacobson and Aaron Delonay, USGS, pers. comm.).

4.2.6.6.6 *Experimental Design*

In a similar manner to the creation of spawning habitats, the experimental design of L2 spawning cue flows needs to accomplish three things: 1) maximize the effectiveness of spawning cue flows, building on the learning from Level 1 studies; 2) create contrasts over space and time to evaluate the effectiveness of this action and test hypothesis H11; and 3) avoid confounding from other potential L2 and L3 actions (i.e., spawning habitat creation, discussed above in section 4.2.6.5.6). If hypothesis H11 is true, it would lead to the prediction that in years and locations with a spawning cue flow, more adult pallid sturgeon would migrate to and then aggregate at all potential spawning habitats (newly constructed, older constructed, and natural spawning habitat locations), as compared to years and locations without a spawning cue flow. Testing hypothesis H11 involves both temporal and spatial contrasts.

Temporal Contrasts. Ideally, contrasts would involve comparing the aggregation of pallid sturgeon in *treatment* years where managers implemented a spawning cue flow with other *control* years in which managers did not implement the spawning cue action. If only one managed flow is implemented, then responses in that year would be compared to other control years with generally similar levels of runoff but without a ‘suitable flow peak’ in April or May. If a Level 2 managed flow were to be implemented (say in years 10 or 11 after the ROD) and it were subsequently decided to implement Level 3 spawning flows every third year, it would then take 15 years to have 5 treatment years. A major challenge with this comparison is that the treatment years are likely to occur in years with lots of reservoir storage and low natural flows (to avoid flood impacts), while non-treatment years could have either low, medium or high natural flows. High natural flows might act as a natural stimulus for spawning aggregations, so these years would be more like a *natural treatment* year than a true control year, and spring flow pulses commonly occur naturally. In summary, only a subset of non-treatment years would be appropriate control years, and criteria for selecting control years will need to be established before Level 2 and Level 3 flow experiments are conducted. Comparisons across years could be confounded by changes in the number of reproductive fish (e.g., decrease of old natural fish; recruitment to spawning of initial hatchery stocks), or sudden changes in temperatures (which also affect spawning). The number of reproductive fish, and river temperatures should therefore be used as covariates in the analysis.

It will be important to simulate this experiment using the collaborative population model linked to the river hydrologic model, so as to determine what magnitude of differences in reproductive behavior are likely to be detectable at reliable levels of statistical power with different numbers of tagged fish. For example, tracking 25 tagged adults with a stationary telemetry network might be sufficient to reliably detect the difference between a 1.0 probability of spawning in treatment years and a 0.0 probability of spawning in control years, whereas 50 tagged adults might be required to reliably detect a less extreme (and perhaps more likely) magnitude of effect (e.g., 0.6 probability of spawning in treatment years and 0.3 probability in control years)[1]. It might be possible to increase the number of tagged fish by tagging reproductive hatchery fish that are not being used in the hatchery to avoid inbreeding effects. It would be informative to compare the migration, aggregation and reproduction of such tagged and preconditioned fish in years with and without spawning cue flows, thereby testing the effectiveness of both spawning cue flows and created spawning habitat.

Spatial Controls. In a year with a managed spawning cue flow, it should be possible to compare spawning behavior at locations upstream of the Platte River confluence where the spawning cue signal is stronger, versus locations downstream of the confluence where the signal gets diluted. This requires careful design of the managed spawning cue flow so that there is a clear signal. Purely from the perspective of a strong experimental

[1] These are just hypothetical examples, not actual calculations of statistical power.

design that separates confounding factors, it would be ideal to have spawning habitats in both upstream and downstream locations, so that the effects of spawning habitats could be disentangled from the effects of spawning flows. However, from the perspective of improving spawning aggregation, it will be preferable to only construct one spawning habitat, so as to not distribute spawners across multiple sites.

4.2.6.6.7 *Decision Criteria*

Decision criteria guide the Technical and Implementation Teams when evaluating monitoring and other information and in developing recommendations for consideration by the agencies. Decision criteria for implementing a spawning cue flow after the first 9 years post-ROD are described in the evidentiary framework (Table 48). If a spawning cue flow were implemented after year 9, the significant experimental control that could be exerted over this action (above the confluence of the Platte and Missouri Rivers) will enhance the ability to detect and quantify reproductive behavioral changes related to flow pulses. However, the flow pulses will still take place within a system where many sources of variability are not controlled, such as weather systems that can abruptly change water temperature or discharge in the mainstem or tributaries. As discussed above in section 4.2.6.6.6 (Experimental Design), there are several confounding factors which will make it challenging to separate the flow pulse signal from other noise in the system created by spatial and temporal variability in flows. It is therefore unlikely that these experiments will result in a statistically rigorous result. Instead, a decision to accept the value of manipulated flow pulses in increasing pallid sturgeon reproductive success, or to reject it, will probably be based on judgement of multiple lines of evidence.

<u>Timelines</u>: The time to implementation at Level 3 and sequencing of this action should be considered in light of other actions. For example, before managers run a flow pulse, they should be assured that functional spawning habitat is available, and that a sufficient number of tagged fish in reproductive condition are present in the river to assess aggregation and spawning. This could mean that additional engineered spawning habitat needs to be in place (see section 4.2.6.5), but presently available spawning sites may suffice to address behavioral metrics. A nine-year time limit for implementation at Level 2 was agreed upon by the USFWS and the USACE to allow for habitat and propagation efforts to enhance the potential success of spawning cue flows (see Section 4.2.1.3). Information derived from passive monitoring of natural flow events could yield a number of different outcomes relative to hypothesis H11 (Table 48), and lead to the conclusion that a spawning cue flow would not be required. The degree of natural variability in flows over the first nine years will be a primary determinant of the ability to test hypothesis 11.

Triggers for Moving to Levels 3 or 4: The trigger for moving to Level 3 implementation would be convincing evidence of upstream movement, aggregation and successful spawning in response to one or more instances of Level 2 spawning cue flows, without unacceptable impacts on human considerations (similar to what is shown on the right side of Table 48. If repeated implementation at Level 3 were to generate a reliable functional relationship between spawning cue flows and the probability of successful spawning, then together with population modeling and survival estimates for other life history stages, it should be possible to estimate the required scale and frequency of this action at Level 4.

4.2.6.6.8 *Level 3 Contingent Actions*

Contingent actions will need to take into account all of the lines of evidence for different factors that may affect pallid sturgeon recruitment, as summarized in Section 4.2.1.3.

4.2.6.7 *Potential Effects of bird actions on pallid sturgeon*

A management action for any one objective along the Missouri River has the potential to affect other objectives, especially if an action involves changes to reservoir operations. USGS has completed a preliminary evaluation of pallid sturgeon sensitivity to potential bird-management actions by looking at how ESH flow pulses would affect pallid sturgeon food-producing and foraging habitats (using the IRC habitat criteria defined in section 4.2.6.3.2; Robb Jacobson, pers. comm.) . These habitats are key components of IRCs and are thought to be critical to growth and survival of age-0 pallid sturgeon. Fall and spring ESH pulse flows (without low summer flow components) resulted in a modest gain (about 10%) in only food-producing habitats and only in a restored upstream reach where the flow regime is strongly linked to releases from Gavins Point Dam. Food-producing habitats were insensitive to ESH flows in downstream reaches where flows are not strongly regulated by releases from Gavins Point Dam and foraging habitats were insensitive to ESH flow releases in all cases. Food-producing habitats were also insensitive to ESH flow pulses in channelized (non-restored) reaches, upstream and downstream. Spring ESH pulses resulted in about a 10% increase in qualifying pallid sturgeon spawning cues (that is, doubled flows above navigation support in May). Though this comparison was limited to just a few sites, it provides a preliminary assessment which suggests that effects of ESH flows on pallid sturgeon habitats could be quite minor. Table 50 provides a qualitative assessment of other actions.

Table 50 Preliminary and qualitative assessment of the effects of bird actions on pallid sturgeon habitats and populations.

Action	Geographic overlap with action area for fish*	Direct effect on fish habitat	Direct effect on fish reproduction or survival	Effects on ability to implement fish management actions (other than budget)
Fall and spring ESH flow pulses	Overlap with potential spawning areas downstream of Gavins Point Dam; far upstream of most IRCs (Figure 36)	Spring pulses could possibly assist pallid sturgeon in upstream movement and aggregation for spawning. (10% increase in qualifying spawning cue pulses) Analysis of 2 sites shows neutral or positive effects on IRCs (see text)	Spring pulses likely to be either neutral or positive effect on spawning success and survival of age-0 fish; Fall pulses unlikely to influence reproduction	Unlikely. Spring ESH flows have somewhat different attributes from the ideal spawning cue flow; the latter would only occur at least 9 years post-ROD; may not be implementable in the same year; an ESH spring pulse might use stored water then unavailable for spawning cue.
Habitat conditioning flows	Overlap with potential spawning areas downstream of Gavins Point Dam; far upstream of most IRCs (Figure 36)	Unlikely, as these flows are lower magnitude than fall and spring ESH flow pulses, which showed neutral or positive effects.	Unlikely given that magnitude is lower than fall and spring ESH pulses, which showed neutral or positive effects.	Unlikely given that magnitude is lower than fall and spring ESH pulses.
Vegetation removal	No.	No.	No.	No.

Action	Geographic overlap with action area for fish*	Direct effect on fish habitat	Direct effect on fish reproduction or survival	Effects on ability to implement fish management actions (other than budget)
Low flow management and lowered flows to reduce take	Overlap with potential spawning areas downstream of Gavins Point Dam; far upstream of most IRCs (Figure 36)	Low flow management would occur after pallid sturgeon spawning, and is unlikely to affect spawning habitat. Effects on IRCs are variable and include increases in foraging habitats in channelized reaches, increases in food-producing habitat in upstream reconfigured reaches, and decreases in food-producing habitats in both upstream and downstream reaches.	No effects on spawning due to differences in timing. May increase age-0 survival through increases in foraging habitat and food-producing habitat. First assess potential for effects on IRC habitat (if nil, then don't need to evaluate effects on survival).	Not in the year of implementation. Storing or releasing water from reservoirs might affect operational flexibility for spawning cue flows in subsequent year.
Mechanical ESH creation and augmentation of sandbars	Limited overlap possible from Gavins Point Dam to Ponca, NE. ESH located in areas of low river energy, whereas spawning habitats would be in areas of high river energy. ESH construction is hundreds of miles upstream of IRCs	Unlikely due to low spatial overlap. Also, addition of sand for ESH replaces natural supply.	Very unlikely.	No.
Reservoir habitat creation	No overlap.	No – pallid sturgeon do not use reservoirs	No.	No.
Reservoir level management	No direct spatial overlap with range of pallid sturgeon.	Unlikely. Possible, through low summer flow effects on IRCs described above. Should be evaluated further to assess how reservoir level management may affect flows in IRCs.	Possible. First assess effect on habitat.	Reservoir level management could affect storage available for spawning cue flow actions and flows in IRCs, especially low summer flows.

Action	Geographic overlap with action area for fish*	Direct effect on fish habitat	Direct effect on fish reproduction or survival	Effects on ability to implement fish management actions (other than budget)
Population protection measures	No.	No.	No.	No.
Off-channel habitat creation	No overlap, as spawning habitat is in channel, and IRCs are much further downstream	No.	No.	No.

If low summer flows are added to consideration, the potential interactions between bird and fish actions increase. Low summer flows as modeled to decrease take of bird nests increased availability of foraging habitat in the upper channelized reaches by as much as 30% and the lower channelized reached reaches by 10%; IRC-qualifying habitats in reconfigured reaches were not sensitive to low summer flows. Low summer flows increased food-producing habitat by 20% in the upstream reconfigured reaches but the food-producing habitats in the downstream reaches were insensitive. Channelized reaches, both upstream and downstream, showed a 10% decrease in food-producing habitats with low summer flows.

4.3 Implement

4.3.1 Implementation Plan

Figure 82 and Figure 82 summarize the current implementation schedules for the actions described above in sections 4.2.5 and 4.2.6, and the associated components at Levels 1, 2 and 3 (in the order of presentation of each of these actions). These schedules build on the plans presented by the USFWS and USACE (2015), and have been updated to reflect both the preferred alternative and current USFWS priorities and timelines, as well as joint USFWS and USACOE work on prioritization of Level 1 and Level 2 activities, described in Appendix F.

Figure 83 and Figure 84 provide the currently proposed schedule for all Level 1 and Level 2 components in the Upper and Lower Missouri River (respectively), for the first five years after the ROD, based on the prioritization described in Appendix F. The longer term schedule for Level 1 and Level 2 activities is presented in Appendix F. The schedule will require a well-funded and focused surge in research activity conducted by multiple research teams that work in close coordination (see Appendix F).

As noted in section 4.2.1 summarizing the Lower Missouri River Pallid Sturgeon Framework (USFWS and USACE 2015), the timeframe for implementation may be adjusted as knowledge is gained from Level 1, 2 and 3 actions, hypotheses are tested, and the likelihood of biological benefits is better understood. Budget allocations may also affect the timing of particular activities. The rationale for any adjustments in schedule should be well documented.

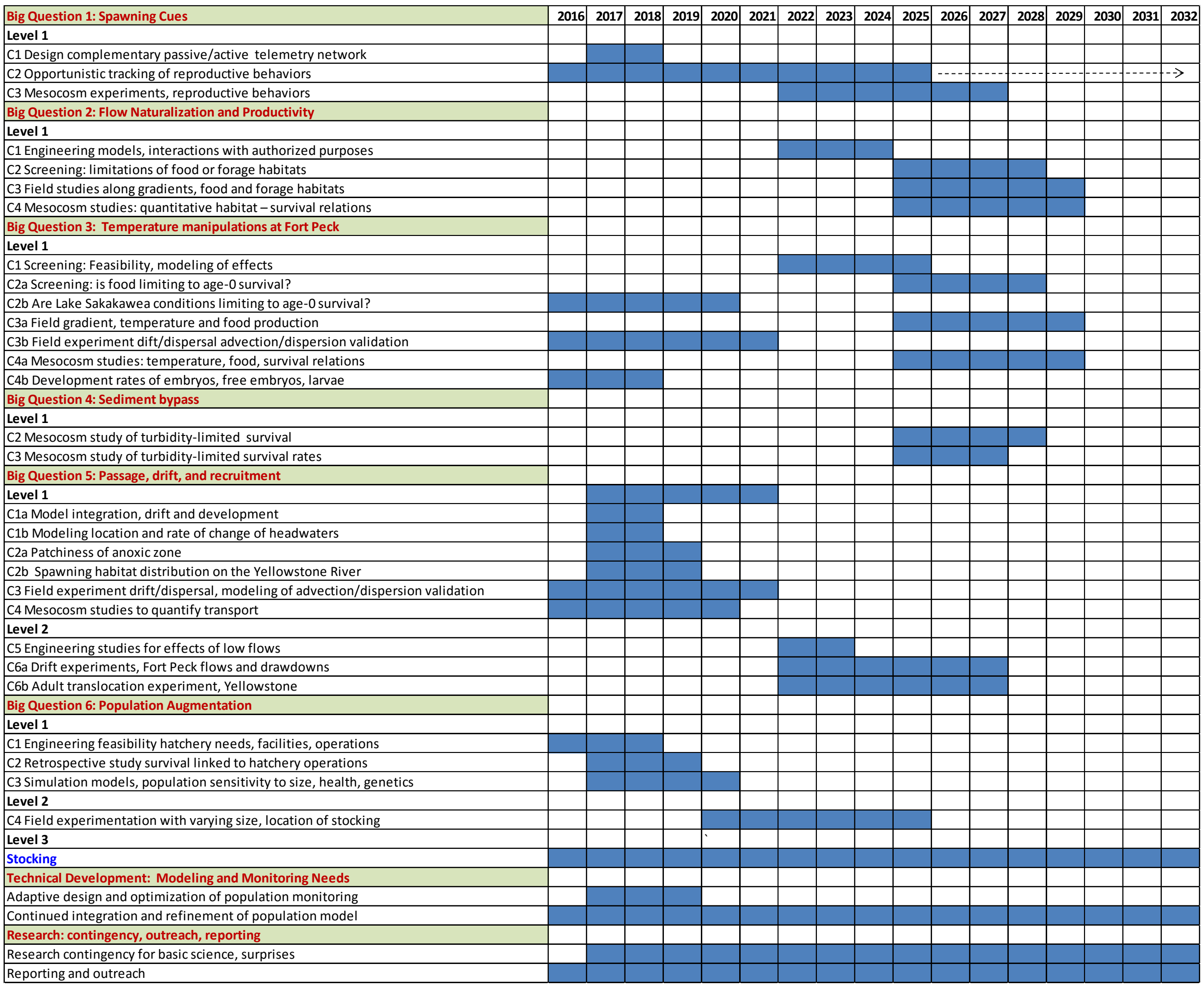


Figure 81. Current schedule for implementation of actions in the Upper Missouri River, revised from USFWS and USACE (2015) to reflect the preferred alternative and current USFWS priorities and timelines, and described in sections 4.2.5 of this report. Arrows represent flexibility in the timing of implementation. This figure is an illustration of the intended implementation schedule. There may be further adjustments in the schedule. In-river actions at Level 2 and Level 3 are shown in bolded blue text.

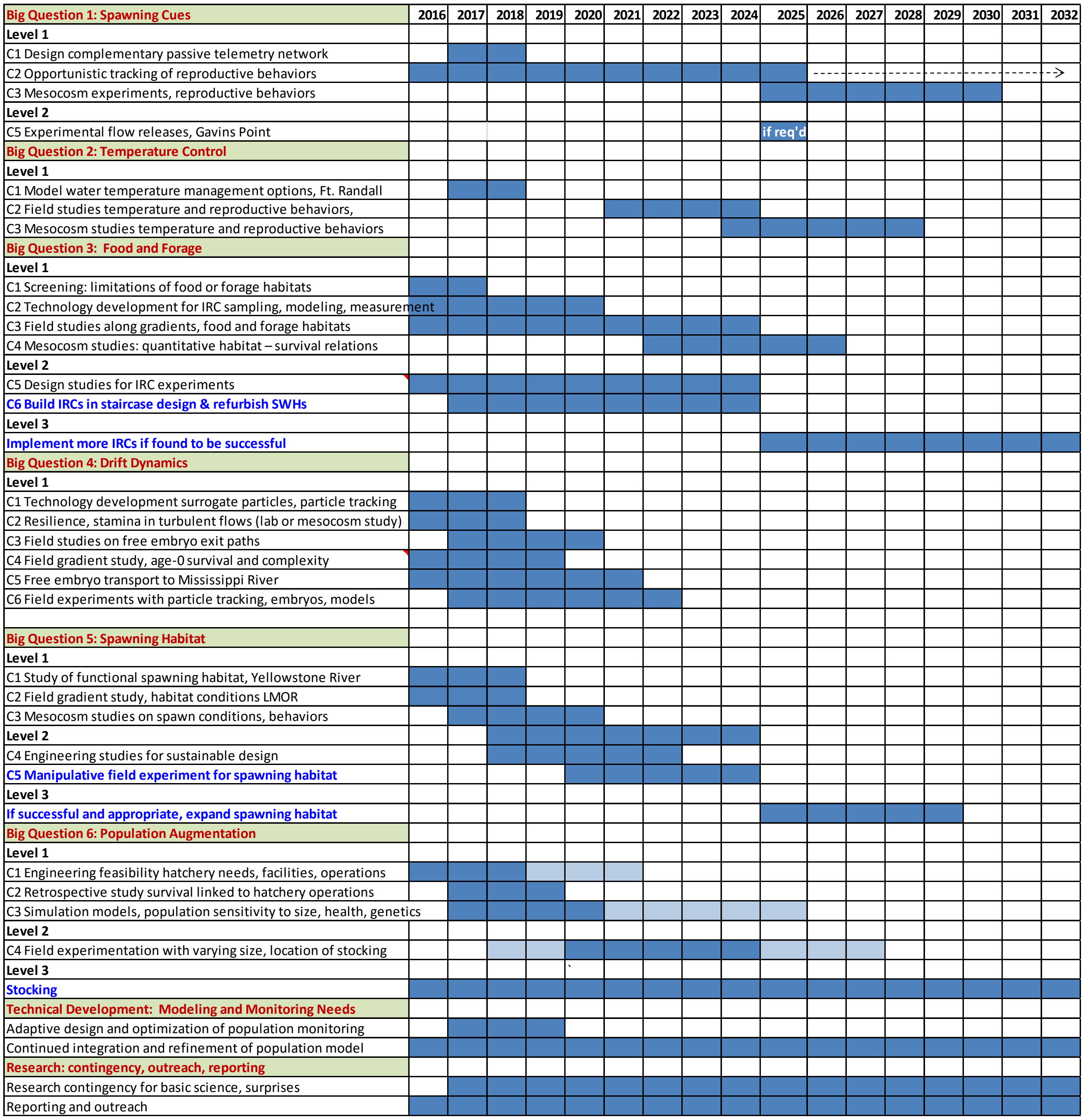


Figure 82. Current schedule for implementation of actions in the Lower Missouri River, revised from USFWS and USACE (2015) to reflect the preferred alternative and current USFWS priorities and timelines, and described in section 4.2.6 of this report. Arrows represent flexibility in the timing of implementation. This figure is an illustration of the intended implementation schedule. There may be further adjustments in the schedule. In-river actions at Level 2 and Level 3 are shown in bolded blue text.

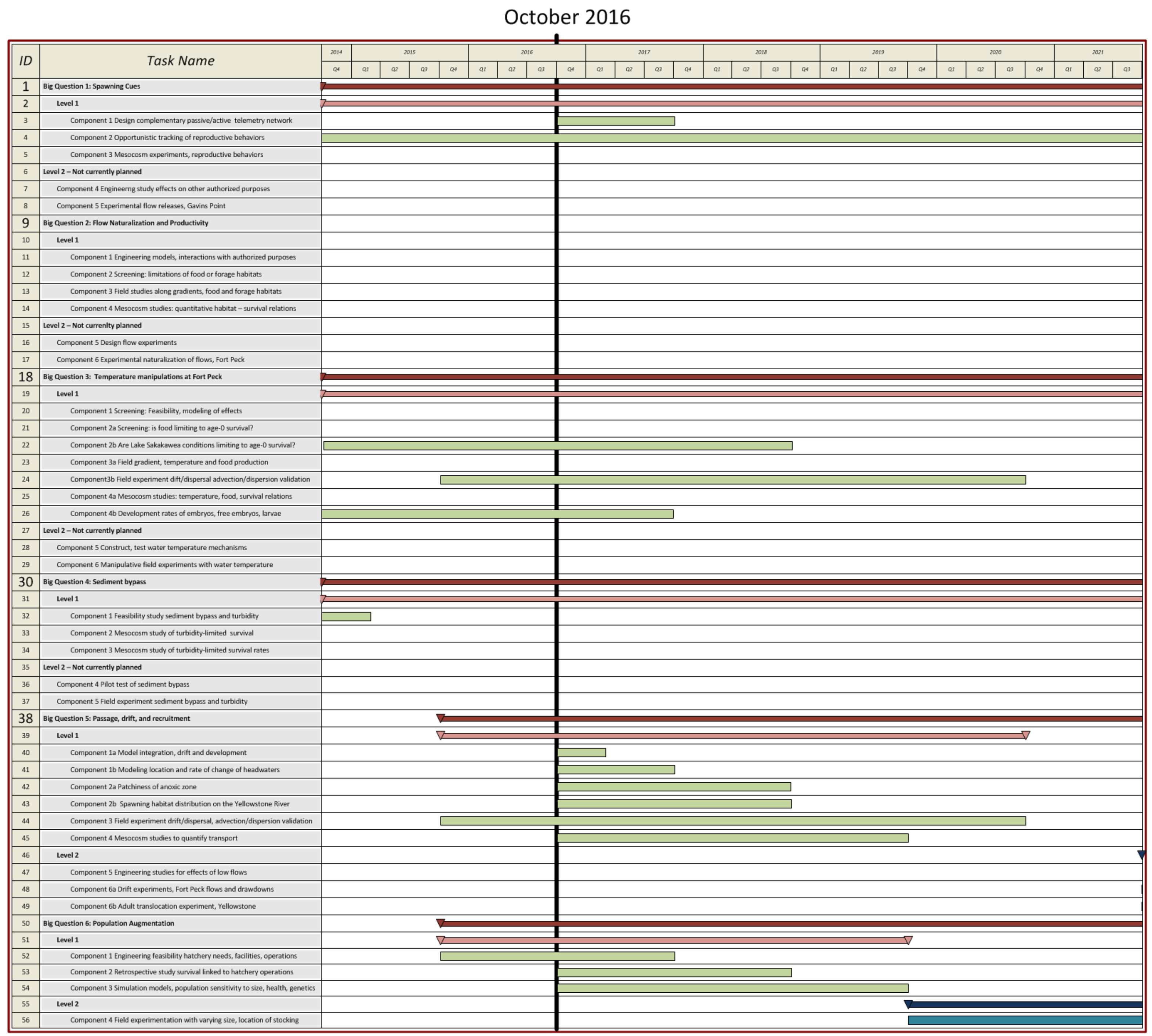


Figure 83. Proposed schedule for all science and AM components (Levels 1 and 2) in the Upper Missouri River during the first 5 years post ROD.

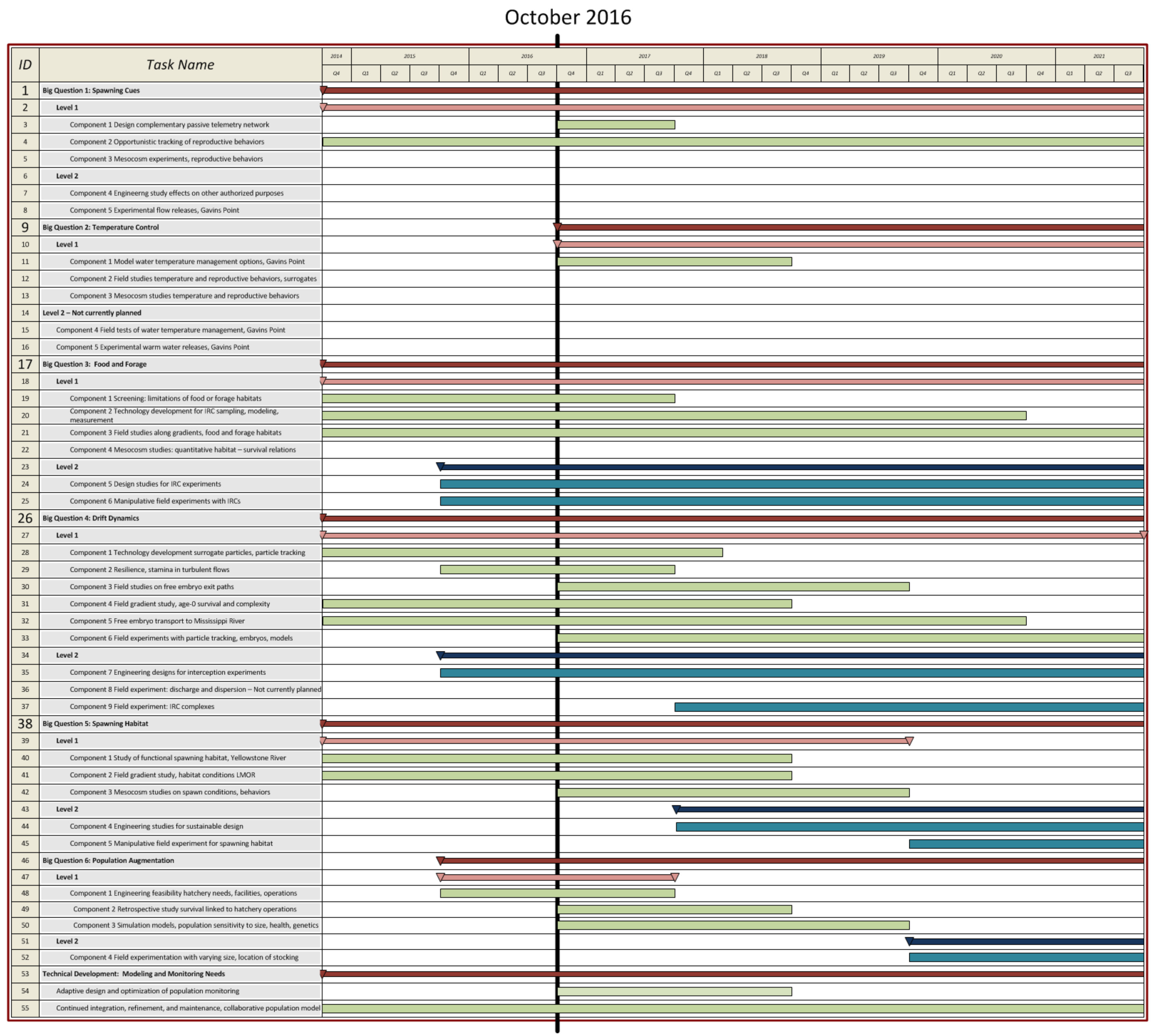


Figure 84.Proposed schedule for all science and AM components (Levels 1 and 2) in the Lower Missouri River, during the first 5 years post ROD.

4.4 Monitor

There are 3 types of monitoring that need to be conducted as the AM Plan proceeds:

- Implementation Monitoring – did the action get successfully completed as intended?
- Process / Action Effectiveness Monitoring – is there an ecological response that will increase survival or appropriately inform the next Level of implementation towards achieving increased survival?
- Population Monitoring – is the population growing, attaining the right size?

Foundational research is required at Level 1 to support all three forms of monitoring, including the design of new protocols, the establishment of monitoring hardware such as stationary telemetry networks, and the development of models and power analyses to test out monitoring protocols and experimental designs.

Implementation monitoring is essential to determine if intended actions did in fact occur. This is important to document compliance and essential for cause-effect evaluations of action effectiveness. Scientists need to know where and when a given type of action was present in order to assess whether pallid sturgeon might have been exposed to the effects of that action.

Appendix D describes the proposed revisions to current protocols for population monitoring, replacing a catch per unit effort approach with a mark-recapture approach. Population monitoring is a complex issue which will need further review. As explained in Appendix D (section B.1.3), and to be further tested by Level 1 research, there are three broad reasons for improving the current methods of population monitoring:

1. Current methods of population monitoring rely on catch per unit effort (CPUE), which is confounded by by factors that affect catchability, like changes in flow, does not provide accurate data for model calibration, and in the Lower Missouri River is poorly correlated with trends in stocking of hatchery fish;
2. Mark-recapture estimates of various life history stages will provide much better estimates of survival rates and abundance for use in the collaborative population model, which will be used to assess the potential population-scale benefits of Level 2 and Level 3 actions. The model will also be used in the revised design of the population monitoring protocol, so that the monitoring protocol and model structure will be well integrated.
3. Accurate estimates of population size will be an important input to decisions on stocking (which need to account for density dependence, and use population abundance as an integrative measure of the effectiveness of stocking), and ultimately on recovery (which requires an estimate of the population size, not just its trend).

Appendix E contains references to the current monitoring protocols for process / effectiveness monitoring; these protocols need to be reviewed, applying the principles outlined in Appendix E. Table 51 summarizes the metrics to be used for each type of monitoring for each Level 2 and Level 3 action described in sections 4.2.5 and 4.2.6. Appendix K provides a summary of metrics used to detect the effectiveness of various actions, as well as metrics used for tracking the status and trends of the pallid sturgeon population.

Table 51. Summary of metrics to be used for implementation, process / action effectiveness and population monitoring for each Level 2 and Level 3 action described in sections 4.2.5 and 4.2.6. Hypotheses listed in first column (e.g., H8, H9) are those most relevant to the action, as discussed in section 4.2. The section listed in the first column provides a more detailed description of metrics associated with a given action; other metrics are listed in Appendix K.

Level 2 / 3 Action	Implementation monitoring	Process monitoring	Population monitoring
Augmentation [H8, H9] [H20, H21] Metrics: section 4.2.5.1.5	-meeting stocking targets by age, hatchery and release location -meeting health criteria in hatchery -fulfilling experimental design of Level 2 management experiments	- Number, size, age, location, habitat and origin of released and captured pallid sturgeon -fish condition, genetics, disease levels -density of hatchery-origin free embryos and larvae found in preferred rearing habitats	-estimated survival probabilities of hatchery fish to age-1,2 and 3, by stocked size, age, hatchery of origin, release location -modelled long term change in population based on survival probabilities of hatchery origin fish (e.g., probability of quasi extinction, population growth rates) - effective population size
Intake Dam [H7] Metrics: section 4.2.5.2.5	-safe upstream and downstream passage of adults -safe downstream passage of embryos, free embryos and larvae	-density of free embryos and larvae found in preferred rearing habitats (and not headed for anoxic zones of Lake Sakakawea) -estimated improvement in spawning and recruitment from passage around Intake Dam (same metrics for monitoring spawning as for spawning cue flows)	-modelled long term change in population based on estimated proportional increase in successful spawning due to passage around Intake Dam (if such an increase occurs)
IRC Habitat [H17, H18, H19] Metrics: sections 4.2.6.3.5 and 4.2.6.4.5	-“effective acreage” (acre-days of available IRC habitat/year)	- habitat metrics based on measures of depths, velocities, substrate, habitat complexity - trends in % SWH area with suitable habitat after refurbishment to IRCs -CPUE and Pr (apparent presence) at meso-habitat and project level; - production of food/area -fish condition (% empty/full stomachs; genetics; lipid	-survival of hatchery-reared first-feeding pallid sturgeon larvae in IRCs, refurbished SWH, thalweg, and to age 1 -population size structure analysis (length-frequency distributions of age-1+ fish)

Level 2 / 3 Action	Implementation monitoring	Process monitoring	Population monitoring
		content; length frequency distribution of age-0 fish) and bioenergetics modeling	
Spawning Habitat [H16] Metrics: section 4.2.6.5.5	-# and area of spawning sites created with suitable characteristics (depth, velocity, substrate, and derivative hydraulic variables)	- confirmation of site quality -telemetry data showing relative selection of created spawning sites vs. control sites -attraction/specificity of adults to different spawning substrates; site confirmation that eggs are not buried -confirmation of spawning (see evidentiary framework on spawning cue flows - Table 48)	-modelled long term change in population based on estimated proportional increase in successful spawning due to creation of high quality spawning habitat (if such an increase occurs) - field monitoring of recruitment to age-1,2,3
Spawning Cue Flows [H11] Metrics: section 4.2.6.5.5	-flow monitoring to check whether spawning cue flow had expected timing, magnitude, and longitudinal spatial distribution	-movement and aggregation of spawning males and females in response to spawning cue flow -multi-receiver, 3D telemetry and acoustic video to confirm egg release events - male: female ratios in spawning aggregations (if sufficient # males tagged) -confirmation of female spawning through captured downstream eggs and embryos, and recapture of spawned females	-mesocosm and field-inferred benefit of achieved pulse -modelled long term change in population based on estimated proportional increase in successful spawning due to spawning cue (if such an increase occurs) - field monitoring of recruitment to age-1,2,3 (delayed metric reflecting the cumulative effect of all actions, other stressors and natural variability)

4.5 Evaluate

4.5.1 Evaluation Methods

Table 52 summarizes the methods used to evaluate the effectiveness of various actions, applying the metrics that are summarized above in Table 41, and listed in Appendix K. Each action is broken down into a series of key questions, andthe evaluation methods used to answer each question. The first column of Table 47 includes hyperlinks to the parts of sections 4.2.5 and 4.2.6 describe the details of the experimental designs and evaluation methods for each action, and its associated key questions.

Table 52. Summary of methods for evaluating the effectiveness of Level 3 actions. Some of these actions also have Level 2 management experiments. Hypotheses listed in first column (e.g., H8, H9) are those most relevant to the action, as discussed in section 4.2, and listed in Table 43 and Table 44. [Upper]=Upper Missouri River; [Lower] =Lower Missouri River. L2=Level 2. L3=Level 3. The sections listed in the first column provide more details on the experimental design for each action; Appendix K provides a list of metrics for each management action, as well as status and trend monitoring.

Action	Question [Level, Location]	Methods of evaluating action effectiveness
Augmentation [H8, H9] [H20, H21] Experimental design: section 4.2.5.1.6	Is the region releasing the optimal sizes of hatchery fish (i.e., fingerlings or yearlings)? [L2, Lower]	Use a staircase design over multiple years to compare the survival probabilities of fish stocked as fingerlings vs. yearlings, while accounting for the hatchery of origin and other factors affecting survival rates. See list of metrics in section 4.4
	Is the region releasing fish from the optimal locations? [L2, Upper and Lower][1]	Compare various metrics (e.g., recapture probabilities, recapture location, condition, survival probabilities) of different groups of marked fish that are released from different locations (e.g., upstream vs. downstream of Intake Dam; Missouri vs. Yellowstone River), and then recaptured at multiple locations and times.
	Is augmentation meeting target survival rates, ensuring a 95% probability of persistence over a 50-year period and supporting positive trends in populations? [L3, Upper & Lower] Is there a self-sustaining population in excess of 5000 adult fish in each management unit?	Apply the augmentation strategies developed in Level 2 studies, and compare 3-year running averages of various metrics (see augmentation row in Table 9, section 4.4) to established targets, (as informed by Level 1 and Level 2 studies, particularly population modeling studies).
Intake Dam [H7] Experimental design: sections 4.2.5.2.6 4.2.6.2.4	Do adult pallid sturgeon migrate upstream past Intake Dam, migrate to spawning sites and aggregate there? [L3, Upper]	Tracking of telemetered adult fish using USGS methods.
	Do adults of reproductive age spawn successfully in the Yellowstone River above Intake Dam? [L3, Upper]	Post-spawn monitoring of free embryos, larvae, and juveniles (with genotypes traced to parents), at various locations (e.g., downstream of spawning site, downstream of Intake Diversion Dam)
	Are some of the juveniles (age 3+) collected in the Yellowstone River the progeny of tagged adult fish that migrated upstream of Intake Diversion Dam? [L3, Upper]	Monitoring of age 3+ juveniles in Yellowstone River and assessment of genetic parentage
	What are the attributes of selected spawning sites (useful for design of spawning sites in L. Missouri)? [L2/ L3, Upper]	Document site characteristics of spawning locations (e.g., substrate, velocity, water temperature, suspended sediment, cross-section profile)

[1] This and the above question are example questions; the critical uncertainties to be resolved will emerge from the Stocking and Augmentation Plan under development by the Recovery Team.

Action	Question [Level, Location]	Methods of evaluating action effectiveness
	Do free embryos avoid dispersal into Lake Sakakawea? [L3, Upper]	Apply refined advection/dispersion models.
	Does spawning in Yellowstone River above Intake Dam improve the trajectory of the Upper Missouri River population of pallid sturgeon, and suggest that the population has a 95% probability of persistence over a 50-year period? [L3, Upper]	Apply collaborative population model using estimates from above studies for spawning locations above and below Intake Dam (e.g., frequency of spawning, proportion of successful spawning, indices of relative abundance and survival) to assess overall effect on population.
Interception and Rearing Complexes (IRCs) [H17, H18, H19] Experimental design: sections 4.2.6.3.4 4.2.6.4.4	Do free embryos and exogenously feeding larvae leave the thalweg and enter IRCs? [L3, Lower] Is there sufficient food in IRCs for exogenously feeding larvae to grow better and maintain a healthier condition than reference areas and times?[1] [L3, Lower] Do age-0 fish that occupy IRCs survive better than age-0 fish in reference areas and times? [L3, Lower] What's the population-level effect of improved survival of age-0 fish in IRCs? [L3, Lower] Is food limiting outside of IRC habitats[L3, Lower]	Predicted fate of free embryos from advection/ dispersion models. Testing of these predictions with field monitoring (see below). Staircase design comparisons of IRC habitat sites with reference areas and times, using the metrics listed in Table 9, section 4.4 (e.g., CPUE, probability of apparent presence, food production/area, condition, growth and survival of age-0 fish), and applying covariates to help explain year to year variation (e.g., index of upstream spawning success). Population model projections of the consequences of improved age-0 survival rates.
Spawning Habitat [H16] Experimental design: section 4.2.6.5.6	To what extent does successful spawning occur now? [redesigned PSPAP and other monitoring] Has suitable spawning habitat been created and maintained? [L2/L3, Lower] Are created spawning habitats preferred over other areas by pallid sturgeon in reproductive condition? [L2/L3, Lower] Does successful spawning occur in the created spawning habitat? [L2/L3, Lower] Would creation of more high-quality spawning habitat at Levels 3 and 4 have a significant benefit to the population? [L2/L3, Lower]	Compare metrics listed in Table 51 for the created spawning area(s) (see Figure 77 for possible areas) vs. reference areas (other outside bends used for spawning – see Figure 78) Population model projections of the consequences of creating more spawning habitat
Spawning Cue Flows [H11]	Do spawning cue flows lead to greater aggregations of pallid sturgeon in reproductive condition? [L2/L3, Lower]	Assemble evidence for and against benefits of spawning cue flows from Level 2 mesocosm and gradient studies.

[1] For this to be true, food would need to be a limiting factor that was made less limiting by the creation of IRCs.

Action	Question [Level, Location]	Methods of evaluating action effectiveness
Experimental design: Section 4.2.6.6.6	Do spawning cue flows lead to higher rates of successful spawning? [L2/L3, Lower] Would creation of more spawning cue flows at Levels 3 and 4 have a significant benefit to the population? [L2/L3, Lower]	To the degree possible while accounting for confounding effects, compare metrics listed in Table 9 for years and locations with a strong spawning cue flow vs. years and locations without a spawning cue flow. Population modeling of the consequences of creating more spawning cue flows.

4.6 Decide

Table 41 (from USFWS and USACE 2015) outlined a series of 5 questions relevant to decisions regarding each of the factors reviewed in the EA, and whether actions associated with this factor should be implemented at Level 3:

- Is this factor limiting pallid sturgeon reproductive and/or recruitment success?
- Are pallid sturgeon needs sufficiently understood with respect to this limiting factor?
- Do one or more management action(s) exist that could, in theory, address these needs?
- Has it been demonstrated that at least one kind of management action has a sufficient probability of satisfying the biological need?
- Have other biological, legal, and socioeconomic considerations been sufficiently addressed to determine whether or how to implement management actions to Level 3?

At a somewhat broader level, there are three major categories of decisions on pallid sturgeon (summarized in Figure 62):

A. Is there enough evidence at Level 1 to proceed with an action at Level 2?
B. Is there enough evidence at Level 1 and Level 2 to proceed with an action at Level 3?
C. Have time limits been reached for implementation of Level-3 actions?
D. Is there enough evidence at Level 3 to proceed with an action at Level 4?

The evidence that is used for these decisions includes metrics and decision criteria *specific to a single action* as well as the accumulating evidence of the *relative amount of support for multiple actions*. An overview of decision criteria is provided in Figure 65. Metrics and decision criteria pertaining to single actions can be found in Appendix C, as well as in Table 43 and Table 44 for decisions in categories A and B. Decisions related to single actions for categories B and C are discussed in the sub-sections on Metrics and Decision Criteria in section 4.2. For evidence on the *relative amount of support for multiple actions*, this chapter also includes decision trees for recruitment in the Upper Missouri river (Figure 63), recruitment in the Lower Missouri River (Figure 64) and spawning habitat (Figure 78). The collaborative population model (described in Appendix D) will be used to integrate information from Level 1 through 3 studies to provide rank order estimates of the relative benefits of different actions in helping with the recovery of pallid sturgeon.

Evidence is largely about understanding cause and effect. That is, does the cause of implementing an action (or multiple actions) to improve reproduction, growth or survival of pallid sturgeon have a measurable and desired effect on one or more life history stages? How strong is the overall weight of evidence from multiple sources? Previous studies that have retrospectively assessed multiple lines of evidence for potential causes of changes in biota (Forbes and Callow 2002; Burkhardt-Holm and Scheurer 2007, Diefenderfer et al. 2011, Marmorek et al. 2011) have generally looked at four different factors: 1) a *plausible mechanism* by which the cause could create a biological effect (which makes sense scientifically); 2) the biota are *exposed* to the causative factor (i.e., the cause overlaps the distribution of the species in space and time) ; 3) changes in biota are *correlated in space and time* with the causative factor; and 4) there is *experimental evidence* that the causative factor can create the hypothesized effect (e.g., from laboratory, mesocosm or field experiments, or natural events that are opportunistic experiments). Diefenderfer et al. 2016 provide a more comprehensive conceptual framework for evaluating the evidence for cumulative effects in areas subjected to ecosystem restoration actions.

Table 53 summarizes the criteria for deciding whether to move from a Level 2 action to a Level 3 action, and whether to move from Level 3 to Level 4 (i.e., decision categories B and C). These criteria are based on the 'Decision criteria' parts of section 4.2, and the decision-relevant questions from Table 52 (most of the questions listed above). The colored columns to the right of Table 53 show five possible answers to each question, drawn from the approach used in the Platte River Recovery Implementation Program (PPRIP 2014), and similar to other approaches used for weight of evidence syntheses (e.g., Peterman et al. 2010, Marmorek et al. 2011). Details on decision criteria are provided in the sections listed in the first column of Table 53. Chapter 2 of this AMP describes the governance process for the Missouri River Management Plan.

Table 53. Summary of decision criteria to be applied to the currently proposed set of Level 3 actions. Hypotheses listed in first column are those most relevant to the action, as discussed in section 4.2. The sections listed in the first column provide more details on the decision criteria for each action. Appendix K provides a list of metrics for each management action, as well as status and trend monitoring.

Level 2 / 3 Action [Hypothesis]	Decision Criteria / Questions	Answers				
		Clearly NO.	Likely NO.	Incon-clusive	Likely YES.	Clearly YES.
Augmentation [H8, H9] [H20, H21] Decision criteria: sections 4.2.5.1.7 and 4.2.6.2.5	Is augmentation meeting target survival rates, ensuring a 95% probability of persistence over a 50-year period and supporting positive trends in upper and lower river populations? [L3, Upper and Lower] Is there a self-sustaining population in excess of 5000 fish in each management unit?					
Intake Dam [H7] Decision criteria: section 4.2.5.2.7	Do adult pallid sturgeon migrate upstream past Intake Dam, migrate to spawning sites and aggregate there? [L3, Upper]					
	Do adults of reproductive age spawn successfully in the Yellowstone River above Intake Dam? [L3, Upper]					
	Are some of the juveniles (age 3+) collected in the Yellowstone River the progeny of tagged adult fish that migrated upstream of Intake Diversion Dam? [L3, Upper]					
	Do free embryos avoid dispersal into Lake Sakakawea? [L3, Upper]					
	Does spawning in Yellowstone River above Intake Dam improve the trajectory of the Upper Missouri River population of pallid sturgeon, and suggest that the population has a 95% probability of persistence over a 50-year period? [L3, Upper]					
Interception and Rearing Complexes (IRCs) [H17, H18, H19]	Do free embryos and exogenously feeding larvae leave the thalweg and enter IRCs? [L3, Lower]					
	Is there sufficient food in IRCs for exogenously feeding larvae to grow better and maintain a healthier condition than in reference areas and times? [L3, Lower]					

Level 2 / 3 Action [Hypothesis]	Decision Criteria / Questions	Answers				
		Clearly NO.	Likely NO.	Incon-clusive	Likely YES.	Clearly YES.
Decision criteria: sections 4.2.6.3.6 and 4.2.6.4.6	Do age-0 fish that occupy IRCs have a higher survival probability than age-0 fish in reference areas and times? [L3, Lower]					
	What's the population-level effect of improved survival of age-0 fish in IRCs? [L3, Lower]					
Spawning Habitat [H16] Decision criteria: section 4.2.6.5.7	Has suitable spawning habitat been created and maintained? [L2/L3, Lower]					
	Are created spawning habitats preferred over other areas by pallid sturgeon in reproductive condition? [L2/L3, Lower]					
	Does successful spawning occur in the created spawning habitats? [L2/L3, Lower]					
	Would creation of more high-quality spawning habitat at Level 4 have a significant benefit to the population? [L2/L3, Lower]					
Spawning Cue Flows [H11] Decision criteria: section 4.2.6.6.7	Do spawning cue flows lead to greater aggregations of pallid sturgeon in reproductive condition? [L2/L3, Lower]					
	Do spawning cue flows lead to higher rates of successful spawning? [L2/L3, Lower]					
	Would creation of more spawning cue flows at Levels 3 and 4 have a significant benefit to the population? [L2/L3, Lower]					

5 Human Considerations

This chapter is organized according to the five steps of the AM cycle introduced in Chapter 1:

1. **Assess** (Section 5.2), which provides objectives and for Human Considerations (HCs) and summarizes the related results of the MRRMP-EIS analyses;
2. **Plan and Design** (Section 5.3), which outlines the management actions under the MRRP and the approach for addressing HCs under the AM Plan;
3. **Implement** (Section 5.4), which describes the operational decision making and Water Management functions for the System;
4. **Monitor** (Section 5.5), which summarizes the concerns, metrics, and monitoring strategies for HCs;
5. **Evaluate** (Section 0), which summarizes the evaluation of monitoring results, new information, model updates and validation, and the use of ancillary information and unexpected events and the role of the HC Team; and
6. **Decide** (Section 5.7), which summarizes key management decisions and associated tools including predictive models, decisions to reevaluate alternative management actions, adjustments to operations to minimize HC impacts, and associated processes under the MRRP.

Associated appendices include Appendix A (Protocols and procedures for decisions), Appendix H (Monitoring protocols for Human Considerations) and Appendix I (Assessments for Human Considerations).

5.1 Background

The USACE operates the Missouri River Mainstem Reservoir System (System), which includes six dams, in accordance with the Master Water Control Manual (Master Manual) to serve eight Congressionally authorized purposes; flood control, navigation, hydropower production, water supply, water quality, irrigation, recreation and fish and wildlife. Combined, operation of the System and the BSNP annually generate approximately $2.2 billion (FY2015 dollars) in benefits to the nation (see Chapter 1 of the MRRMP-EIS). In operating the System for these purposes, the USACE must comply with all applicable laws and regulations, including the ESA. The Missouri River Bank Stabilization and Navigation Project (BSNP) was designed to provide reliable Missouri River navigation. The ESA requires the USACE to avoid jeopardizing the continued existence of any federally listed species when operating the BSNP.

The Missouri River has been modified to meet a variety of HC interests for more than a century. Physical works such as dams created the opportunity to manage - to some degree - the flow of water through the mainstem. From the beginning, management operations sought to improve matters for a range of goals. The first efforts were concerned mainly with issues of flood control and navigation, but with the expansion of infrastructure in the 1940s as a result of the 1944 Flood Control Act, the wider range of Congressionally authorized project purposes identified above also needed to be satisfied. Addressing these needs along with legal obligations to Tribes, endangered species and other factors is the challenge in conventional operation of the System.

Because some priorities for water use are mutually contradictory, the need to find a reasonable balance among HC interests has therefore always been central to the operation of the System. In 1960, the previous decade's implicit operational rules for doing so were encoded into a Missouri River Mainstem Reservoir System Master Water Control Manual, commonly referred to as the Master Manual (Ferrell 1993). The Master Manual was subsequently revised during the 1970s, and again in March 2004, following a 14-year period (1989-2004) of public involvement, to include more stringent drought conservation measures. The most recent revision of the Master Manual occurred in March 2006 to include technical criteria for a bimodal spring pulse from Gavins Point (USACE 2006).

The USACE, in coordination with the USFWS, undertook the MRRMP-EIS to develop a suite of actions that meets USACE ESA responsibilities for the piping plover, interior least tern, and pallid sturgeon. The focus of alternative development for this EIS was on actions necessary to avoid jeopardy to these species in light of a recent synthesis and analysis of scientific information accrued over roughly the past decade. The EIS also considered the effects of proposed actions on Human Considerations (HCs) – the term used in the Missouri River Recovery Program (MRRP) to address the interests of stakeholders. These include the authorized purposes as well as the many other services afforded by the system. Minimizing the impacts to HCs while fulfilling the requirements of the ESA is a fundamental objective for the MRRP. This chapter discusses how HCs were addressed during the EIS and how they will be considered during implementation of the AMP to achieve this objective.

5.2 Assessing Human Considerations

5.2.1 Objectives

Minimizing the impacts to HCs while fulfilling the requirements of the ESA is a fundamental objective for the MRRP.

5.2.2 How HCs are considered in operational decision making

The Master Manual is the guidance document that helps determine how water should be released from the six reservoirs for the benefit of the entire Missouri River basin. Human considerations were integral to the development of the Master Manual with the goal of serving the eight Congressionally-authorized project purposes (see below), meeting the contemporary needs of the basin, fulfilling the USACE's responsibilities to the Tribes, and complying with relevant environmental laws, including the ESA.

The reservoir system is designed to capture spring and summer runoff to provide flood risk management and allows the USACE to manage releases throughout the year to accommodate the other seven authorized purposes: navigation, irrigation, water supply, hydropower, fish and wildlife, recreation, and water quality.

The six USACE dams spanning the Missouri River control runoff from approximately half of the basin. The combined storage capacity of all six System reservoirs is 72.4 MAF, about three times the annual runoff into the System above Sioux City. This high ratio of storage capacity to runoff lends an unusual degree of flexibility to the regulation of the multipurpose reservoir system. The System is also unique in the fact that 88 percent of the combined storage capacity is in the upper three reservoirs of Fort Peck, Garrison, and Oahe.

The System storage capacity is divided into four unique storage zones for regulation purposes (see Figure 85). The bottom 24 percent of the total System storage capacity comprises the permanent pool designed for sediment storage, minimum fisheries, and minimum hydropower heads. The largest zone, comprising 53 percent of the total storage capacity, is the carryover-multiple use zone which is designed to serve all project purposes, though at reduced levels, through a severe drought like that of the 1930's.

The annual flood control and multiple use zone - occupying 16 percent of the total storage capacity - is the desired operating zone of the System. Ideally, the System is at the base of this zone at the start of the spring runoff season. Spring and summer runoff is captured in this zone and then metered out throughout the remainder of the year to serve the other project purposes, returning the reservoirs to the base of this zone by the start of the next runoff season. The top seven percent of the System storage capacity is the exclusive flood control zone. This zone is used only during extreme floods, and evacuation is initiated as soon as downstream conditions permit.

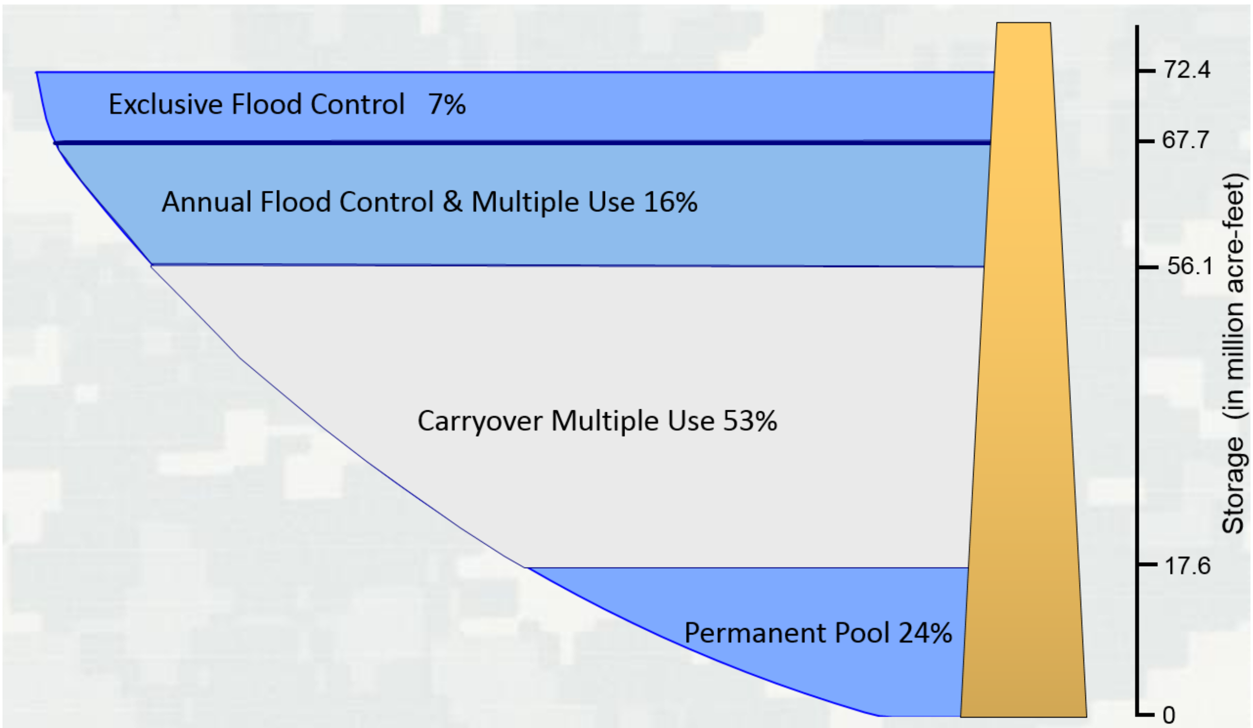


Figure 85. Missouri River system reservoir storage allocation; values represent cumulative capacity of the six main-stem reservoirs. Source: http://www.nwd-mr.usace.army.mil/rcc/reports/pdfs/rcc2015summary.pdf

The Water Control Plan, detailed in Chapter VII of the Master Manual, is designed to achieve the multipurpose objectives of the System. The two primary high-risk flood seasons are the plains snowmelt season, which extends from late February through April, and the mountain snowmelt period, which extends from May through July. Runoff during both of these periods may be augmented by rainfall. The winter ice-jam flood period extends from mid-December through February. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August).

The normal eight-month navigation season extends from April 1st through November 30th during which time System releases are scheduled, in combination with downstream tributary flows, to meet downstream target flows. Winter releases after the close of navigation season are much lower, and vary depending on the need to conserve or evacuate System storage while managing downstream river stages for water supply given ice conditions. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April through June. Nesting of the two Federally-protected bird species occurs from early May through mid-August.

The water control plan includes the following concepts:

- the division of the individual system reservoirs into storage zones, as described above
- specific technical criteria to define the level of service for navigation and other downstream uses, including winter releases for water supply, and to allow evacuation of stored flood water in a manner that minimizes flood risk
- recommended minimum daily flows for water supply, irrigation, and downstream fisheries
- guidelines to provide rising reservoir levels for reservoir fish spawning, intra-system unbalancing, and specific technical criteria for a spring pulse from Gavins Point dam for the benefit of the endangered pallid sturgeon
- reservoir regulation options for use during the tern and plover nesting season to provide habitat and minimize incidental take.

These concepts are codified in the Master Manual. Referred to as the "technical criteria", they are summarized in Missouri River Mainstem Reservoir System - System Description and Regulation (USACE 2007), and presented in Attachment 4 of Appendix A of this AM Plan.

Collectively, the specific technical criteria do not fully prescribe the way the system is managed. Other aspects of system regulation are more flexible, allowing for operational flexibility and professional judgment, including releases for hydropower production, irrigation and recreation. This decision space may be more or less available in any given year depending on the system storage status and long term forecasts for water supply (i.e. projected inflows into the mainstem river) for the coming year.

Each year the Corps's Missouri River Basin Water Management Division (MRBWMD), prepares an Annual Operating Plan (AOP) that presents pertinent information and plans for regulation of the mainstem system under widely varying water input conditions. The AOP examines a range of potential runoff scenarios that span 80 percent of the historical record. The draft AOP is circulated for public review by October of each year. Public meetings are generally held in October and, after consideration of Tribal and public comments, a final AOP is published in the December-January timeframe. Spring public meetings are conducted to provide an update on the current hydrologic conditions and projected System regulation for the remainder of the year as it relates to implementing the Final AOP.

The studies included in the AOP provide an array of reservoir levels and releases that may be expected under five runoff scenarios. The AOP describes the likely effects of the five scenarios for the year ahead, and in doing so communicates the likelihood of outcomes of interest to stakeholders. For example, the 2015-16 draft AOP indicated that that for the 2016 water year the full flood control capacity of the reservoir system would be available at the start of the runoff season, that the use of the Exclusive Flood Control Zone was not anticipated under any of the five runoff scenarios covered in the AOP, and that full service flow support under all runoff scenarios would be available to start the navigation season.

Actual real-time regulation of the System is accomplished using the best information and tools available and is adjusted to respond to changing conditions on the ground. As the runoff season unfolds, there is a possibility that real-time regulation plans will indicate runoff volumes, reservoir levels and releases outside those anticipated in the AOP. Should that occur, the USACE will appreciably increase its communication and outreach efforts to convey that information to stakeholders throughout the basin so that other Federal, state and local agencies, Tribes, communities, and local residents can take appropriate actions (USACE 2015).

HCs were central to the development of the Master Manual, and therefore regulation of the reservoir system in accordance with the manual allows the authorized purposes to be served and the corresponding HCs to be considered. Real time operations are adjusted on occasion to better serve specific project purposes or reduce impacts to HCs, but these adjustments are made only after evaluating impacts to all authorized purposes.

5.2.3 Assessment of effects of actions under the MRRMP

During the development of the MRRMP, long-term implications for HCs of a wide range of alternatives were estimated using various tools and approaches and explored with stakeholders over several rounds of engagement. This section reviews how this was done as links can be made to proposals for using some of these techniques in future HC analysis under an AM Plan.

In August 2014, MRRIC reached final consensus on “Human Considerations (HC) Objectives and Performance Metrics” (MRRIC 2014) a 90- page report that detailed how MRRIC would prefer to see potential impacts from alternatives on human considerations expressed. HCs were broadly organized into the four primary accounts of Environmental Quality (EQ), National Economic Development (NED), Regional Economic Development (RED) and Other Social Effects (OSE). Within each account, performance measures for various HCs were outlined, along with flow charts that illustrated how changes in physical components of the system could lead to ultimate outcomes of concern expressed in performance measures. An example of one such flow chart, for recreation is shown in Figure 86 below.

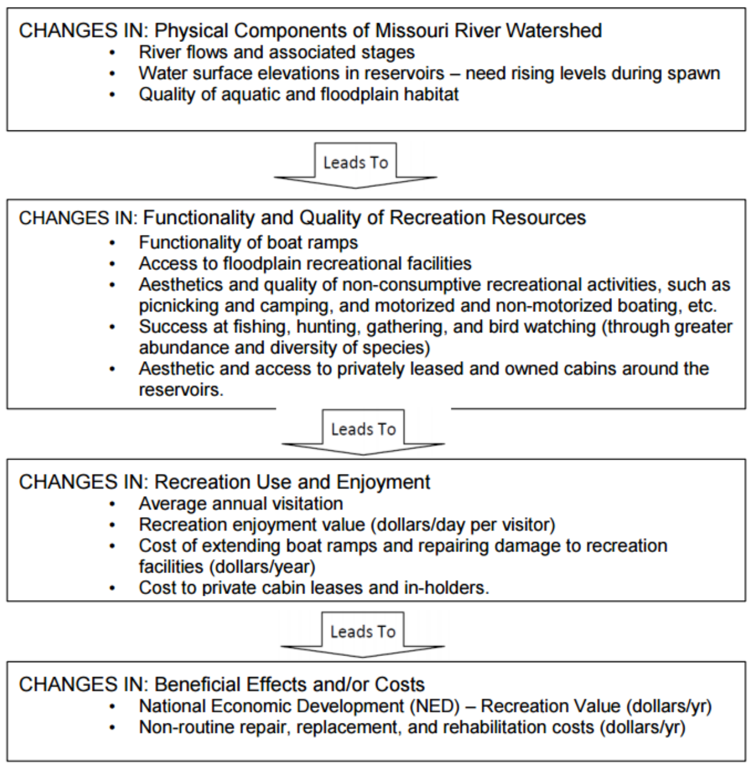


Figure 86. Flow chart of inputs considered for recreation.

In this particular case, the ultimate performance measure for recreation is expressed in dollars per year. However, there are many analytical stages to arriving at this number, some of which require considerable time and resources to develop. In the preliminary stages of alternative review, other tools were therefore used to help communicate how alternatives might affect HC interests:

- Hydrology and Hydraulics Visualization - (H&H) modeling by the USACE resulted in daily stage and flow predictions for several thousand cross sections of the Missouri River mainstem for each alternative. Data were made available to stakeholders for a subset of locations though an interactive spreadsheet tool, HydroViz. With this tool and knowledge of critical flow and stage levels for any given HC, a qualitative comparative assessment of impacts on HCs could be made.
- Proxy measures - During all but the final round of alternative development, proxy measures were used to help compare the relative impacts of alternatives. Proxy measures were selected in collaboration with MRRIC from the upper end of the flow

chart diagrams. For example, in the case of recreation, proxies were developed that summarized how H&H differences would change the proxies (see DEIS Chapter 2 and Appendix A: Human Considerations Proxies and Round 1 and 2 Bird Alternative Proxy 2 Results for further discussion of this process).

Table 54. Sample proxy list for recreation.

Objective / Location	Proxy Metric	Units	Description	Directionality
Recreation/Reservoirs and River Reaches	Number of days with operable boat ramps	# of Days	Operable boat ramps are when stages and elevations fall between minimum and maximum normal boat ramp elevations	High
Recreation/River Below Gavins Point Dam	Number of chutes, backwaters, or shallow water habitat areas	#s	The number of chutes or number of shallow water habitat areas provide a proxy for recreation in terms of potential opportunities for recreational access, slower river water velocities, and safety.	High
Recreation/Three Upper Reservoirs	Number of days above the conservation pool elevation, the mid-2000s drought elevation, and an elevation between these elevations at upper three reservoirs	# of Days	Conservation pool elevations represent important elevations to support both access and fisheries health. Drought pool elevations from the mid-2000s represent important elevations to evaluate how severe drought affects access and fisheries health effects. The pool elevations between the conservation pool and drought elevations represent important elevations to evaluate alternatives.	High
Recreation/Three Upper Reservoirs	Normal to improved fishing success at three upper reservoirs	Yes/No	Fishing success is defined at upper three reservoirs through rising spring reservoir elevations	High (Number of yeses)

Because most proxies were readily derived from H&H modeling, they could be calculated and summarized within 2-3 weeks of the completion of H&H model runs. In this way, numerous iterations of alternatives could be examined. An important limitation of proxies, however, is that while they are helpful for comparing relative performance across alternatives, they may not provide information on the significance of impacts (e.g. how important is a 14-day reduction in number of days of summer boat ramp access?). Proxy measures were also left unweighted in terms of relative importance across locations, though supplementary information (e.g. # boat ramps per area) was provided where possible to help inform this consideration.

A summary of the proxies used in the development and screening of bird test alternatives are shown in Table 55.

Table 55: Summary of proxies used during the development of the MRRP

Resource Area	Proxies considered
Commercial Sand and Gravel	Average annual change in sediment accumulation rate at St. Joseph, Kansas City, and Hermann
Cultural Resources	Days and site-days of greater-than-normal erosion and/or exposure risk in reservoir and river reaches.
Fish and Wildlife	Change in Aquatic/Floodplain Habitat Classes along the mainstem Acres of wetland habitat classes along the mainstem Number of occurrences of flows below 9,000 cfs (thought to be associated with dewatering) in the Ft Randall to Lewis and Clark Lake reach
Flood Risk and Interior Drainage	Days of flood stage exceedance Days of flood stage +5' exceedance Interior drainage flapgate elevation exceedance
Hydropower	Annual seasonal generation (MWh) Seasonal generational value ($) Seasonal maximum capacity (MW)
Irrigation	Number of days outside normal operating conditions during the irrigation season by county
Property Tax Base	Number of acres that would be acquired by the Federal Government, as an indicator of lost local tax revenue
Navigation	Number of days at or above full service Number of days above at least minimum service Season Length Service level at Sioux City, Omaha, Nebraska City and Kansas City
Recreation	Number of days of boat ramp operability by season Number of days that upper three reservoirs are at conservation pool, mid-elevation or minimum drought elevation (indicators of conservation and fisheries health) Number of years of "good' fishing success years
Thermal Power	Number of days that water intakes are inoperable Number of days that river temperatures exceed thresholds considered to be problematic
Wastewater	Number of days below low flow criteria
Water supply	Number of days outside normal and shutdown operating elevations for numerous municipal, commercial and industrial facilities

- Analysis of the MRRMP-EIS alternatives - Finally, the MRRMP-EIS alternatives were evaluated using the detailed analyses described in Chapter 3 of the Draft EIS and accompanying Human Considerations technical reports. Themethods used to calculate National Economic Development (NED), Regional Economic Development

(RED), Environmental Quality (EQ) and Other Social Effects (OSE) measures followed USACE guidance (Planning Guidance Notebook ER 1105-2-100).

These model results provided the best available estimates of how management actions might affect HCs for *long term planning purposes*, and were vital in aiding conversations about alternatives during the MRRMP-EIS review process. However, precise predictions of how particular actions may affect specific HCs in any given year cannot necessarily be made using these methods. The long-term planning analyses of impacts to HCs from the MRRMP-EIS alternatives were based on H&H models that are different from the operational models used by USACE to plan for the year ahead and to operate the system on a daily and hourly basis.

5.3 Plan and Design

5.3.1 Management actions considered in the MRRMP-EIS

The EA identified and screened a range of management actions, including new operations that might be undertaken to avoid jeopardizing the three Federally-protected species. A subset of these actions was incorporated into the six alternatives evaluated in the MRRMP-EIS. Some actions were included in all alternatives, while others were included in only one of the six alternatives.

A preferred alternative has been identified for the Draft MRRMP-EIS. A selected alternative will be identified in the Final EIS and a proposed action described for Section 7 consultation with the USFWS. Following the consultation, a Record of Decision (ROD) will determine which set of actions may be implemented in the AM program. (This process is described in Section 2.2.5). Following the ROD and during implementation of the MRRP, new information acquired about action effectiveness, population dynamics, and system performance may lead to a determination that the actions in the ROD are insufficient and that other actions should be evaluated for future implementation.

This Draft AM Plan accompanies the Draft EIS and reflects the preferred alternative, but retains the broader set of management actions and associated decision criteria developed as part of the DEIS/AMP process. They are organized into three categories:

1) Category 1 - actions that have been evaluated in the DEIS and identified as part of the Preferred Alternative;
2) Category 2 - actions evaluated in the DEIS but not identified as part of the Preferred Alternative;
3) Category 3 - actions not evaluated in the DEIS.

Following the ROD, actions will be sorted in a similar fashion according to whether or not they are included in the ROD and/or evaluated in the MRRMP-EIS. Actions in category 1 following the ROD could be implemented at a programmatic level when needed. Actions in categories 2 and 3 could not be implemented programmatically, but may be explored further through research and pilot-scale implementation, as described in Sections 3.2.4.2 and 3.2.4.3 for the birds and Section 4.2.4 for the fish. The distinction between Categories 2 and 3 is significant because the processes that must be followed to use actions not in the ROD will, in part, depend on whether and how the action was evaluated in the EIS and if those analyses are still sufficient (See Section 2.2.5).

Management actions for birds fall into three general types: 1) those that create habitat with construction or flows, 2) those that improve habitat quality or availability through construction, modification, or flows, and 3) those that directly protect nests, chicks, and/or adults to improve survival. Actions targeting bird populations or their habitats identified in the Preferred Alternative include (see Section 3.2.4.1)

- In-channel habitat construction
- Flow management to avoid take
- Sandbar augmentation and modification
- Vegetation management
- Predation management
- Human restrictions measures

In addition to the above measures, actions evaluated as part of the EIS but not included in the Preferred Alternative include (see Section 3.2.4.2).

- Habitat-forming flow releases (Spring and Fall)
- Lowered nesting season flows

For pallid sturgeon, actions identified in the Preferred Alternative include the following (see Sections 4.2.5 and 4.2.6):

- Population augmentation
- Mechanical construction of IRC habitat
- Mechanical construction of spawning habitat
- Fish passage at Intake Dam on the Yellowstone River
- The potential for a test spring pulse flow aimed at synchronizing pallid sturgeon spawning

Under the Preferred Alternative, efforts focused on the pallid sturgeon include the scientific research described as Level 1 and 2 activities in Section 4.2.4 and detailed in Appendix C.

Changes in flow regime for pallid sturgeon recruitment were the only actions evaluated in the EIS but not included in the Preferred Alternative (except as a potential test operation). (see Sections 4.2.5 and 4.2.6):

Several of the flow actions listed above and under consideration are outside the boundaries set by the Master Manual at the time of analysis, and would require revisions to be made to the Master Manual prior to implementation. Guidance on the steps necessary for this to occur is provided in Attachment 5 of Appendix A and is discussed in several sections in Chapter 2.

5.3.2 How HCs are considered in site-specific planning and design of actions under the preferred alternative

Under the preferred alternative, the USACE will be implementing actions outlined in the ROD as prescribed by the requirements set forth in the BiOp and the AMP. They will operate from a five-year Work Plan, wherein activities in the current FY are generally in implementation, and have already undergone significant programmatic and site-specific planning and design. Management actions planned for the following year (FY+1) would have undergone similar evaluation and have been budgeted by the USACE. Subject to appropriations and some modification due to changed site conditions, these projects are generally “shovel ready”. Note that significant new findings, decision criteria in the AM Plan, or system conditions that prevent construction could, in addition to appropriations, affect the implementation of those projects.

Generally speaking, the projects identified in out years (FY+ 3 and FY+4) will have been identified in general scope, but will not have undergone significant site-specific planning and design. Within the current year, the planning and design for specific projects is usually focused on those slated for implementation in FY+2. Those projects will be the focus of the Work Plan development process and, consequently, to planning and analysis similar to the process used to evaluate alternatives under the MRRMP-EIS. Alternative sites will be considered relative to Program objectives, targets, constraints (budget, etc.) and impacts (including beneficial and adverse impacts to HCs). These will be evaluated using the same tools and procedures employed for the MRRMP-EIS, except that the tools may have been updated or otherwise improved through implementation, monitoring, assessment and validation.

Under the programmatic EIS performed for the MRRMP, specific projects will be subject to a more detailed and site-specific environmental assessment than was possible when the programmatic EIS was conducted. The subsequent document is an Environmental Assessment if the programmatic EIS addresses adequately the environmental effects of the specific component. If the generic EIS does not address appropriately these impacts, a supplemental EIS is required. That EIS is targeted on the specific environmental impacts that were not fully discussed in the programmatic EIS. Supplemental analysis may also be required where there are significant new circumstances or significant new information relating to the proposed project or its impacts.

The essential components of the above efforts are, for each project (or set of projects if so treated), a discussion of the proposed action, its environmental impacts (including impacts to HCs), reasonable alternatives to the proposed action and their consequences, mitigation of adverse impacts and any irreversible commitments of resources. Once the alternative combinations of projects (specific management actions at specific sites) have been evaluated in the planning process and a tentatively selected plan identified, each specific project is subject to the traditional USACE Preconstruction Engineering and Design process. Cost estimates will be prepared, along with construction specifications, operation and maintenance O&M requirements, AM standards and criteria, monitoring plans, as warranted.

As projects are contemplated in out-years (FY+4 and FY+3), then considered in more detail at the FY+2 stage (including site-specific analyses) as part of the Work Plan development and budgeting process, and finally revised and refined (as needed) in FY+1, there are ample opportunities for evaluation, re-evaluation and engagement around possible HC effects. Additionally, monitoring and assessment of implemented projects and validation of the models and tools used to support HC analyses provide added opportunity to revisit plans based on new understanding of impacts (adverse and beneficial) of categories of management action on HCs.

5.3.3 How HCs are considered in planning and design of actions outside the preferred alternative

Chapter 3 of the DEIS describes the iterative process of how actions for Federally-protected birds and fish were assembled into alternatives and assessed for both their efficacy in meeting their primary objectives with respect to these species, but also for their impacts on human considerations. Through these iterations, HCs were examined in detail and efficient alternatives were identified. Further, after a detailed analysis was completed on the Draft MRRMP-EIS alternatives, a subsequent analysis investigated the specific circumstances that could potentially lead to the greatest negative impacts to

HCs from each alternative (see Section 5.7.4). Potential amendments to the formulation of alternatives with actions outside the preferred alternative have been proposed and are described in Section 5.8. Should any of these actions be reconsidered in future, the use of these amendments may help further reduce avoidable impacts on human considerations, though further analysis may be required.

Independently of the application of the impact reduction measures outlined above, any reconsideration of actions outside the preferred alternative is likely to initiate a new round of assessments similar to those described in Chapter 3 of the DEIS. Additionally, measures not included in the EIS are subject to a full NEPA evaluation, and actions previously considered may require a supplemental EIS if there are significant new circumstances or significant new information relating to the proposed project or its impacts (see Section 1.1.6).

5.4 Implementing the MRRP

Implementation schedules for pallid sturgeon actions are outlined in Section 4.3.1. No comparable schedule exists for the bird actions; implementation needs will be driven by the current population status and the current and projected availability of ESH, which will change with system storage and releases. Budget availability, new information and other factors add uncertainty to the implementation plans and schedules for management actions, and the Work Plan will require ongoing updates.

The Work Plan is a rolling, five-year projection of the most current projection of implementation plans and schedules. The Work Plan for the current year is typically implemented as planned, but may deviate from the Work Plan developed during the prior year's planning effort as a consequence of changed field conditions or budget, or on the basis of new information. Such changes would require approval at the appropriate level and include the necessary collaboration/coordination as outlined in Chapter 2.

Plans for the following year are treated similarly, as the budget is generally set (subject to appropriations), but has added flexibility over the current year's plans. Out-year plans are mostly for strategic planning and budgeting purposes, but also provide stakeholders an early indication of likely action implementation.

During the implementation step, species and HC metrics or proxies will be monitored according to the requirements discussed in Section 5.5. Real-time monitoring of conditions could reveal situations that could require adjustments to be made in implementation.

In such a case, a decision needs to be made whether or not to continue with the existing operations or to adjust in some way. These decisions, if they involve flow modifications, would be communicated in the same manner in which all flow management actions are communicated, with the MRBWMD in the lead for making those communications. For changes to implemented projects not involving flows, the MRRP will utilize the Program's website to communicate the changes.

5.5 Monitoring for Human Considerations

5.5.1 Introduction

This section discusses how the USACE currently monitors HC-related issues, and discusses proposals for improvements as a result of implementing the MRRMP-EIS. These proposals require further review and consultation with the HC Team and with the agencies as part of the implementation of the AM Plan.

The HC impact analysis in chapter 3 of the DEIS estimates the national economic, regional economic, environmental and other social effects that would be expected to result from implementation of each of the MRRMP-EIS alternatives. This analysis has influenced the identification of a preferred alternative in the DEIS and will ultimately inform the final selected alternative for the plan.

Inevitably, there are uncertainties in these estimates and, once implemented, decision makers need to know if estimates are essentially accurate or prove to be misleading. Further, in AM implementation of actions, accurate feedback on the predicted and observed impacts to HCs can help improve the quality of information for ongoing and future decision making.

For some HCs, sufficient information for decision making is probably already being gathered and no further action is reasonably required; for others, it may not necessarily be possible to know if predicted impacts on HCs are sufficiently accurate unless specific, suitable information is systematically collected.

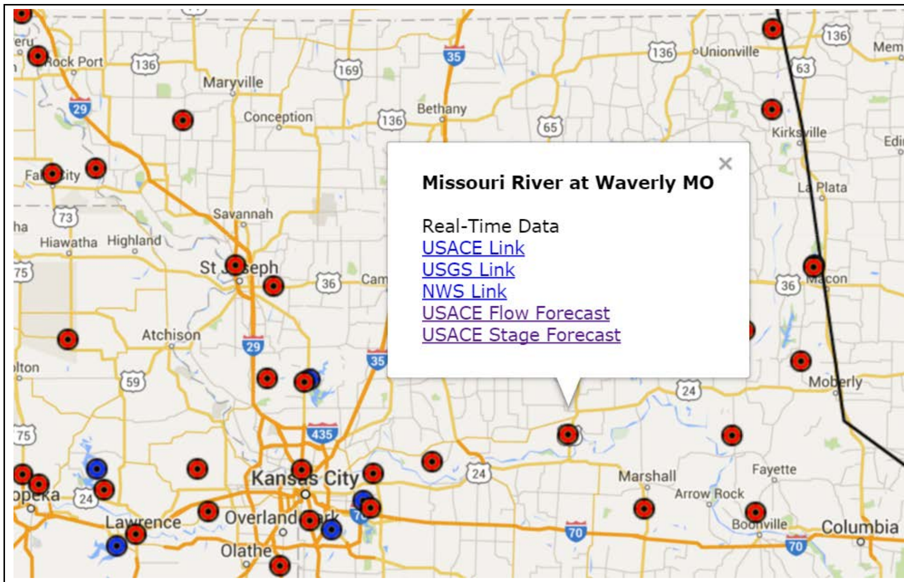
In this section, the uncertainties that exist in making estimates of impacts on HCs are examined. An approach to determining which uncertainties are the most important to resolve is discussed, and a preliminary prioritized list of candidate studies and actions to do so is put forward for future discussion as part of the implementation of the plan

5.5.1.1 *How HCs are currently monitored (independent of the MRRP)*

The USACE Master Manual Chapter V describes the various data collection and communication networks used to monitor the system. Other information is available from other sources noted below. Some key points include:

- A wide range of data are collected on existing and anticipated hydrologic and meteorological conditions (e.g. snowpack depths, evaporation rates, temperatures etc), including real time automated reporting of hydrological and reservoir flow and stage elevation data. This information is not only crucial for operating the system, but is also helpful in understanding impacts on HCs, since most HC impacts are directly correlated to river and reservoir flow and stage/elevation readings (over various timescales).
- Much of this information is available to the public in real time today by the USACE and USGS. For example, Hourly Data Collection Platform (DCP) data are available online at: http://www.nwd-mr.usace.army.mil/rcc/current.html, while maps, graphs, and tables describing real-time, recent, and past streamflow conditions for USGS gages are available at: http://waterwatch.usgs.gov/
- The National Weather Service (NWS) also provides real-time and forecast data for various points on the river. In this case, information is also provided on observed historical flooding impacts associated with various stage levels (e.g. http://water.weather.gov/ahps2/hydrograph.php?wfo=fsd&gage=grws2)
- Stage-discharge trends and rating curves at various locations throughout the system are periodically updated by the USACE based on information from the USGS, as are the hydrologic and hydraulic models that are calibrated with this information. These tools and data can be used with stage-damage functions to estimate the effects of flows on certain HCs.
- Other HC impacts are periodically examined and reported upon in various Technical Reports issued by the USACE. For example, the flow requirements to meet navigation targets were studied in 2000 (USACE 2000a).
- Major events, such as floods, are occasionally the subject of post-event investigations that result in updated information on the effects of flows on HCs. For example, a Post 2011 Flood Event Analysis of Missouri River Mainstem Flood Control Storage (USACE 2012) examined how additional flood control storage could reduce flood risk in the future and the impacts such a change might have on navigation, water supply, hydropower, recreation, etc.
- USACE personnel make numerous reconnaissance trips to portions of the Missouri River that are affected by project releases and of the reservoirs to obtain information pertinent to System regulation. Effects of unusual release rates or reservoir levels are also documented by field observations.

- Stakeholder concerns regarding HC impacts are gathered during the AOP stakeholder review process.
- MRBWMD routinely receive feedback (usually via phone calls) from the public on various issues when flows or elevations reach levels of concern.



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MISSOURI RIVER FORECAST
0600 HOUR STATION FLOWS KCFS

	OBSERVED				TDY	FORECAST						
DATES	2	3	4	5	6	7	8	9	10	11	12	13
						14	15	16	17	18	19	20
GAPF	17.0	17.1	17.1	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
						17.0	17.0	17.0	17.0	17.0	17.0	
BAGF	26.2	26.0	26.0	26.0	9.5	19.0	19.0	19.0	19.0	19.0	9.5	9.5
						9.5	9.5	9.5	9.5	9.5	9.5	
AKIF	2.1	2.0	2.8	1.7	1.7	1.6	1.5	1.5	1.5	1.4	1.4	1.4
						1.3	1.3	1.3	1.3	1.3	1.2	1.2
SUXF	21.0	20.1	19.7	19.5	19.9	19.6	19.5	19.4	19.3	19.2	19.1	19.1
						19.0	18.9	18.9	18.8	18.8	18.8	18.7
DENF	22.8	22.4	22.0	21.7	21.9	21.8	21.5	21.2	21.0	20.8	20.6	20.4
						20.2	20.0	20.0	19.9	19.9	19.8	19.8
TUIF	4.7	4.6	4.3	4.1	4.0	3.9	3.8	3.4	3.2	3.1	3.0	2.8
						2.7	2.6	2.5	2.5	2.4	2.3	2.2
OMAF	32.1	31.8	31.1	30.5	30.5	30.4	30.1	29.3	28.6	28.0	27.6	27.2
						26.9	26.6	26.3	26.1	26.0	25.8	25.7
GRNF	2.7	2.8	2.8	2.8	2.8	2.7	2.6	2.5	2.4	2.2	2.2	2.1
						2.1	2.1	2.1	2.0	2.0	2.0	2.0

Figure 87. Example of real time online flow and stage observed and forecast information available today,

Monitoring is also undertaken to assess the effects of projects implemented as part of the ongoing maintenance of the BSNP, related mitigation actions, projects undertaken as part of the MRRP, and other flood risk management, navigation, and ecosystem restoration initiatives. Although some of the specific monitoring requirements vary depending on the project objectives, authority, and other factors, there are regular monitoring efforts conducted in the lower Missouri River to track levee safety, and responses in channel sedimentation and stability. These monitoring efforts are conducted or overseen by the H&H Engineering staff from the Districts, and are used to update models and assess effects to authorized purposes.

5.5.1.2 *Sources of Uncertainty in Predicting HC impacts*

The hydrological and HC modelling undertaken for the MRRMP-EIS was a sophisticated undertaking. However, as with all models, it is important not to confuse modelling (from which much can be learned) with reality. Examining sources of uncertainty in modelling and considering their implications for management can help consider the limitations of modelling predictions and also identify opportunities for reducing some uncertainties in the future.

Figure 88 summarizes some of the main sources of uncertainty in estimating impacts of management actions on HCs. Uncertainties concerning the top four boxes affect (to some degree) not only each of the HCs, but the target species too. Their associated uncertainties and implications are discussed in the model documentation (see Fischenich et al. 2014) and were considered during the model review and certification processes. Methods for reducing the uncertainties are described in the EA reports (Fischenich et al. 2016) and are represented in the monitoring, analysis and model validation needs for the species (see Chapters 3, 4 and appendices). Some considerations specific to HCs (e.g. ice-jam flooding from ESH) described in this chapter may include additional analyses associated with model uncertainties or uncertain physical relationships.

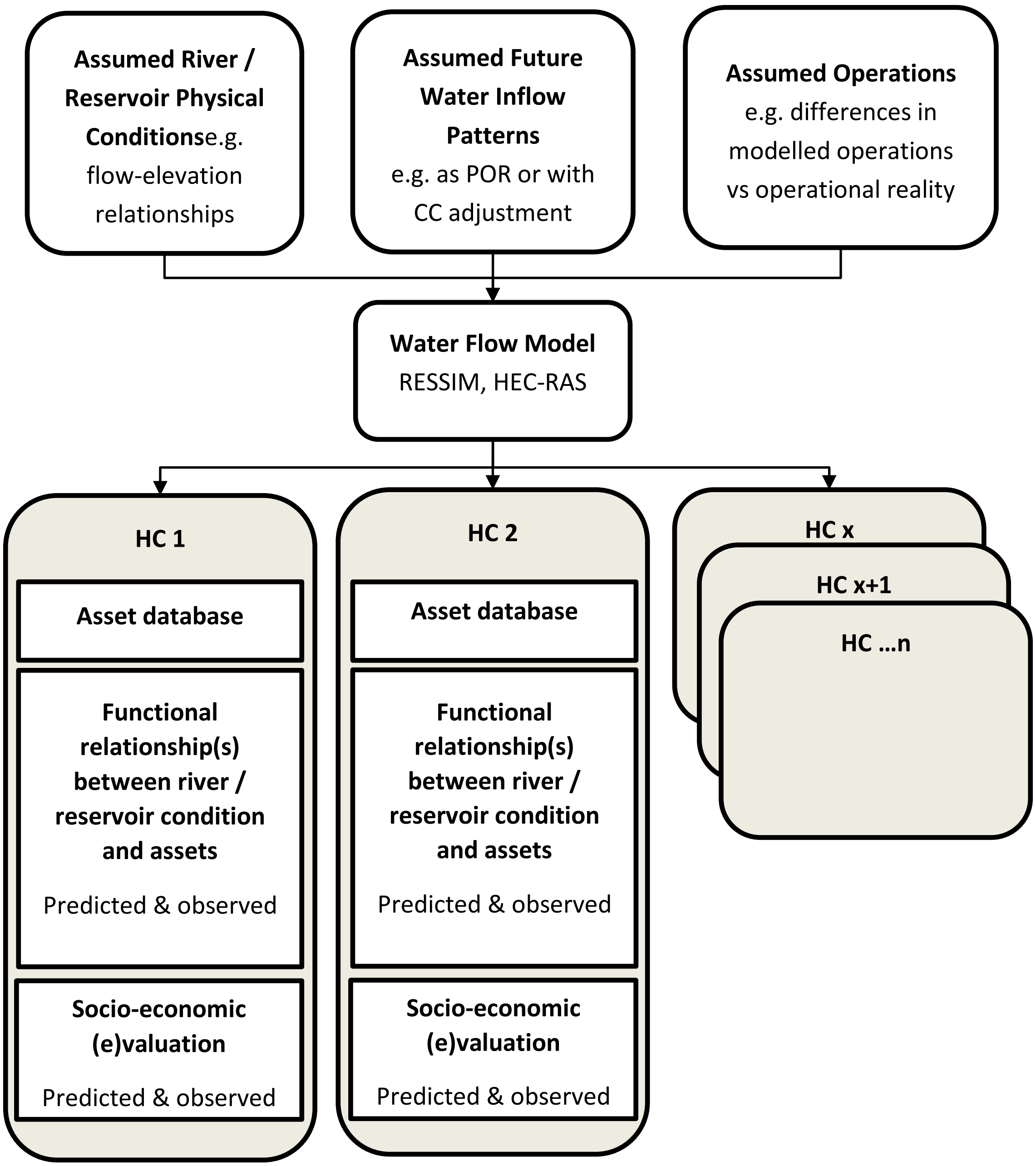

Figure 88. Main sources of uncertainty in estimating impacts of alternatives on HCs

5.5.1.2.1 *Assumed river physical conditions*

The hydraulic modelling used to assess effects for the MRRMP-EIS employed a river channel geometry represented by surveys undertaken in 2012, with each alternative modified by a build-out of differing degrees and distributions of constructed pallid habitat (See DEIS Chapter 2 for details). Changes in channel morphology over time were not represented in the models. This was a reasonable assumption since the purpose was to examine the relative performance of management alternatives under identical conditions, and the challenge of doing so against a changing backdrop of river morphology would be unnecessarily complex. It is known, however, that sediment aggradation and degradation is occurring along the river, and this issue is being addressed by the USACE through ongoing monitoring and analysis as well as periodic focused studies both external and internal to the MRRP. A further but related uncertainty in the modeling for the MRRMP-EIS is that the actual location, size and nature of habitat for the pallid sturgeon is not fully predictable at this time; those details will evolve over time as the site-specific designs are formulated.

5.5.1.2.2 *Assumed future water inflow patterns*

For the purposes of the management plan, it was assumed that a reconstructed 82-year period of historical inflows is representative of the flows and ambient conditions that could be expected in future. Reconstructing this historical data set required its own assumptions, and given the large range of natural variation in the Missouri River, the previous 82 years may or may not be reasonably representative of the range of historical variation. Moreover, the use of historical inflow data makes no accommodation directly for potential changes in future inflows resulting from climate change. The hydrological implications of climate change for this study is discussed further in the appendix "Climate Change Assessment – Missouri River Basin" to the Hydrogeomorphic EA (Fischenich et al. 2016).

5.5.1.2.3 *Assumed operations*

It is assumed that the operational rules for the various alternatives have been encoded accurately and that they reasonably mirror how human operators would operate the system under similar rules and conditions. This has been verified as part of the model review and certification processes. However, this is again a simplification necessary for modelling, and operators do often retain some flexibility to make real-time decisions while still meeting rules. These real-time decisions are always more mindful of avoiding unnecessary negative outcomes than are the algorithms embedded in the models, and typically employ information or data not available to the models.

5.5.1.2.4 *Hydrologic and hydraulic model uncertainty*

It is assumed that the suite of RES-SIM and HEC-RAS models provide functionally accurate representations of the hydrology, reservoir operations and hydraulics for the System under the input conditions (discussed in Fischenich et al. 2016). These models have been both calibrated and validated, and have undergone considerable internal and external review. However, the models do not include all pertinent processes, and consequently may deviate from actual conditions under some circumstances and over time. Changes in channel conditions due to bank erosion or channel degradation, for example, are not reflected in or simulated by these models and could affect resulting river stages. A relative high degree of uncertainty exists in the ESH models, which provide estimates of how much ESH can be expected in each reach due to sediments forming sandbars and subsequently being eroded as a result of varying water flows in the system (see Fischenich et al 2016).

Beyond uncertainties that are common to all flow-based changes to the system, for each HC, there are typically uncertainties surrounding each of the following issues:

5.5.1.2.5 *Asset database uncertainty*

Most HCs involve the development and/or maintenance of one or more databases of 'things on the ground' that are important to people and are potentially affected by MRRMP-EIS alternatives. Uncertainties can arise when these databases are incomplete or have misleading attributes (e.g. incorrect water intake shutdown elevations). It is not always necessary to have a complete database in order for it to serve its purpose at a programmatic level; for example, it is not necessary to account for every boat ramp or every water intake, so long as the information contained is representative enough for decision-making at this scale.

5.5.1.2.6 *Uncertainties in the predicted functional relationship(s) between river and reservoir conditions and assets*

To predict how particular HCs might be affected by changes in habitat construction or flow regimes, it is necessary to develop one or more functional relationships between these changes and primary and sometimes secondary impacts on the interest. Primary impacts are often those that were tracked using proxy metrics during the development phase of the MRRMP-EIS process, and include examples such as hydropower generation and days at various flood stages. Some HCs have very clear functional relationships between flows and primary impacts (e.g. boat ramp accessibility), but others are more complex and multi-staged (e.g. predicting how changes in flow regimes and longer term storage differences might impact reservoir recreation visitation). Some predictions would not necessarily benefit significantly from on the ground verification, whilst others would.

5.5.1.2.7 *Uncertainties in socio-economic (e)valuation*

The final step in estimate impacts to HCs is to interpret how the changes in primary or secondary impacts should be evaluated (or valued) in terms of its relative significance to people locally, regionally or nationally. For the most part, USACE is adhering to established models for doing so, and those models typically have the benefit of having been tried and tested in a variety of contexts, nonetheless, they are not without uncertainties. Sometimes these uncertainties could be reduced by comparing predicted impacts with observed impacts, though in practice this too can be complex.

5.5.2 Reducing uncertainties through monitoring

While there are several sources of uncertainty in predicting impacts on HCs, not all uncertainties matter for the purposes of planning, and some are more significant than others for decision making.

Monitoring can be employed to help reduce uncertainties in a variety of contexts and can be valuable for:

- Confirming that planned activities are undertaken properly (compliance monitoring)
- Passively observing actual impacts on the ground to provide data against which to compare predictions or to watch out for possible unintended negative impacts
- As part of carefully crafted experiments to help test cause and effect hypotheses

Although some data can be obtained from third parties or with little or no incremental effort to the program, other possible studies, while providing valuable information, could compete for resources that might otherwise be used for other program priorities. It is essential to have a structured and disciplined approach to identifying monitoring proposals for HCs in this process.

The process of identifying and specifying monitoring needs for HCs, and the specific identified studies introduced here should be not be considered definitive. Rather it should be seen as a starting point for discussions. The intent is for the HC Team to further consider the issues and provide recommendations for monitoring and analysis needs under AM implementation of the MRRP.

5.5.2.1 *Selecting what to monitor – implementation and compliance monitoring*

In general, implementation and compliance monitoring typically has relatively little scope for discretion for what could or should be undertaken. Some compliance monitoring is legally required or prescribed by professional codes of practice, and typically involves common-sense and low cost activities (e.g. good record keeping, noting the conditions under which an action is implemented). Moreover, much compliance monitoring is undertaken already by default (e.g. operational details such as river flow rates and reservoir storage levels are continuously monitored already).

5.5.2.2 *Selecting what to monitor - effectiveness monitoring*

Some effectiveness monitoring also has a low cost, and some is also automatically monitored (especially those with well-established hydrologic response curves, e.g. boat ramp availability). Even in such cases, data needs to be analyzed to extract meaning, and such data analysis requires resources.

However, effectiveness monitoring could easily consume large discretionary budgets unless careful consideration is applied to the selection of which outcomes are most valuable to monitor. Effectiveness monitoring provides useful background reference information, but it does not necessarily provide or link up with other useful diagnostic information that might ultimately be required to understand why the status and trend of a particular outcome might be changing. A key consideration, therefore, is to ensure that to the extent possible effectiveness monitoring is integrated with targeted studies (discussed below).

Some considerations for determining which areas to focus on for effectiveness monitoring may include:

Responsiveness to management actions. The MRRMP-EIS analysis indicated which aspects of HCs, in which locations and under which seasons are most likely to be affected by specific actions (e.g. spring or fall habitat creation releases). HC indicator selection should focus first on those areas predicted by the analysis to be differentially affected by the new operations.

Significance of potential impact being monitored. The MRRMP-EIS analysis also revealed the potential magnitude of HC impacts. All else equal, HC indicators should focus on high potential impact areas.

Representativeness to underlying concern. When selecting indicators, consideration should be given to the relationship between the indicator and the underlying issue of interest; the closer this relationship, the better. Care needs to be taken to identify non-linear relationships between an indicator that can be measured and the underlying interest.

Credibility and verifiability. It is important that decision makers and stakeholders have access to accurate and credible information. Credibility may be imparted by various characteristics of a situation, but is enhanced when readings can be checked (e.g. through regular QC reviews) or are subject to spot auditing.

Cost effectiveness of collection / interpretation. All else being equal, the least cost way of obtaining required information should be sought.

Versatility. Where a single measurement could act as an effective indicator for a wide range of issues, it should be preferred.

Timeliness for intended purpose. Information is needed on different timescales. When HC indicators are selected, thought should be given to the practicality of whether information from each source could be made available in time for its intended use.

Ability to simplify. Because of the scale of the task at hand, it will be important to seek out indicators that can be scaled back or simplified over time once the indicators map to actual impacts.

Engagement and partnership. Information from various sources should be sought and welcomed; however, all information should be subject to the credibility and verifiability tests previously mentioned.

5.5.2.3 *Selecting what to monitor - targeted studies*

Targeted studies may be expected to require the most resources, but should also have the potential to deliver the greatest benefit to decision makers. Features of circumstances where targeted studies might be of highest value (and therefore have the highest priority) may include:

- Where the MRRMP-EIS HC analysis has identified a potentially high value impact associated with at least one alternative but where there is a large uncertainty as to the probability and/or consequences of the hypothesized impact;
- Where the influence of this uncertainty is significant to understanding the overall MRRMP-EIS HC analysis for a resource area;
- Where future management choices may be influenced by resolving or reducing the uncertainty;
- Where there is a realistic and practical way of reducing the uncertainty, in a way that could be expected to have sufficient statistical power or otherwise to provide compelling weight of evidence within a reasonable timeline;
- Where there is a high ratio of the value to managers of the information anticipated to be gained from the study relative to the cost (money, time etc) of acquiring the information.

5.5.2.4 *Target study screening and prioritization questions*

The above considerations can be used to help screen and prioritize candidate target studies under the MRRP AM Plan. The questions below are drawn from those considerations and are provided as examples, cast in a relatively open-ended form. The HC Team should revise these as needed to guide screening and prioritization activities.

What is the key assumption / relationship / hypothesis needing analysis? Summarize the source of uncertainty in understanding or estimating the potential impacts of alternatives on a resource area.

How wrong or inaccurate could the base assumption be? There are often limits to how wrong an assumption could reasonably be. If being off by the maximum possible error is unlikely to influence a decision, then the issue may not require further investigation. Being wrong or inaccurate is not necessarily important; sometimes even an order of magnitude of error in one assumption may not be of significance to an overall output.

How frequently is the issue relevant? The consequences of some uncertainties may be felt continuously or every season or year. Some events, such as major floods, occur rarely but may lead to significant impacts when they do occur. Other issues may require an unlikely combination of factors to align before the assumption becomes relevant. In cases where extremely large consequences could result, this may nevertheless be a valid reason to investigate further. However, all else equal, priority should be given to those issues that are likely to be relevant more often than not.

How readily could new information resolve the issue or reduce the uncertainty? Not all uncertainties can readily be resolved or reduced through desktop or field studies. A priority study would provide actionable information in a timely way.

How conclusive could this new information be expected to be? A major challenge on the Missouri River will be to provide information that can help distinguish the signal of an impact associated with a particular management action from the noise that results from the large range of natural variation on the river. Care must be taken to ensure that the information collected can ultimately be used to resolve the issue.

What resources would be required to acquire this new information? Outline the approach to address the uncertainty and estimate (at first to an order of magnitude), the cost of the investigation, including staff time and other resource requirements.

What is the return on investment? Aggregating the above, describe (or otherwise estimate) the relative value of the new information that the study could yield relative to the cost of acquiring it.

5.5.3 Screening to identify higher priority monitoring studies.

Uncertainties related to HCs that were identified during the MRRMP-EIS were screened and prioritized to establish an initial set of monitoring and assessment needs. Included were two basic sets of potential studies: 1) those associated with uncertainties surrounding HC effects from mechanical habitat creation actions in the Preferred Alternative, and 2) those associated with uncertainties from flow actions, including possible test flows under the Preferred Alternative and other flows evaluated in the DEIS that could be required to meet objectives at some future point.

This initial screening exercise was executed by the AM Team with input from the technical specialists working on the EIS and that developed the EA. It is intended to provide the HC Team with a starting point for their efforts and to provide the agencies with an early estimate of monitoring needs and costs for planning and budgeting purposes. It is understood that the HC Team will revisit and revise/refine this list using more complete information and with broader input so that they can make sound recommendations to the Management Team.

Drawing from the discussion of prioritization factors presented in Section 5.5.2, the AM Team used the following considerations and approach to identify which of the uncertainties are most significant to decision making and whether monitoring, additional studies or other actions are warranted:

Importance of an uncertainty: The importance of an uncertainty is implied by:

- consideration of how large an uncertainty is suspected to be, including if and how it interacts with other uncertainties (the greater the uncertainty or more likely it is to combine with other uncertainties, potentially the more important)
- consideration of the magnitude of the adverse impacts from being wrong (the greater the possible negative consequences associated with the uncertainty, the more important)
- consideration of the significance to decision-making of reducing the uncertainty (i.e. the more likely that resolution of the uncertainty could lead to different, senior management-level decisions being made, the more important).

The candidate studies were graded on a 1 to 5 point scale for each of the three factors based on the judgment of analysts. Overall importance of reducing the uncertainty was calculated simply as the sum of the three sub-considerations.

Effectiveness of a study to address the uncertainty: Studies or other actions are expected to be effective if they can significantly reduce an uncertainty within the timeframe required for decision making under the MRRP. The ability to resolve the uncertainty efficiently weighs in favor of undertaking the study.

The relative effectiveness of the study in reducing the uncertainty was also rated on a 1 to 5-point scale, where 1 indicates that the study would have a relatively low likelihood of reducing the uncertainty and a 5 indicates that the study would either remove or very significantly reduce the uncertainty.

Cost of a study to address the uncertainty: The cost of the study should consider the full range of resources required to undertake the study. The lower the cost of a study, the more resources remain available for other program needs and so the higher the priority. Costs for each study/activity were estimated at order-of-magnitude.

The overall value of a study is considered to be one that is both effective and that reduces an important uncertainty. For the purposes of this analysis, a score for overall study value is read off from the lookup table shown in Figure 89. It can take the range of 1 to 10, where 10 indicates a highly effective study that resolves a very important uncertainty.

		Study Effectiveness at resolving or reducing the uncertainty				
		5	4	3	2	1
Overall importance of reducing the uncertainty	15	10	9	8	6	5
	13-14	9	9	7	6	5
	11-12	8	7	6	5	4
	9-10	6	6	5	4	3
	7-8	5	5	4	3	2
	4-6	4	4	3	2	1
	3	3	3	2	1	1

Figure 89. Lookup table for calculating the overall value of a study.

Finally, after the cost for the study was approximated, the ratio of study value to cost gives a relative sense of the value of acquiring the information. A summary of these judgments is presented in Figure 90.

Potential HC Monitoring Studies and Screening

Concern (Expressed as an Hypothesis/Reason for Evaluation) / Sub-Concern (Expressed as an Hypothesis/Reason for Evaluation)	Relevant Interest Groups (P-Primary; S-Secondary): Agriculture	Cultural Res.	Dredging	Flood Risk	Irrigation	Local Gov't	Navigation	Recreation	Thermal	Wastewater	Water Quality	Water Supply	Potential actions to resolve or reduce the concern	Relative importance of addressing the concern: Degree of Uncertainty	Significance of Impacts	Significance to Decisions	Overall	Ability to Resolve: How well could the action reduce the uncertainty?	Overall Study Value: Using Lookup table in Chapter 5.	Approx Cost: Approx cost? $000s	Rel. Value of Info: Overall Study Value / Cost	Priority: H-M-L
Constructed Habitat (Preferred Alternative)																						
Constructed habitat can reduce conveyance and result in localized increases in stage that can induce flooding.	P			P		S		S					Predict, then monitor stages at habitat construction sites using a BAC design. IRC sites can be used to monitor and model conveyance effects.	3	5	4	12	4	7	400	0.02	M
Constructed ESH can induce ice jamming, resulting in localized and reachwise increases in stage and flooding.	S	P		P		S			S	S		S	Conduct a study of the effects of ESH on ice jam formation and try to identify critical thresholds.	3	4	4	11	3	6	250	0.02	M
(see above)													Monitor ice jam formation in conjunction with ESH implementation, using scaled implementation to help identify thresholds.	3	4	4	11	2	5	100	0.05	**H**
Constructed habitat can raise local water surfaces and, hence, local ground water levels, leading to interior drainage impacts.	P					P		S					Monitor ground and surface water levels at sites adjacent and immediately upstream of habitat construction sites to determine effects.	3	4	3	10	2	4	400	0.01	L
Constructed habitat can lead to changes in local flow patterns, inducing localized and systemic bank erosion, threatening infrastructure and land	P	P			P	S	S	S	P	P		P	Monitor erosion at habitat construction sites using a BAC design.	3	3	4	10	4	6	300	0.02	M
Construction of ESH causes local erosion that exposes important cultural resources, state parks, historical properties, etc.		P				P		S						3	5	5	13	4	9	300	0.03	**H**
Constructed habitat can cause shifts in local/reachwise sediment dynamics, leading to localized bed level adjustments (scour and	P			S	P		P	S	P			P	Monitor bed-elevation changes.	2	3	3	8	4	5	200	0.03	M
IRC construction can cause localized shoaling that affects performance of the BSNP.	S		S	S			P						Same as above	2	3	3	8	4	5	200	0.03	M
IRC construction can cause localized sediment deficiencies that impact commercial sand production.	S		P	S			S						Same as above.	2	3	3	8	4	5	200	0.03	M
Habitat construction can cause local sediment deposition that effects water intakes.	S				P	S			P			P	Same as above	2	3	3	8	4	5	200	0.03	M
Habitat construction causes short-term increases in turbidity.						S		S	S		P	P	Construction practices could be altered to minimize delivery of sediment to the river. Effects are easily measured, connected to construction activities. Presumably, municipal and industrial water supply are biggest stakeholders. Water quality itself is not a big issue because ecosystem evolved with greater turbidity.	2	2	2	6	4	4	150	0.03	M
ESH construction speeds the export of sediment from the Gavins Point to Sioux City reach, accelerating the point in time when bed degradation downstream of Sioux City is exacerbated by reduced sediment supply.	S	P	P	S	S	S	S	S	S	S	S	S	Effects of ESH on sediment advection can be measured with high precision; modeled with somewhat less. This is a longer-term problem compared to many others, and that could affect perception of priority.	3	4	2	9	4	6	300	0.02	M
IRC construction provides recreational opportunities: camping, boating, fishing, hunting						S		P					This is the potential positive side HC effects. Predictions of recreational usage at these sites is presumably low, but visitation can be measured with precision.	3	2	3	8	4	5	150	0.03	**H**
ESH construction provides recreational opportunities: camping, boating, fishing, hunting						S		P					See above.	3	2	3	8	4	5	150	0.03	H
Flow Changes (In EIS but Outside Preferred Alternative)																						
Flow changes affect visitation and unit day values in ways that are under / overestimated by the DEIS								P					Co-ordinate and enhance State creel data gathering to reduce / resolve uncertainties in DEIS estimates	1	2	2	5	3	3	60	0.05	M
DEIS analysis made assumptions concerning actual responses to low water that may be under / overestimating impacts					P								Undertake a survey of intake operators to better understand responses to low water situations	2	1	2	5	3	3	50	0.06	M
Effects of flow release on river temperature assumed in DEIS may be under / overestimating impacts										P			Systematize the monitoring of water temperature data based on water temperature model input needs	3	5	5	13	5	9	100	0.09	**H**
DEIS analysis made assumptions concerning actual responses to low water that may be under / overestimating impacts												P	Undertake a survey of intake operators to better understand responses to low water situations	2	1	1	4	3	3	60	0.05	M
Navigation economic impact costs assumed in the DEIS are outdated an maybe under / overestimating impacts							P						Navigation shipping study (pilot, or full)	2	1	2	5	5	4	180	0.02	L
FRM database may be indicating false positive / negatives associated with various flow conditions				P									Flood Impact groundtruthing during test or naturally occurring high-flow periods	2	3	4	9	4	6	100	0.06	M

Figure 90.Preliminary prioritization of HC monitoring studies

The candidate HC monitoring studies outlined in this chapter represent only a small number of the studies that could be considered. If the purpose were to precisely account for all potential HC impacts of the Management Plan, a larger number of studies may have been evaluated. However, the studies put forward are candidates proposed by the AM Team and analysts involved in the EIS as providing good potential value in improving the status of information for decision making and a reasonable starting point for the Program to consider.

Even so, the combined cost of the studies presented here represents a significant investment and it is not clear that the Program has a responsibility to fund them or that resources for these studies should be diverted from other uses (e.g. project implementation for species benefits). For these reasons, the monitoring studies are presented here with a relative priority from a HC value of information perspective for decision makers to consider, but without comparison to other Program investments.

It is expected that the uncertainties that might be addressed and their rankings according to the above factors might well change over time, so it is important that these be reconsidered from time to time. It is envisioned that the HC Team will do just that as a central part of their charge.

5.5.4 Monitoring of HCs under the MRRP Preferred Alternative

Based on the screening discussed in the previous section, a handful of potential focused studies and monitoring/assessment actions were identified for actions included in the Preferred Alternative of the DEIS. The following sections briefly outline the concern and the scope of the proposed studies. Study scopes and/or monitoring and assessment protocols are presented in Appendix H.

Stakeholders have articulated concerns that ESH and IRC habitat projects could have negative consequences for human considerations, including socio-economic benefits and cultural resources. Most of these concerns are related to perceptions that habitat projects may negatively affect flood stages, groundwater levels, ice jams, or channel conditions (erosion or deposition) and would subsequently impact interests (e.g. navigation or water intakes). At the same time, it is possible that ESH and IRC projects could have positive socio-economic benefits, by increasing the capacity of the channel to convey floodwater and providing recreational benefits, for example. Hence, investment in monitoring of outcomes from ESH and IRC projects as they relate to HCs may be warranted.

Assessment of effects of ESH and IRC on human considerations generally requires data collection sufficient to address cause and effect; e.g. is flooding or bank erosion or shoaling the result of the project or the result of background variation of the river? This question can be challenging to answer in a highly dynamic river system. There are three potential approaches to establishing an assessment of cause and effect:

- **Before/after monitoring**. Before/after monitoring seeks to establish processes and rates at a site before manipulation and after manipulation so the amount of change can be associated with the manipulation. The before/after approach is frequently limited by the ability to monitor the before condition sufficiently to establish baseline conditions. In a river system characterized by high inter-annual to inter-decadal variability establishment of sufficient of baseline conditions may require many years of monitoring. Pre-existing data may be useful in some cases, but data that were not collected specifically for the monitoring question at hand are frequently poorly focused.

- **Control/impact monitoring**. In control/impact monitoring a manipulated site is match to a non-manipulated (control site) and differential change is taken as the result of the manipulation. The challenge in control/impact designs is establishing that sites are sufficiently comparable.

  Before/after and control/impact designs are frequently combined in so-called BACI designs. The "staircase" design for IRCs (chapter 4) is a type of BACI design that takes into account time-varying construction of IRC sites. The ability of a BACI or staircase design to capture changes in a way that can be used to infer cause and effect is also dependent on length of baseline (before) monitoring and comparability of control and impact sites.

- **Computational modeling**. The third general approach is to use computational modeling of sites, with and without manipulation, to assess sensitivity of human considerations to the ESH or IRC project. The utility of a modeling approach depends on the reliability of the type of model being used. For example, computational hydraulic models comparing pre- and post-IRC construction water surface elevations may be considered sufficiently reliable to evaluate effects of construction on conveyance. On the other hand, models to predict bank erosion or ice-jam effects may not be considered sufficiently reliable to evaluate the effects on human considerations.

Variations or combinations of these three general approaches will likely be necessary to provide useful assessments within budget and time constraints.

Another consideration in these assessments is the value of quantitative data compared to qualitative or semi-quantitative data. Evaluations may benefit from a phased approach in which qualitative data are used to establish whether a process is important (for example, do aerial photographic surveys indicate new patterns of flow after construction of ESH?) followed, if needed, by a quantitative assessment of how much, if any, bank erosion is caused by the new flow patterns.

Note that the proposed studies outlined below and in the appendix will be updated as the WP for the MRRP is formulated. The descriptions, scopes and protocols presented in this AM Plan should be regularly updated to reflect current and proposed studies based on the approved WP.

With respect to potential impacts on Tribal cultural sites, NHPA Section 106 and 110 will be followed as management plan actions are implemented based on NHPA Programmatic Agreements and consultations.

5.5.4.1 *Monitoring to address flooding concerns associated with constructed Interception and Rearing Complexes (IRCs)*

Concerns were raised by stakeholders during the MRRMP's development that constructed IRC habitat can reduce conveyance and result in localized increases in stage with subsequent flooding. Model studies show the magnitude of effects are small (within measurement error) and actually decrease stages for most flows, and model results are supported by basic hydraulic principles. The significance of this concern is high and the value of information (VOI) is high because the results of the proposed study should dispel pervasive concerns and may document stage reductions, nor increases, associated with the proposed IRCs.

The proposed study involves the application of the USACE HEC-RAS models to study reaches where IRCs are to be implemented and then monitoring actual stages in those reaches using a Before-After-Control (BAC) study design. Comparisons between predicted and monitored stages can be used to either a) validate the models, or b) recalibrate and then validate the updated models. The IRC sites identified as part of the experimental design for pallid sturgeon (see Section 4.2.6.3) can be used to model and monitor conveyance effects, and the monitoring proposed for the IRC study (see Appendix E) can be adjusted slightly to accommodate the needs for the HC study.

Water surface elevations in reaches with IRCs as well as in control reaches will be surveyed using either Lidar or conventional hydrographic survey equipment and real-time kinematic global positioning systems (RTK GPS) or differential global positioning systems (DGPS). Transect spacing will depend upon the particular site and should provide sufficient spatial coverage for creating continuous surface maps of depth, elevation, and velocity given the expected amount of spatial variation due to site specific features as well as variation expected under variable discharges. Repeat surveys will be conducted at each site utilizing the same transect design for subsequent surveys. Appendix E illustrates an example reach with transects spaced at 20-m intervals perpendicular along the recommended sailing line. Additional longitudinal survey lines along the banks and in the thalweg may be used to improve accuracy of continuous surface maps. The frequency and timing of surveys will largely depend upon flow and water levels. At a minimum, one survey per site per year will take place, but additional surveys will be scheduled as needed in order to obtain data for a sufficient range of flows to develop rating curves and evaluate/validate the hydraulic models.

Details for the proposed study are provided in Appendix H.

5.5.4.2 *Monitoring to address localized sedimentation concerns associated with constructed Interception and Rearing Complexes (IRCs)*

The concern here is that geomorphic adjustments in and adjacent to IRCs could result in localized scour or deposition, resulting in human consideration effects like bank erosion, scour near river infrastructure, or deposition in the navigation channel. The staircase statistical design for assessing IRC habitat changes is well suited for addressing these questions, although the frequency and extent of channel resurveys may need to be increased for the human considerations.

The IRC staircase evaluation design includes complete topobathymetric surveys in treatment and control reaches. These surveys will be used to construct hydrodynamic models for evaluating the extent and temporal persistence of habitat types and for evaluating transport from the navigation channel to the IRC. We expect that the channel configuration at an IRC site will continue to evolve and adjust through some time period post construction, and that the newly constructed IRC may also have a dynamic erosion and deposition regime that differs from control sites. For this reason, the IRC reaches will need to be periodically resurveyed to update the models. These resurveys can also be used to assess the human considerations, in particular if, where, and how much erosion and deposition occurs over time. To address human consideration concerns, the spatial scope of the surveys may need to be increased somewhat upstream and downstream to evaluate all potential effects. Resurveys for IRC habitats would be annual or biennial right after survey and then increase in years between surveys as time progresses. For the case of erosion or deposition that may relate to specific socio-economic concerns, some complementary within-year resurvey may also be advisable.

Details for the proposed study are provided in Appendix H.

5.5.4.3 *Monitoring to address flooding concerns associated with constructed Emergent Sandbar Habitat (ESH)*

Concerns were raised by stakeholders during the MRRMP that constructed ESH habitat can reduce conveyance and result in localized increases in stage with subsequent flooding. Model studies show the magnitude of effects are small (within measurement error) for the size and spacing of sandbars as historically implemented under the MRRP, and actually decrease stages for most flows, and model results are supported by basic hydraulic principles demonstrate that ESH has the potential to cause measurable localized increases in water surface elevation. The significance of this concern is high and the value of information (VOI) is high because the results of the proposed study can be used to develop guidelines for the siting and design of ESH so as to avoid or minimize the effects of water surface elevations.

The proposed study involves the application of the USACE HEC-RAS models to study reaches where ESH is to be implemented and then monitoring actual stages in those reaches using a Before-After-Control (BAC) study design. Comparisons between predicted and monitored stages can be used to a) validate or recalibrate and update the models, b) develop general criteria for planning and design of ESH, and c) refine designs for individual ESH projects.

Water surface elevations in reaches with ESH as well as in control reaches will be surveyed using either Lidar or conventional hydrographic survey equipment and real-time kinematic global positioning systems (RTK GPS) or differential global positioning systems (DGPS). Transect spacing will depend upon the particular site and should provide sufficient spatial coverage for creating continuous surface maps of depth, elevation, and velocity given the expected amount of spatial variation due to site specific features as well as variation expected under variable discharges.

Repeat surveys will be conducted in each study reach utilizing the same transect design for subsequent surveys. Additional longitudinal survey lines along the banks and in the thalweg may be used to improve accuracy of continuous surface maps. The frequency and timing of surveys will largely depend upon flow and water levels. At a minimum, one survey per site per year will take place, but additional surveys will be scheduled as needed in order to obtain data for a sufficient range of flows to develop rating curves and evaluate/validate the hydraulic models.

Details for the proposed study are provided in Appendix H.

5.5.4.4 *Monitoring to address potential ice-jamming and related flooding concerns*

associated with constructed Emergent Sandbar Habitat (ESH)

Sandbars have been identified as a possible contributor to ice jamming on some rivers, resulting in localized and reach-wise increases in stage and flooding. Ice-jam floods are common on the upper Missouri River, and the potential for localized flooding downstream of Garrison Dam is of particular concern. Predicting the effects of ESH construction on flooding potential, if any, will require a greater understanding of the causes and effects of ice jams in the reach. Ice jams can cause considerable channel scouring, avulsion, remove vegetation in the riparian zone, and affect the morphology of sandbars upstream from the jam, within the jam, and downstream from the jam when it breaks up and releases a pulse of water (Ettema and Daly, 2004).

This topic has received comparatively little study, and separating the effects of ESH construction from other geomorphological processes in the reach may be a challenge. Two potential studies were identified as part of the initial screening of HC monitoring for the MRRP. The first study involves mining of historic ice formation records and associated ESH conditions to try and obtain a useful relationship. The second study involves real-time monitoring of ice conditions and water surface elevations in reaches with and without ESH over time so as to obtain data useful for simulating ice jamming and flooding in the reach. It may be difficult to run a controlled experiment given the high natural variability of ice formation in the reach. Nevertheless, the study could use the considerable real-time data already collected in the reach along with other technologies such as Lidar, satellite-based remote sensing, and digital field camera deployments to develop high benefit/cost datasets with strong cause/effect value.

Additional detail for the proposed studies will be developed by the Technical Team, coordinated with the HC Team, and incorporated into Appendix H. The significance of this concern is high and the value of information (VOI) is high because the results of the proposed studies can be used to develop guidelines for the siting and design of ESH so as to avoid or minimize the potential for ice jam formation and the effects of related jams on local flooding.

5.5.4.5 *Monitoring to address localized erosion concerns associated with constructed Emergent Sandbar Habitat (ESH)*

Constructed ESH can cause changes in local flow patterns, potentially inducing localized and systemic bank erosion. This can be a significant concern, particularly where cultural resources or infrastructure are threatened or where private land loss may occur. Erosion is a natural phenomenon that is both common and widespread. However, accelerated erosion can occur where ESH severely restricts channel conveyance or causes localized hydraulic conditions conducive to bank scour.

The proposed study involves the monitoring and study of reaches where ESH is to be implemented using a Before-After-Control (BAC) study design to assess bank erosion frequency and magnitude and the impacts of any observed erosion. Comparisons between project and control reaches as well as before and after comparisons of project reaches may yield important information that could lead to the development of general criteria for planning and design of ESH and help refine individual ESH projects through AM. Bank erosion is difficult to accurately predict using numerical models particularly where the erosion processes are highly stochastic, such as on unrevetted portions of the Missouri River.

Topographic and bathymetric surveys will be conducted in reaches with ESH as well as in control reaches using either Lidar or conventional hydrographic survey equipment and real-time kinematic global positioning systems (RTK GPS) or differential global positioning systems (DGPS). Transect spacing will depend upon the particular site and should provide sufficient spatial coverage for creating continuous surface maps of bankline position, elevation, and vegetation coverage given the expected amount of spatial variation due to site specific features as well as variation expected under variable discharges.

Repeat surveys will be conducted in each study reach utilizing the same transect design for subsequent surveys. Additional longitudinal survey lines along the banks and on the perimeter of ESH may be used to improve accuracy of continuous surface maps. The frequency and timing of surveys will largely depend upon flow and water levels. At a minimum, one survey per site per year will take place, but additional surveys will be scheduled as needed in order to obtain data demonstrating the response of bank erosion to particular conditions.

Details for the proposed study are provided in Appendix H.

5.5.4.6 *Monitoring associated with test flows*

The Preferred Alternative includes a provision for a Level 2 in-river spawning cue release test. If included in the Record of Decision (ROD), the test flow would consist of a one-time release from the System after year 8 if Level 1 studies do not provide a clear answer on whether a spawning cue is important. This flow was one of several evaluated in the DEIS. The impacts of this flow were analyzed under Alternative 6 of the DEIS. The Level 1 studies will include monitoring naturally occurring high flows to gage species response. The Level 2 test will include extensive monitoring to show the effects, if any, on the species, if Level 1 studies are insufficient in determining species response.

A detailed design for HC monitoring for this test flow has not been undertaken because to do will require additional information than is currently available. USACE and the HC Team will consider a monitoring regime associated with such a test flow if it is required and when the specifications for such a flow become clearer.

5.5.4.7 *Other studies and opportunistic monitoring under the Preferred Alternative*

Changes to channel configurations that increase habitat values for piping plovers and pallid sturgeon also have the potential to increase attractiveness of the river for recreational users. As a result, socio-economic benefits may also accrue in habitat rehabilitation projects. This is due to the attractiveness of increased channel complexity, increased sandbar availability, and generally increased habitat diversity in IRC and ESH projects. Sandbars (as ESH or in IRCs) are especially valued by recreational river users as campsite and picnic destinations where appropriate. Increased channel complexity around ESH and IRC projects are also likely to increase habitat values and sportfish production. These benefits may be substantial: over a one-year time inter al in 2004, recreational use of the Lower Missouri River was calculated to be worth $20.1 million to $38.7 million (Sheriff and others, 2011). Hence, recreational use may be worth assessing to allow a complete and accurate evaluation of tradeoffs.

Assessment of recreational use would likely make use of the BACI or staircase design, comparing recreational usage in control and treatment reaches. A useful metric would be simply number of visits and this can be effectively determined using remote, time-lapsed photography. Simple analysis of the photographic dataset could entail relative numbers of visitors whereas more complex analysis could classify type of visit and relate to economic impacts.

It may be possible to consider opportunistic monitoring of high priority HC issues associated with the Level 1 pallid sturgeon natural flow events that could yield information on spawning cue flow requirements. This is a discussion that could be initiated between the HC and Fish Teams at an early opportunity.

5.5.5 Monitoring considerations for potential future management actions

As DEIS Chapter 3 shows, the largest potential for negative impacts to human considerations come from the use of flow modifications. As discussed in Chapter 2, the preferred alternative may not be sufficient to meet the objectives of the MRRP, and it might be necessary to consider other alternatives, including actions involving flow modifications. These may include those actions evaluated in the MRRMP-EIS or other, as yet undefined actions that would be dictated by the science and understanding developed through the AM Program.

Given this, it is prudent to consider the kinds of monitoring for human considerations that might be necessary in such a case. In this section, three situations are considered:

1. Monitoring of HC issues that could be undertaken now in order to create better baseline data against which to understand the impact of potential future flow modifications,
2. Monitoring of HC issues that could be undertaken and completed before a flow modification action is taken, and
3. Monitoring of HC issues that could be only undertaken in the event of a flow modification.

In all cases, consideration should be given to the fact that channel changes are a consistent feature of the river and the relevance of monitoring results over time should be a factor considered in monitoring activity design and use.

5.5.5.1 *Monitoring of HC issues that could be undertaken now in order to create better baseline data against which to understand the impact of potential future flow modifications*

This section describes a range of activities that could be undertaken soon after the implementation of the AM Plan is initiated to help better prepare for a potential future circumstance when a flow modification could be required. These activities are thought to have relatively low cost (confirmation of this would be required) and would have a range of benefits.

The primary purpose of these activities is to reduce uncertainties about how operations (current and potential future) affect HCs and to organize or systematize the collection of decision-relevant baseline information. The proposals listed here would help confirm or refute predictions on which areas would or would not be affected by potential changes to flow releases and would serve to focus attention on them if and when required. It could help MRBWMD in its daily operational choices and would help economists and analysts develop more complete and reliable correlations between historical data and impacts.

Secondary benefits of these activities would be to help improve the relationships and communication pathways between Tribes, stakeholders and the USACE regarding the links between flow changes and impacts on HCs, both now and under potential future scenarios. In the early years of the AM Plan, it would encourage regular structured conversations between the USACE and the HC Team regarding the details of how flow choices affect interests. Doing so would help identify key indicators and methodologies that could be referred to in actual planning situations should flow releases be used at some time in the future. This would help build a shared sense of understanding on specific issues that may currently be unclear for any party.

The following are preliminary suggestions that could be further discussed and developed by the HC Team, in collaboration with the USACE.

Create an online information clearing house for HC data

As discussed above, there is currently no systematic collection or organization of information regarding the impact of system operations on HCs. Information technology advances in the past decade have made doing so a reasonable proposition. The data collected could come from various sources and relate to different aspects of the impact pathways between USACE operations and impacts to HCs. At the present time, the USACE is not committed to undertaking or facilitating this kind of data management due to the formidable challenges such compilation would entail; however, it can appreciate the potential added value such information could have on AM planning.

For discussion purposes, examples of data that could be collected and made accessible in a central location could include:

- Current and historical weather, snowpack levels, inflow, river stage, system storage, reservoir elevation etc. (much of which, as previously discussed, is already available online in various places)
- Automated data transfers of information currently being collected by stakeholders (e.g. water temperature measurements, water quality measurements, hydroelectric generation data, navigational craft data etc.)
- Information submission forms and data upload interfaces that enable the public to send the USACE information relevant to ways in which system operations might affect them (or perceive to affect them). For example, data on recreation user data might be sought and collected on a regular basis; information on flood damages associated with particular circumstances could be quickly shared; information on irrigation problems or water supply intake issues could be photographed and the details uploaded and logged etc.

Not all information gathered in this way would be actionable by the USACE, or necessarily relevant to decision making due to compounding issues such as the need to establish the veracity and accuracy of data submitted by outside parties. However, it would provide for information exchange upon which discussions could be had with the HC Team. All such data collection would need to be subject to similar (and strict) provisions for ensuring high information quality. This is discussed further in Chapter 6.

The EIS uses the best currently-available information. Future decision making could be even better informed through actions taken in the coming years to reduce decision-relevant uncertainties where possible. The following paragraphs summarize initial considerations for HC monitoring priorities by resource area. Not all resource areas are covered at this time, but future HC Team discussions could develop these ideas in a similar fashion.

Recreation

Overall, recreation impacts can be mostly inferred from factors that are already being monitored – the location of constructed habitat, and changes in river stage and reservoir elevations, fishing success, and fishery health. During the development of the MRRMP-EIS, substantial effort was dedicated to updating and refining USACE's database of recreation resources, including boat ramps, residency of visitors, types of visitors, etc.

The greatest information need, however, appears to be the need to confirm the assumed relationship between system operations and various types of visitation. From the statistical regressions on the lakes conducted by the project team, visitation at the lakes was most influenced by summer lake elevations. A better understanding of how anglers and other types of visitors respond to lake elevations and fishing pressure would further refine the impact from system operations on lake visitation. Some of this information is currently being collected by various state agencies although data collection is not consistent across lakes and is not collected every year in most cases. Predictions of visitation could be improved through the use of visitor surveys that seek to clarify what features of the recreational experience most strongly influence visitation choices. For example, in the case of an angler, how important is fishing success relative to reservoir elevation in determining visitation choices?

Visitor use surveys in the river reaches could also improve precision around day use value, since there remains some uncertainty about some activities (e.g., paddleboard activities) and whether these visitors prefer low flows or high flows and is there a threshold that would be important to consider in a decision to visit the area? Some of this information is being collected by state Fish and Game visitor and creel surveys but could be expanded to better understand how river flows affect various types of recreation activities on the river.

When calculating regional economic impacts, more precise information on the relative proportion of local versus non-local visitors would help better estimate how much money is being spent by whom and whether the source of the expenditure is local or from outside the region. Some states are again collecting this information as part of their visitor and creel surveys.

The USACE could therefore engage with states to examine what information is being collected and consider which, if any, data gaps for the purposes of this program are not being collected. If valuable information is being missed, USACE could consider co-funding state data collection based on a value of information evaluation. For example, it would be useful to know whether building mechanical habitat for pallid sturgeon or plovers increases or decreases recreation values.

Irrigation

Although the project team is confident in predictions of impacts of system operations on irrigation intakes, some uncertainties remain that could be addressed at relatively little cost. For example, it is assumed that if the river or reservoir level falls below a certain intake operating threshold, as established and reported by the operator of that irrigation intake, the intake will lose access to water for a full day. This may not be true and the current irrigation evaluation could over-estimate negative impacts to irrigation (for example, many of the intakes are portable and may be able to access water below critical thresholds by moving the intake).

There is imperfect information on the technological and operational responses open to irrigators at the various locations. For example, the model evaluates one likely response of irrigation intake users to adverse conditions (river stages and reservoir elevations falling below intake operating elevations), namely, a change in crop production. While it is reasonable that irrigation intake users might consider a range of other responses (e.g., switching to a groundwater source, incurring costs to move the intake to the water, growing a different mix of crops, or selling the land), this model is unable to evaluate these alternative responses. Also, the extent of use of portable intakes is not fully understood.

Further, as a result of inadequate data, the irrigation economic model does not capture changes in cost to irrigators as a result of changing river/reservoir conditions. Interviews with numerous intake owners, operators, and service providers failed to uncover data or information that could be used to build a consistent cost profile for irrigation intake owners and operators when they experience adverse river or reservoir conditions. Consequently, it is assumed that production costs, as reported in crop enterprise budgets, remain constant for a wide variety of irrigation conditions.

A survey of irrigation operators could gather further information on the following issues:

- Further refine the current database of intake operators, improve the accuracy of critical intake and operational thresholds;
- Further refine the cost response to these issues: how do costs actually change with changes in water flows in the river. For example, what is the relative cost of moving intakes versus other potential responses (reduced crop yields)? Clarify which operators have access to alternative sources of water, and at what point these other sources of water would not be available;
- Improve the understanding of how yield varies by water loss. The model currently assumes a linear relationship between yield and access to water through intakes up to a maximum loss in crop production: the yield and crop enterprise budgets for "dry land" farming areas. More information on how crop yields for different crops respond to various numbers of consecutive days without water (some crops may be more resilient than others) along with the effects of evapo-transpiration could be gathered.

Thermal Power

Modelling suggests that MRRMP-EIS alternatives with additional flow releases relative to No Action (Alts 2, 4, 5 and 6) results in changed frequency and duration of intake operability in both the upper and lower river. In addition to intake operability concerns, temperature issues may be experienced in the lower river. Higher river temperatures may cause thermal power plants to exceed thermal discharge limits and have reduced operational efficiencies; under current conditions, the regulatory and operational limits are approached and sometimes exceeded. If, as a result of changes in flow releases and subsequent storage recharge, river flows in the lower river were reduced during a hot summer period relative to No Action, river temperatures could increase above regulatory and operational thresholds, with reductions in power generation and increased costs to replace reduced power generation and lost capacity during peak power periods.

"Thermal Power Technical Report" discusses in substantial detail the information base on which the impacts of the alternatives' thermal power impacts were estimated. In general, uncertainties associated with the ability to predict intake issues and their effects on thermal generation are considered small. The database of intakes is considered robust, and river stages and reservoir elevations are well understood. However, channel geometry complexities in certain locations may give rise to uncertainties when linking flow and elevation patterns to actual operational difficulties.

There is likely low uncertainty concerning the potential impacts of habitat creation (via construction or flows) on thermal power. The EIS notes that most power plants are in urban areas that are well away from any sites likely to be considered suitable for habitat creation and site-specific planning would minimize adverse impacts to sensitive infrastructure such as power plants. Although there are six power plants in the Garrison Dam to Lake Sakakawea reach that could be affected by the creation of ESH habitat, site specific planning would result in relatively small, temporary, adverse impacts.

There are important uncertainties concerning thermal impacts, however. These include:

- There is a limited data set of only 15 usable years of temperature data from the temperature model. Actual river temperatures are an important input into the model and are not systematically collected in a way that would be optimal for monitoring and predictive modelling.

- The predictive temperature model itself has other uncertainties.

- There are uncertainties surrounding the calculation of lost capacity value associated with the potential loss of generation from the MRRMP-EIS alternatives.

- It is uncertain how state regulators would actually act in individual situations when thermal power discharges are in violation of permits. Some power plants have sought variances to maintain operations by showing that their thermal effluent does not have adverse environmental impacts. Other plants would need to derate or reduce power generation to meet NPDES requirements.

One of the primary uncertainties concerning thermal power relates to understanding the relationships between operations and temperature at susceptible power plants. Currently, each power plant monitors river temperature locally. However, NPDES permit temperature monitoring requirements differ and are often not required to be undertaken daily. Daily monitoring of river temperatures by power plants and reporting to the USACE (or possibly to USACE via the state water quality regulatory agency) as well as the consistent notification to the USACE of any operational or regulatory impacts to power generation from river temperatures is a necessary component of a monitoring program. The largest single gap in the ERDC temperature model is the availability of historical temperature information at the correct locations and in a uniform format (hourly or daily temperature data). If river temperature monitoring at key locations were to be centralized and optimized with respect to location (e.g. in tributaries as well as around local plant sites), the USACE would not only have a better real-time understanding of the issue but would also improve their future ability to understand how future management changes might affect temperature in the river.

To better understand how river bed geomorphic changes (early life stage habitat) affects river temperatures, temperature monitoring at the site level should be undertaken while considering the timing of habitat construction upstream and in proximity to power plants.

Water Supply

MRRMP-EIS alternatives with additional flow releases relative to No Action (Alts 2, 4, 5 and 6) generally result in increased frequency and duration of periods with lower reservoir storage (associated with flow releases) and lower river flows (associated with system recharging following a flow release) than would have been the case under No Action.

“Water Supply Technical Report” discusses in substantial detail the information and assumptions used to estimate impacts on water supply access from the management plan alternatives. In general, there are uncertainties regarding how water supply managers would react to changing river conditions and the evaluation of impacts only considered one possible approach (use of submersible pumps), During the development of the MRRMP-EIS, intakes showing potential sensitivity to differences in alternatives were researched further on a case by case basis to verify information on intake thresholds etc. Moreover, many of the water intakes in the system, particularly around reservoirs, were upgraded in the early 2000s during the period of low water during that time. These intakes, under most circumstances, would be unlikely to be affected by any changes in flows resulting from the MRRMP-EIS alternatives.

The proxy analysis showed that impacts are expected to occur to water supply intakes under current system operations. It was assumed that this impact is being caused by degradation that is occurring in several river reaches and that water supply managers would need to make improvements to the intakes to address the degradation. This degradation is not caused by any changes associated with the Management Plan. The analysis did not attempt to evaluate significant intake modifications that would occur as a result of degradation issues, but instead focuses on incremental changes that would occur as a result of the Management Plan.

The accuracy of the existing inventory of water supply intakes and reaction of managers to changing river conditions could be further improved through the use of interviews with water supply managers. Many such managers have already been interviewed during the MRRMP-EIS development. The additional interviews would seek to further confirm the operation and operability of certain intakes during periods when predictive modelling indicates problems should be anticipated. It would confirm the capacity of each intake and would probe further about operators' experiences under specific water conditions.

Navigation

Changing water management patterns resulting from the EIS alternatives could affect the ability of commercial vessels to transport goods on the Missouri River. Alternatives with additional flow releases relative to No Action (Alts 2, 4, 5 and 6) generally result in differences in frequency and duration of periods with lower river flows (associated with system recharging following a flow release) than would have been the case under No Action.

The "Navigation Impact Analysis Technical Report" discusses in substantial detail the data and methods employed to estimate the navigation impacts from the alternatives. In general, uncertainties associated with predicting navigation impacts are considered to be relatively low for a study of this type, because the estimation methods followed for this analysis have been developed, tested and confirmed over a number of decades by the USACE that are outlined in Engineering Regulation (ER) 1105-2-100 Planning Guidance Notebook, April 2000.

Nevertheless, some uncertainties remain. There is uncertainty about the precise flows that are required for commodities to move on the water. For example, the Waterborne Commerce Statistics Center (WCSC) data shows sand and gravel commodities moving on the water when less than minimum service is occurring, but Master Water Control Manual Missouri River Review and Update Study, Volume 6A-R: Economic Studies Navigation Economics (Revised) (1998) states the towing companies would be seriously impacted by flows less than minimum service.

The MRRMP-EIS analysis assumed that water traffic impacted by low water events has the potential to move off the water, which may not always be the case. It assumes a flat level of future demand, which may not be the case.

Uncertainty is also introduced through the use of transportation savings functions and assumptions that were necessarily based on an economic study from 1998. Though a transportation rate analysis was published in 2002, the last comprehensive study relating changes in flows to shipping and related economic issues on the Missouri was published in 1998. A new study could update the relationship between changes in flows and transportation rate savings by particularly focusing on the costs associated with shipping and the next least cost option. A comprehensive study could be expensive, but the need for such an approach could first be tested through the use of a pilot study that would investigate a smaller number of movements to explore the additional value of updating rates and costs for all movements. If the pilot study reveals that the 1998 values can simply be scaled, then the larger study might not be necessary.

Hydropower

"Hydropower Technical Report" discusses in substantial detail the information base on which the impacts of the alternatives' hydropower impacts were estimated. In general, uncertainties associated with predicting hydropower impacts are considered to be moderate because, though actual hydropower generation is continuously monitored and analyses comparing this information with river flows are routinely undertaken, the modeling and energy prices used for the analysis contain some inherent uncertainties detailed below.

One source of uncertainty in predicting impacts to hydropower appear to be assumptions made in shaping modeled daily average flows into hourly flows in order to better simulate generation value. The differences between the alternatives are very small in percentage terms. Because the NED values associated with hydropower are large in absolute terms (in the hundreds of millions of dollars per year), even small inaccuracies could give rise to large errors in dollar terms. However, although absolute values are important for decision making, it is likely that any inaccuracies in establishing the absolute generation value would apply similarly across all alternatives.

Another source of uncertainty in predicting impacts to hydropower is the assumptions made in energy and capacity prices. There is a lot of uncertainty and volatility in the energy market pricing and forecasted energy prices and energy prices can shift dramatically from year to year. These changes could potentially greatly impact the absolute value of each alternative and the differences between them. However, these changes should not affect the ranking of alternatives and the relative differences between each alternative and the no action alternative.

No additional information collection is therefore recommended at this time.

Flood Risk Management

The "Flood Risk Management Environmental Consequences Analysis Technical Report" discusses in substantial detail the information base on which the impacts of the alternatives' flood risk management impacts were estimated. In general, uncertainties associated with predicting flood risk management impacts are relatively low because the inventory of structures that could be affected by flooding is considered relatively robust.

Considerable effort was made as part of the Management Plan to confirm the accuracy of elevations for locations that appeared to show differences between the alternatives.

Groundtruthing predicted impacts will be of key importance for FRM if flow actions were contemplated. However, there are opportunities to begin groundtruthing flood risk management modelling predictions under the preferred alternative, by monitoring the nature and extent of damage associated with assets under certain circumstances, particularly in any high flow years that may happen to occur in the early years of the implementation of the AMP. As previously noted, however, given the dynamic nature of the river channel, consideration must be given to the temporal relevance of groundtruthing activities.

For sites with the highest associated dollar impacts, a detailed groundtruthing study might also consider alternatives to accepting the damages associated with flooding (for example by moving a sensitive asset, by protecting it or by making it less vulnerable to flooding waters).

Other Issues

Working with USACE during the implementation of the Plan, the HC Team could identify other areas that would benefit from the collection of the kind of information outlined here. These requests should be subject to the screening methodology outlined above.

5.5.5.2 *Important or necessary to resolve before undertaking an important management action*

Some uncertainties are critical to overcome before a decision could be made to implement a decision authorizing a flow release include the following:

The channel capacity of inter-reservoir reaches varies depending on the amount of aggradation or degradation that occurs during periods of low or high runoff, and, in some locations, downstream pool levels and tributary inflows. Consequently, high flow releases from reservoirs must be managed to minimize impacts to downstream private property. The preferred alternative includes a provision for a Level 2 in-river spawning cue release test. If included in the Record of Decision (ROD), this test would consist of a one-time release from the System after year 8, if Level 1 studies do not provide a clear answer on whether a spawning cue is important. Additionally, flow actions for the creation of ESH were investigated, but not included in the preferred alternative for the Draft MRRMP-EIS.

The MRRMP-EIS analysis shows that the proposed flow for pallid sturgeon and the ESH creation flows, as currently defined, could potentially inundate private lands along the Missouri River, in the reach between the Ft. Randall and Gavins Point dams, as well as downstream of Gavins Point due to coincident flows from tributary rivers. This impact is one the USACE has sought to minimize in its selection of its preferred alternative. USACE will continue to analyze the flow's potential impact on flood risk management and if these impacts are covered by any existing easements. Where an easement does not already exist, the MRRP will continue to effectively strategize how to 1) address uncertainties regarding potential impacts, and 2) minimize the impacts prior to any test flow release. Minimization through acquisition of easements and will be investigated, though current authorities and funding for such efforts are extremely limited.

Given the relatively high impacts associated with temperature in the lower river for thermal power under Alternative 2, it would be important to reduce this uncertainty before undertaking a nesting flow operation. This could occur as part of the temperature research mentioned above.

The MRRMP-EIS analysis indicates that some increased flood risk may exist with the ESH and spawning cue related actions. Section 5.8 explores some modifications to alternative definitions that might help reduce some of these impacts if they were ever to be implemented, and it is noted there that additional water inflow monitoring in certain tributaries may help mitigate some of the additional risk posed by these operations. This could be undertaken prior to a flow release being implemented as minimization measures.

5.5.5.3 *Monitoring of HC issues that could be only undertaken in the event of a flow modification*

If flow releases were to be implemented, a program of field-based groundtruthing around sensitive assets may help reduce remaining uncertainties, though these would need to be carefully targeted to ensure that the value of information justified the expenditure. This suggests an exercise could be undertaken as part of the Plan involving the HC Team and USACE analysts to identify and prioritize specific groundtruthing activities to undertake during a specific planned flow event. The selection of activities would depend on the precise flow under evaluation. For example, different sites and features may be threatened under recruitment flows, vs ESH spring release flows versus ESH fall release flows etc. Even across the spring release alternatives 2, 4 and 6, the different nature and timing of the releases may imply different monitoring regimes for HCs.

Therefore, specific groundtruthing studies would need to be designed by the Technical and HC Teams and adopted by the USACE nearer the time of potential implementation.

5.6 Evaluating Effects of Actions on HCs

5.6.1 Evaluation of Human Considerations in an annual cycle

The annual planning cycle begins with an assessment phase in which the AM Technical Team reviews the current status of system, bird, fish and HC metrics and indicators. The team would also work with the MRBWMD to assemble information on the upcoming year's hydrological and meteorological situation. Typical information compiled would include (but not be limited to):

- Storage, snowpack, long-term runoff and regulation forecasts, current reservoir level status etc.,
- Updates on recent habitat availability and trend, as well as physical changes on the river (e.g. any significant changes resulting from high flows, previous years' physical works, new information on aggradation or degradation, etc.,)
- Changes in species condition and outlook in the context of the previous year and over the long term. This would include an assessment of the quantity of bird habitat available at various locations, for example, as well as habitat and population forecasts including sensitivity and scenario analyses thereof using the same predictors employed by the MRBWMD in developing the AOP.
- Status of any Level 2 experiments being undertaken on the system or planned for the coming year.
- Results of research activities that might offer insight into new opportunities or trigger implementation of any identified management actions; results of lines of evidence assessments related to hypotheses that might result in the rejection of a hypothesis.
- Status of HC metrics/indicators and any major changes to HC situations, with a special focus on multi-year considerations (e.g. are there any notable multi-year drought or flood impacts being felt by a particular interest group).
- Any significant HC activities or conditions that might limit potential management actions (e.g. scheduled navigation traffic to Sioux City).

Once the season is over, an evaluation of the previous season's predictions would be informative for planning efforts for the following year. Such a review would likely be more intensive in the early years of the plan after novel management actions potentially involving HC impacts have been undertaken. Over time, as experience and knowledge of the actual impacts of these management actions is gained, the intensity and rigor of the post-season evaluation may be expected to reduce.

The nature of a post-action review of impacts for the ESA species are discussed in Chapters 3 and 4. Various issues related to HCs including those outlined in the following sections may also be considered as part of the review.

5.6.1.1 *Comparison of annual predictions versus monitored impacts.*

Although not possible in every case, it should be possible in some cases to compare the range of outcomes that were predicted from a particular management action with the monitored (i.e. measured) impact on a given HC. This is most readily done for proxy-style indicators of the type that predict the number of days above a threshold thought to be associated with an impact.

A post-season review could investigate comparisons of the predicted versus observed proxy indicator levels and predicted versus observed harm (or benefit) observed on the ground. In some cases such evaluations might be straightforward, but in many situations more involved analysis will be required. Over time, calibration could occur between the predicted outcomes and measured ones; however, establishing the validity of a causal relationship between actions and measured response or impacts would be necessary before decisions based on the information could be used.

As discussed above, such comparisons would be greatly facilitated by the ability to 'hind-cast' estimates of what would have happened without the operation, particularly in cases involving flow actions. Results of these comparisons would be shared with the appropriate technical team, the Management Team, and the HC WG and would be discussed, at a minimum, at the Fall Science Meeting and/or the AM Workshop.

To effectively monitor HCs, methods may need to be developed to integrate select HC indicators into operational models in order to provide real time or short term forecasts of potential effects based on operational decisions. This could be for information purposes only, or may factor into the decisions themselves, depending on the outcomes of analyses, selected management actions and monitoring agreements, and evaluations of the resulting data.

A parallel may be drawn here to the hypothesized impacts of management actions on birds and fish discussed in Chapters 3 and 4. In these chapters, hypotheses are made about birds and fish might be affected by certain changes in physical conditions. The steps of AM are undertaken to test how well observations match the predictions made in advance in order to learn how to improve predictive capacity.

Similarly, the tools described above – H&H modeling, proxy measures and full performance measure analyses – are essentially *hypotheses* about how HCs will be affected by physical and/or operational changes. A monitoring and AM program can be used to assess how HCs are actually affected by any changes to the flow regime, to compare these observations with predictions, and to evaluate appropriate responses to the findings.

The adaptive nature of bird and fish actions means that managers may wish to try particular combinations of tools that are within the decision space created by the MRRP and for which modelled predictions would appear to be acceptable, but for which precise estimates of HC implications cannot be made. Decisions about which HC outcomes might require monitoring will be affected by considerations such as the degree of uncertainty, associated risk, likelihood of that information affecting decisions, costs, resource availability, etc.

5.6.1.2 *Comparison of longer term predictions versus monitored impacts.*

Some impacts will not be able to be determined on an annual basis, but will instead require longer term assessments. As with the ESA species, it may be difficult to quantify or attribute MRRP actions to impacts on certain HCs, and careful thought will need to be given to the selection and development of specific HC measures to monitor to ensure that the data collected can be used for this purpose. Advanced analytical and / or 'big data' techniques may be required in some cases. These methods should be developed by the HC Team in collaboration with the USACE during the early years of implementation of the Plan. As with the analysis results described above, the long-term performance would be shared with and discussed by the appropriate AM Teams and the HC WG.

The evaluation phase sets the context for the planning and design step. The plans for the coming year are considered and, if necessary, Oversight level decisions are made.

5.6.1.3 *Define species needs for the coming year*

Under the selected alternative that will be described in the ROD, there are inherent variations in implementation that are still compliant with NEPA for a programmatic EIS, like the MRRMP-EIS. For example, IRC habitat development is evaluated in the MRRMP-EIS and is currently part of the preferred alternative. However, the design of IRC habitat could evolve over time based on information gathered through the AM process. Site specific design may require additional NEPA coverage before construction of IRC habitats. The need for additional NEPA analysis will be determined by USACE on a case by case basis.

For actions that deviate substantially from the ultimately selected alternative described in the ROD, additional steps to comply with various regulations will likely be required, but again such determinations will be made on a case by case basis MRRMP-EIS (see Section 2.2.4). For birds, this may include considering, for example, whether a flow release for ESH creation is likely suitable (or necessary), or whether conditions better suit or can be met using mechanical construction or some combination of the two. If the necessary authorizations are in place, a summary of any special monitoring requirements for the year ahead should be developed at this point of analysis, along with high-level costs so monitoring of the action could occur.

5.6.1.4 *Where appropriate, define alternative means of meeting species goals*

Even under the preferred alternative, there are usually alternative means available for meeting the same needs. If the options available are expanded to include some of the actions evaluated in the MRRP-EIS but not in the preferred alternative (see Section 2.2.4), different approaches may exist. For birds, this may include considering, for example, whether a flow release for emergent sandbar habitat creation is likely suitable (or necessary) in the year ahead, or whether conditions better suit or can be met using mechanical construction or some combination of the two. Note that although the MRRP might have authorized the use of flows up to a particular scale as an *option* to create bird habitat, it may not be a feasible, preferable or otherwise appropriate in any given year (for a variety of reasons). A summary of any special monitoring requirements for the year ahead should be developed at this point of analysis, along with high-level costs.

5.6.1.5 *Estimate consequences of alternatives*

At this stage, a predictive assessment of the consequences of the one or more alternatives should be made on the following:

- The ESA species – are the alternative(s) sufficient as part of the multi-year program to comply with the Biological Opinion and the findings contained therein?
- HCs – what are the predicted impacts of the alternatives on HCs that are expected to be affected by them? Are these predictions within the decision space enabled in MRRP AM Plan?
- What are the predicted impacts of the alternatives on other in-river activities not accounted for in the HCs, including ongoing Level 2 experiments or other USACE management actions on the river that could be affected differently by the management actions?

- Are there any other management or logistical considerations for preferring one alternative over another?

These questions lend themselves to an abbreviated form of PrOACT analysis, though this need not suggest an excessively onerous analytical undertaking, and could instead be a simple assessment of pros and cons of each of the alternatives. The important point is to have a process that recognizes that any given alternative carries with it a range of complex consequences that need to be considered each year.

Importantly, even if only one alternative is being proposed for the year, some form of prediction of its consequences (within an appropriate range of uncertainty) should be made. This information will be used in subsequent steps of the annual AM planning cycle and will inform monitoring needs (if any).

Note that methods to estimate HC impacts would need to be in place; the models used for the proxy analysis may or may not be the same as those required for this purpose.

5.6.1.6 *Evaluate tradeoffs and develop an approach for the coming year*

The selected management actions/alternatives, along with supporting research and monitoring identified for the year ahead should be considered by the Management Team and MRBWMD and, with appropriate consultation with stakeholders as outlined in Chapter 2, a corresponding recommendation provided to the agency Oversight in the form of a draft WP identifying the proposed management action. The plan is presented at an annual forum of the MRRIC, who may provide comment and/or make a consensus recommendation regarding the plan.

5.6.1.7 *Prepare detailed Work Plan for the coming year*

As a final planning step, agency leadership at the Oversight level decides on the course of action and the decisions are incorporated into a final Work Plan as per the current situation and the Work Plan is made available for stakeholder review. In the event any flow measures are included in the plan, the appropriate additional coordination, as described in Chapter 2 and as required by other policies would occur (including, as required, modifications to the Master Manual), and those plans would be incorporated into the AOP by MRBWMD. Decisions on the general approach to the year ahead, subject to suitable appropriations and conditions, are finalized at this point.

5.6.2 Model updating and validation analyses

A primary mechanism for capturing and applying learning is incorporating new information collected during the previous year, as appropriate, into the models. This includes a) assessments based on monitoring data updated on an annual basis, b) information from targeted studies or short-term monitoring (e.g. geomorphic assessments following flow events) and c) information from external studies deemed to be of sufficient quality and relevance.

Model validation procedures test model accuracy and precision by comparing model predictions with observations that were not used to parameterize the model. Periodic updates to the models may be required to reflect changed conditions in the system, new System operations, improved understanding, etc. Validation of existing models and any model updates in the future is strongly encouraged, subject to consideration of the sensitivity and accuracy of the models and the extent to which model errors might affect decisions.

Recommendations for model updates or validation may be made by the HC Team to the Management Team. The updates and validation activities will generally be conducted by the Technical Team, but they may consult with the HC Team and/or Management Team about the use of additional information and should report on the effects of the changes being made as relevant to decision-making.

5.6.3 Trade-off analyses to support Work Plan development

There are several forms of economic and/or decision analysis that could be undertaken to help support the evaluation of alternatives. This is discussed further in Chapter 2 (see Section 2.4.5.2) and in Section 5.7.3.

5.6.4 Incorporation of new information

Research that is conducted over the course of the year is summarized in the annual AM report. MRRP-funded research will typically be reported upon in the Fall Science Meeting and the Annual AM workshop. Relevant non-MRRP research findings will also be discussed in the report when available, with consideration given to the level of QA/QC and peer-review or related evaluations such findings have undergone and to the design and strength of studies.

Occasionally, new or unexpected information might become available that has the potential to significantly alter some aspect of management under the MRRP and which is not captured in the annual AM science process. This may be a matter of timing (urgent findings which miss the AM reporting cycle) or because the information was not identified by the Technical or HC Teams. Such information would be vetted and addressed through the process described in Section 2.5.4. Important insights emanating from the vetting process would be incorporated into the AM process in the same way as other monitoring and assessment results.

5.6.5 Ancillary information

Additional information that reflects learning or provides important insight into decision making but was not targeted through specific monitoring or studies should be captured and synthesized as part of the evaluation process. Examples of ancillary information include: observations about flood conditions on agricultural lands during a flow event; local changes in bed level that might reflect shoaling or scour; measurements of stage relative to water intakes over a low flow period; or patterns of erosion caused by flows within normal ranges. To the extent possible, such information should be quantified and systematically reported along with monitoring data in annual reports. Other information sources can be included if appropriately vetted (see section 2.5.4). Such information can be used to adapt local management actions, help explain patterns in monitoring data (e.g. multiple local factors could result in unusually high or low stage in a reach), and identify questions and hypotheses for future research and analyses. The quality of ancillary information will vary and may be subject to bias due to how factors are observed and when they are noted and should be assessed when data is collected and/or compiled. Ancillary observations may indicate the need for more systematic monitoring of factors not previously monitored.

5.7 Decisions under AM

5.7.1 Decision making process

The USACE has historically engaged in various forms of passive AM by incorporating information about the effects of management actions on HCs into short-term and longer-term decision making when managing the System. At present, the incorporation of new information is undertaken within the discretion of the MRBWMD, sometimes with review from stakeholders during AOP consultations. Appendix I of the Master Manual presents and discusses various ways in which the USACE undertakes AM on the Missouri River. These decisions are generally manifest as part of the AOP process.

The annual decision-making process for the MRRP is described in full in Section 5.6.1 with a brief summary focused on the role of the HC Team provided here. Following the evaluation phase and the release of the Draft Annual AM Report, the HC Team meets to review monitoring and assessment related to HC issues and to make recommendations regarding needed monitoring or assessment in upcoming years. Activities for the current FY are already set, and budgets have been established for FY+1. The HC Team may identify priority adjustments to the plans for FY+1, but their focus is on specific planning for FY+2 and general planning, including estimates of budget needs, for FY+3 and FY+4.

In considering monitoring and assessment needs, the HC Team is encouraged to apply the factors outlined in Sections 5.5 and 0. Recommendations from the HC Team are provided to the Management Team for their consideration in formulating the Draft Work Plan. The Draft Work Plan is taken under consideration by the agencies and MRRIC, and the HC WG may provide draft recommendations to the MRRIC to support that effort, either separately or as part of a combined report with the Bird and Fish WGs.

The strategy outlined above parallels the activities of the Bird and Fish Teams except those teams are also providing priority recommendations on management actions. The HC Team does not weigh in on management actions as that is a responsibility of the full MRRIC. Decisions on which management actions get implemented are made by the USACE with input from the USFWS and MRRIC, potentially including consensus recommendations by the MRRIC. The process through which MRRIC engages in these decisions is outlined in Section 0.

5.7.2 Decisions regarding monitoring and assessment for HCs

As part of the annual process to update the Work Plan, the HC Team will revisit HC-related monitoring and assessment activities and provide recommendations on priority needs, including the cessation of monitoring when information and knowledge is sufficient to support decisions. The Missouri River is a complex system and a large number of endpoints could in theory be monitored. All monitoring and subsequent analysis of data requires resources that could otherwise be redirected. Issues should not necessarily be monitored simply because there would be some value to knowing. Instead, it is important to think carefully about might constitute the highest possible value for money when evaluating monitoring possibilities.

The factors listed in Section 5.5.2 and the process outlined in Section 5.5.3 provide a starting point for the HC Team in considering monitoring and assessment needs. The HC Team is encouraged to refine the approach and to update the guidance in this AMP to reflect the process and factors employed following procedures outlined in Chapter 2 for updates to the AM Plan. Feedback from the other teams, particularly the Management Team, and from the MRRIC and agency Leadership should factor into decisions regarding the approach to the Team's recommendations.

5.7.3 Decisions regarding the implementation of the preferred alternative

Implementing the preferred alternative will require a large number of decisions to be made over many years. The institutional context for these decisions is described in Chapter 2 and their technical subject matter is described in Chapters 3 and 4. This section discusses how human considerations might or might not be incorporated.

The majority of decisions outlined in Chapter 3 and Chapter 4 that are applicable to the preferred alternative have relatively few direct implications for human considerations. There are numerous technical judgments and decisions to be made around each stage of research study assessment, design, implementation, monitoring and evaluation cycle that, for the most part, concern issues only of science. Some such decisions may have implications for HCs ultimately (e.g. decisions on overall bird status evaluation judgments, decisions to revise targets or metrics, decisions to move from Level 1 to Level 2 research programs), but HCs are not (and should not) be a consideration in these.

Some decisions within the scope of the preferred alternative that do have the potential for HC impacts include those concerning:

- Siting and design of habitats for mechanical construction;
- Mechanical habitat construction timing and approach;
- Human access management in sensitive areas for birds;
- When and how to implement a pallid spawning cue test flow, if required.

Emergent sandbar habitat for birds and spawning habitats for pallid sturgeon are in-river and their construction has relatively limited implications for human considerations. Pallid sturgeon IRC complexes require bank-side land, but have specific geophysical requirements that suggest biological functional priorities may dominate consideration of all but the most compelling HC issues when deciding upon preferred locations. Specific habitat construction siting decisions may be amenable to Cost Effectiveness and/or Incremental Cost Analyses. Candidate locations would be first identified using biological criteria then cost effectiveness-based methods used to identify the most cost-efficient combination of locations to meet the required biological need. Locally-important site issues (e.g. addressing concerns around potential for impacts on intakes, potential for ice-jam effects, etc.) or other local site considerations would be considered on a site-by-site basis during the planning and PED phases, and would be addressed through a) the Work Plan development process (by the Implementation-level and Management teams, and b) the site-specific NEPA activities or compliance with other laws.

As discussed in Chapter 3 of the MRRMP-EIS, there is potential for impacts to various HCs from mechanical habitat construction. Of particular concern are issues related to the potential for site-level flooding and/or riverbed changes leading to localized problems for intakes or navigation, water quality, and general construction disturbances of noise and traffic. These issues will be avoided or minimized through the application of established Best Management Practices (BMPs) long established by the USACE as well as the planning process. Similarly, human access management for the protection of bird habitat would be undertaken in ways that minimize unnecessary inconvenience using established USACE protocols.

As an example of how local site issues might be incorporated into decision making during the implementation of the preferred alternative, consider the situation in which bird habitat (ESH) creation is needed in the reach between the Garrison Dam and Lake Oahe. Flood risk management concerns have been expressed for this reach given uncertainties regarding the effects of ESH on the location, rate and magnitude of ice formation in that reach. In such a case, addressing the decision using a structured decision making technique (such as either a Multiple Account Evaluation (MAE) or Multi-Attribute Utility Analysis) could help provide a framework for engaging decision makers, scientists and stakeholders in understanding the trade-offs between competing alternative approaches. The exact criteria to consider would be specific to the decision context and would need to be developed in collaboration between the Bird and HC Team. Such a framework would allow the open discussion of construction costs, biological performance, flood risk tolerances and any other issues deemed worthy of consideration.

The preferred alternative provides for the potential use of a Level 2 spawning cue flow in the first increment, to be implemented only in the case that 1) science cannot resolve the question of whether spawning cue events might be helpful without resort to field data and 2) a suitable flow from which to study this issue has not arisen during the normal course of operations.

A spawning cue flow action of this type was studied in detail in the MRRP-EIS in Alternative 6 and its range of potential effects on HCs has been estimated.

5.7.4 Decisions regarding the implementation of new actions outside the preferred alternative

As discussed in Section 2.2.5 and illustrated in Figure 91, actions analyzed in MRRMP-EIS alternatives but that are not in the preferred alternative could be nevertheless be implemented, though this would require a new decision document and could require Master Manual modification (as outlined in Attachment 5 of Appendix A).

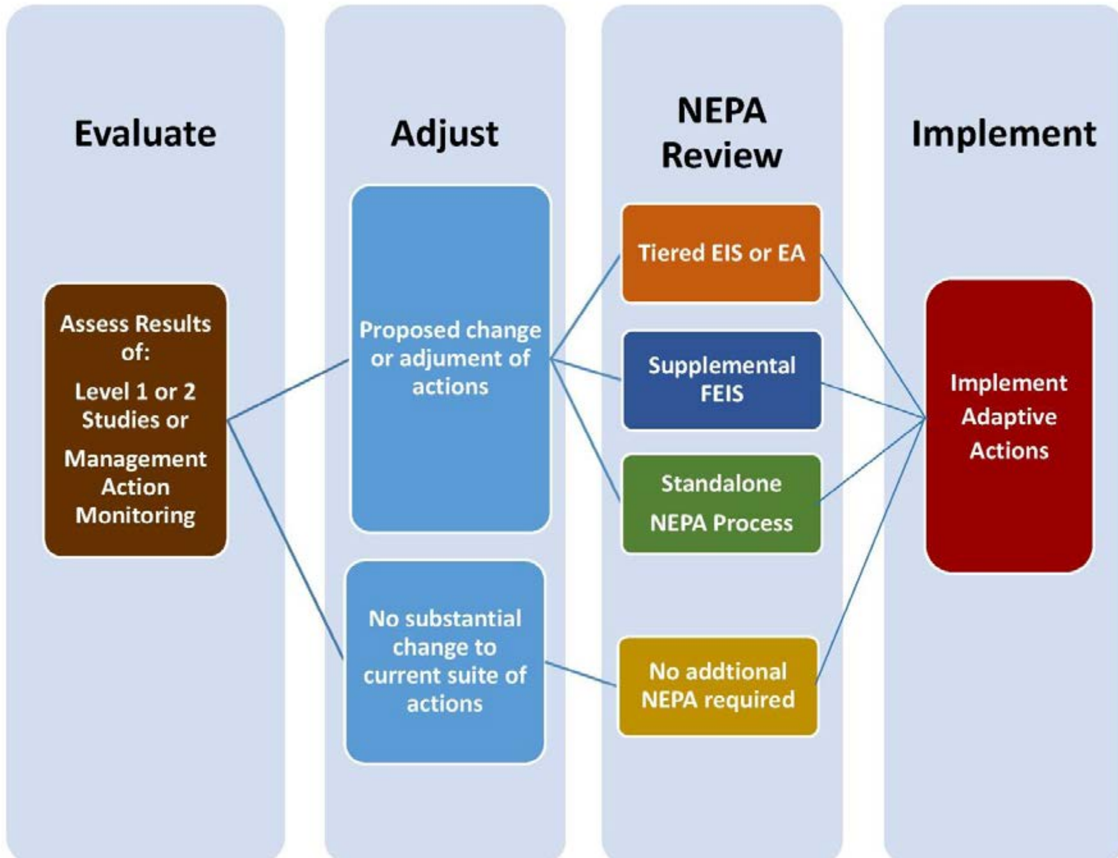

Figure 91. Integration of the NEPA Compliance Process in the AM Framework

An example of a situation that could require such steps could be as follows: in the years after a ROD is issued, no high flows naturally occur on the river that create emergent sandbar habitat. Instead, flows in the river steadily erode the existing sandbars, and those sandbars that do remain become mature and cannot effectively be made sufficiently productive through vegetation and predator management activities. Bird monitoring shows declining fledge ratios, negative lambda values and declining populations; the bird status and need matrix (Section 3.5.3) indicates that bird objectives will not be met and there is a need to rapidly increase the rate of habitat creation. In short, it is discovered that action must be taken to increase ESH.

In this scenario, the first course of action would be to bolster mechanical habitat construction to achieve the targeted acreages. In the event mechanical construction is projected to fall short of targets and a continued deficit is projected, a decision would likely be made to consider what actions outside of the preferred alternative could be undertaken. One option might include consideration for actions outside the ROD but considered in the MRRMP-EIS (e.g. an ESH flow release, either in the spring or fall [examined in MRRP-EIS Alternatives 4 and 5, respectively] or the use of a reduced nesting flow [a component of Alternative 2]). Alternatively, novel solutions that have emerged as a consequence of new knowledge or additional analyses could be considered.

The decision to pursue alternatives outside the ROD would have important implications for the MRRP and potentially some HCs. Either approach would require additional actions and decisions before it could be implemented (see Section 2.2.5). There are two general approaches to help minimize negative impacts to HCs.

The first would involve consideration of the use of a number of alternative definition modifications that have been conceptually developed to protect human considerations from the most negative consequences associated with actions that were examined in the MRRMP-EIS. These potential modifications are discussed in Section 5.8.

The second would involve the use of a structured decision-making approach to explore the relative advantages and disadvantages of different options. This would mirror to some extent the process undertaken to evaluate alternatives under the MRRMP-EIS, though with important differences. As a first step, feasible alternatives to meet the biological need would be identified, working initially from the actions explored in the MRRMP-EIS.

An analysis would be then undertaken to estimate the impacts of these alternatives on the range of HCs. The nature of this analysis would depend on the context for the decision. If a quick decision is needed, the HC team would work to assemble the best available evidence from the MRRMP-EIS, amended as required from learning in the intervening time, to estimate the range of biological, program management HC and other impacts associated with each approach.

Because certain parameters about the actual situation would be better known, the uncertainty around effects to HCs may be lower than in the MRRMP-EIS, which considers an 82 period of record. For example, system storage (high or low) is known to be a strong influence on some HCs – and since system storage varies over multiple years, in any given year that variable will be approximately known.

In either case, decision makers and, time permitting, MRRIC, would be informed to understand the trade-offs involved and given an opportunity to express preferences for one approach over another.

The exact nature of the analysis to be used and the HC performance metrics that would be most appropriate cannot be determined at this time. However, a task for the HC

Team at the initiation of the AM Plan could be to investigate the types of performance metric that may be available for each HC, and which might be used under varying circumstances decision-making circumstances. In some cases, economic methodologies from the MRRMP-EIS might be readily transferrable. In others, proxy metrics or curves relating proxy indicator values to economic values may be developed.

5.8 Potential Alternative Definition Modifications Intended to Reduce Impacts to HCs

5.8.1 Context

The analysis of MRRMP-EIS alternatives provides a rich source of information for understanding the specific circumstances that give rise to the most acute impacts to HCs. An analysis examined the impact on HCs in each year of the period of record, focusing on the net change in NED for each resource area, and sought to explain why the most negative impact years occurred. RED and OSE impacts are typically correlated to NED impacts for any given resource area. The analysis found that for most HCs there were various circumstances created by the alternatives that give rise to a small number of unusually high impact difference years. In discussions with MRBWMD, several proposed amendments have been conceptually outlined that it is thought might better inform decisions that could help avoid or reduce the impact of each of the actions associated with each of the MRRMP-EIS alternatives if they were to be implemented. These proposed changes do not *concern activities included in the preferred alternative (with the exception of the potential spawning cue test flow)*, but do address actions that could be implemented in the course of the plan under the circumstances outlined in Section 5.7.4 following procedures laid out in Section 2.4.5 and described more generally in Chapter 2.

Each potential modification proposed here is seeking to address special circumstances created by the alternatives based on information that would be available at the time (i.e. without requiring knowledge of how the future will unfold, as is possible in modelling exercises). Some are amendments that could simply be written into an alternative's definition (e.g. never allow releases to go below x) or require other modifications to practices (e.g. more targeted tributary monitoring).

With a small number of minor possible exceptions, the proposed modifications do not influence the severity of the worst absolute impacts to HCs. The largest absolute impacts to HCs tend to occur under extreme wet or dry hydrological years (natural variances), and in those situations the EIS alternatives tend to behave identically and in tandem with the No Action alternative because there is very little operational scope for discretionary decision making in these circumstances. Flow releases from Gavins point using 2011 data, for example, are essentially identical across all alternatives during the period of concern. This is because all EIS alternatives have rules embedded in them that are intended to avoid making extreme situations worse. All alternatives have rules that seek to avoid exacerbating high flood risk situations, or that prevent the use of flow releases to create habitat when system storage is low.

Instead, the proposed modifications proposed here are seeking to avoid or mitigate larger impacts relative to the impacts that *would have been experienced under No Action*. These differences tend to occur in years that are wetter or drier than average, or when system storage is close to but above thresholds permitted for flow releases.

These potential modifications should be considered *suggestions for discussion purposes* only until their full range of implications are better understood. Changing any element of an alternative's behavior and definition will create a chain of impacts that it is impossible to understand without further modelling. Also, each time a flow operation for endangered species is abandoned or foregone out of consideration for HCs, the ecological benefits of that alternative to the endangered species are also foregone (and in some cases made worse). More modelling would need to confirm the net benefits of these rules prior to being implemented.

For this reason, the potential modifications are presented as *conceptual outlines* and *without proposed specific parameters*. These would need to be established through further analysis and with consideration given to the risk tolerances (for species benefits versus HC benefits) of decision makers.

If the preferred alternative in the Draft EIS is selected for this plan, there would be opportunity to perform such analyses in preparation for possible future implementation of alternatives with flow releases.

5.8.2 Methodology for identifying the proposed modifications

Each resource area was carefully examined to identify data years with the largest positive and negative differences from No Action. Charts for each that aligned impact years with flow release years were developed and studied (examples follow in the description below). For all of the larger differences, HydroViz was consulted to help understand precisely what circumstances were leading to the unusually large impact. In some cases, there is an obvious and direct relationship between a flow release and an impact on a resource area. For others, the impact mechanism is subtler and requires study of sequences of years of hydrology differences between an alternative and No Action to understand.

Once the circumstances behind the large impact were understood, discussions with USACE Water Management helped establish whether the impact might be avoidable using minor amendments to the alternative definition or by another mechanism. In some cases, differences between No Action and a flow alternative could be attributed to minor modelling inaccuracies or issues could be resolved readily using the operational flexibility already permitted within the Master Manual.

In developing this analysis on a resource-area by resource area basis, it became clear that certain circumstances were affecting multiple HCs in the same way. One issue and its associated potential mitigation identified during an analysis of impacts on irrigation was found to be equally effective for reservoir recreation, for example. For this reason, this section is structured through a presentation of the rules themselves rather than on a resource-area basis, although they are typically illustrated with reference to only one HC.

5.8.3 Possible Alternative Definition Modifications Intended to Reduce Impacts to HCs

5.8.3.1 *"ESA species population and status considerations"*

As modelled, alternatives' flow releases are assumed to occur whenever the hydrological conditions permit under the rules of an alternative. No consideration is given to whether there is an actual biological need for such releases in that particular year. As discussed in DEIS Chapters 3 and 4, there are often a variety of biological reasons why flow modifications may not be beneficial or even desirable. For example, there is no need to perform an ESH-creation release if sufficient ESH already exists as the result of previous hydrological conditions or mechanical construction.

The proposed modification is not strictly one introduced for the benefit of HCs, but since it has an important direct effect on HCs it is reiterated here for clarity and emphasis. The definition of significant benefit would need to be determined, but the issues involved are discussed in Chapters 3 and 4.

5.8.3.2 *Low storage release considerations*

Some HCs, including irrigation and recreation in the upper three reservoirs, have NED benefits that are closely and positively correlated to system storage. Annual average system storage over the period of record for the DEIS Alternatives is shown in Figure 92.

For much of the period of record, the storage is aligned across the alternatives. In these years, there is a relatively small difference between the alternatives' performance for irrigation and reservoir recreation. However, there are several periods of time in this period where the storages of the alternatives separate – most noticeably this occurs in the late 1950s and early 1960s, in the early 1990s and in the mid-to-late 2000s.

As discussed in EIS Chapter 3, Alternatives 2 and 4 have the most adverse impact to recreation on the reservoirs in the upper basin. Figure 93 shows the change in recreation on the reservoirs in the upper basin NED from No Action for Alternative 4. Comparing Figure 92 and Figure 93, it can be seen that the most negative impacts to upper basin reservoir recreation occur in the same time periods as low storage events, as previously noted. But we can also see that ESH release events (shown as red bars) are not the ones associated with the worst impacts. A similar impact profile can be observed for irrigation.

Examination shows that, while not unusually impactful directly, the flow releases sometimes appear to trigger a series of years with negative impacts, e.g. following releases in 1931 (recreation NED data are unavailable for the 1931 release and so cannot be seen in the figure), 1961 and 2003. On investigation, we observe a situation that is common to several HCs that are sensitive to low-system-storage situations:

It is helpful to explore the reasons why the early 1960s result in unusually high impacts relative to No Action. In data year 1961, both No Action and Alternative 4 are at a system storage that is close to the 42 MAF threshold line (i.e. the minimum storage allowed under Alternative 4 for which ESH flow releases can occur). Under the rules of Alternative 4, an ESH-creation release is permitted in that year. However, subsequent years have low inflows and the system cannot quickly recharge. In the 1962 data year, the previous year's release has forced storage to be lower. In 1963, inflows allow storage and recreation benefits to increase under No Action. However, under Alternative 4 this recovery does not occur in the same way. This sequence of factors caused 1963 to be the single worst difference year for Alternative 4. This series of years appears to be the major single event that drives negative upper river recreation on the reservoirs in the upper basin and irrigation impacts over the period of record, though a similar sequence of events can be seen in the late 2000s.

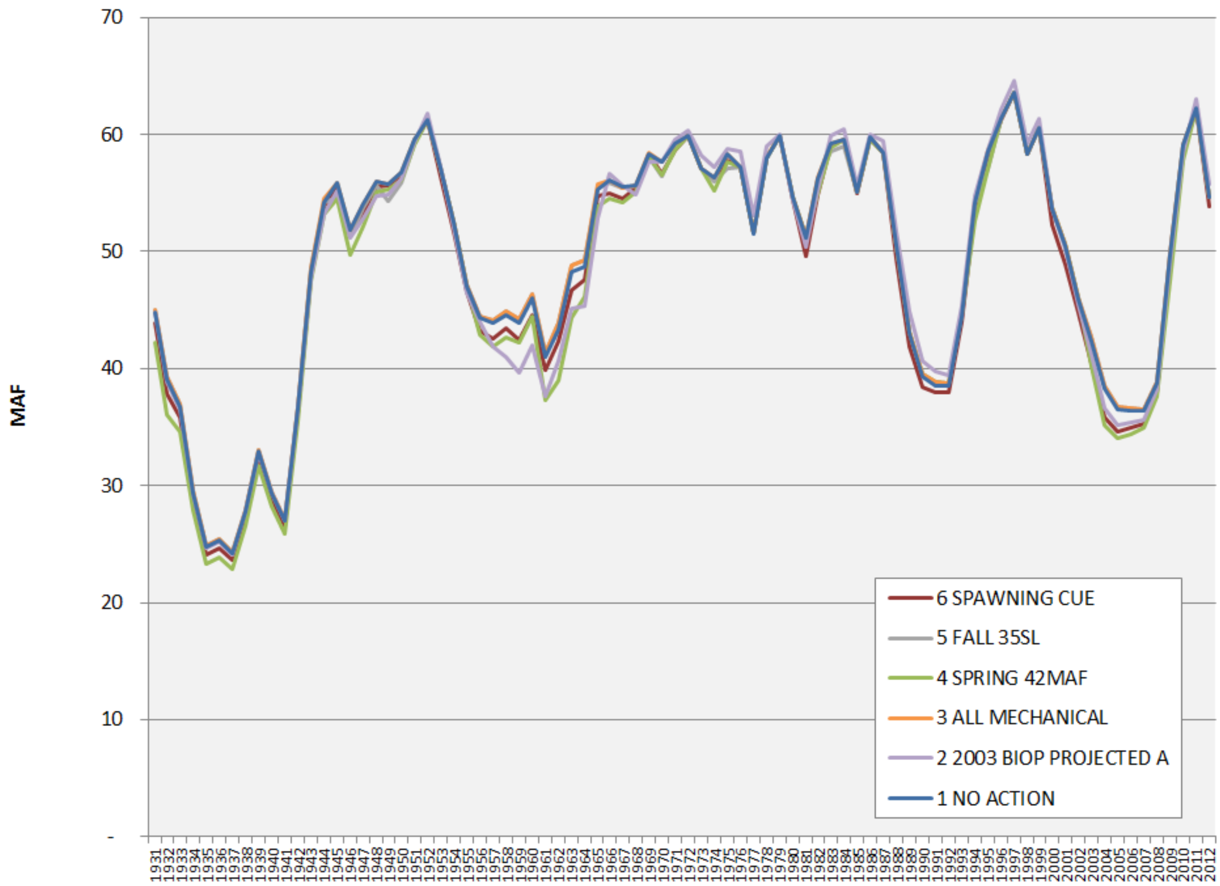

Figure 92: Annual Average System Storage over the Period of Record for the DEIS Alternatives

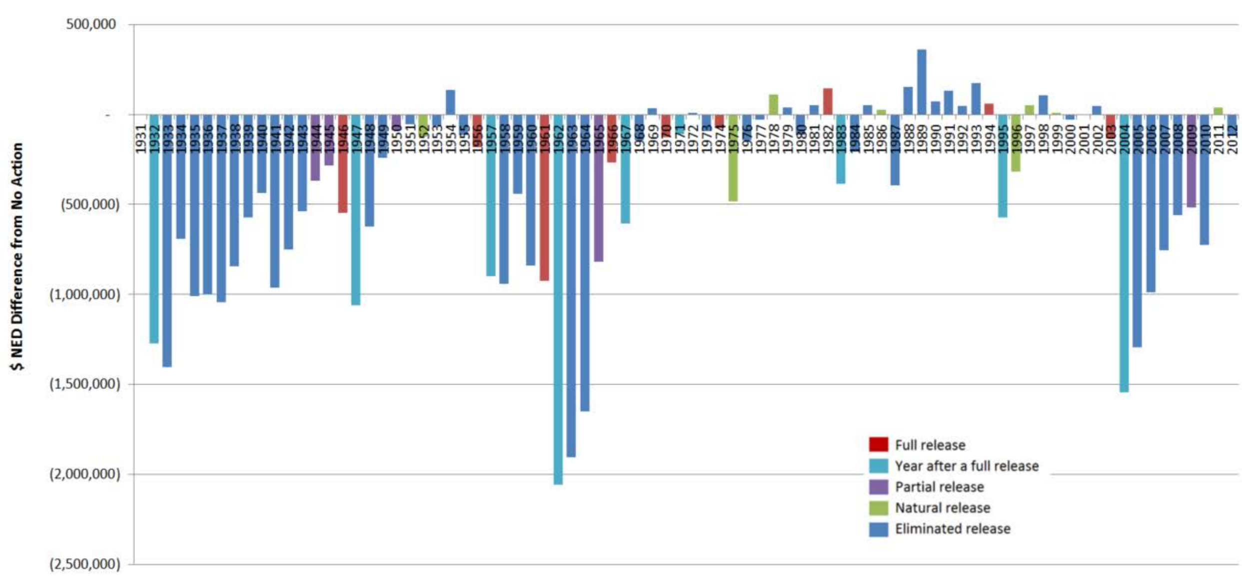

Figure 93. Upper Recreation NED Difference from No Action by Release Type for Alternative 4.

To avoid these impacts, several alternative definition modifications might be considered:

The first could involve changing the storage threshold below which releases may occur. For Alternative 4, this threshold is 42 MAF and for Alternative 2 and 6 the threshold is 40 MAF. Alternative 5, which does not appear to be vulnerable to this kind of effect, is defined using navigation storage levels rather than system storage, but it has an approximate equivalent storage threshold of 54 MAF. Increasing the storage thresholds associated with Alternatives 2, 4 or 6 may therefore decrease the likelihood of a 1960s-like sequence of events.

Increasing the thresholds, however, would have the effect of reducing the frequency of releases, and therefore should be expected to result in less effective results for the ESA species over the long term.

A second approach might be to leave the thresholds as they are, but to cancel or avoid releases if a second set of circumstances are also present. For example, if storage has been relatively low for a number of years (and close to the storage threshold for a release), absolute adverse impacts to recreation on the reservoirs in the upper basin and irrigation will have accrued. Releasing for species under such circumstances may be expected to further extend or exacerbate the risk period for these HCs and could be reconsidered, particularly if the species requirements are not themselves acute.

5.8.3.3 *Dry year storage refilling considerations*

This issue was revealed through an analysis of thermal power impacts in the upper river, but has significance for all intake-sensitive issues in both the upper and lower river.

A flow release from an alternative by definition discharges a larger quantity of water from a dam than would otherwise have been the case under the No Action alternative in a relatively short period of time. Once discharged, system storage is lower than it would have been without it. To recharge the system storage to its normal desired operating condition, more water must be accumulated in the upper three reservoirs than would have been the case under No Action. Therefore, during this period, there is less water released to the river than would have been the case before. If flows in the river are already low, then the situation could arise where a flow release, once passed, causes river flows to lower below the shut-down intake elevation, reducing power generation and causing increased costs to utilities and power plants.

An example of this is shown in Figure 94, which shows stage at Bismarck in 2009 for No Action and Alternative 4. In this data year in the upper river, across all alternatives, a relatively high-flow spring transitions into a low-flow summer. In the modelling, Alternative 4 has a full flow release in this year that leaves system storage at a lower level for Alternative 4 than would have been the case under No Action. Subsequent system refilling under Alternative 4 in 2009 during mid-September and October is therefore occurring against a backdrop of unusually low river flows. This leads to intake issues associated with this alternative in this year, and a negative impact of tens of millions of dollars, a substantial contributor to the overall average estimated impact for this Alternative on this resource area alone.

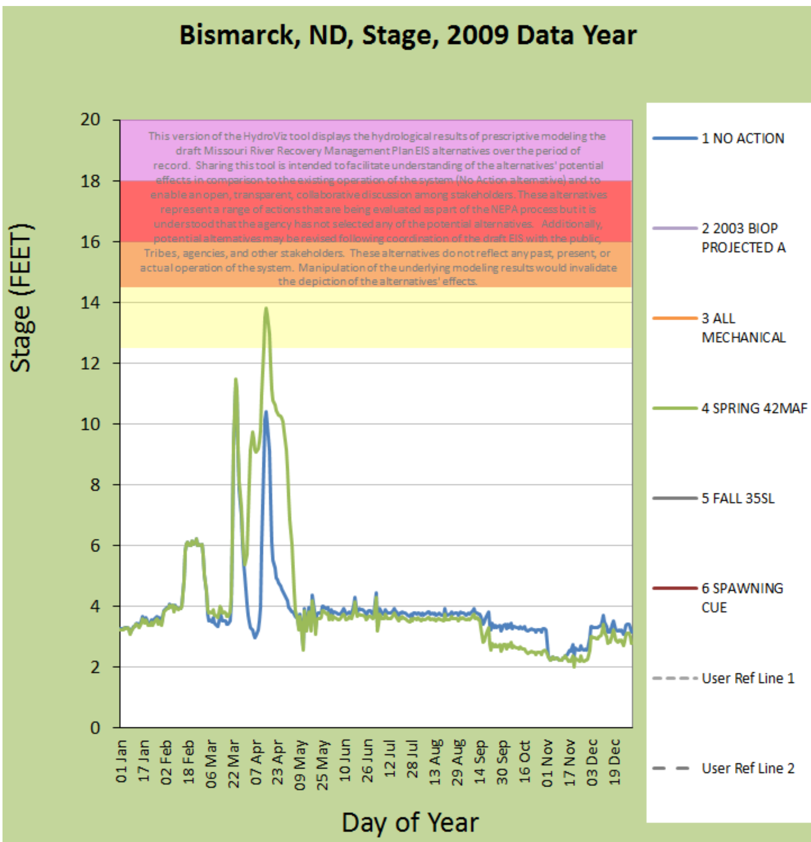

Figure 94. Modelled stage at Bismarck in 2009 under two Alternatives

This type of event could be avoided by a number of approaches. Thermal plant and other sensitive intakes could be reconfigured or replaced to make them less susceptible to low flows, or definitions of situations governing ESH flow releases could be modified.

Another approach might be to monitor sensitive intake elevation risks and release extra water from Garrison to ensure they remain functional, with system refilling occurring later. In the upper river, the USACE's preferred approach to this issue is to evaluate if the minimum release at Garrison during the fall period is problematic with respect to water intakes, and to amend it if so. Such a change may or may not be possible within the operational flexibility provided by the Master Manual. Further modelling would be required to fully investigate the system-wide implications of this change.

5.8.3.4 *Hot dry summer thermal power considerations*

The thermal power plants that use Missouri River water for cooling are subject to state water quality temperature standards. DEIS alternatives that reduce volumetric flowrate in the river during a hot summer period could contribute to higher river temperatures relative to No Action. Low summer flow events under Alternative 2 could cause water quality standards to be exceeded when otherwise they would not have been under No Action.

An ERDC Water Temperature Model discussed in DEIS Chapter 3 shows that the low summer flow events as simulated under Alternative 2 increase river temperatures in the lower river when compared to No Action. The economic implications of these events appear to be in the tens of millions of dollars from reduced costs to replace power generation to meet water quality standards and costs to replace lost capacity. However, there are a number of uncertainties in this analysis.

USACE would likely work with power plant operators and regulators to use the operational flexibility provided by the Master Manual to avoid shutdown of multiple thermal power plants if this outcome appeared imminent. This would be true under any implemented alternative.

Given its heightened risk in this respect, if Alternative 2 were to be implemented, further analysis would be required to confirm that there is sufficient discretion within the Master Manual rules to accommodate this issue and to clarify the system-wide implications of such an operational modification. One important consideration would be that low summer flow operations for birds cannot simply be abandoned once started without the possibility of a sizeable adverse impact on birds that may have taken advantage of the additional habitat provided by the low flow operation.

5.8.3.5 *Spring release supplementary flood risk minimization*

Modeling suggests that alternatives with spring flow releases appear to have unusually high impacts to flood risk management issues in four data years: 1950, 2009, 1944 and 1982. The single largest event relative to No Action occurs with Alternative 4 under 1950 data.

Figure 94 illustrates the latter case, but the same explanation applies for each of these years. From this figure, we see that the No Action (blue line) sharply increases in April, the result of a sudden inflow from the Heart River. Under Alternative 4 (green line) this year coincides with a flow release that adds additional water on to this natural event. Regular flood avoidance rules do not prevent or discontinue this flow release because the flows rise suddenly *after* the flow release has already been initiated, and because the model does not employ flood checks in Bismarck.

As the hydrograph shows, the rapid rate of stage increase in the Bismarck area from the tributary inflow presents a challenge to avoid or mitigate. The Bismarck example has a relatively short lag time between release and impact (Bismarck is about 70 miles downstream of Garrison Dam), but in other locations identified in the modelling where this effect is seen the lag time between flow releases and impacts are longer, further reducing USACE's ability to react in time to avoid impacts. For these reasons, the overall effectiveness of measures to avoid or mitigate the increased flood risk issues associated with spring flow releases is uncertain, and may not be large.

If an alternative with a spring flow release were to be pursued, actions that could be undertaken to help avoid or mitigate this situation could include:

- Increase the use of advanced Quantitative Precipitation Forecasting (QPF) techniques in tributaries and in the river;

- Increase the use of continuous monitoring of flood stages in potentially affected areas (perhaps in tributaries) in order to more rapidly be alerted to actual flood risks

It might be possible for improved weather forecasting efforts along tributaries like the Heart River to provide more advance warning about such events. This could combine an analysis of snowpack conditions as well as local precipitation events. Additionally, in the modelling, flow releases are not stopped when flooding occurs in Bismarck because there are no operational flood checks there. In actual operation, it is unlikely that a flow release for endangered species would continue during a flood event.

A further issue affecting spring flood risk concerns the presence of ice in the river. Ice increases flood risk in the channel by reducing its effective capacity. Modelling cannot predict which years have ice. In reality, the USACE would not release additional water into the channel for species flows if ice were present.

5.8.3.6 *Fall release supplementary flood risk minimization*

A parallel situation to the spring release occurs with the fall release associated with Alternative 5, though to a considerably lesser degree because inflows in the period of release are less volatile than in the spring, and because Alternative 5 has a lower expected number of releases than Alternative 4 due to its higher minimum release threshold. Nevertheless, there are some examples of rapid inflows from tributaries into the Missouri River resulting in an increase in flood risk during an Alternative 5 flow release (e.g. using 1982 data for the lower river – a partial release that is cut short by existing flood control rules, but not before incremental damage has accrued).

As with the spring flows, it is possible that if Alternative 5 were to be implemented, increased use of advanced Quantitative Precipitation Forecasting (QPF) techniques in tributaries that have the highest likelihood of creating this kind of problem in the October to November release window might help avoid or mitigate this issue to some degree, though the effectiveness of this action would need to be studied. As with the spring release, the inherently sudden nature of these inflows combined with river travel time may limit the Corps' ability to respond to such situations.

5.8.3.7 *Fall release agriculture co-ordination*

If Alternative 5 were to be implemented, The USACE may wish to coordinate with farmers around the precise timing of the fall release, should one be planned. In the current modeling, this alternative's flow release is timed to start as late in the year as possible (to avoid impact to farming) while still allowing for a 5.5 week release with a low probability of complications from ice formation at the end of that period. As previously established, it would need to be explicitly stated that in the event of an early ice-up of the river towards the end of a fall release, Alternative 5's flow release would have to be abandoned for flood risk management issues.

However, there may be some scope for discussion on the precise timing of this release that investigates further and more explicitly the balance between a later start to the release and the latest time in the year for which the flow release could be stopped for ice reasons. For example, in some years it may be possible to extend the period of release if ice concerns are clearly not an imminent concern that year, creating more ESH. Conversely, perhaps a later start to the release could be acceptable in some years to avoid agriculture impacts if sufficient ESH has been created before the completion of 5.5 weeks.

5.8.3.8 *Winter low-flow avoidance*

Under Alternative 2, a maximum winter release of 16 kcfs is prescribed, which is lower than that prescribed for No Action. Low flows over the winter are important for all alternatives to avoid flooding risk associated with ice. However, the intent of this additional specification for Alternative 2 is to increase the probability of high storage in the system in spring to allow for a more effective spring pulse for pallid sturgeon.

There are a number of downsides with this specification of alternative 2, however. Some intake-based HCs suffer disproportionately from the reduced stage during this period.

Additionally, the USACE is forced then to release this extra water in the spring in order to meet the storage targets at the onset of the spring season. In the modelling, this additional release of water, in combination with higher than average inflows, can lead to increased flood risk (Figure 95).

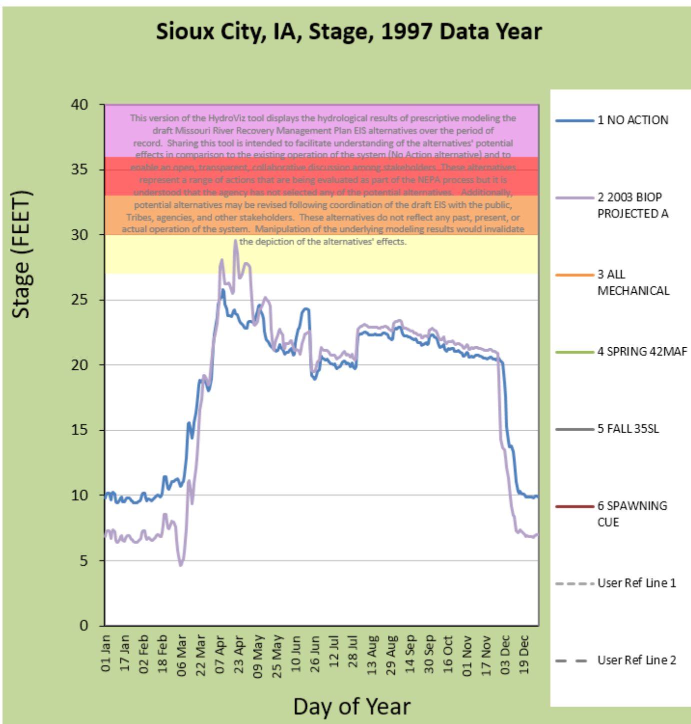

Figure 95. Stage at Sioux City using 1997 data for Alternatives 1 and 4

In some respects, the increased flood risk shown in this situation in the modelling is higher than would actually occur and is a function of the model being aggressive in meeting its ideal storage targets in spring. However, the underlying dynamic is real and if Alternative 2 were to be implemented the requirement for 16kcfs during the winter should be re-examined.

5.8.3.9 *Managing unexpected impacts to HCs*

Provisions for managing unanticipated impacts to species and HCs are integrated into the governance structure detailed in AM Chapter 2. In some respects, USACE water management already uses discretion, given it by law to operate the System for its eight authorized purposes, in modifying operations within the boundaries set by the Master Manual to accommodate emerging HC issues. During the implementation of this Plan, the HC Group would be free to raise such issues to the Management Team level during the regular annual planning cycle and any modifications to operations for the approaching years would be considered at that point.

The case of a sudden, acute HC issue that might preclude the use of a flow release in season (were an alternative to be implemented that contained one) would be raised directly at the Management Team level at the discretion of the USACE.

6 Data Acquisition, Management, Reporting and Communications

6.1 Principles and practices underpinning monitoring and evaluation, data management, and effective communications

This Chapter outlines a set of principles for developing and implementing a monitoring and evaluation (M&E) strategy. Underpinning these principles is recognition that the activities in the AM Plan are intended to increase knowledge of how to best protect and recover listed species, while concurrently meeting authorized purposes and minimizing undesirable effects. Thus, M&E is a crucial post-implementation activity, and many of the activities are optimized for the twin objectives of learning and ecological effectiveness (within HC constraints). The objectives will shift over time and, as the underpinning science and species needs are better understood, actions will focus more strongly on ecological effectiveness, with learning as a secondary benefit.

The principles outlined in this Chapter are drawn from multiple sources designed to ensure the development and iterative evolution of an effective M&E strategy:

1. The Data Quality Objectives process (DQO; EPA 2006), developed by the U.S. EPA to guide development and evaluation of alternative M&E designs to make decisions, is a collection of qualitative and quantitative statements that help to clarify program objectives, define appropriate types of data to collect/analyze, and specify tolerable limits on potential decision errors. This provides a basis for establishing the quality and quantity of data needed to support decisions.
2. Applications of the DQO process and evolutionary development of M&E strategies in various ecosystem restoration, environmental monitoring and species recovery programs provided relevant examples. These include the U.S. EPA's Environmental Monitoring and Evaluation Project (Barber 1994), the Columbia Basin's Collaborative System-wide Monitoring and Evaluation Project (CSMEP 2007), other M&E strategies for the Columbia Basin (Hillman 2006), the Comprehensive Everglades Restoration Program (CERP) Monitoring and Assessment Plan (MAP; RECOVER 2009) and the associated Quality Assurance Systems Requirements (QASR; RECOVER 2004), the Integrated Assessment Program for the Trinity River Restoration Program (TRRP and ESSA 2009), and the Platte River Recovery Implementation Program (PRRIP 2014).
3. Expert advice from scientists familiar with the M&E challenges specific to the Missouri River and other large-scale ecosystems were instrumental.

Effective M&E requires attention to detail organized around each of the steps in the AM cycle (see Figure 5):

1. **Plan/Design:** Assess the problem, identify priority decisions, questions, hypotheses and indicators, and design the M&E strategy for each hypothesis and management decision (this strategy guides the remaining steps)
2. **Implement** management actions
3. **Monitor** the ecosystem, its species and selected metrics for human considerations, and collect appropriate data
4. **Evaluate** monitoring data and determine the implications of the data for priority decisions, hypotheses, and the original M&E strategy
5. **Decide** whether or not to adjust actions, hypotheses and/or the M&E strategy.

In addition to the principles summarized in this section, issues of scale are discussed and the term "actionable science" is defined and discussed in the context of the MRRP. The agencies are committed to a collaborative process for developing and implementing the MRRP, so an open data-management strategy, transparent decision-making, and good reporting and communications are central to success. Section 6.2 provides a summary of monitoring and data acquisition for the system and the listed species. Section 6.3 outlines the approach for addressing "new information", Section 6.3 discusses the needed data management and communications, and quality assessment and quality assurance processes are discussed in Section 6.4.

6.1.1.1 *M&E Principles for the Plan/Design step of the AM Cycle*

The Plan/Design step (Step 1) for the MRRP AM Plan was addressed through the EA and the MRRMP. An M&E design describes the combination of logical, statistical, field/logistical and cost strategies to answering one or more management questions that feed into a management decision. Components of an M&E strategy can include (modified from Hillman 2004):

a) a "statistical" design, which provides the logical structure for testing hypotheses, using spatial and temporal contrasts, and identifying the minimum requirements for implementation monitoring, process / effectiveness monitoring and population monitoring;
b) a "sampling" design which describes the process for selecting sampling sites and sampling times;
c) a "measurement" design outlining the specific performance measures and the protocols used to monitor them at the chosen sites and times; and
d) a "response" design that explains how the monitoring data will be analyzed to make inferences in the AM Evaluate step.

The plan/design step is the most critical part of the AM cycle for development of M&E strategies, since it must anticipate all of the steps to follow. Many of the research activities described for pallid sturgeon under Level 1 will help with the design of M&E strategies. The following principles, drawn directly from the DQO process described in EPA (2006), set the foundation for effective M&E strategies in Step 1:

1. *State the problem* – define the problem based on a conceptual model, identify priority hypotheses and indicators related to management actions
2. *Identify the decision* – state the decision to be made, the actions to be undertaken, the key questions to be answered. Clarify the wording of those questions until they can be answered positively or negatively, specifying location, timing, target populations, relative comparisons and other attributes.
3. *Identify inputs to the decision* – decision criteria, key metrics. Metrics ideally should have: a high signal to noise ratio (not too variable in space or time), have direct relevance to decision criteria, have high cost effectiveness, be ecologically responsive (i.e., do not have a long lag in response to changing conditions), are unambiguously interpretable, have minimal environmental impact and have a clearly defined measurement protocol. Evaluating metrics against these and other criteria (see Table 5-1 in Barber 1994) will help to refine the list of key metrics.
4. *Define the study boundaries* – must be sufficiently large to encompass the distribution of management actions over space and time, and the potential impacts of those actions
5. *Develop a clear path from data to decisions* - Effective M&E strategies have a defensible reason for all information that will be collected, which either directly or indirectly have implications for management decisions.
6. *Develop "if-then" decision rules* – Define a statistical parameter of interest for each metric (e.g., median survival rate or abundance for species; flow, stage or reservoir level thresholds for impacts on HCs), and a set of positive or negative outcomes for each priority question, which can be melded into "if-then" decision rules with biologically or socioeconomically significant effect sizes. Such decision rules may involve multiple questions and metrics, as described for pallid sturgeon (see section 4.6).
7. *Specify limits on decision errors* – Define precision requirements for decisions and acceptable limits for decision errors (e.g. lower precision is required to determine whether pallid sturgeon spawning occurs in a given location than to determine the survival rate from eggs to age-1). False positives for species' metrics (e.g., falsely concluding that an action was effective in helping listed species when in fact it wasn't) could lead to implementation of ineffective actions

in place of effective actions, potentially resulting in negative economic and ecological impacts. False negatives (e.g., falsely concluding that an action had no effect on a population, when in fact it had a positive effect) could lead to negative ecological effects if effective actions are stopped. False positives for HC metrics (e.g., falsely concluding that a management action negatively affected HCs when in fact such impacts were unrelated to the action), might also lead to unnecessary reduction or cessation of an ecologically effective action. False negatives for HC metrics (e.g., concluding that an action had no effect on HCs when in fact it had a negative impact) could have undesirable social and economic effects.

8. *Optimize the M&E design for obtaining data* – Develop and evaluate different M&E designs, examining their ability to meet the required levels of precision at an acceptable cost. Optimization of the design may involve considerable work at Level 1 and Level 2, including various efforts to refine methods before finalizing the design, which leads to the following principles. Monitoring of HC metrics should follow a similar process.
    a. Ensure that important time series are maintained if monitoring protocols are being improved.
    b. Use past data and possibly intensive pilot sampling to gain insight into spatial and temporal variability of key metrics (e.g., relative abundance of age-0 pallid and shovelnose sturgeon within different habitat types), and how relative abundance varies over time and river conditions.
    c. Perform statistical power analyses to determine how false positives and false negatives vary with sampling effort, number of treatment (management action) and reference sites, the staging of implementation of management actions, and the number of years of monitoring before and after the action is implemented (see Appendix E for an example of statistical power analyses applied to IRCs).
    d. Allow for an adjustment period with new monitoring needs, and use pilot approaches to discover bugs and solve initial problems.
    e. Complete laboratory and mescosm work at Level 1 to define biological effect sizes of interest, clarify mechanisms of impact, assess measurement errors and refine monitoring protocols.
    f. Complete modelling studies at Level 1 to simulate different M&E strategies.

6.1.1.2 *M&E Principles for the Implement Stage of the AM Cycle*

The implementation of experimental management actions at Level 2 provides an opportunity to both further species objectives and to refine M&E strategies:

1. Use L2 management experiments to benefit listed species and test M&E strategies, examining their ability to reliably evaluate the effectiveness of management actions, and their effects on selected HC metrics.
2. In designing L2 management experiments, seek to maximize spatial and temporal contrasts within the constraints of both feasibility and authorized purposes.
3. Ensure that L2 management experiments have a low risk of negative effects on listed species (e.g., use hatchery fish in a manner which does not affect stocking programs) and HCs (e.g., implement habitat restoration actions in locations and forms which maximize ecological effectiveness and minimize impacts on HCs).

6.1.1.3 *M&E Principles for the Monitor step of the AM Cycle*

Monitoring (Step 3) includes the following considerations for metrics and data collection:

1. Ensure adequate training of field crews on the sampling and measurement design (the why, in addition to the where, when, how and who).
2. Apply the sampling design and measurement design as laid out in the Design step, and document any deviations from that design.
3. Where there are insufficient field data to estimate measurement error, do replicate tests of monitoring (e.g., the same field crew sampling the same location on the same day; multiple crews sampling the same location on the same day)
4. Collect information on key covariates which might affect sampled values (e.g., turbidity, velocity, temperature) and be helpful in subsequent Evaluate step.
5. Ensure that the data are stored in a reliable data storage and management system, and promptly reviewed for data quality (section 6.4).
6. Apply good principles of data management (section 6.3.2.2).

6.1.1.4 *M&E Principles for the Evaluate step of the AM Cycle*

Evaluation of monitoring data (Step 4) includes determining the implications for priority decisions, hypotheses, and the original M&E strategy. Important principles include:

1. Apply the statistical and response designs laid out in the Design step of the AM cycle, and test out whether the key assumptions of the design have been fulfilled.
2. Synthesize multiple metrics and multiple lines of evidence in decision-focused assessments.
3. As problems are detected in analyzing the data, develop and evaluate possible revisions to the sampling and measurement designs.

6.1.1.5 *M&E Principles for the Adjust Step of the AM Cycle*

An important component of the Decide step (Step 5) of the AM cycle involves determination of whether or how to adjust actions or decision, with the following important guidelines:

1. Test pilot data evaluations (and the decision criteria developed in AM step 2) with managers to ensure that the M&E strategy is providing the appropriate inputs to decisions, in terms of form and content.
2. If changes to existing M&E protocols are considered, particularly those with implications for trend analyses, ensure that there is a sufficient period of overlap of the old and new methods to permit cross-comparisons.
3. Ensure that changes being considered to management actions are harmonized with the overall experimental designs and objectives for all system components.

6.1.2 Issues of scale

The effects from implementing the MRRP projects must be monitored at both system-wide and local scales. The ISP is responsible for the design and implementation of system-wide monitoring of birds and fish, and will work with the individual MRRP PDTs for design and implementation of monitoring to determine local effects and project performance. To guide implementation of the system-wide program, the AM Team is developing the MRRP Monitoring and Assessment Plan (MAP), an associated Quality Assurance Requirements (QAR), and a QA/QC document. Materials addressing monitoring and assessment that comprise the MAP are presently included in several chapters, appendices and attachments to the AM Plan (see particularly chapters 3, 4 and 5; and appendices D, E, G, H and I). These materials and associated QAR will be integrated together into the complete MAP as part of the implementation of the AM Plan. The MAP and the individual project monitoring plans will be closely coordinated to ensure that measures and targets selected by the project teams are consistent with system-wide measures and that duplication of effort is effectively minimized.

Monitoring at the project scale should ensure appropriate temporal and spatial coverage of monitoring parameters, which may require filling gaps in the MAP monitoring effort or adding additional project-level parameters not included in the MAP, particularly for monitoring action effectiveness at local scales.

6.1.3 Actionable science

For the MRRP to meet its objectives and work effectively with its partners and stakeholders, it is important that decisions be based on the best available science (see Murphy and Weiland 2011, 2016 for a definition). The science is currently challenged by a number of underpinning uncertainties (see Jacobson et al. 2015, Buenau, et al. 2016, Fischenich et al. 2016; and see Sections 3.1.2.5 and 4.1.2.5), and the AMP includes a number of studies aimed at addressing these challenges. Meanwhile, implementation decisions are necessary in order to meet the requirements of the ESA and avoid jeopardizing the listed species.

The term “actionable science,” was coined by the Department of Interior’s Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS 2015) and it serves as a useful concept for guiding the information necessary to support MRRP decision-making while fulfilling the best-available science mandate. Actionable science provides data, analyses, projections, or tools that can support decisions regarding management of the risks and impacts of operations on the Missouri River. Ideally co-produced by scientists and decision makers, actionable science creates rigorous and accessible products to meet the needs of stakeholders.

The following principles, adapted from ACCCNRS 2015, are presented to guide efforts for producing actionable science and are entirely consistent with the principles for monitoring and evaluation described in section 6.1:

- Scientists, decision makers and stakeholders working in concert are more likely to arrive at actionable science than scientists acting alone.
- Start with a decision that needs to be made. Research needs are rarely precisely known (and seldom clearly specified) in advance, so must be identified collaboratively and iteratively.
- Give priority to processes and outcomes over products, and use the process to build connections across disciplines and organizations, and among scientists, decision makers, and stakeholders.
- Periodically evaluate the utility of products and processes, and the ability to take actions based on the science developed by the program. Use the lessons learned to adjust products and processes as needed, and to refine the definition of “actionable” based on evolving views of risk.

This approach recognizes that actionable science is not only actionable information, but also includes longer-term processes and relationship building to help ensure the appropriate use of that information. Time and resources will be required to develop and maintain interpersonal interactions among scientists, decision makers, stakeholders and other users of the scientific information. Deploying these services efficiently and effectively also requires building connections across disciplines, and among the organizations engaged in the effort. The budgets for the program and individual projects, project evaluations, and staff incentives and evaluations should reflect commitment to this need.

6.2 Monitoring and data acquisition

The MRRP Monitoring and Assessment Plan (MAP) is the primary guide for evaluating the performance of the MRRP. The MAP is an integrated system-wide monitoring and assessment plan that: (1) provides a framework that supports measurements of the responses of habitats, species and human considerations at both project and system-widescales, to determine how well MRRP is achieving its goals and objectives; (2) helps identify and prevent unintended adverse outcomes from management actions; and (3) supports and enables AM for updating and improving the Plan, as well as management actions, when needed. The scientific and technical information in the MAP is organized in such a way as to facilitate status and performance assessments and report these findings in annual system status reports.

> **Note:** Materials addressing monitoring and assessment are presently distributed among chapters 3, 4 and 5 and appendices D, E, G, H and I to the AM Plan. We refer to these collectively herein as the Monitoring and Assessment Plan (MAP). These materials, and associated Quality Assurance Requirements (QAR) will be integrated into the MAP as part of the implementation of the AM Plan.

The MAP is structured around the conceptual ecological models (CEMs), which are organized by species, but also provides a framework for system-wide monitoring and assessment for the MRRP. Implementation of the MAP builds on trends relative to reference conditions and baselines established for the MRRP to detect change including unexpected responses of the ecosystem, and address not only “what” is happening (e.g., status and trends) but “why” it is occurring (e.g., stressors-response functions), which is essential for implementing AM. Monitoring designs and protocols to assess the effectiveness of specific management actions are tailored to those actions, as described in chapters 3, 4 and 5, as well as in Appendix E (for IRCs).

Data acquisition practices for individual projects will follow the overall monitoring and evaluation strategy designed for the AM program. Methods of acquiring field data need to be fully integrated with the overall monitoring and evaluation strategy for each component of the AMP, to ensure that, to the extent budget and field conditions permit, necessary data are acquired, receive QA/QC reviews, and are entered into a secure data management system with all associated metadata, as described in section 6.3. The specific objectives and approaches associated with individual projects will likely necessitate

6.2.1 Pallid sturgeon monitoring data acquisition and analysis approach

Pallid sturgeon monitoring data have been collected by multiple teams from several state and federal agencies who have been involved with the MRRP since its inception. This approach has been used for both the Pallid Sturgeon Population Assessment Program and the Habitat Assessment and Monitoring Program. HAMP and PSPAP monitoring coordinators (USACE) manage contracts with partners, coordinate monitoring activities, work with monitoring teams to adjust monitoring efforts if needed, and assist with data analysis and reporting. See Appendix D for a review of current PSPAP guidance and a proposed substantial revision to the current protocols for population monitoring. Other data collection protocols specific to evaluating the effectiveness of Interception and Rearing Complexes are summarized in Appendix E.

This multi-team approach has several advantages. Long-term monitoring efforts benefit from a consistent approach and sustained expertise. Substantial pallid sturgeon expertise has been developed within these agencies and long-term involvement of these partners has resulted in needed consistency. Since the missions of these partner agencies overlap with the MRRP objectives, these partnerships help ensure that MRRP activities are closely coordinated with similar and potentially beneficial actions of partner agencies. Finally, inclusion of multiple partners in monitoring efforts helps offset the bias, perceived or real, within any one partner agency, including the USACE.

It is vitally important that fish monitoring crews understand the key hypotheses to be tested, the overall monitoring and evaluation strategy, and the reasons for the specific details incorporated into fish monitoring protocols, Understanding the ‘why’ of a monitoring and evaluation program will help to ensure that the ‘what’, ‘where’, ‘when’ and ‘how’ are correctly implemented. This deeper understanding by field crews will also catalyze communications between field crews and Technical Team members regarding field observations which may be particularly relevant to the existing set of big questions and hypotheses, as well as potentially suggesting other factors to be considered (e.g., potential predators or competitors to pallid sturgeon that frequently appear in the same places and times as various life stages of pallid sturgeon).

Historically, fish monitoring crews have had little involvement in subsequent data analyses. Some partners have the necessary expertise to assist in these analyses, however, and because analyses will be identified in advance through the AM Plan, some of these analyses (if appropriate to the expertise of contractors) can be included in monitoring contracts, framed around specific hypotheses and questions from the AM Plan. This will allow the MRRP to capitalize on the expertise of partners (i.e., providing key contributions to the Technical Team) while focusing their work in the non-sampling seasons on the most productive efforts. In the past, the limited off-season analyses which were conducted by individual partners have been uncoordinated and often not focused on the most important information needs of the MRRP. Involvement of monitoring crews in conducting pre-defined analyses will provide a cost-effective means to ensure timely data analysis. In addition, the PSPAP and HAMP coordinators' duties will be redirected to allow more focus on data analyses and reporting.

6.2.2 Bird monitoring data acquisition and analysis approach

Bird monitoring data are currently collected by USACE staff with a heavy reliance on part-time summer employees. This approach works well for the bird monitoring needs as it allows for a high level of staffing during the season (May-August) when the birds are on the Missouri River. This approach also offers potential to adjust staffing levels relatively quickly based on system conditions. For example, a high water year may significantly reduce the area to sample and temporary staffing levels can easily be adjusted. A disadvantage of this approach is the inexperience and annual turnover of many of the bird monitoring staff. This is a challenge that has been identified and is being addressed in order to ensure the needed consistency and quality of data collection. For example, additional oversight and field assistance by roaming veteran staff in 2015 has helped to increase consistency among crews. Recent reviews of the strengths and weaknesses of alternative methods for monitoring key bird metrics (Schwarz and Porter 2016) provide a basis for considering possible improvements to existing monitoring protocols. Staffing requirements will depend on what bird monitoring protocol is selected (see section 3.3.3 and Appendix G for a discussion of bird monitoring protocols).

Analyses of bird monitoring data are performed annually by the USACE bird monitoring coordinator including trend analyses and take reporting. Utilizing a full-time bird monitoring coordinator to lead these analyses ensures consistency, commitment, and the necessary close communication with USACE water management.

6.2.3 System status and HC data acquisition and analysis

System status refers to conditions of the reservoir system, riverine segments, and affected resources. Status measures include primary measures such as tributary inflows, reservoir storage levels, outflows (discharges and stages), channel condition, sediment transport, and water quality parameters. Status measures can also be usefully extended to secondary measures of system resources, such as power production, habitat availability, water supply, navigation support, flooding and other HC metrics. The reasons for monitoring system status include:

1. Information is needed to guide operational decisions. For example, reservoir releases and downstream stages are needed to evaluate, manage and minimize downstream flooding, a key concern to stakeholders.

2. Information is needed to assess AM Plan components. For example, reservoir releases, stages, and discharges are needed to evaluate piping plover and pallid sturgeon habitat availability.

3. Information is needed to assess effects of AM Plan components on human considerations. For example, river stages, sediment transport and state of interior drainage are needed to evaluate effects of flow releases and other actions (e.g., habitat creation) on agricultural production.

4. Information is desired to understand unanticipated changes in the river and associated resources. For example, low reservoir releases, high air and water temperatures, and local thunderstorms may generate local inflows with high nutrient concentrations, resulting in low dissolved oxygen and fish kills. As discussed in Chapter 4, low oxygen concentrations in the bottom waters of Fort Peck Lake and Lake Sakakawea reservoirs cause mortality of pallid sturgeon embryos (Guy et al. 2015).

Investments in monitoring for these types of information will certainly vary by category. Category 1 is essential to Missouri River System operations and continued investment is highly justified. Categories 2 and 3 are additive to category 1, and are central to AM of the habitats and species; return on investment for monitoring this information is considered high but may be implemented variably depending on affected resources. Information relating reservoir releases, river stage, and water intake efficiencies, for example, may be prioritized for category 3. Which human-consideration metrics will be included in system status monitoring will be based on results of the impacts analysis being conducted for the EIS, the preferred alternative, and the range of factors discussed in Section 5.5. For years in which flow actions are not implemented (all years under alternative 3 in the EIS), a major focus of HC monitoring is likely to be in the immediate vicinity and downstream of projects to construct ESH, IRCs or spawning habitat. Monitoring priorities and strategies will be discussed and designed collaboratively with stakeholders as part of the AM Plan development process, and periodically reviewed following the processes laid out in Chapter 2.

Category 4 relates in large part to water-quality data and return on investment to the MRRP is not as clear as the other categories, except in cases where they directly influence MRRP decisions (e.g., the extent of anoxic waters in the bottom waters of Lake Sakakawea has important implications for decisions on Upper Missouri pallid sturgeon actions, as discussed in the summary of the EA in section 4.1.2). Water-quality stressors result from combinations of USACE management actions and from widespread actions beyond USACE authority. Examples include point discharges from municipal and industrial water-treatment facilities and non-point discharges of nutrients, sediment, and bacteria from basin agricultural sources. Concerns about water quality are therefore shared among many agencies and authorities. Although it is reasonable to expect all riverine biota to be affected to some extent by water quality, specific water-quality stressors to piping plovers and pallid sturgeon did not emerge as dominant hypotheses from the EA, except for the issue discussed above for Lake Sakakawea oxygen concentrations. Therefore, no clear link between water quality and AM of the two species presently exists. Some level of foundational water quality monitoring may be justified to the MRRP to avoid risk and to prepare for unanticipated conditions, and the USACE plans to work with other Federal and State agencies and other stakeholders to seek a cost-effective, collaborative ambient water quality monitoring program to assess status and trends of parameters that may affect habitats and socio-economic values.

Analysis of the system status information will be performed annually by the Technical Team, and will include trends analyses and model validation results along with other data related to system status. This information will be presented at the AM Science and AM Workshop and included in the annual report.

6.2.4 Research data acquisition

Many research efforts will be relatively short term (i.e. 1 to 3 years). For most research, the MRRP Integrated Science Program will utilize a competitive proposal solicitation process open to government agencies, public sector contractors, and universities through an open Request for Proposals. Research projects will be selected on the basis of their support of MRRP AM needs, demonstrated capabilities of proposers, the value of information, and cost effectiveness. Selections will be made by the USACE but informed by proposal reviews from an independent panel. The selected researcher will then become the principal investigator for that particular research project. Solicitation of proposals should occur far enough in advance so that information on potential costs and timelines is available as budgets are being developed. The Integrated Science Program is committed to the use of peer review and will refine peer review guidelines for reviewing research proposals, publications, and other products or deliverables.

If research or monitoring efforts have little staff turnover or outside influence, they can suffer from a narrow perspective and a tendency to not question the current paradigm while missing key lessons learned in other systems. These challenges can be overcome in the AMP with appropriate independent reviews, interdisciplinary feedback at annual AMP science meetings and workshops, a competitive research proposal process, and increased room for scientific influence from outside the basin (e.g., a defined role for Federal Recovery Teams).

Many Level 1 science components for pallid sturgeon will be implemented concurrently, subject to budget constraints, which will require an intensive effort to organize the science plan, coordinate multiple science components, and communicate interim findings to all parties.

6.2.5 New Information

New or newly introduced information related to the listed species life history, their habitats, or system response requires a consistent and rigorous review process. Information derived as a product of the research and monitoring of the MRRP will be subjected to the review processes outlined throughout this AMP. Review is also needed for the occasional “new information” that originates outside the Program. That review process will help ensure that the MRRP is using the best available and verifiable science information in informing AM decisions. Under the current structure, this process will progress through the Technical Team and will end up as a topic of review by the Independent Science Advisory Panel, as described in detail in section 2.5.4. The new information process has been used in 2016 for the issue of fish condition, as described in section 4.1.2.4.

6.3 Data and Information Management

6.3.1 Overview

Adaptive management programs need to manage data in ways that accurately transform information into decision-relevant learning, facilitate and enhance communication, share and protect data appropriately, have a reasonable cost of development and upkeep, and can adapt to changing program needs.

The data management system for the MRRP must be able to take a variety of data inputs generated by the MRRP and by outside sources, perform a variety of functions to transform that data into actionable and accessible information, and communicate that information in the right form and time to meet the needs of different user groups (Figure 96).

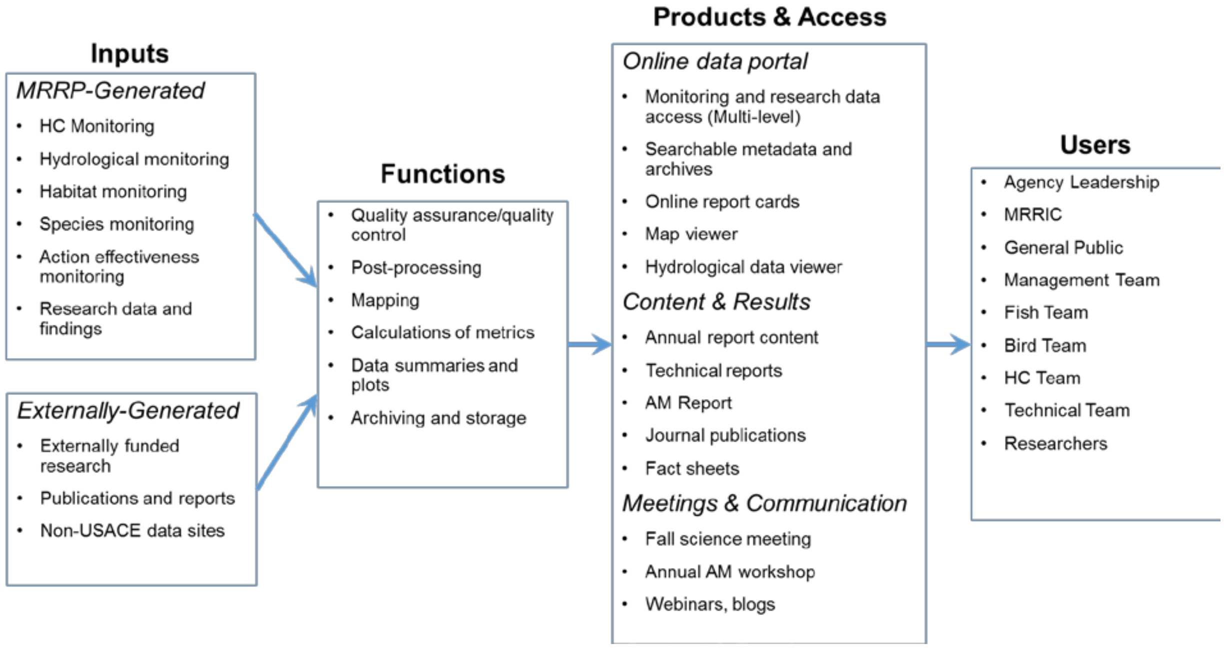

Figure 96. **A conceptual model depicting the management of data to inform the MRRP.**

6.3.1.1 *Users and their needs for information*

As shown on the right side of Figure 96, there are multiple user groups with widely varying needs for information on the MRRP. The preferred forms of work products to meet those needs (described in section 6.3.3.1), include:

- succinct summaries of decision-relevant results for decision makers and managers;
- focused summaries for the bird, fish and HC teams;
- non-technical summaries for MRRIC and the general public;
- more detailed supporting evidence for the technical staff who advise decision makers and managers;
- raw and refined data extractable by multiple search criteria for the Technical Team and researchers.

These information needs will vary at different stages of the AM cycle (as described in section 6.1), and at different times of the annual cycle (described in section 2.4.2). The following short sections provide an overview of the user groups shown in Figure 96 and their general information needs. These user needs will be defined in much more detail through a User Needs Assessment, to be conducted in the fall of 2016 (described in section 6.3.4.1).

6.3.1.1.1 *Monitoring staff*

The monitoring staff will need to input, QA, and access information generated from the monitoring program, including data, metadata, and derived applications of the data (e.g., population estimates of piping plovers derived from field sampling efforts). The DMS should streamline these processes to enable timely data use and reduce the potential for human error.

6.3.1.1.2 *Researchers*

Researchers will need to submit data and metadata, as well as research findings and publications. MRRP-funded researchers will have certain rights and obligations regarding data ownership, sharing, and publication as specified in their contracts. Researchers not funded by the MRRP may also submit data, but with different rights and obligations according to their funding sources. Researchers from federal agencies also have obligations for public access to their data. The DMS should facilitate data sharing and permissions to enable researchers to submit and share data as appropriate with minimal time demands, but at the same time assuring that all submitted data is quality assured.

6.3.1.1.3 *Technical Team*

The Technical Team needs to access a wide variety of information and to ensure the accuracy and completeness of information used in data synthesis and evaluation. Testing hypotheses requires integration of data from diverse sources, and evaluation of many different lines of evidence. Effectively meeting the needs of monitoring staff and researchers will partially fulfill the needs of the Technical Team, as will forms of data organization and evaluation driven by the scientific and learning needs of the AM program. The Technical Team can also benefit from data-processing and reporting tools that automate routine analyses and visualizations to shift time away from repetitive tasks and facilitate prompt reporting.

6.3.1.1.4 *Bird, Fish and HC Teams*

At the implementation level, staff are both generators and users of monitoring and research information. They require access to on-the-ground decision-relevant information including site-specific monitoring and research results and real-time status of hydrology, species, and habitat. They also require the ability to efficiently quantify and document actions implemented and their outcomes. MRRIC members on the Bird, Fish and HC Teams will have access to data summaries and post-QA/QC data that is not otherwise restricted from release by policy.

6.3.1.1.5 *Management and Oversight*

Decision makers at the management and oversight levels require ready access to summary and status information, particularly as related to species' objectives and targets, implementation commitments and forthcoming decisions on program actions and expenditures. While most decisions will be guided by information synthesized by the Technical, Bird, Fish and HC Teams, managers and members of the oversight level will also have an interest in directly accessing information; their information needs will be identified, and will likely evolve over time.

6.3.1.1.6 *MRRIC and public*

Stakeholders, partner agencies, and members of the public have a broad range of information needs and interests, from real-time hydrological data to species status to research findings. In most cases, summaries and information in report-card format will be more useful than raw data sets; in other cases access to more detailed information for those who are interested can be made available after accounting for data sensitivities. Needs, tools, and access requirements for these groups will be determined.

6.3.2 Purpose and Objectives

6.3.2.1 *Objectives of the Data Management System (DMS)*

The overall objectives of the MRRP DMS are to:

1. Provide a portal to information on the MRRP that is specifically designed to meet the needs of researchers, planners, decision makers, stakeholders, and the general public;
2. Address the needs of a diverse group of data providers and consumers to facilitate efficient planning and execution of the MRRP AM project;
3. Provide access to the data required for planning and decision making in a timely manner; and
4. Facilitate awareness amongst related programs in the Missouri River Basin including those not directly part of the MRRP which overlapping interests and information.

6.3.2.2 *Principles and Guidelines*

The design and development of the DMS will be guided by the following principles:

1. There will be a commitment to a high level of transparency, recognizing that there may be certain data sets that have access controls associated with them through Federal or other policies.
2. The system will be designed to minimize the unnecessary duplication of data. The proposed 'system of systems' vision is of a dedicated portal to information that is stored on other systems.
3. Implementation will make use of existing technologies and systems where possible and appropriate. Building on existing systems avoids unnecessarily re-creating what has already been done well.
4. The identification and reduction of institutional and technological barriers to the sharing of information will be a priority for system design and implementation.
5. Policies and procedures associated with the DMS will avoid being overly prescriptive about how scientists manage their data while recognizing the need for applying and managing appropriate data quality standards.
6. The DMS will promote the use of standards for data exchange and reporting. Where data is gathered using program funding, requirements for data provision and reporting will be made explicit.

6.3.2.3 *High Level System Requirements*

In order for the DMS to be most effective it is critical to understand what information is needed by whom and when and ensure that this information can be provided in required formats with appropriate levels of QC.

We are not starting this process from scratch. High-level data management and technology needs and concerns have already been identified within the MRRP and during the EA and AM development processes. At the very highest level the requirement for the DMS can be summarized as:

> To provide a single user friendly access point for accessing all relevant information on the MRRP so that information required for planning and decision making is available on a timely basis in appropriate formats meeting required quality standards.

While the detailed requirements analysis has not yet been completed, some of the candidate high level requirements for the data management system have been identified and are summarized in the following sections.

6.3.2.3.1 *Information Stewardship*

1. Accommodate varied sources and types of information, including information generated external to the program.
2. Capture and maintain decision-relevant information including monitoring data, research data and findings, supporting information, scientific reports, project performance reports, summary status reports for systems/species, project activity reports, analyses of results of activities, and key reports for decision makers.
3. Protect MRRP information assets at a level necessary to achieve the desired degree of ownership and user access control, honoring formal data use agreements, legal standards, publication rights, and user rights and responsibilities that are enacted by data owners or delegated custodians.
4. Capture and document the information used to make decisions.
5. Accommodate access to legacy data to capitalize on existing MRRP investments when feasible.

6.3.2.3.2 *Access to Information*

6. Provide reliable and timely data access for technical teams and external researchers, facilitating communication and communication of information.
7. Provide easily searchable meta-data (i.e., data describing the nature of a given data document).
8. Facilitate and enhance the communication of decision-relevant information through accessible and searchable online interfaces and data visualization tools that are customized to target user groups.
9. Clarify which data exist, how they have been analyzed and applied, and what further applications they have.
10. Provide access to near-real-time hydrological data and accompanying visualization tools to help understand the effects of reservoir management on habitat, species, and human considerations.

6.3.2.3.3 *Processing and Analysis*

11 Accelerate learning by processing information into formats that are ready for use by technical staff, managers, partner organizations and stakeholders.

12 Provide fast, accurate processing of species and habitat information so that outcomes of the previous year's monitoring can be used in the upcoming AM evaluation and decision cycle.

13 Provide summaries for management, partners and the public.

14 Ensure tools are practical for use by data generators, saving time rather than creating additional workload.

6.3.2.3.4 *System Management and Quality Assurance*

15 Adjust to changes over time in data, software, and user needs.

16 Ensure a reasonable cost of development, use, and upkeep.

17 Establish governed QA/QC standards, tools and processes to ensure information is available and reported promptly.

18 Facilitate report creation, reducing or eliminating bottlenecks that delay the communication of information, and freeing up staff time spent on conducting repetitive tasks to being able to engage in research.

19 Maximize accuracy in data acquisition, processing, and reporting by reducing data disparity and providing automated measures of quality.

20 Maintain data integrity and its measure of uncertainty.

6.3.3 Reporting and communication

Data reporting and communication will serve several needs including providing information useful for decision-making as well as fostering understanding of stakeholders and the general public. Each audience has somewhat different needs, and therefore requires different forms of information, with varying levels of detail. These varying needs will be further understood and documented through the user needs assessment in the fall of 2016 (described below in section 6.3.4.1). It will be important to develop, implement, and periodically re-evaluate a communication plan which considers all of the different audiences, and the diverse forms of reporting that are most appropriate to each audience (e.g., decision-oriented syntheses, annual reports, reporting sessions, science workshops, peer-reviewed reports and journal articles, fact sheets, videos, presentation summaries). The MRRP generates a wide range of communication products, including all of the above.

6.3.3.1 *Types of work products*

Reporting will include annual reporting of system state such as ESH availability, implementation results (what actions were actually undertaken and to what extent), bird and fish monitoring results, progress toward answering big questions and working hypotheses, effects on HCs, and syntheses of the effectiveness of actions.

Annual and periodic AM reports serve the critical purpose of evaluating effectiveness of management actions toward meeting species objectives, including reporting the status and trends of the three species and their habitats. Annual reports have been very successfully used in the Platte River Recovery Implementation Program (PRRIP)[1], particularly as these reports are accompanied by an annual AM Plan Reporting Session in which the previous year's findings are presented and discussed. AM reports also include a MRRP score card that communicates the status of new learning in relation to management hypotheses (see Table 53 in section 4.6 for a possible score card approach for synthesizing multiple lines of evidence related to pallid sturgeon action hypotheses).

The AM Report contains recommendations from the Bird, Fish and HC Teams for adjustments to management actions and suggestions for prioritizing research, monitoring assessment and other Program activities in development of the annual MRRP Work Plan. The Annual AM Report is the primary vehicle for summarizing research, monitoring and data analysis results in a manner that ensures new learning is incorporated into MRRP decisions and that these decisions are made based upon the best available science. AM reports will be made available to the Management Team, agency leadership, MRRIC and the ISAP for their review and recommendations. Effecting sharing and maximum transparency of the information used in decision-making will be a key guiding principal in reporting.

To translate scientific information and communicate results and recommendations, a series of work products will be produced. Table 56 outlines the products and identifies various user groups listed as both preparing and receiving work products. Since each user group has a diverse composition and occasional turnover, and a need for documenting past results exists, requiring information transfer both within and between

[1] The PRRIP "State of the Platte Report" (e.g., PRRIP 2014) has proved to be a very effective communication tool. The report is organized hierarchically, providing a tabular summary of current understanding of the answers to 11 Big Questions (for decision makers), 3 to 5 page syntheses of evidence for each Big Question and related hypotheses, specific subsections on 'decision implications', recommendations from the PRRIP Independent Science Advisory Committee (ISAC) and responses to these recommendations, and hyper-linked endnotes to all of the primary reports and references used as evidence.

groups. There are also diverse levels of interest in technical information within MRRIC and the general public; providing a hierarchy of linked information (from high-level report cards down to detailed technical reports from which summary information is derived) will permit different users to dive into the details as deep as they'd like.

Table 56. Work product and other forms of information access.

Work Product / Information Access	Purpose/Message	Prepared By	Primary Audience
Online Portal to Raw Monitoring Data (see section 6.3.6)	Access raw data and metadata for scientific analyses (e.g., test hypotheses, improve models, assess status and trends) Allow upload of quality-assured data Restrict access to some data	Data providers Research scientists Technical Team Information Management Team	Research scientists Technical Team
Online Portal to Data Summaries and all Work Products	Status and trends of projects, habitats, species, and HC indicators at various spatial scales Quickly generate maps, graphs and tables for other work products Apply exploratory tools (e.g., Hydroviz) Provide single entry point to other work products	Research scientists Technical Team Information Management Team	Technical Team Management Team Scientific community Bird, Fish and HC Teams Independent Panel MRRIC General Public
Technical Reports	Analysis of monitoring data Modification of conceptual ecological models Evaluation of hypotheses and big questions related to tern, plover and pallid sturgeon population dynamics Reports on effects of actions on HCs	Technical Team	Technical Team Management Team Scientific community, Bird, Fish and HC Teams, Independent Panel MRRIC
Fall Science Meeting	Review initial observations from the field season regarding the system Describe project performance and monitoring Identify analytical needs Serve as an in-Progress Review (IPR) Allow Water Management to provide a briefing on the draft AOP	Management Team Technical Team Research scientists	Oversight Team Management Team Technical Team Bird, Fish and HC Teams Independent Panel MRRIC

Work Product / Information Access	Purpose/Message	Prepared By	Primary Audience
Draft and Final AM Report	Annual synthesis of technical reports into messages for decision-makers regarding management action performance (e.g., continue or modify management actions) Links to technical reports Includes MRRP Report Card, which documents answers to big questions and reports on new learning.	Management Team Technical Team	Oversight Team Management Team Bird, Fish and HC Teams Independent Panel MRRIC
Annual AM Workshop	Presents recent findings to be included in the Annual AM Report; allows for interactive dialogue with scientists to better understand findings	Management Team Technical Team Research scientists	Oversight Team Management Team Bird, Fish and HC Teams Independent Panel MRRIC
System-scale AM Evaluation Reports	Report progress towards achievement of programmatic goals, objectives, sub-objectives and targets. Recommendations for adjustments to management actions at Program level.	Management Team Technical Team	Oversight Team Management Team Bird, Fish and HC Independent Panel MRRIC
Periodic Adjustment Mandates	Adjustments requiring immediate attention e.g., unanticipated flow events	Management Team Technical Team	Oversight Team Management Team Bird, Fish and HC Independent Panel MRRIC
Draft and Final Work Plans	Describe the AM activities to be conducted over the next 2 FYs	Management Team Technical Team	Oversight Team Management Team Bird, Fish and HC Independent Panel MRRIC
Fact Sheets for R&D efforts and significant findings	Succinct summaries of progress made on testing key hypotheses, implementing and evaluating actions, key concepts	Technical Team Research scientists	Oversight Team Management Team Bird, Fish and HC Teams MRRIC General Public
Journal Publications	Describe methods, results and implications of research findings Allow for peer review	Technical Team Research scientists	Greater scientific community Bird, Fish and HC Independent Panel

Work Product / Information Access	Purpose/Message	Prepared By	Primary Audience
Webinars	Provide an overview of progress on implementation of the AM Plan Obtain feedback	Management Team Technical Team	Oversight Team Management Team Bird, Fish and HC Teams MRRIC
Model Manuals	Provide guidance on how to use publically available models	Technical Team Research scientists	Technical Team Greater scientific community
Science Blogs and Videos	Provide easily understood summaries of recent work (e.g., https://www2.usgs.gov/blogs/csrp/) Engages interest Visualize scale of challenges	Technical Team Research scientists	Oversight Team Management Team Technical Team Bird, Fish and HC Teams MRRIC General Public

6.3.3.2 *Product approvals*

The USACE has final approval responsibility for products and deliverables that are the responsibility of the MRRP. This approval process follows the steps as outlined by The USACE and the Division Commander has the final authority on any product approval. However, because of the collaborative nature of the Program and the need to delegate approval for some products to a more appropriate organizational level, the approving entity varies with the specific product and, in some cases, involves signatures from cooperating agencies.

6.3.3.3 *Timing and distribution mechanism for products*

The timing of delivery of information (and various work products) will be driven by three processes: 1) the need for very rapid information to manage water during each year; 2) the ongoing process of learning by the Technical Team and research scientists, which requires rapid access to multiple forms of quality-assured information; and 3) the annual cycle of AM governance (described in section 2.4.2).

6.3.4 Proposed work plan for developing the Data Management System (DMS)

The proposed work plan for the development of the DMS consists of a series of phases, starting with a careful analysis of the users and their diverse requirements, followed by a review of these requirements involving MRRP stakeholders to ensure accuracy and completeness.

After the requirements analysis and documentation, the development process will proceed through system design and implementation phases. In this section we focus on the requirements analysis. The later phases will be documented in more detail once the requirements have been clearly defined.

6.3.4.1 *Requirements Analysis*

The requirements analysis includes a research component followed by documentation and review.

6.3.4.1.1 *Objectives of Requirements Research*

The overall objective of the requirements research will be to describe the functions and work products each user group will require, what specific products should be available to them on what time schedule, and how they will interact with the DMS. More specifically:

1. What information should be available, to whom, when, through what interface/process, in what format, and with what quality standards?
2. How should the different data sets and information products be stored and accessed?
3. What metadata needs to be maintained to ensure data is properly described and is accessible in the simplest way possible given any access controls?
4. What processes and procedures need to be in place for data management at all levels, for example QC?
5. What are the business processes and timelines that should drive the data management process?

These questions will be addressed through consultations with potential DMS users including both data providers and consumers, background research on the capabilities of existing systems, and identification of the key barriers to meeting system objectives.

6.3.4.1.2 *Task 1: User Needs Assessment*

A list of information and data needs will be compiled from the AMP, organized into meaningful categories, and used as a starting point for eliciting feedback and input from a wide range of different potential users of the DMS. This compilation will be designed to allow potential users to focus on their specific areas of interest based on their roles with the MRRP.

The compilation will be developed in collaboration with the core team and then shared more broadly with people across a range of expected DMS users. A more complete articulation of user needs will be built through a mix of individual review and feedback as well as small group discussions. It will be important to many different aspects of the user community involved, and to make wise use of existing committees, subgroups, and protocols for interaction.

6.3.4.1.3 *Task 2: Review of Existing Systems*

Existing systems will be reviewed from several different perspectives:

- Existing data and information sources currently relevant to the MRRP that will need to be incorporated into the overall system of systems – see section 6.3.6 below;
- Portal systems that can be used to provide examples of different functionality and user interface approaches – see section 6.3.5.3; and
- Systems that could potentially be used as part of the technology for developing the DMS.

Candidate systems for review will be elicited both from the core team and other users during Task 1.

6.3.4.1.4 *Task 3: Identification of Barriers to Implementation*

Barriers to implementation will be researched in a number of ways, including during the idenfication of user needs in Task 1. It will be important to understand what current limitations and issues are faced by MRRP data and information users so that we can ensure that these are addressed as far as possible in the DMS. Some of the issues to be considered include:

- Data funded in one program may be hard to share with another;
- Researchers unwilling to share data before publishing;
- Institutional and policy barriers to sharing specific types of data; and
- Format and data documentation issues.

The MRRP will not be the first data management initiative to encounter these types of issues and it will be important to learn from others. The Long Term Ecological Research Network (https://lternet.edu/) has done considerable work resolving these types of issues and will be a valuable source of information.

6.3.4.1.5 *Task 4: Requirements Review and Final Requirements Documentation*

The results of the user needs assessment in Task 1 and the research into existing systems and barriers to implementation in Tasks 2 and 3 will be compiled into a set of draft requirements for review. The review process has not yet been finalized but will involve an initial review by the core team followed by a wider review by a larger group of MRRP stakeholders who are interested in the DMS.

6.3.4.1.6 *Schedule*

The proposed schedule for completing the requirements analysis is:

Task 1. User needs assessment – September 2016 to January 2017
Task 2. Review of existing systems – October 2016 to January 2017
Task 3. Identification of barriers – October 2016 to January 2017
Task 4. Requirements review and final documentation – February to April 2017

It is proposed that the detailed design of the DMS will continue through 2017 with implementation starting in 2018 following approval of the AM Plan.

6.3.4.2 *User Needs Assessment*

The user needs assessment will begin in the latter part of 2016. In this section we describe some of the considerations to be included in the assessment.

6.3.4.2.1 *Participation*

The user needs assessment will be structured around broad types of users in order to focus on issues most relevant to these roles. The proposed user groups directly related to the MRRP have been described in section 6.3.1.1 and include:

- Monitoring staff,
- Researchers working on the Missouri River and its major tributaries,
- Technical Team,
- Bird, Fish and HC Teams,
- Management Team
- Oversight Team,
- MRRIC members, and
- Interested general public.

Participants may also be broadened to include researchers and groups involved in other programs with similar interests to the MRRP.

Specific groups and individuals within those groups will be identified for participation in this task based on discussion with the MRRP core team.

6.3.4.2.2 *Topics to be Covered*

The structure for determining user needs will be further developed as Task 1 process. Here we present some initial topics that will be covered based on our preliminary discussions and analysis.

Topics for all participants:

1. Tools/systems/or data sources that are important for us to consider as we develop the DMS

Topics to cover in the user needs assessment for information providers:

2. Types of information currently generated that is relevant to the MRRP, e.g.
    - Monitoring data
    - Research reports
    - Summary reports
    - Data portals available to a wider audience
    - GIS data available to a wider audience
3. Additional types of information that could be provided
4. Current access controls or restrictions on data access and sharing of this information, e.g.
    - Information is public
    - Data access agreements required for sharing.
    - Information has strong privacy/confidentiality restrictions.
    - Specific controls you would like to see on your data...?

Topics to cover in the user needs assessment for information consumers:

5. Information critical to each role related to MRRP
6. Information needed for one or more roles that is not currently available
7. Technical or institutional barriers currently hampering access to information
8. Ideas on how to address these hurdles
9. Requirements for this information in specific formats or with particular summaries
10. Preferred format and access methods
11. Specific milestones/decision points when this information is needed (on an annual cycle)

12. Currently methods of accessing information on the MRRP
13. Data quality standards required for the information used by different user groups

6.3.4.3 *DMS Development and Implementation*

Following the completion of the requirements process the DMS will move into the implementation phase. At this point there has been no decision on the details of the implementation approach and this will likely depend on the selection of the agency and/or team who will lead the development. We would expect that there will be a system design phase where there would be input from appropriate members of the MRRP team, as well as information technology experts within the USACE.

Some of the decisions to be made early on in this phase will be around:

- priorities for development;
- the use of existing platforms and tools;
- the selection of the development team; and
- hosting options.

In addition to the requirements for DMS functionality these decisions will also need to take into account budgetary and scheduling constraints, and the approach to be taken to the long term management, operation, and maintenance of the DMS.

A key task in developing the implementation approach will be developing a plan for phasing and scheduling. The schedule will depend on the complexity of the overall design, the priority for different requirements, and budgetary constraints.

Several technology solutions supporting MRRP monitoring programs are already in place). Fusing newly-developed technology with existing MRRP investments where feasible will provide a foundation for decision support that can grow as priorities shift with the AM process. Suitable technology development to support the dynamic MRRP will be able to evolve over time without having to be rebuilt from scratch when programmatic needs shift. The technology architecture and components will be built to come and go while the rest of the system remains completely operable.

6.3.5 DMS Structure and Functionality

The products needed to address MRRP needs will include websites, analytic software, dashboards, databases, catalogues, maps, and reports. All technology products share a need for some common functionality, such as a secure computing environment, information (metadata) about where the data came from, and its attributes (e.g., locations and times sampled, sampling design, monitoring protocols, methods of computing metrics, precision, accuracy). To make development effective and efficient, the same structure will be used for all common functionality when possible across all MRRP systems.

6.3.5.1 *User Interface Components*

While the details of the data management system design will be developed during the requirements analysis, experience with other similar systems provides a basis for considering some of the different functionality that may be included.

1. General Information and Communication
    - Calendars of events related to MRRP
    - News feeds/significant events related to project components, timelines, results etc.
2. Compiled and Summarized Information interfaces
    - Dashboards showing the system status (projects, habitat, species' abundance, flows, reservoir levels, river stage)
    - Report cards focused on key issues (e.g., state of current understanding with respect to key hypotheses)
3. Data access
    - Tabular/text based interfaces for finding and viewing information using searchable metadata
    - GIS/Mapping interfaces for finding and viewing information
4. Analytical tools
    - Automated report generation and/or query engine to produce charts and tabular results tables, for example for hydrological data
    - Access to analytical software operating on raw data such as demographic models for birds and fish, habitat models, floodplain models.

6.3.5.2 *Conceptual Architecture*

Based on the principles, guidelines, and high level objectives described in the previous sections we can describe a conceptual architecture for the DMS as shown in Figure 97.

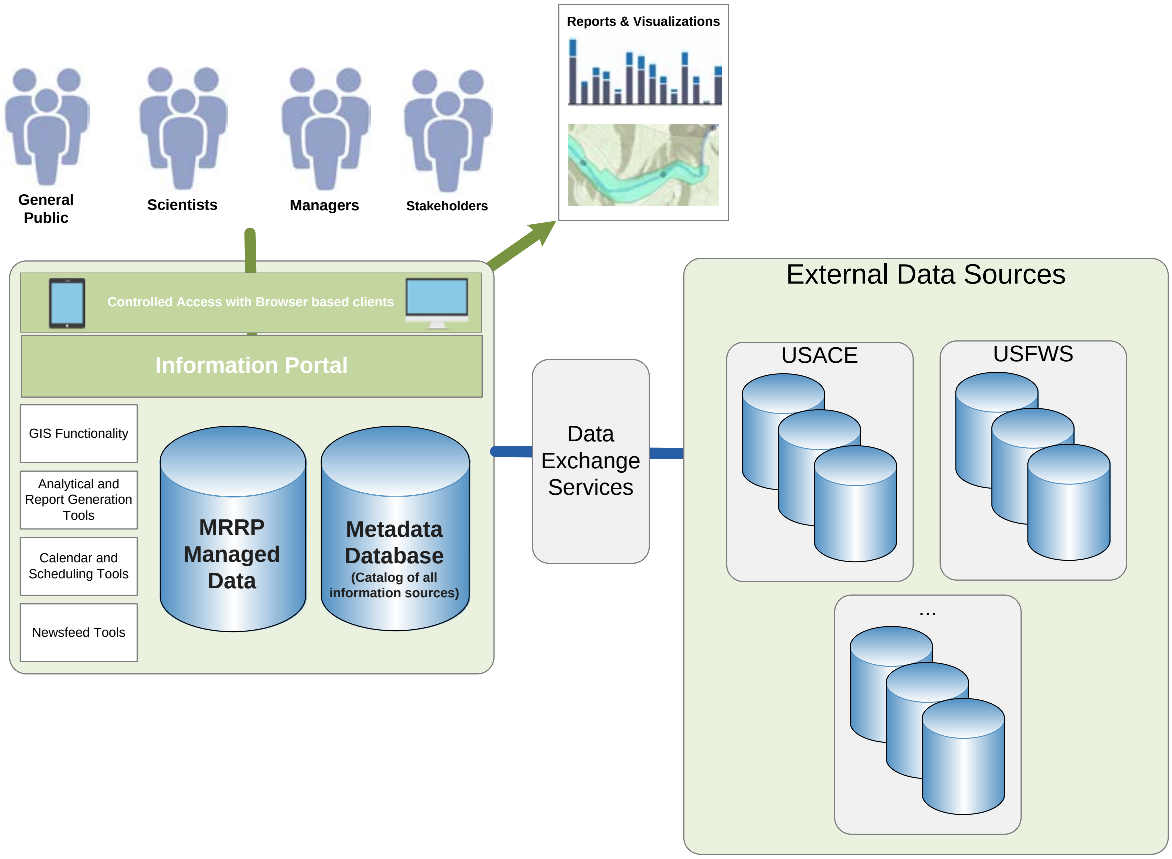

Figure 97. Conceptual Architecture for the MRRP DMS

The key components to note in this architecture are:

1. A single portal to all required information and tools for all user types;
2. Controlled access for certain information and tools based on the requirements of the data and tool providers;
3. The majority of data maintained in systems controlled by the agencies currently generating and managing that data (right side of Figure 97) with a smaller amount of MRRP specific data managed directly by the DMS (left side of Figure 97);
4. Data exchange services based on defined standards to allow direct access to data from the DMS across multiple systems;
5. A comprehensive and searchable metadata database describing data sources and information in all locations; and
6. A variety of user friendly tools to facilitate finding and accessing information in user friendly tabular and map based formats.

6.3.5.3 *Information management portal examples*

The MRRP Data Management System will not be the first system to address many of the requirements that have been identified. While it is too early to in the design and development process to focus on the details of user interface design it can still be useful to consider other systems and how effective they have been in addressing these requirements. Reviewing these related systems also provides a more concrete basis for discussion of user needs and options during the requirements analysis phase.

6.3.5.3.1 *The Long Term Ecological Research Network (LTER)*

The LTER Network site (https://lternet.edu/) demonstrates some of the characteristics and functionality being considered for the MRRP DMS:

- Clean user interface with role rapid entry points on the top of the first page: "For Researchers", "For Educators & Students", "For Decision Makers";
- Access to a data portal;
- A news feed;
- Featured information/sites of current interest; and
- Some background information on the network.

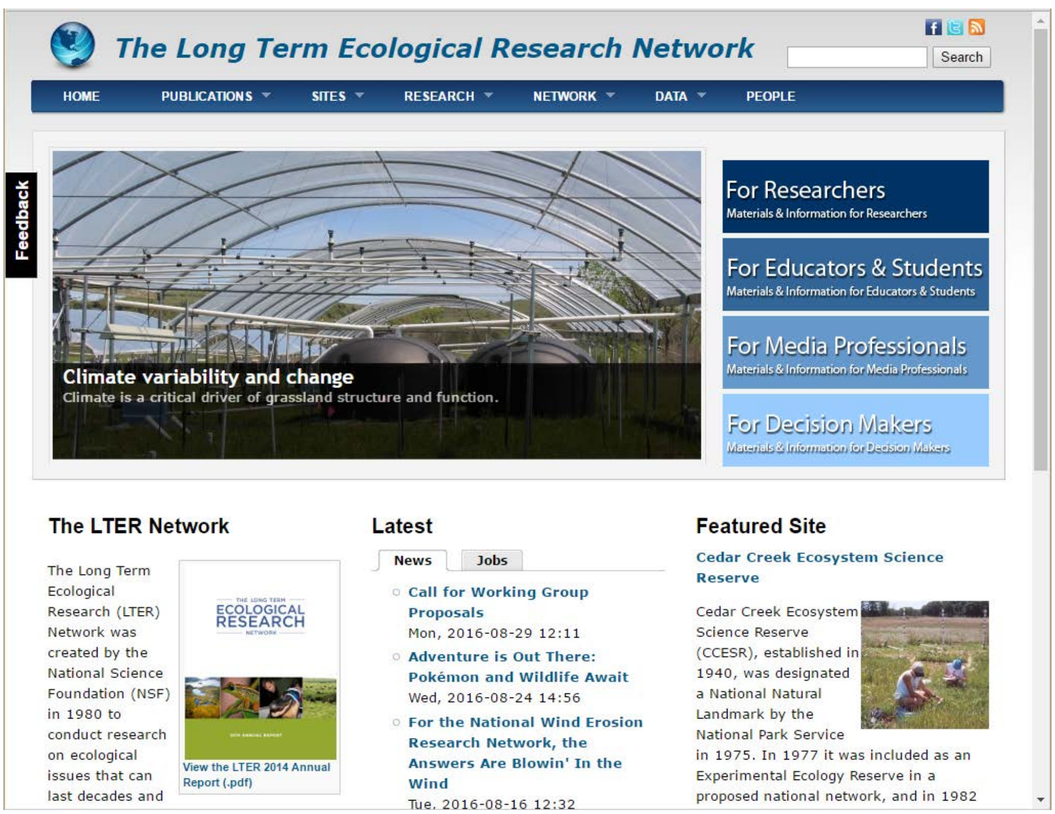

Figure 98. Portal example from LTER Network

Links from the main page connect to a range of tools and background information including sections on requirements for data management plans.

The data portal for the LTER Network (https://portal.lternet.edu/nis/home.jsp) allows browsing and searching through data packages. A Map Portal (https://lternet.edu/sites/map) provides a simple map-based interface for accessing information on different sites and projects.

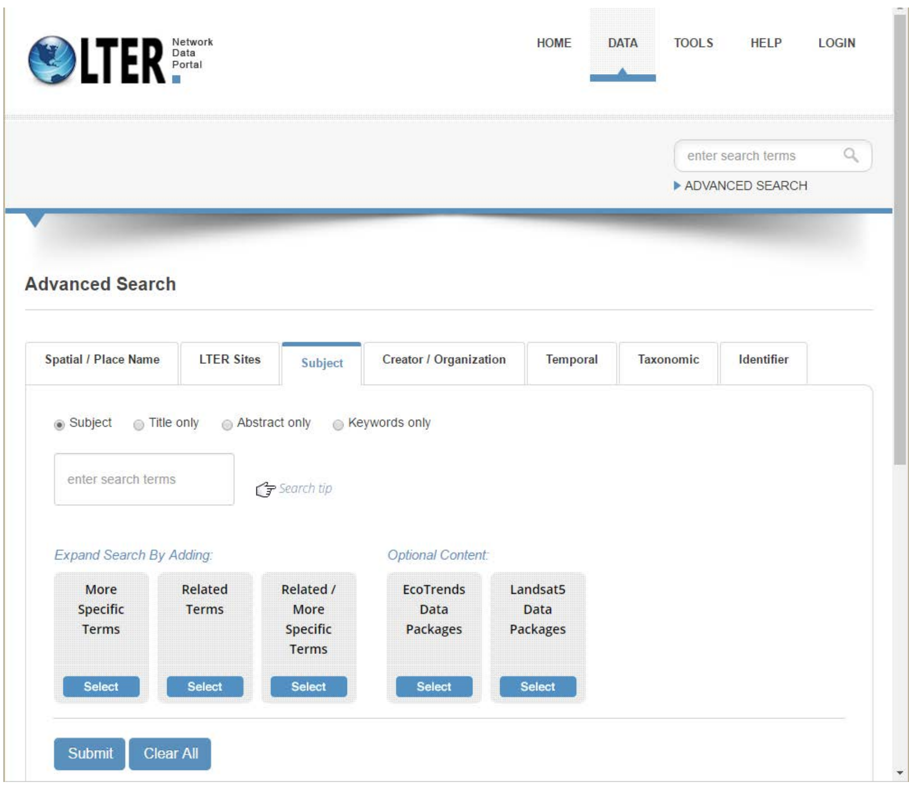

Figure 99. Advanced metadata catalog search example from LTER Network

6.3.5.3.2 *Louisiana Coastal Wetlands Planning, Protection and Restoration (CWPPRA)*

The CWPPRA site (http://lacoast.gov/new/Default.aspx) and associated Coastwide Reference Monitoring System provide (CRMS) (http://lacoast.gov/crms2/home.aspx) provide another example of some of the functionality being considered. As for the LTER Network site there is a main landing page with background information, current events/news, and linkages to a range of tools and background information.

The CRMS interface is focused more specifically on access to information through a range of different tools.

The system includes a full GIS interface with automated generation of report cards and other data summaries.

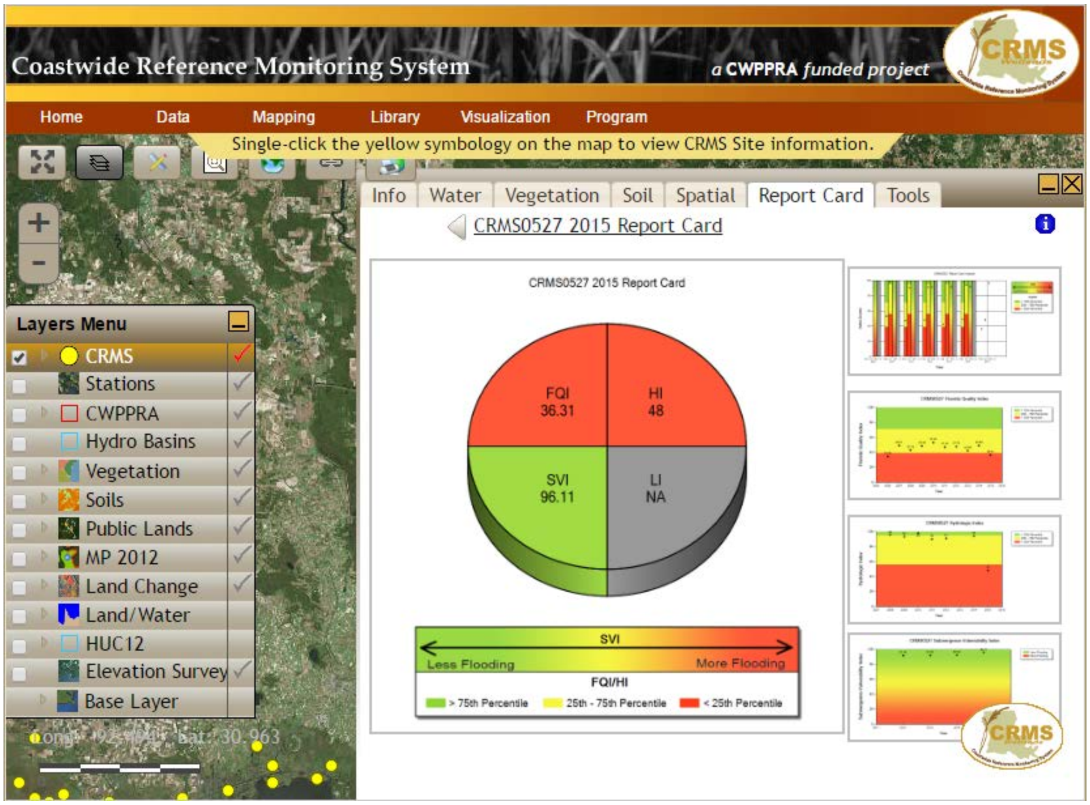

Figure 100. GIS interface with Report Cards example from the CRMS Portal

6.3.5.3.3 *Colorado State University – eRAMS*

The eRAMS (https://erams.com/) system is a platform for building accessible and scalable analytical tools and models. As such it can both provide examples of ways of addressing MRRP requirements but could also be considered as a platform for implementing the MRRP DMS. The eRAMS system utilizes the Amazon cloud and has access to a wide range of publically available data including USGS Stage data.

Of particular note for the eRAMS system is its ability to support models based on both publically accessible and other data such as the flow analysis toolkit. A large array of these tools have already been developed and are available; other enterprise tools could be developed to meet specific needs of the MRRP community.

6.3.5.3.4 *Trinity River Restoration Program Online Data Portal (TRRP.net)*

The Trinity ODP (http://odp.trrp.net) addresses many of the same requirements as the MRRP DMS; searchable metadata for a wide range of different reports and data sources, a map based interface, and customized tools for time series analysis of specific data sets. The ODP software is in the public domain and structured to be easily transferred to other river basins. A video demonstration is available at: https://www.youtube.com/watch?v=GtyG3mb09TI

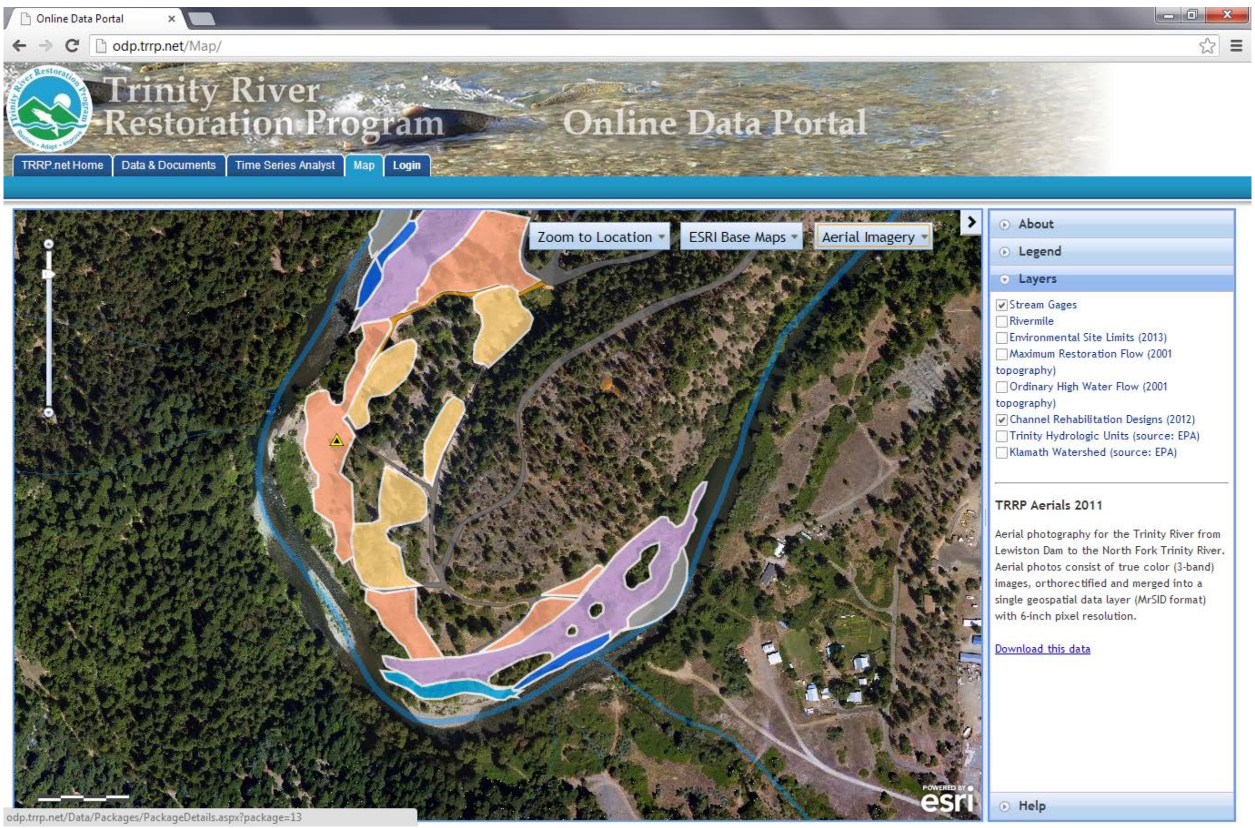

Figure 101. GIS interface example from the Trinity Online Data Portal

6.3.6 Integrating Existing Data Management Systems

The decision to integrate, migrate, or adapt existing technologies will be based on the needs and priorities of the AM objectives being evaluated. In some cases, it may be sufficient to leverage existing data management assets, particularly if users find that they are working well. In other cases, an adapted or new solution may be required. A phased approach may also be used to gradually shift functionality to newer systems, by first adapting existing systems, if source code is available. For legacy commercial products that cannot be modified, migration may be the best option.

Several existing monitoring program data management systems are catalogued below, which were previously developed to provide centralized collection, storage, and dissemination of piping plover and least tern survey data, and pallid sturgeon survey data from the Missouri River Basin. Collectively, these systems also support maintenance of data quality standards for survey data and provision of real time information for decision-making processes.

6.3.6.1 *Least Tern and Piping Plover Data Management System (TPDMS)*

https://rsgisias.crrel.usace.army.mil/intro/dms.dmsintro.main

The Tern and Plover Data Management System (TPDMS) was designed to enter, store, maintain, and disseminate data from the Tern and Plover monitoring program. During the field season data are updated on a daily basis by field crews, using ESRI's ArcPad software on Trimble GPS units. Field software provides immediate QA/QC of data entries in the field. Data entry has been streamlined using an upload process on the website which loads data files from the GPS units directly into the Oracle database. The TPDMS web interface provides a portal to real time and historic reports, a map interface, data entry modules, and tools for field crews. Built in validation routines and manual approval provide for rigorous data standards and ensure quality data are available for reports and data presentation which can be used by partners and decision makers. The system provides multiple levels of access to the data and information ensuring data integrity. A username and password are required to gain access to the system due to the sensitivity of data on the location of endangered species. Access can be requested online through the website.

6.3.6.2 *Pallid Sturgeon Population Assessment Website (PSPA Website)*

The Pallid Sturgeon Population Assessment Website was designed as a tool for field crews to enter and maintain data for the Pallid Sturgeon Population Assessment Program (PSPAP) and Habitat and Mapping Program (HAMP). Field data are collected electronically using a custom-built MS Access application on Xplore tablets with integrated GPS capability. The field application contains built-in validation routines providing for QA/QC in the field while the data are being collected. The website provides a portal where files from field computers can be directly uploaded into the Oracle database making it available to users immediately. Tools for field crews and additional validation routines have been built into the PSPA website to further improve data quality. This system is currently only available to field offices collecting the data and to the data administrators. Public content has yet to be developed.

Appendix D to this Plan proposes a substantial revision to the current protocols for population monitoring, which will be reflected in the software used for data collection.

Current protocols for requesting data from the PSPAP require a data request for each analysis which must be approved by the PSPAP teams. This step will typically be unnecessary in the future because key analyses and certified information users will be identified ahead of time. Only unplanned analyses from new information users will require additional coordination and approvals from monitoring teams, likely following protocols similar to those currently existing in the PSPAP.

6.3.6.3 *Pallid Sturgeon Collaborative Population Dynamics Model*

This model is described in Jacobson et al. (2016a) and summarized in section 4.1.2.3 and Appendix D of this AM Plan. The EA team has developed and deployed a version of the model online as a proof of concept (see https://mcolvin.shinyapps.io/pallid_sturgeon/). A basic version of the model will be deployed on the web, permitting users to explore the outcomes of different actions and hypotheses over 50-year time periods, and incorporating random variation to reflect uncertainty in both environmental conditions and functional relationships. The Technical Team will use a combination of the web based tool and a local application which permits greater complexity in various attributes (e.g., spatial resolution, stochastic replication, individual based models, time horizon), although if the online model is hosted on an internal server, then various constraints may be reduced.

6.3.6.4 *USFWS National Pallid Sturgeon Database (NPSDB)*

https://www.fws.gov/moriver/pallid/pallid_search.cfm

The purpose of the National Pallid Sturgeon Database is to compile, store, and disseminate all data on pallid sturgeon captures, across the range of the species, to support recovery efforts. The database is also used to record stocking data for the pallid sturgeon propagation program. An online tool has been developed to provide access to simple recapture histories of individual fish based on PIT tag number. More complete datasets are shared with programs such as PSPAP on an annual basis after the data from all programs have been compiled.

6.3.6.5 *Pallid Sturgeon Genetics Data*

All entities involved in pallid sturgeon monitoring and research are required by the USFWS to collect genetics samples from pallid sturgeon lacking identifiable hatchery marks. Genetics samples are sent to several different labs depending on analysis needs.

These data are recorded on a standardized genetics datasheet which is included with each sample and stored and maintained by the respective genetics lab. Information on the capture location, ancillary information, and the genetics sample ID are incorporated into the NPSDB. Genetics information is valuable for many purposes, including relating surviving offspring to their parents.

6.3.6.6 *Hydrologic Engineering Center River Analysis System HEC-RAS*

http://www.hec.usace.army.mil/software/hec-ras/

This software allows the user to perform calculations of one-dimensional steady flow, 1 and 2-dimensional unsteady flow, sediment transport, mobile bed movement, water temperature and water quality. HEC-RAS is a foundational tool used to support geomorphic calculations for both bird and fish habitat applications, as well as to support estimates of effects on human considerations.

6.3.6.7 *Hydrologic Engineering Center Reservoir System Simulation*

http://www.hec.usace.army.mil/software/hec-ressim/

The Reservoir System Simulation (HEC-ResSim) software (developed by the U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center) is used to model reservoir operations at one or more reservoirs for a variety of operational goals and constraints. The software simulates reservoir operations for flood management, low flow augmentation and water supply for planning studies, detailed reservoir regulation plan investigations, and real-time decision support. HEC-ResSim can represent both large and small scale reservoirs and reservoir systems through a network of elements (junctions, routing reaches, diversion, and reservoirs) that the user builds. The software can simulate single events or a full period-of-record using available time-steps. HEC-ResSim is a decision support tool that meets the needs of modelers performing reservoir project studies as well as meeting the needs of reservoir regulators during real-time events, to minimize impacts on human considerations.

6.3.6.8 *Missouri River Basin Water Management Information*

The MRBWM office maintains a public website at www.nwd-mr.usace.army.mil/rcc. This site contains information concerning System regulation. The website includes forecasted reservoir levels and dam releases as well as historic data in both tabular and graphic formats. It contains user-friendly, clickable maps to observe graphical streamflow and System project data. The MRBWM office performs streamflow forecasting at select locations and these results are provided for comparison to the official NWS forecast. The NWS forecasts are available as a link from the MRBWM website. The website contains special news releases regarding closure of the river for navigation during extremely large flood events, deviations from proposed regulation plans, water control plan information meetings, nesting operations of threatened and endangered species, and other significant items that occur on an unscheduled basis. In addition, the USACE produces numerous public reports on a daily basis that provide continual updates of the System's status, recent activities and changes in regulation of reservoirs. These reports are available to the public on the MRBWM website or by email.

6.3.6.9 *Comprehensive Sturgeon Research Project (CSRP)*

CSRP datasets describe the locations, movements, physiological indicators, and genetics of individual monitored fish, as well as ancillary data related to water temperature, water quality, habitat availability, and habitat use. The bulk of the data reside in two datasets housed at the USGS, Columbia Environmental Research Center, Columbia, MO: 1) The Sturgeon Information Management System (SIMS), and 2) the Missouri River Hydroacoustic Habitat Dynamics System (MRHHDS). More information on these databases is available in Jacobson et al. 2015a. Access to these datasets can be arranged through requests to the chief of the River Studies Branch, USGS–CERC, Columbia, Mo.

6.3.6.10 *Pallid Sturgeon Research literature database*

The Pallid Sturgeon Effects Analysis team has created an Endnote™ database (Thomson Reuters New York, New York) with links to literature cited in the EA reports. This database is meant to be an archival record of information sources and will be sharable among agencies and scientists working on pallid sturgeon recovery, subject to applicable copyright laws. This database contains literature citations for scientific information relevant to understanding pallid sturgeon population dynamics, Missouri River physical and chemical processes, riverine ecology, flood plain ecology, and other native and nonnative species. The Endnote™ database and library assembled for the pallid sturgeon EA is limited to sources cited in the EA documents; however, a larger database and library is maintained by USGS–CERC, which contains records related to river processes, native, and endangered species.

6.3.6.11 *Physical Habitat Assessment Data*

Physical survey data is available from both the Kansas City and Omaha districts Hydrology and Hydraulic Branches. Data include bathymetry surveys, sediment-sample collection, acoustic Doppler current profiles, and two-dimensional hydrodynamic models. The Kansas City district has developed a software package called Cross Section Viewer which was designed for storage and retrieval of cross section data.

6.3.6.12 *Water quality data*

Currently water quality data are collected by each district. Specific needs for water quality data have been described in Chapter 4 of this plan, and in Appendix K.

6.3.6.13 *USGS National Water Information System*

http://waterdata.usgs.gov/nwis

The USGS National Water Information System provides access to water-resources data collected across the nation, including the Missouri River basin. The USGS investigates the occurrence, quantity, quality, distribution, and movement of surface and underground waters and disseminates the data to the public, State and local governments, public and private utilities, and other Federal agencies involved with managing water resources. Information available through this site include surface water, groundwater, water quality, and water use data.

6.3.6.14 *Monitoring of Emergent Sandbar Habitat*

Data that accounts for ESH characteristics are collected and available through the MRRP ISP. Datasets include satellite imagery, remote sensing habitat classifications generated from satellite imagery, ESH accounting summary datasets, and habitat quality line intercept data. Imagery data are stored on a local GIS server and also provided to the Omaha district GIS Service Center for storage and dissemination. All other datasets are stored on local servers with the ISP and are available on request.Moriverrecovery.org

The moriverrecovery.org website is the public portal to the MRRP. It provides access to current status of the MRRP, the Missouri River basin model, tribal and MRRIC links, MRRP documents library, and background information on all MRRP implementation, planning, monitoring, and research projects. A mapping component provides for spatial exploration of the basin. It is envisioned that this website will provide a mechanism for timely sharing of monitoring and research results to the public.

6.3.7 Responding to existing and emerging information needs

The MRRP has established an Information Management team to provide input to the approach and stewardship of data management and technology planning for the AM process. The Information Management team will support all information users, and determine how to best provide information to support existing and emerging needs in the AM process. Examples of information needs that have already been identified include:

- a unified catalogue of existing data;
- improved integration of plover population data with emergent sandbar habitat assessments;
- near real-time planning support for water managers with respect to potential plover nest take;
- improved dissemination and integration of hatchery-to-hatchery and hatchery-to-river data to integrate and clearly communicate historical and current fish tracking information;
- provide complete time series of hydrologic and climate variables, for the Technical Team and other scientists; and
- integration of pallid sturgeon data from multiple sources.

Once a new information need is identified, the Information Management team will conduct the following steps:

a. gain a better understanding of existing data and components (databases, websites, spreadsheets, etc.) that may or will exist, determine who the custodian(s) is/are of the data, identify where and how the data are being stored, and how the data may or may not be connected;
b. identify potential users of the data and how a product that provides a view of the data can be tailored to each specific user group to maximize its value and utility;
c. identify any sensitivities that may be associated with the data to provide the appropriate level of security;
d. determine the appropriate time interval by which the data must be updated;
e. define who will maintain the data , and how;
f. determine when and how often endpoints (websites, desktop applications, etc.) will be reviewed to determine their continued relevance to the program and identify any necessary modifications;
g. facilitate access to all relevant data, manage the development of system conceptual models and architecture, define QA/QC standards and deployment considerations;
h. create or modify systems to address existing and future needs that may be identified (e.g., websites, software, reporting products)
i. subject all websites, software, reports or other products to an internal review and user group testing before final deployment.

6.4 Quality assurance and quality control

A complex process will be required to collect, organize and rapidly assess all of the data required to support the MRRP AM Plan. That complexity in turn requires a systematic process for data QC, to ensure that decision-makers and stakeholders have confidence that the data used to support decisions are scientifically sound, of known and documented quality, and suitable for their intended use. This process must include the means to determine whether the data fully meet standards and what to do if they do not.

The Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP) provides instructions for preparing Quality Assurance Project Plans (QAPPs) for any environmental data collection operation (IDQTF 2005). A QAPP is a formal document describing in detail the QA/QC, and other technical activities that must be implemented to ensure that data and related analyses satisfy stated performance criteria, how performance measures are verified and validated and how to proceed if there are any limitations in the data that prevent attainment of the required level of accuracy.

The MRRP QAPP (see Appendix I) was developed to address system-wide and project-specific environmental monitoring QA/QC, including data collection, analysis, and archiving activities, throughout the entire AM cycle, activities which are summarized in section 6.1. All agencies and contractors involved in environmental data acquisition during MRRP implementation are required to adhere to the provisions of the QAPP. The information presented in the QAPP (or referenced therein) serves as the basis of the quality system for all monitoring activities conducted during MRRP implementation and details QA/QC requirements, including establishing data quality objectives and guidance for data management. Also included are procedures and references for biological, hydrologic, geomorphic and other relevant sample collection, laboratory methods, and data assessment protocols.

The QAPP will be updated and refined periodically to strengthen the QA program. All agencies, contractors, etc., involved in environmental data acquisition during MRRP implementation are required to adhere to the provisions of the QAPP. A biennial Quality Assurance Review (QAR) will be conducted by an independent entity to provide MRRP management and stakeholders with an assessment of the state of data quality for MRRP. The goals of the QAR are to identify practices that contribute to data quality, identify data quality problems and best management practices, report on the activities of the AM Teams, and recommend improvements to the quality system for MRRP monitoring. As such, when specific data quality issues are discussed in this report, a less-than-perfect assessment is meant to identify an opportunity for continuous process improvement, not failure.

6.4.1 Basic Principles for Quality Assurance

AM of the MRRP will require many decisions that will be made on the basis of information available at that time. The following principles (consistent with the principles described in section 6.1) will help ensure that those decisions are made using the best information possible, and serve to guide the development of the QAPP and its periodic review and improvement.

Quality. Information quality is integral to every step of the AM cycle. The AM Teams should employ appropriate practices to ensure quality during the creation, collection, maintenance and dissemination of data and other information. Any information used for decision-making should be thoroughly reviewed by expert staff and appropriate levels of management. Both internal and external review and approval policies and procedures should ensure, to the extent practical, that disseminated information and data are accurate and timely, appropriate for consumption, uncompromised and useful to decision-makers, stakeholders and the public.

Objectivity. The MRRP AM Program relies upon information that is accurate, clear, complete and unbiased both in its content and in its presentation. The relevant subject matter experts and appropriate levels of management should review information before it is disseminated, among other things, to evaluate whether the information is accurate, reliable and unbiased, including an assessment of collection, generation, and analysis of relevant information and data. The review also should consider the presentation of the information to ensure that it is put in the proper context and presented in a clear, complete and unbiased manner. The sources of data used in decision making should be identified so that decision makers, stakeholders and the public can assess for itself the objectivity of those sources. This includes adequate disclosure about underlying data sources, quantitative methods of analysis and assumptions used, to facilitate reproducibility of the information according to commonly accepted scientific or statistical standards by qualified third parties. Periodic external reviews or audits of information should be conducted to ensure that it is objective.

Utility. Information and the appropriate form and vehicle for its presentation and dissemination should be evaluated by relevant subject matter experts, along with appropriate levels of management, to ensure its usefulness to the intended purpose. This includes ensuring that the information is organized, written, and summarized in a manner that facilitates its understanding and use by the intended audience. The information also should be reviewed to ensure its timeliness and continuing relevance for the intended audience.

Integrity. The AM Program should ensure necessary precautions for information security pursuant to the Computer Security Act of 1987, the Government Information Security Reform Act of 2000 and the Security of Federal Automated Information Resources, OMB Circular A-130 (February 8, 1996). The protective measures should cover the following information resources: sensitive data, software, hardware, physical facilities and telecommunications. The information security measures should assure that the information system has a level of security that is commensurate with the risk and magnitude of the harm that could result from the loss, misuse, unauthorized disclosure or improper modification of the information contained in the system. Information which should not be made public (e.g., the specific locations of bird nests or sacred tribal sites) must be kept secure.

6.4.2 Data Quality Objectives (DQOs)

Data Quality Objectives (DQOs, described in section 6.1) define the type, quality, and quantity of data needed to make defensible decisions when implementing the AMP. They identify the requirements for a field investigation and the limits on tolerable error rates. They also indicate the intended end use of the data, including decisions that may be made based on the information generated.

Additional DQOs may be required for specific projects or studies not envisioned at the time of developing the AMP, or for which the necessary information to develop DQOs did not exist. In those cases, and when reviewing and updating existing DQOs as new information becomes available, the AM Teams should rely upon the seven-step process outlined in Guidance for the Data Quality Objective Process (EPA 2006), summarized in section 6.1.1.1.

The DQO process has both qualitative and quantitative components. The qualitative steps encourage logical and practical planning for environmental data collection activities, while the quantitative steps use statistical methods to design a data collection operation that will efficiently control the probability of making an incorrect decision. Although the quantitative steps of the DQO process are important, investigators and decision makers may choose not to apply statistics to every environmental field investigation. In some cases, the team may utilize only the qualitative steps of the DQO process during the investigation planning phases to generate authoritative data.

6.4.3 QAPP organization and content

The QAPP has been prepared for use by entities involved with implementing the environmental monitoring and assessment components of the MRRP. These include program managers, project personnel, agency representatives and private consultants involved in designing monitoring plans, preparing contractual statements of work for monitoring activities, and reviewing or validating data. Contractors involved in data gathering activities, such as field measurements, observations or examinations, calibrations, and data analyses may also utilize the QAPP to determine program, sampling, and analytical protocols and requirements.

The MRRP QAPP is a project-specific plan organized to address four basic elements, as required by the Uniform Federal Policy (IDQTF 2005):

- Project Management and Objectives
- Measurement and Data Acquisition
- Assessment and Oversight
- Data Review

All QAPPs must address all elements detailed in the UFP-QAPP Manual (IDQTF 2005). In some cases, certain elements do not apply to the MRRP. In those cases the requirement is addressed with a simple statement of why the information is not relevant. Although Appendix I is the QAPP for the MRRP, some of the requirements are found elsewhere in the AMP or in other external documents. In those cases, the information is cross referenced in the appendix and details the information in the plan and its location.

6.4.4 QAPP implementation responsibilities

Each agency, contractor, consultant, and individual involved with MRRP monitoring must share responsibility for maintaining knowledge of the QA/QC program and for adhering to the procedures identified in the QAPP. However, the ultimate responsibility for implementation of the QA/QC program rests with the ISP.

The ISP, working and coordinating with the various AM Teams, is charged with implementation and oversight of the MRRP QA/QC program and will ensure that monitoring adheres to the QAPP. The ISP is responsible for dealing with QA issues, establishing a mechanism for distribution of quality system information and changes, and ensuring data meet or exceed the DQOs of the AMP. Some of the ISP responsibilities with respect to the AMP include the following:

- Developing and implementing data review criteria
- Conducting audits of field and laboratory activities
- Performing QA reviews of monitoring data
- Implementing laboratory and field performance evaluation (PE) programs to assess consistency among entities involved in the data collection activities
- Producing biennial Quality Assessment Reports and submitting them to management and MRRIC

- Developing Quality Management Plans for the AMP and associated annual quality assessment reports
- Coordinating governmental and commercial laboratories to ensure adequate training, coordination, and consistency in laboratory and field procedures
- Initiating/conducting systems audits, performance audits, and corrective actions
- Reviewing new and alternative methods and requests for sample modifications
- Conducting data verification, validation, and quality assessment as needed
- Coordinating training for these functions and making sure the guidelines are followed and any deficiencies are corrected.

Standardized monitoring/data collection methodologies, sampling schemes, laboratory analytical methods, and QA and reporting procedures for each of the monitoring parameters will be agreed upon and used by all participating investigators in the program for collecting, processing, and managing data. Any changes in methods during the implementation of the plan, once approved, will be documented. The ISP will also interact with the MRRP Management and MRRIC Work or Task Groups to review and comment on all data-related technical specification; ensure that a proper data QA/QC process will be in place, particularly for data acquisition contracts; and review contract Statements of Work (SOWs) for monitoring.

6.4.5 Alternative Procedures or Variances

To maintain a level of standardization and consistency and to help ensure verifiable data quality, adherence to QAPP provisions is critical. However, the intention of QAPP is not to be restrictive, but rather to encourage agile responses to identified challenges, as well as to stimulate the creation of new methods and innovations. Proper approvals, including those of any regulatory agency, if deemed necessary by the ISP, are required prior to implementing a variance from the QAPP. Variances may involve the use of alternate laboratory or field procedures, QA/QC elements, and data validation or data management procedures. Variances may be driven by project limitations, a need for enhancements or improvements, such as better technology, or for experimental or research purposes. The QAPP details processes that will be used for review and approval of variances for water quality monitoring and analysis; alternate biological, ecological, and hydrologic procedures; and remote sensing procedures and protocols. The ultimate goal of the variance process is to ensure that the proposed alternative procedure or method will produce data of a quality appropriate to the study’s objectives, and consistent with MRRP data gathering activities.

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Science and Adaptive Management Plan
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Science and Adaptive Management Plan

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Missouri River Recovery Program

J. Craig Fischenich

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS 39180

Kate E. Buenau

Marine Science Laboratory
Pacific Northwest National Laboratory
U.S. Department of Energy
1529 W. Sequim Bay Rd.
Sequim, WA 98382

Joseph L. Bonneau, and Craig A. Fleming

U.S. Army Corps of Engineers
Omaha District
Gavins Point Project Office
Yankton, SD 57078

David R. Marmorek

ESSA
600 – 2695 Granville Street
Vancouver, BC Canada V6H 3H4

Todd Gemeinhardt

U.S. Army Corps of Engineers
Kansas City District
Kansas City, MO 64106

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Monitored by Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd, Vicksburg, MS 39180

Abstract

The Missouri River Recovery Program (MRRP) is undergoing a transformation resulting from 2011 recommendations by an Independent Science Advisory Panel and the Missouri River Recovery Implementation Committee (MRRIC). An Effects Analysis study established the best available scientific information and provided the foundation for an Adaptive Management Plan (AM Plan) that addresses lingering uncertainties and improves management decisions while implementing actions that avoid jeopardizing the three federally listed species in the system. This draft AM Plan includes a process for resolving critical uncertainties using a framework consisting of four implementation levels: 1) research, 2) in-river testing of hypotheses, 3) scaled implementation of select management actions, and 4) full implementation. The decision criteria for moving to higher levels of implementation are included. A NEPA evaluation of alternative management actions identified an initial suite of actions that will be implemented to meet the objectives of the MRRP. This Draft AM Plan accompanies the Draft Missouri River Recovery Management Plan-Environmental Impact Statement and provides the roadmap for the implementation of the selected alternative and for the identification of subsequent management needs should the initial suite of actions fail to meet objectives. The AM Plan will be implemented collaboratively by the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and MRRIC following the governance process outlined in the AM Plan.

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Preface

These appendices accompany the Draft Adaptive Management Plan (AM Plan) for the Missouri River Recovery Program (MRRP). Further revision of this document is planned. A finalized draft will be submitted along with the draft Missouri River Recovery Management Plan-Environmental Impact Statement (MRRMP-EIS) in 2017.

The purpose of this draft is not to convey a determined suite of actions for adaptive management (AM) but rather to present AM concepts, methods and decision criteria that might be employed in the final AM plan. Alternative suites of actions and associated research are being evaluated under the National Environmental Policy Act (NEPA) as part of the MRRMP-EIS. The outcome of the NEPA process will be a selected alternative which, in conjunction with Endangered Species Act (ESA) Section 7 consultation outcomes, will constitute the actions for immediate implementation.

The authors have utilized the actions included in the draft EIS (DEIS) to illustrate the concepts, methods and decision criteria necessary to an AM Plan for the MRRP. These actions include those proposed in Planning Aid Letters (PALs) from the U.S. Fish and Wildlife Service (USFWS). Discussion of these actions in this draft report does not constitute selection of any potential actions; their inclusion is merely to help demonstrate how AM might be implemented for various actions. The final AM Plan will be based on the selected alternative in the Record of Decision.

Some details regarding the AM Program will be determined or refined through ongoing interactions with the agencies, stakeholders, and independent reviewers. Recognizing these limitations, it is intended that this draft provides sufficient insight into the scope and nature of the MRRP AM Plan that reviewers can fairly evaluate the plan, offer constructive comments and engage in discussions regarding improvements to be incorporated into the final AM Plan.

We gratefully acknowledge the many people who contributed to this draft. Robb Jacobson of the USGS and the Pallid Sturgeon EA Team, in particular, provided monumental assistance in the development of these appendices. We would like to acknowledge contributions to key sections of this work and technical reviews provided by the other two Effects Analysis Teams; Clayton Ridenour, Mary Roth, Mark Harberg and Aaron Quinn of the USACE Omaha District; and Casey Kruse, Wayne Nelson-Stastny, and Carol Smith of the USFWS. Technical reviews and comments were provided by Chantel Cook, Coral Huber, Brad Thompson, and Tim Welker of the USACE; Wyatt Doyle, Rob Holm, Steven Krentz, Landon Pierce, Dane Schuman and Ryan Wilson of the USFWS; David Adams, Justin Haas, Gerald Mestl and Kirk Steffensen of the Nebraska Game and Parks Commission; the Upper Bain Pallid Work Group; Michelle Klose, on behalf of a consortium of state representatives; and several members of the AM ad hoc

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Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
ounces (mass)	0.02834952	kilograms
pounds (force)	4.448222	newtons
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

Acronyms and Abbreviations

AAMR	Annual Adaptive Management Report
AAR	After Action Report
AM	Adaptive Management
ANOVA	Analysis-of Variance
API	Application Program Interface
AWP	Annual Work Plan
BA	Before-After
BACI	Before-After-Control-Impact
BiOp	Biological Opinion
BSNP	Missouri River Bank Stabilization and Navigation Project
CEM	Conceptual Ecological Model
CEP	Critical Engagement Point
cfs	Cubic Feet per Second
CI	Confidence Interval
CJS	Cormack-Jolly-Seber
CORE	Cooperating for Recovery Team
CPUE	Catch Per Unit Effort
CWA	Clean Water Act
CWT	Coded Wire Tag
DOI	Department of the Interior
DQO	Data Quality Objectives
EA	Effects Analysis
EIS	Environmental Impact Statement
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESC	Executive Steering Committee
ESH	Emergent Sandbar Habitat
FWG	Federal Working Group
HAMP	Habitat Assessment and Monitoring Program
H&H	Hydrology and Hydraulics
HQUSACE	Headquarters of the U.S. Army Corps of Engineers
IDM	Information Data Management
IP&S	Integrated Planning and Science
IRCs	Interception and Rearing Complexes

ISAP	Independent Science Advisory Panel
ISETR	Independent Social Economic Technical Review Panel
ISP	Integrated Science Program
ISPMT	Integrated Science Program Management Team
kcfs	thousand cubic feet per second
Master Manual	Missouri River Basin Mainstem Reservoir System Master Water Control Manual
Mitigation ACT	Mitigation Project Agency Coordination Team
MRBWMD	Missouri River Basin Water Management Division
MRRIC	Missouri River Recovery Implementation Committee
MRRMP	Missouri River Recovery Management Plan
MRRRP	Missouri River Regional Review Panel
MRRP	Missouri River Recovery Program
NEPA	National Environmental Policy Act
NRC	National Research Council
NWD	Northwestern Division
NWO	Omaha District
NWK	Kansas City District
O&M	Operation and Maintenance
PDT	Project Delivery Team
PIR	Project Implementation Report
PIT	Passive Integrated Transponder
PM	Program or Project Manager
PNNL	Pacific Northwest National Laboratories
PrOACT	Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs
PSPAP	Pallid Sturgeon Population Assessment Program
QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
Reclamation	U.S. Bureau of Reclamation
RM	River Mile
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
RPMA	Recovery Priority Management Area
SAM	Science and Adaptive Management workgroup
SPA	Strategic Programmatic Assessment task group
SPDT	Senior Project Delivery Team
SWH	Shallow Water Habitat

System	Missouri River Mainstem Reservoir System
TBD	To Be Determined
T&E	Threatened and Endangered
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WG	Working Group
WRDA	Water Resources Development Act

Glossary

Active adaptive management – The active form of adaptive management employs management actions in an experimental design aimed primarily at learning to reduce uncertainty; near-term benefits to the resource are secondary.

Adaptive action – A course of action to be implemented as defined in the Adjust step (Step 5b of the Adaptive Management (AM) process) if the performance of a particular management action is not as anticipated and requires correction. In cases where the action is pre-defined, it is referred to as a "contingency action".

Adaptive Management (AM) – Adaptive management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process.

Alternatives –A specified combination of management actions that collectively are deemed to meet minimum performance levels for the endangered species. In the Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs (PrOACT) process, the trade-offs associated with various alternatives on multiple interests are explored in order to find the alternative(s) that minimize unnecessary negative impacts and is/are otherwise thought to be the best balance of impacts on a wide range of interests. Alternatives are used to address the objectives.

AM Report – Annual or periodic report that documents new learning based on monitoring results, evaluates progress towards meeting species objectives, and contains recommendations for adjustments to management actions. The Annual AM Report is contained with the Annual Report on Biological Opinion (BiOp) compliance.

Annual Work Plan (AWP) – This document includes real estate actions, habitat creation actions, monitoring of physical and biological responses to actions, and research activities. It is used by product delivery teams to implement management actions annually.

Biological Opinion (BiOp) – Document stating the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) opinion as to whether a Federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat. Specifically in the MRRP, the USFWS 2000 Biological Opinion (BiOp) found that the operation of the Missouri River Mainstem Reservoir System and Missouri River Bank Stabilization and Navigation Project (BSNP), as proposed by the Corps, would likely jeopardize the continued existence of three federally listed species: the piping plover, least tern, and pallid sturgeon. The BiOp was amended in 2003 to note that, with additional mitigated actions proposed by the Corps, operation of the System and the BSNP would not likely jeopardize terns and plovers, but would jeopardize pallid sturgeon. In this document, the amended BiOp is referred to as the USFWS 2003 Amended Biological Opinion.

Conceptual Ecological Models (CEMs) – CEMs are graphical depictions of an ecosystem that are used to communicate the important components of the system and their relationships. They are a representation of the current scientific understanding of how the system works.

Contingency action – A pre-evaluated adaptive action that is implemented when triggered by defined decision criteria without the need for further deliberation or decision.

Critical uncertainties – Uncertainties that impede the identification of a preferred alternative management action.

Critical Engagement Point (CEP) – Specific points in the formulation or implementation phases of adaptive management when the agencies engage with the Missouri River Recovery Implementation Committee (MRRIC) for input. These can be concurrent with, or in addition to, routine MRRIC plenary meetings.

Decision criteria – Broadly refers to the set of pre-determined criteria used to make AM decisions. Performance metrics, targets, and decision triggers are considered to be different types of decision criteria. They can be qualitative or quantitative based on the nature of the performance metric and the level of information necessary to make a decision.

Decision space – A term used to characterize a range of operational discretion for flows (or potentially other actions) that is "acceptable" to stakeholders, effective in achieving objectives, and within the bounds of actions evaluated under NEPA. Management actions would generally occur within this region and any operation outside this decision space would require further coordination and approval.

Decision trigger – Decision triggers are pre-defined commitments (population or habitat metric for a specific objective) that trigger a change in a management action. Decision triggers are addressed in the Evaluate step (Step 4 of the AM process) specifying the metrics and actions that will be taken if monitoring indicates performance metrics are or are not reaching target values. In some cases a decision trigger may be learning a new piece of information that triggers the Continue/Adjust/Complete step (Step 5 of the AM process).

Delphi process – The Delphi process is a method of eliciting expert opinion (Normand et al. 1998). While many variations of the process exist, there are generally three common features: 1) qualified experts provide their responses to a set of questions in a structured format; 2) the answers to these questions are synthesized across all respondents and presented back to the same set of experts; and 3) the experts jointly discuss the reasons for variation in the first set of responses (or lack thereof), and through dialogue potentially revise their opinions. A modified Delphi process was applied by Jacobson et al. (2016b) to prioritize candidate hypotheses.

Effects Analysis (EA) – The purpose of this effort is to conceptually and quantifiably make explicit the effects of operations and actions on the listed species by specifically evaluating the effects of hydrologic and fluvial processes on the Missouri River, as well as ongoing management actions under the USFWS 2003 Amended Biological Opinion and other Mitigation actions, on the status and trends of the listed species (piping plover, interior least tern, and pallid sturgeon) and their habitats.

Environmental Impact Statement (EIS) – A document which summarizes and analyzes environmental impacts of a proposed action and alternatives.

Evaluation – Conduct analyses to compare measured results with anticipated outcomes related to decision criteria for specific management actions to determine whether the implementation should be continued, adjusted, or completed.

Event-driven reporting cycle – In addition to the annual and periodic AM reports (on a routine reporting schedule), reporting may also be event-driven, where new observations or data resulting from an unforeseen event suggest a decision trigger or targets have been reached.

First increment – The suite of proposed actions in the Management Plan that are collectively anticipated to “avoid jeopardy” in the foreseeable future (~10 – 15 years). The First Increment will include actions for pallid sturgeon for Levels 1 through 3 of the Lower Pallid Framework to ensure NEPA coverage for future implementation.

Fundamental objectives – Fundamental objectives are used to formalize the desired outcome of the program in terms of biological response. They are derived to achieve avoidance of jeopardizing the three species from USACE actions on the Missouri River and articulate the ends the program is trying to achieve.

Global hypotheses – Set of possible, biologically important hypotheses, relevant to population dynamics that are derived from conceptual ecological models.

Human considerations – A set of objectives with associated metrics and proxy metrics that are related to the wide array of uses and stakeholder interests on the

Missouri River. They form the basis for some of the monitoring and decision criteria in the AM Plan.

Hypotheses reserve – A concept that seeks to explicitly manage the broad suite of hypotheses developed through the (EA) and highlighted in the CEM. In this concept hypotheses can be brought forward or moved back into reserve as information and understanding directs. The hypotheses reserve concept includes; 1) hypotheses that are not deemed important to investigate at this time, 2) have high uncertainty and require further investigation, and/or 3) are outside USACE authority.

Initially modeled hypotheses – Subset of working management hypotheses determined by USACE to be within jurisdiction and applicable authorities, and therefore selected for modeling in Phase 1 of the (EA).

Integrated Science Program (ISP) – The component of the MRRP that is responsible for conducting scientific monitoring and investigations. The ISP monitors federally listed species under the Endangered Species Act (ESA), the habitats upon which they depend, and researches and monitors critical uncertainties.

Implement – Implementation of the preferred alternative.

Implementation Level (or Level) – Refers to one of four classifications of action that could be implemented to assist pallid sturgeon as part of the MRRP (see also *Pallid Sturgeon Framework*). The levels include:

- **Level 1: Research** – Studies without changes to the system (Laboratory studies or field studies under ambient conditions).
- **Level 2: In-river testing** – Implementation of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response.
- **Level 3: Scaled implementation** – A range of actions not expected to achieve full success, but which yields sufficient results in terms of reproduction, numbers, or distribution to provide a meaningful population response and indicate the level of effort needed for full implementation.
- **Level 4: Ultimate required scale of implementation** – Implementation to the ultimate level required to remove an issue.

Investigations – Research activities that are intended to generate information that will fill the key gaps in understanding and reduce uncertainty associated with implementation of management actions.

Jeopardy – As defined by the Endangered Species Act (ESA), jeopardy occurs when there is an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Limiting factor – A factor that controls the growth, abundance or distribution of an organism. For example, factors that limit the survival of terns, plovers and pallid sturgeon have been identified and serve to identify and organize potential management actions.

Lower Missouri River – The reach of the river downstream of Gavins Point Dam (RM 810) as it pertains to management for pallid sturgeon

Management actions – Proposed or potential actions to be taken by the Corps to address species needs on the Missouri River. Management actions were prescribed by the USFWS 2003 Amended Biological Opinion as Reasonable or Prudent Alternatives or actions outside the BiOp if necessary to achieve species objectives.

Management hypotheses – Statements (in affirmative hypothesis form) that a specific management action will be effective in eliminating factors that are thought to be limits to population growth.

Missouri River Recovery Management Plan (MRRMP; also MRRMP-EIS or Management Plan) – A suite of management actions that avoids jeopardizing the continued existence of piping plovers, interior least terns, and pallid sturgeon, thereby permitting the continued operation of the Missouri River reservoir System and the Bank Stabilization and Navigation Program (BSNP). It includes actions proposed by the Missouri River Recovery Implementation Committee, and complies with the National Environmental Policy Act (NEPA) and other statutory mandates, regulatory requirements and authorizations. MRRMP may also refer to the three-year process to programmatically evaluate the MRRP and develop a suite of actions that meet ESA responsibilities. The Management Plan or MRRMP-EIS are umbrella terms that include the MRRMP, the Environmental Impact Statement (EIS) and the AM Plan.

Means objectives – Describe ways of achieving the fundamental objectives and specify the way and degree to which the fundamental and sub-objectives can be achieved. They are used to further develop management actions and alternatives and are potentially useful in tracking progress towards fundamental objectives in the near-term when a response in the fundamental objectives may not be detectable in shorter time frames due to a delayed species response to management actions or other reasons.

Monitoring – In the context of the MRRP-AM Plan, monitoring is the process of measuring attributes of the ecological, social, or economic system. Monitoring has multiple purposes, including: to provide a better understanding of spatial and temporal variability, to confirm the status of a system component, to assess trends in a system component, to improve models, to confirm that an action was implemented as planned, to provide the data used to test a hypothesis or evaluate the effects of a management action, and to provide an understanding of a system attribute which could potentially confound the evaluation of action effectiveness.

MRRP Adaptive Management Plan – The purpose of this Adaptive Management (AM) Plan is to describe a formal AM process led by the U.S. Army Corps of Engineers (USACE) and U.S. Fish and Wildlife Service (USFWS) in implementing the Missouri River Recovery Program (MRRP or Program).

National Environmental Policy Act (NEPA) – Requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet NEPA requirements federal agencies may be required to prepare a detailed statement known as an Environmental Impact Statement (EIS).

Objectives – Objectives define an endpoint of concern and the direction of change that is preferred. Objectives are concise statements of the interests that could be affected by a decision — the "things that matter" to people. In Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs (PrOACT,) objectives typically take a simple form such as; minimize costs, increase population number, increase habitat availability.

Pallid Sturgeon framework– An organization of Missouri River Pallid hypotheses that allows for the description of activities (research to management actions), decision criteria, uncertainty, risk, impacts, costs, time frame and constraints.

Passive adaptive management – In passive AM, management actions are directed primarily at achieving resource objectives and those actions are improved using knowledge gained from monitoring and assessment.

Performance metric – A specific metric or quantitative indicator that is monitored and can be used to estimate and report consequences of management alternatives with respect to a particular objective. There are specific species, habitat, and economic performance metrics in this Adaptive Management Plan.

Problem – A question or concern that is being addressed in the decision making process.

Program – The "Program" refers to those elements that are at the level of the overall Missouri River Recovery Program such as the Annual Work Plan (AWP) and the Program Management Plan.

Project Implementation Report – Contains site-specific information, alternative designs and project features, the anticipated benefits of the project, and documentation for compliance with the National Environmental Policy Act (NEPA) disclosing the potential affects to the quality of the human environment from project implementation.

Proxy metric – Type of performance metric. Generally a proxy metric is an indirect metric used to represent a natural metric like population number (e.g., number of boat ramp days). Proxy criteria are those that correlate well with objectives that are otherwise difficult to measure or estimate.

Quantitative predictive models – Numerical models used to predict biological and ecological responses as a function of management or restoration actions.

Risk – An uncertainty coupled with an adverse consequence; ideally expressed as the product of the two components, with uncertainty represented as a probability.

Species objectives – see fundamental and means objectives.

Strategy table – A visual tool for combining management actions into thoughtfully crafted alternatives.

Structured Decision Making (SDM) – Organized approach to identifying and evaluating creative options and making choices in complex decision situations. It is used to inform difficult choices, and to make them more transparent and efficient. PrOACT is a specific application of SDM to collaborative problem solving employed by USACE in the development of the Missouri River Recovery Management Plan.

Sub-objectives – The sub-objectives are aspects of the fundamental objective described in more detail that need to be addressed to achieve the fundamental objective. They are intended to provide direction in the short term, provide objectives meaningful for adaptive management, and focus efforts on the desired short-term outcomes while contributing to the fundamental objective.

Success criteria – A qualitative or (preferably) quantitative description of the conditions for which the parties agree that the objectives have been sufficiently met. Usually expressed in terms of the performance metrics.

Target – Targets are a specific value or range of performance metric that define success. Targets can be quantitative values or overall trends (directional or trajectory).

Trade-offs (also Trade-off analysis) – A trade-off is when one alternative performs well on one metric but poorly on another relative to another alternative. Reasonable people may disagree about which is the best alternative because they value the two metrics differently, thus value trade-offs involve making judgments about how much you would give up on one objective in order to achieve gains on another objective. By analyzing trade-offs, the PrOACT process tries to help find the alternative a) that eliminates unnecessary trade-offs and b) that people agree is the 'best balance' of trade-offs possible.

Trigger – A form of decision criteria serving as a threshold or condition that, when met, initiates some action or decision.

Uncertainty – Circumstances in which information is deficient. Leaning while doing under the adaptive management process provides a framework for reducing program uncertainties over time.

Upper Missouri River – Mainstem of the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea, and the Yellowstone River for an unspecified distance upstream of the confluence with the Missouri River.

Variability – A measure of how much a set of conditions differs from the mean or median state.

Working dominant hypotheses - Set of plausible, biologically important hypotheses, relevant to population dynamics of pallid sturgeon. Derived from importance values in conceptual ecological model, scored by expert elicitation survey.

Working management hypotheses - Set of management hypotheses linking management actions to working dominant hypotheses. Derived from pathways identified in conceptual ecological models and matched to working dominant hypotheses. Scored by expert elicitation survey.

Appendix A. Attachments

Note: This is an incomplete draft document. It has not received a substantive technical, policy or editorial review, and is being circulated for Agency review and comment prior to general release on May 25, 2016. Please see the Preface for related caveats. Comments or suggestions should be provided to the lead author at Craig.J.Fischenich@usace.army.mil

Attachment A.1 – MRRIC Charter (14 Aug. 2014 Revision)

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Missouri River Recovery Implementation Committee Charter

July 1, 2008
(as amended August 14, 2014)

Preamble

The Secretary of the Army (Secretary) hereby establishes the Missouri River Recovery Implementation Committee (Committee) as authorized by Section 5018 of the 2007 Water Resources Development Act (WRDA) to make recommendations and provide guidance on a study of the Missouri River and its tributaries and on the existing Missouri River recovery and mitigation plan. The Committee will provide a collaborative forum for the basin to come together and develop a shared vision and comprehensive plan for Missouri River recovery. The Committee will help guide the prioritization, implementation, monitoring, evaluation, and adaptation of recovery actions. The Committee will include broad stakeholder representation to ensure a comprehensive approach to Missouri River recovery implementation while providing for congressionally authorized Missouri River project purposes and to ensure that public values are incorporated into the study and the recovery and mitigation plans.

I Purpose and Scope

a) The Purpose and Scope of the Committee are to:

i. Provide recommendations and guidance on a study of the Missouri River and its tributaries to determine actions required to:

1) Mitigate losses of aquatic and terrestrial habitat

2) Recover federally listed species under the Endangered Species Act of 1973

3) Restore the ecosystem to prevent further declines among other native species

ii. Provide guidance with respect to the existing Missouri River mitigation and recovery plan, including recommendations on:

1) Changes to the implementation strategy as a result of adaptive management

2) Coordination of the development of consistent policies, strategies, plans, programs, projects, activities, and priorities for the Missouri River recovery and mitigation plan

3) Exchange of information regarding programs, projects, and activities of the agencies and entities represented on the Committee to promote the goals of the Missouri River recovery and mitigation plan

4) Establishment of such working groups as the Committee determines to be necessary to assist in carrying out the duties of the Committee, including duties relating to public policy and scientific issues

5) Facilitation of the resolution of interagency and intergovernmental conflicts between entities represented on the Committee associated with the Missouri River recovery and mitigation plan

6) Coordination of scientific and other research associated with the Missouri River recovery and mitigation plan

7) Preparation of an annual work plan and associated budget requests

iii. Provide recommendations and guidance that will include:

1) Recognition of local stakeholders' social and economic, historical and cultural, flood control, irrigation, agriculture, internal drainage, water supply, water quality, navigation, hydropower, thermal power, science, natural resources, conservation, and recreation issues, and any other issues identified by the Committee

2) Identification of impacts to stakeholders

3) Identification of actions that will benefit multiple uses of the river

4) Avoidance, minimization, and/or mitigation of adverse impacts

b) Participation in the Committee by Tribal entities does not substitute for nor replace federal requirements to consult with Tribal entities pursuant to federal laws and regulations, such as: Executive Order 13175, Tribal Consultation; any federal agency's trust responsibilities to a federally recognized tribe in the Missouri River Basin or a tribe that has historically been on the Missouri River; and/or replace any treaty or right thereof such as: the Portage des Sioux Treaty (July 1815); the Treaty of Ft. Laramie, 11 Stat. 749 (Sept 17, 1851); the Treaty with the Omaha, 10 Stat. 1043 (March 16, 1854); the Treaty of Ft. Laramie, 15 Stat. 635 (April 29, 1868); Title VI-Cheyenne River Sioux Tribe, Lower Brute Sioux Tribe, and State of South Dakota Terrestrial Wildlife Habitat Restoration Act of the Omnibus Consolidated and Emergency Appropriations Act of 1999, PL 105-277, 112 Stat. 2681, 2861-660-670 (October 21, 1988), as amended by Title IV of the Water Resources Development Act of 1999, PL 106-53, 113 Stat 269, 385-397 (August 17, 1999), and as otherwise amended; and any other treaty or right. Cooperation with the federally recognized tribes engaged in this process should be interpreted as "in good faith."

c) Participation in the Committee by State, Tribal, or Federal entities does not limit their discretion; alter, affect, impair, delegate, or relinquish their statutory or other legal rights and responsibilities, including any right to legal remedies; or otherwise waive their sovereign immunity under applicable law; create any new right to any type of administrative review or create any new right to judicial review or any other right or benefit, substantive or procedural, enforceable by or against these entities or any other stakeholder participating in the Committee; and affect Tribal reserved water rights, treaty rights, or water rights administered by the Tribes and/or States, including the "Winters' Doctrine", Winters v United States, 207 U.S. 564 (1908). If the processes and procedures of the Committee would impede the implementation of any action for which agencies of the States, Tribes, or United States are obligated under law, that agency reserves the right to proceed with fulfilling those obligations in such manners as it may deem appropriate.

d) Participation in the Committee by State, Tribal, or Federal entities is also contingent upon availability of funding or appropriation by their respective State, Tribal, or Federal authorities, and their participation does not obligate any specific amount of expenditures in furtherance of this Charter; such expenditures being at the discretion of the State, Tribal, or Federal entity.

II Convening Authority

The Committee is convened under the authority of Section 5018 of the Water Resources Development Act of 2007.

III Definitions - Glossary of Terms and Acronyms

a) Adaptive Management: A type of natural resource management in which decisions are made as part of an ongoing science-based process. Adaptive management involves testing, monitoring, and evaluating applied strategies and incorporating new knowledge into management approaches that are based on scientific findings and the needs of society. Results are used to modify management policy, strategies, and practices. The purpose of adaptive management is to help meet environmental, social, and economic goals, increase scientific knowledge, and reduce tensions among stakeholders. (Source: Adapted from Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management and the U.S. Department of the Interior Technical Guide)

b) Consensus: All non-federal members of the Committee can support or live with an action or recommendation when quorum requirements are met.

c) Guidance: The process by which recommendations are used to inform appropriate agencies about Missouri River recovery-related activities.

d) Lead Agency: The U.S. Fish and Wildlife Service (USFWS), the U.S. Army Corps of Engineers (Corps of Engineers), and other agencies as necessary for specific issues.

e) In Good Faith: The sincere intention to deal fairly and equitably with Tribes and others, without deception. The willingness of all Committee members to interact openly, honestly, and respectfully with all other members.

f) Meeting: A gathering of the Committee lasting one or more partial or full days, as defined in the Committee's operating procedures and guidelines.

g) Mitigation: This sequential process includes (a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (c) rectifying the impact by repairing, rehabilitating, or restoring the affected human or natural environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of an action; (e) compensating for the impact by replacing or providing substitute resources or environments. (Source: Adapted from the Council on Environmental Quality, 40 CFR 1508.20)

h) Participating Agency: Federal agencies involved in the Committee process other than the USFWS or Corps of Engineers unless designated as a lead agency for a specific issue.

i) Plan: The Missouri River recovery and mitigation plan referenced in Section 5018 (B)(3)(b) of the Water Resources Development Act of 2007.

j) Public Notice: Notice given to members of the public at least thirty (30) days prior to an event. It shall include but not be limited to written notice given by e-mail and by regular mail to:

  i. All members of interest groups who shall sign up to receive notice

  ii. Persons who have been designated by members of the Committee to receive notice

  iii. Newspapers and radio stations generally covering the basin and to four (4) specific newspapers recommended by members of the Committee

k) Quorum: A quorum shall consist of those Committee state representatives and those Committee tribal representatives who are present at the meeting and 51% of the stakeholders as identified in Section 5(a)(v), who are at the time appointed to the Committee.

l) Recommendations: Official suggestions, comments, or advice representing the consensus of the Committee and provided to the appropriate governmental or non- governmental agencies, groups, or persons.

m) Recovery: Improvement in the status of a species listed under the Endangered Species Act to the point that it is not likely to be in danger of extinction in the foreseeable future throughout all or a significant portion of its range. (Source: Adapted from USFWS Regulations and the Endangered Species Act)

n) Restoration: To fully or partially reestablish the attributes of a naturalistic, functioning, and self-regulating system. (Source: Engineer Pamphlet 1165-2-502: Ecosystem Restoration - Supporting Policy Information, USACE)

o) Secretary: Pursuant to 10 USC 3016(b)(3), the Assistant Secretary of the Army for Civil Works shall act for the Secretary of the Army for the purposes of this Charter.

p) Stakeholder: Any organization or individual that has a direct interest in actions or decisions of the Missouri River restoration, recovery and mitigation plan, or study. For the purposes of Section 5 of this Charter, representatives of Federal Agencies, Tribes, and States are not considered stakeholders. In the appointment process, all things being equal, preference will be given to residents of, or organizations located in or adjacent to, the basin.

q) Study: The study referenced in Section 5018 (a) of the Water Resources Development Act of 2007.

r) Substantive Issue: An issue for which the Committee is considering developing recommendations and other decisions identified as substantive in the Committee's operating rules and procedures.

IV Charter Amendment

The Committee may propose amendments to the Charter in accordance with its decision making process. Public notice will be given and public comments will be received prior to the Committee recommending the amendment to the Secretary for final adoption.

V Membership and Representation of Interests

a) Members and Alternates
   i. The Secretary will maintain a list of the members and

alternates of the Committee.

b) Federal Agencies

i. Federal agencies with programs affecting the Missouri River may be members of the Committee. Federal agency membership may include those agencies currently represented on the Missouri River Basin Interagency Roundtable (MRBIR) and any other federal agency designated by the Secretary. This includes federal agencies with management responsibilities, jurisdiction by law, regulatory authorities, technical expertise, and/or resource responsibilities affecting the Missouri River. To initiate the Committee, the lead agencies will be the U. S. Army Corps of Engineers and the U. S. Fish and Wildlife Service. Participating federal agencies may include the Bureau of Reclamation, Natural Resource Conservation Service, Environmental Protection Agency, Western Area Power Administration, United States Geological Survey, Maritime Administration, the National Park Service, and any other agency designated by the Secretary.

ii. Federal agencies will not be counted for purposes of Committee quorum requirements and will not participate in the determination of consensus recommendations.

iii. Federal agencies that wish to participate in the Committee will inform the Secretary of their agency's interest, explaining why they wish to be involved, and provide the name of their Committee representative and an alternate.

iv. Lead Federal Agencies will be represented on the Committee by officials at the Senior Executive Service (SES) level or their deputies. Lead Federal Agency representatives will participate fully and completely in all Committee meetings and any sub-committees or panels formed by the Committee.

v. Participating Federal Agencies will be represented by officials appointed by their respective agencies. These representatives will be available to answer questions, provide information, and state their opinions and recommendations at Committee meetings (including any subcommittees and panels) on recommendations directly affecting the Participating Federal Agency's management or resource responsibilities, jurisdiction by law, or regulatory authorities.

vi. Participating Federal Agencies will be able to participate temporarily as a Lead Agency, at the SES or their deputy level, when any issue being discussed or considered by the Committee could directly affect the Participating Federal Agency's management or resource responsibilities, jurisdiction by law, or regulatory authorities.

c) States:

i. As states located in or near the basin, the following states are eligible for membership in the Committee. For those states that choose to participate, the governor shall appoint one (1) representative and one (1) alternate.

1) Iowa
2) Kansas
3) Missouri
4) Montana
5) Nebraska
6) North Dakota
7) South Dakota
8) Wyoming

d) Tribes:

i. The following tribes are eligible for membership in the Committee. Those tribes that choose to participate will appoint one (1) representative and one (1) alternate in accordance with tribal procedures.

1) Ft. Peck Assiniboine and Sioux Tribes
2) Blackfeet Tribe
3) Cheyenne River Sioux
4) Chippewa Cree Tribe
5) Crow Creek Sioux Tribe
6) Crow Nation
7) Eastern Shoshone Tribe
8) Flandreau Santee Sioux Tribe
9) Ft. Belknap Indian Community
10) Iowa Tribe of Kansas and Missouri
11) Kickapoo Tribe of Kansas
12) Lower Brute Sioux Tribe
13) Northern Arapaho Tribe
14) Northern Cheyenne Tribe
15) Oglala Sioux Tribe
16) Omaha Tribe of Nebraska
17) Ponca Tribe of Nebraska
18) Prairie Band of Potawatomi Nation
19) Rosebud Sioux Tribe
20) Sac and Fox Nation of Missouri in Kansas and Nebraska
21) Santee Sioux Nation
22) Sisseton - Wahpeton Sioux Tribe

23) Spirit Lake Sioux Tribe
24) Standing Rock Sioux Tribe
25) Three Affiliated Tribes
26) Turtle Mountain Band of Chippewa
27) Winnebago Tribe of Nebraska
28) Yankton Sioux Tribe
29) Osage Nation

e) Stakeholders:

i. There will be a maximum of twenty-nine (29) stakeholder members, broken down into the interests below. Each interest shall have a maximum of two (2) representatives and two (2) alternates.

1) Navigation
2) Irrigation
3) Flood Control
4) Fish and Wildlife
5) Recreation
6) Water Quality
7) Water Supply
8) Agriculture
9) Conservation Districts
10) Waterway Industries
11) Major Tributaries
12) Thermal Power
13) Hydro power
14) At large/other interests, e.g. cultural and historic preservation
15) Local Government
16) Environmental/conservation organizations

VI Appointment, Terms of Office, and Attendance

a) Terms

The standard Committee appointment will be for a term of three years. At the first organizational meeting of the Committee, through a random drawing, one-third of the stakeholders will be appointed to a one-year term. Another third will be appointed to a two-year term. The final third will be appointed to a three-year term. This provision applies to the initial terms of the founding Committee members. Thereafter, all terms will be three years.

b) Term Limits

There will be no limit to the number of terms a member may be appointed to serve.

c) Stakeholder Member Appointments and Vacancies:

i. Stakeholder vacancies will be published in the Federal Register and public notice will be given and broadly disseminated within the Missouri River basin by the U.S. Army Corps of Engineers. Interested parties will submit applications to the Secretary. Applications from interested parties will be forwarded to the Committee for the purpose of providing a recommendation of appointment following its decision-making process. For the initial appointments, the Planning Group, which assisted in the development of this Charter, will provide recommendations to the Secretary. The Secretary will appoint stakeholder members for terms in accordance with paragraph 5(a)(v)(2)(a).

ii. Each year the Committee will forward to the Secretary a list of those stakeholder members whose terms will expire and those who wish to remain on the Committee. Incumbent members wishing to remain on the Committee do not need to re-submit an application to the Secretary. Members may continue to serve until the Secretary appoints a replacement.

d) Stakeholder Application Qualifications:

Stakeholders will demonstrate they represent an interest in the Missouri River basin.

e) Alternate Members:

Alternates will apply in the same manner as stakeholder members and will be recommended by the stakeholder member. Upon appointment by the Secretary, the alternate will serve during the temporary absence of the member. In the instance of the permanent absence of the member, the alternate will fill the remainder of the term.

f) Termination

i. If a member is not in attendance or represented by an alternate at two consecutive meetings, the Committee may recommend termination of that member and alternate to the Secretary after giving notice to the affected parties and giving them the opportunity to respond.

ii. A member or alternate will notify the Chair if they are no longer able to serve. The Secretary will be notified of the vacancy.

VII Roles, Responsibilities, and Leadership

a) Chair and Vice-Chair

i. The Committee shall select a Chair and Vice Chair who may be a member of the Committee. The Chair will be responsible for protecting the interests of all Committee members and alternates. S/he will act in a fair and balanced manner with respect to the Committee's operation and the conduct of Committee meetings. The Chair will strive to determine the views of all Committee members regarding Committee advice and work to achieve consensus.

ii. The Chair will be responsible for running Committee meetings, including opening, enforcement of operating rules, and adjournment. The Chair may call a meeting subject to the public notification procedures of the Committee. The Chair will be responsible for collaboratively developing meeting agendas and reviewing draft meeting minutes and summaries for accuracy and completeness.

iii. The Chair shall have the authority to represent the scope and purpose of the Committee and convey the consensus decisions of the Committee to agencies, elected officials, and in public settings, but shall not act in a lobbying capacity.

iv. The Chair and Vice Chair will serve or be removed with the consensus of the Committee. The term of office of the Chair and Vice Chair will be one (1) year, with the opportunity for reappointment. Should a Committee member believe the Chair and/or Vice Chair are not performing in a fair and balanced manner, it is the responsibility of the member to raise his/her concerns to the Chair or to the full Committee for consideration.

v. The Vice-Chair will assume the duties of the Chair in her/his absence.

vi. The Chair and Vice-Chair shall be selected at the last meeting of the calendar year and assume office at the first meeting of each calendar year.

vii. The Chair and Vice-Chair shall not be employees of the federal government.

b) Member and Alternate Responsibilities

i. Members and alternates are expected to honor their commitment to seek consensus.

ii. All members and alternates will be accurate and respectful with regard to their communications with others.

iii. Members and their alternates will be responsible for representing the interests and concerns of the organizations, institutions, and constituencies they represent.

iv. It is the affirmative responsibility of members and alternates to voice dissent if they cannot support or live with a recommendation. If a member objects to a recommendation, it is also his/her affirmative responsibility to articulate the reasons behind the objections and to provide an alternate proposal if possible.

v. Members and alternates are free to abstain from a determination of consensus for whatever reasons. However, it is the responsibility of each member and alternate to affirmatively state his or her desire to abstain from participating in a determination of consensus if she/he so chooses. Abstentions will not affect the determination of a quorum.

vi. Members and alternates will adhere to the Committee's charter, operating procedures, and ground rules. They are expected to give due consideration to the procedural guidance and recommendations of the Chair.

c) Working Groups and Subcommittees
The Committee may create special work groups or sub-committees as necessary to accomplish its purposes. These may include individuals not on the Committee.

d) Written Directives and Scopes of Work
Prior to commencing work, the Committee will provide each working group or sub- committee written instructions that outline the purpose of the work and the tasks being requested, as well as specifying its members, their roles and responsibilities, the expected work products, and the specific time frames for reports and completion of the group's work.

e) Independent Panels
Lead and participating agencies may convene panels independent of the convening agencies as requested by the Committee to advise the Committee on substantive issues as identified by the Committee. The Committee will recommend panel members as established by its operating procedures.

VIII General Committee Operations

a) Operating Procedures and Guidelines

The Committee will develop a set of operating procedures and guidelines to set forth in detail how it shall conduct meetings and accomplish the requirements of this charter.

b) Meetings

i. Meeting frequency and location

1) The first meeting of the Committee will be convened by the Secretary on or before October 1, 2008.

2) The Committee will meet a minimum of two (2) times per year and will determine meeting dates and locations.

c) Communications, Record Keeping, Documents, and Reports

i. Open meetings

Except as provided herein, each Committee meeting will be open to the public. Interested persons shall be permitted to attend, offer public comment, or file statements with the Committee.

ii. Executive sessions

The Committee may call an executive session that is closed to the public upon the consensus of the members present. An executive session may only be called for legal, personnel, or property transfer issues directly pertaining to the Committee. Decision-making will be conducted during the open meetings.

iii. Notice of meetings

Public notice of each such meeting of the Committee will be given as provided for in the Operating Procedures.

iv. Minutes and approval of minutes

Detailed minutes of each Committee meeting will be kept by an independent, qualified note taker. These minutes and summaries of the minutes will be approved by the Committee in accordance with its decision making process.

v. Availability of records

Any records, reports, transcripts, minutes, appendices, working papers, drafts, studies, agenda, or other documents which were made available to or prepared for or by the Committee will be available for public inspection and copying, except as provided by law.

vi. Assessment and Self-Evaluation

The Committee will conduct a self-evaluation of its operations every year.

vii. Reports

The Committee will submit an annual report to the Secretary.

IX Consensus and Decision Making

a) Process

i. The Committee's goal is to reach consensus on all substantive issues brought before it. Federal Agency representatives may participate [per section 5(a)(ii)] in the discussion of all matters pending before the Committee and provide their opinions, input, and suggestions. The Committee will only make recommendations where there is a consensus. Federal agencies will not participate in the determination of the Committee's consensus recommendations.

ii. Consensus recommendations will be made using a two-step process with information, discussion, proposal development, and tentative consensus at the first meeting and actions no sooner than the next meeting to assure adequate notification of and deliberations by Committee members and the interests they represent. Upon consensus of the Committee, the two-step process may be waived except for recommendations to federal and/or other agencies and Charter amendments.

iii. If consensus cannot be reached, the Chair will designate a period of time to be set aside to address the issue during at least two different meetings. If consensus still cannot be reached, the meeting minutes will not characterize or quantify the level of support for the differing views.

iv. Once consensus is reached on any recommendation, the Chair will ask the Lead Federal Agency representatives involved with the issue being considered whether they can endorse the recommendation. The Lead Federal Agencies will be requested to respond immediately to the Committee, if possible, or by an agreed upon date. Lead Federal Agency endorsement is not necessary for a consensus recommendation to be submitted to the appropriate government entity.

v. Once recommendations and guidance are delivered by the Committee to the Secretary, it is requested that s/he, in coordination with other participating Federal Agencies, agrees to provide the official federal position on the issue and outline the steps to implement the recommendations by an agreed upon date or provide the reason(s) for not implementing the recommendation.

vi. Committee members are free to abstain from a determination of consensus. Abstentions will be recorded in the meeting minutes when requested by the individual who wishes to abstain.

b) Reports, Work Plans, and Proposals

i. The U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, and other agencies as requested by the Committee will provide reports at least on an annual basis, related to Missouri River and tributaries recovery, mitigation, and restoration, which include the status of recovery activities for the pallid sturgeon, interior least tern, and piping plover. In addition to construction, monitoring, research, and propagation activities, the annual reports will address:

1) Number of pallid sturgeons, interior least terns, and piping plovers present over their entire ranges, where available
2) Downlisting and/or delisting criteria, including target numbers, for the pallid sturgeon, interior least tern, and piping plover for the Missouri River and their entire ranges
3) Comparison of numbers for the pallid sturgeon, interior least tern, and piping plover with previous years' reports
4) Progress and effectiveness of adaptive management toward the pallid sturgeon, interior least tern, and piping plover recovery
5) Other reports as requested by the Committee.

ii. Reporting agencies will be prepared to respond to specific questions from the Committee, by an agreed upon date, regarding recovery status and recovery activities.

iii. Federal agencies involved in recovery, mitigation, and restoration efforts in the basin will submit status reports, work plans, and cost estimates to the Committee at least annually.

iv. Other federal, tribal, and state agencies, as well as non-governmental organizations may also submit recovery and restoration proposals for review by the Committee.

c) Budget, Funding, and Support Services

i. General

1) Subject to the availability of appropriations and subject to the

limitations of the Secretary's authorities, the Secretary shall provide funding to achieve the purposes of the Committee as described in Section 5018.

2) Annual funding level recommendations for the Committee will be developed through annual coordination between the Committee and the Secretary.

X Interactions Outside The Committee

a) Web Site

The Secretary will maintain a Web site as a clearinghouse for Committee related information.

b) Annual Conference

The Committee may host an annual conference to provide information to the public on the Missouri River Recovery and Mitigation Program including plans and studies as referred to in Section 5018 and any other plans related thereto.

Attachment A.2 – MRRIC FINAL Operating Procedures and Ground Rules (May 23, 2013 Amended Version)

Table of Contents

Missouri River Recovery Implementation Committee (MRRIC) Operating Procedures and Ground Rules

The Secretary of the Army (Secretary) has established the Missouri River Recovery Implementation Committee (MRRIC) as provided by SECTION 5018 of the Water Resources Development Act of 2007. The operating procedures and ground rules established herein have been developed to support and facilitate the MRRIC process but do not alter or modify the MRRIC Charter.

1) Purpose for MRRIC:

As stated in the MRRIC Charter:

a) The Purpose and Scope of the Committee are to:

i) Provide recommendations and guidance on a study of the Missouri River and its tributaries to determine actions required to:

(1) Mitigate losses of aquatic and terrestrial habitat

(2) Recover federally listed species under the Endangered Species Act of 1973

(3) Restore the ecosystem to prevent further declines among other native species

ii) Provide guidance with respect to the existing Missouri River mitigation and recovery plan, including recommendations on:

(1) Changes to the implementation strategy as a result of adaptive management

(2) Coordination of the development of consistent policies, strategies, plans, programs, projects, activities, and priorities for the Missouri River recovery and mitigation plan

(3) Exchange of information regarding programs, projects, and activities of the agencies and entities represented on the Committee to promote the goals of the Missouri River recovery and mitigation plan

(4) Establishment of such working groups as the Committee determines to be necessary to assist in carrying out the duties of the Committee, including duties relating to public policy and scientific issues

(5) Facilitation of the resolution of interagency and intergovernmental conflicts between entities represented on the Committee associated with the Missouri River recovery and mitigation plan

(6) Coordination of scientific and other research associated with the Missouri River recovery and mitigation plan

(7) Preparation of an annual work plan and associated budget requests

iii) Provide recommendations and guidance that will include:

(1) Recognition of local stakeholders' social and economic, historical and cultural, flood control, irrigation, agriculture, internal drainage, water supply, water quality, navigation, hydropower, thermal power, science, natural resources, conservation, and recreation issues, and any other issues identified by the Committee.

(2) Identification of impacts to stakeholders.

(3) Identification of actions that will benefit multiple uses of the river.

(4) Avoidance, minimization, and/or mitigation of adverse impacts.

2) This Document

a) Definition of Words and Terms

Definitions listed here are in addition to those set out in the MRRIC Charter.

i) **Missouri River Basin Interagency Roundtable (MRBIR):** The established forum for federal agencies advocating a collaborative approach to solving issues within the Missouri River watershed.

ii) **MRRIC:** The Missouri River Recovery Implementation Committee.

iii) **Meeting:** A physical face-to-face gathering of the Committee lasting one or more, partial or full days.

iv) **Substantive Issue:** An issue for which the Committee is considering developing recommendations and guidance consistent with the Committee’s purpose and scope as well as other issues identified as substantive by any member of the Committee.

b) Updates and Revisions

Revisions to these operating procedures and ground rules shall be made by the consensus of MRRIC using the decision process outlined in the MRRIC Charter.

3) Operating Procedures and Ground Rules

a) Individual Participants

i. Representation of Interests

MRRIC members and their alternates will be responsible for representing the interests and concerns of the organizations, institutions, and constituencies they represent.

ii. Conflict of Interest

All Committee members have the affirmative responsibility for representing the interests and concerns of the organizations, institutions, and constituencies they represent and the other interests set forth in the Charter and in the performance of such duties do not have any conflict of interest. Beyond Committee advocacy, Committee members are obligated to avoid and disclose any individual ethical, legal, financial, or other conflicts of interest involving MRRIC.

iii. Preparation and Attendance

(1) Members will make every effort to attend meetings, to participate actively, to be prepared to discuss information and issues, and to be available for work between formal meetings. Meeting agendas will not allocate time for recapping past discussions and decisions for the purpose of updating those members who have missed past meetings.

(2) Members will notify the facilitation team and Chair if they are unable to attend meetings.

iv. Sharing and Considering Information and Perspectives (*Items 3-7 Approved by MRRIC on October 25, 2012*)

(1) Members agree to respect each other. Members will avoid personal attacks and the use of intimidation.

(2) Meeting participants will silence their personal electronic devices

(e.g., cell phones and pagers) and will not talk on cell phones inside the meeting room during meetings to avoid interruption of group discussions and MRRIC work.

(3) MRRIC is a collaborative forum for the basin stakeholders, states, and Tribes to come together and develop a shared vision and comprehensive plan for Missouri River recovery.

(4) As such, MRRIC members acknowledge their responsibility to utilize MRRIC as the forum for raising and addressing concerns and issues related to the duties of the Committee.

(5) If a member raises an issue in MRRIC and does not feel their interests are sufficiently met in the course of deliberations, they should strive to make that as clear as possible to the rest of the Committee.

(6) If the member ultimately determines they need to explore other avenues beyond MRRIC to have their interests met on a MRRIC-related issue and that action could impact the full Committee, they have a "good faith" obligation to inform the group.

(7) The Charter defines "In Good Faith" as "the sincere intention to deal fairly and equitably with Tribes and others, without deception. The willingness of all Committee members to interact openly, honestly, and respectfully with all other members."

v. Members and Alternates

(1) The Chair will conduct a written roll call at the beginning of each meeting. Only the member or (in the member's absence) his/her alternate may participate in discussions and decision making.

(2) A MRRIC member may designate an alternate as provided in the MRRIC Charter.

b) Expectations for Chair

The Chair will act as provided for in the MRRIC Charter. Expectations include but are not limited to:

i. Presiding over, and leading meetings of MRRIC, including the opening and closing of all meetings.

ii. Collaboratively develop draft meeting agendas based on input from MRRIC and review draft meeting minutes and summaries for accuracy and completeness.

iii. Be responsible for protecting the deliberative process and act in a fair and balanced manner with respect to MRRIC's operation and the conduct of its meetings.

iv. Explore and incorporate the views of all MRRIC members in achieving consensus.

v. With the permission of MRRIC, have the responsibility and authority to represent and convey the views of MRRIC to agencies, elected officials, and the public.

c) Resolving Compliance with Ground Rules and Operating Procedures

i. Should a question or concern arise regarding the conduct of members of MRRIC or its staff, an individual is encouraged to discuss the issue directly with the person involved. There is no expectation that MRRIC members will be informed of this discussion unless it becomes the joint decision of the parties involved.

ii. Should a one-on-one conversation be inadequate to resolve the issue, the person raising the concern may request a conference call or in-person meeting with the Chair to discuss the issue and seek a satisfactory resolution. Part of the resolution of the issue at this level will be a decision as to whether MRRIC should be informed of the issue and its resolution.

iii. Should the issue remain without satisfactory resolution, the person raising the concern may bring the issue to MRRIC for discussion and resolution. The resolution of the issue at this level will be documented in the meeting summary.

iv. If resolution cannot be achieved through all of the means above, the issue will be forwarded to the Secretary of the Army for discussion and resolution.

d) Consensus and Decision-Making

i. Consensus decision making shall be as provided in the MRRIC Charter.

ii. Agenda items that involve actions or decisions will be clearly identified on meeting agendas and sent out with read-ahead materials.

e) Decision Making Roles and Responsibilities

i. Members of MRRIC are expected to honor their commitment to seek consensus.

ii. It is the affirmative responsibility of each MRRIC member to voice dissent if they cannot support or accept a recommendation. If a member objects to a recommendation, it is also their affirmative responsibility to articulate the reasons behind the objection and to provide an alternate proposal, if possible.

iii. MRRIC members are free to abstain from a determination of consensus for whatever reasons. However, it is the responsibility of each MRRIC member to affirmatively state his or her desire to abstain from participating in a determination of consensus if they so choose. Abstentions will not affect the membership requirements for a quorum.

f) General MRRIC Operations

i. Use of Time

(1) MRRIC members and staff, and agency staff, will respect each other by being on time. Meetings and work group conference calls will begin and end as scheduled unless otherwise agreed to by consensus of the participants.

(2) When making comments, MRRIC members will be considerate of the time needed for others to share their perspectives.

ii. MRRIC Records, including Guidance

(1) MRRIC staff will maintain a written record that will accurately summarize decisions and recommendations made by MRRIC at its meetings. These written minutes and summaries will be prepared in draft form and will be clearly identified as draft documents. All MRRIC members will be provided an opportunity to suggest revisions to the draft meeting minutes and summaries before they are approved by MRRIC. Draft meeting notes will be provided to the Committee fifteen (15) working days after the meeting.

(2) All MRRIC guidance shall be documented in writing in meeting minutes and summaries.

(3) Public notice of each meeting of the Committee will be given as provided for in the Charter Definitions.

iii. Working Groups

(1) MRRIC may create special working groups to address specific issues directly related to MRRIC's purpose. Prior to commencing work,

each of these work groups will have a short, written directive that outlines their purpose and tasks, as well as specifying the membership, their roles and responsibilities, the expected products, and the specific time frame for completing the group's work.

(2) Agenda Work Group: The chair will collaborate with a rotating agenda working group. Stakeholder, tribe and state Committee members will volunteer each meeting for the next meeting. The work group will not exceed seven (7) stakeholders, tribe, and state members selected at the discretion of the Chair. No member will serve on this work group for more than two consecutive meetings. The Chair will ensure that the membership is balanced. The Chair will work with all appropriate entities necessary, including the facilitation team, to create the agenda.

(3) Process for Rotating Work Group Points of Contact (*approved by MRRIC July 22, 2010):*

Overview:

There are types of work groups (the process for operation of the agenda work group is contained in the Operating Procedures and Ground Rules, Section 3)f)iii)(2).

- Ad hoc - An ad hoc work group is formed to take care of a specific issue and then the work group dissolves. This type of work group would have one point of contact (POC) for the life of the work group.
- Standing - There should be co-points of contact for the standing work groups, such as but not limited to:
  - Communications/IT
  - Science and Adaptive Management

(i) Point of Contact Eligibility[1]

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1 Clarification to the Process for Rotating Work Group POC's:

Following the July 2010 MRRIC meeting a few members had questions about the eligibility section of the process to rotate work group points of contact. The Nominating Work Group's intent behind the eligibility section is to encourage leadership among the stakeholder, Tribe, and state Committee members. Occasionally a work group may identify a Federal Committee member to serve as a co-POC for a work group. This is likely to be the exception

- A point of contact should be a Committee member or alternate and be a member of the work group.

(ii) Point of Contact Term

- The term for the POC should be two (2) years for the standing work groups and the life of an ad hoc work group, so long as the participant is a Committee member
- The terms between the co-points of contact will be staggered
- There are no term limits for a point of contact
- The terms will run with the calendar year

(iii) Selection Process

- The POCs for standing work groups;
  - In a work group meeting; volunteers for POC are requested from among the Committee, approved work group membership, and then endorsed by the work group
  - The POCs are selected by the full Committee at the last meeting of the year using the voting and consensus process steps 1–3 (stated in section iv).

(iv) The POC for ad hoc work groups:

The following steps take place before the full MRRIC;

- At the time the ad hoc work group is created, work group members are identified and approved by the MRRIC.
- From the work group members, volunteers are requested to serve as a POC.
- The proposed POCs are selected by the full Committee using the voting and consensus process steps 1–3 (section iv).

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rather than the norm. Volunteers for work groups should be encouraged. The standing work groups are intended to have two POC's and at least one of the POC's must be a stakeholder, Tribe, or state Committee member.

1. Committee members vote for nominees on slips of paper in rounds until there is a majority. Each stakeholder, state, and tribal member present at the Committee meeting must vote or the ballot is spoiled. Between each round of voting, members may take a five (5) minute break. Questions may be asked of the candidates in front of the full Committee before each subsequent round of voting.

2. Once there is a majority preference, the Committee makes a consensus decision to select a POC by show of hands.

3. If there is no consensus, the process starts again.

(4) Process for Updating Work Group Members (approved by MRRIC October 21, 2010)

(i) Responsibilities of Work Group members
Individuals joining MRRIC work groups are expected to regularly engage in work group calls, be familiar with materials in advance of calls, and notify the work group POC and/or facilitator if they cannot participate in a work group call or meeting. When a work group member cannot be on a call, or attend a work group meeting, the member is expected to support the decisions of the work group. In accordance with the MRRIC Charter, it is the affirmative responsibility of a member to voice dissent if they cannot support, or live with a recommendation. If a member objects to a recommendation, it is also their affirmative responsibility to articulate the reasons behind the objections and to provide an alternative proposal if possible.

(ii) Annual Renewal of Ongoing Work Group Members (to take place at the second MRRIC meeting of the federal fiscal year)

a) Facilitator provides POC's with list of work group member participation for the year.

b) POC(s) ask work group members who in the work group wants to continue.

c) The POC(s) will present list of continuing work group members to MRRIC (provided as a read ahead to MRRIC)

d) MRRIC discusses and makes decisions

(iii) Addition of new work group members between plenary MRRIC meetings (Approved by MRRIC May 5, 2011)

a) New work group members who are current MRRIC members, alternates, or agency staff may participate in work group calls and discussions but not engage in work group decisions. The list of individuals who want to join a work group will be noticed and approved at the first available plenary MRRIC meeting (e.g., new work group members are noted on the agenda).

b) Individuals who are not MRRIC members, alternates or agency staff may participate in work group calls and discussions, but may not engage in work group decisions until approved by MRRIC. The list of individuals who want to join a work group will be noticed at the first available plenary MRRIC meeting (e.g., new work group members are noted on the agenda).

iv. Independent Panels

The Committee shall recommend panel membership to the convening agency as provided in the MRRIC Charter.

v. Annual Self-Evaluation

No later than ninety (90) days after the ending of the federal fiscal year, MRRIC will complete a self-evaluation that includes the following:

(1) Review of the efficiency of the MRRIC Charter and Operating Guidelines along with recommended changes, if necessary.

(2) Review the adequacy of membership as provided in the Charter and recommended changes, if necessary.

(3) Review of annual work plan, level of success in completing work plan tasks, and recommended changes to the work plan tasks, format, or process, if necessary.

vi. Annual Report to the Secretary

No later than ninety (90) days after the ending of the federal fiscal year, MRRIC will submit an annual report to the Secretary detailing MRRIC's accomplishments and failures of the previous fiscal year, as well as recommended Charter changes and membership appointments.

vii. MRRIC Work Plans, Agendas, or Goals

The Committee will develop work plans, agendas, or goals.

g) Expectations for Interactions Outside the Committee

Public input during meetings:

i. All meetings shall be open to the public. MRRIC staff will be responsible for collecting and documenting public input for MRRIC consideration. MRRIC will determine how best to incorporate public comment into its work.

ii. The public will be given the opportunity for at least one formal comment period during the course of each meeting day.

iii. Public comment periods are designated for the public. Seated members of MRRIC will not make statements during public comment periods.

iv. Members of the audience and other observers will be asked to refrain from making statements except during public comment periods.

h) Internal Communications

i. Meeting agendas and materials will be distributed not less than seven (7) days prior to each meeting by MRRIC staff. This will include an updated MRRIC contact list.

ii. When requested, individual communications from MRRIC members to the entire group will be distributed by MRRIC staff.

i) External Communications and Activities

All members will be accurate and respectful with regard to communications with others.

j) Protocol for Informing MRRIC Members and Alternates About All Meetings, Webinars, and Conference Calls (*approved by MRRIC on February 4, 2010*)

i. Commencing immediately, the calendar section on MRRIC's WebEx home page will list the dates and times for upcoming work group conference calls or meetings, webinars, or other activities scheduled between MRRIC meetings. The entry will also list the point(s) of contact and facilitator, and the facilitator's phone number and email.

ii. The facilitator assigned to the call, meeting or other activity will post the event on WebEx in a timely fashion, with the understanding that some calls are scheduled with short notice.

iii. A non-member interested in joining a work group conference call or meeting will notify the appropriate facilitator, by e-mail or phone, at least three (3) days in advance of the scheduled call or meeting. This advance notice will allow the facilitator time to ensure sufficient phone lines are available; provide the member or alternate with an agenda, relevant documents and call-in information; and notify the point(s) of contact of the desired participation.

iv. The non-member should notify the facilitator, if there are any specific agenda topic(s) upon which he or she desires to be heard.

v. During the conference call or meeting, the non-member may listen in as an observer. Generally, non-members will be given an opportunity to ask questions at the end of a call unless they have let the facilitator or POC know that they have a comment they would like the work group to consider. Non-members may not participate in decision making.

If a non-member joins work group calls on a continuous basis, the non-member will be asked to consider joining the work group.

k) **Meeting Frequency, Dates, and Locations** (*approved by MRRIC October 21, 2010*)

The Committee shall meet four (4) times per year. The length of each meeting, date, and location shall be determined by the USIECR through collaboration with MRRIC, the Chair, the lead agencies, and others as necessary to make those arrangements which best meet the needs of MRRIC in conducting its business.

l) **MRRIC Vice-Chair Responsibilities and Selection Process** *(approved by MRRIC July 22, 2010)*

i. Description of Duties and Time Commitment Per Committee Charter: See section 5.b.i (1-7) "Roles, Responsibilities, and Leadership" (page 11) specifically paragraph 5 "The Vice-Chair will assume the duties of the Chair in her/his absence."

ii. Additional Duties:

1) Work with Facilitation team and Committee Chair in preparation for agenda work group calls and in preparation for Committee meetings. Work includes discussing the best use of Committee time, developing meeting agendas, reviewing draft documents.

2) Participate on agenda work group calls between MRRIC meetings.

3) Work with Chair on preparing communications in Committee's annual report

4) Conduit for Committee stakeholders

5) May continue to represent his/her stakeholder interest while serving in the capacity as Vice-Chair including participating on work groups as a representative of their interest category.

- The individual is expected to be clear when he/she is speaking on behalf of his/her interest category or as the Vice-Chair.
- It is recommended that the Vice-Chair not serve as a work group point of contact.

iii. Time Commitment: The Vice Chair requires a substantial time commitment above a person's time commitment as a Committee member.

iv. Experience/Attributes of Vice Chair

Once the slate of nominees is established the following experience or attributes should be considered in the vice-chair nominees.

1) Understand the different interests on Committee.
2) Available to make this position your priority for scheduled meetings and between meeting work group activities.
3) Impartial approach.
4) Able to work with Committee Chair and Facilitation team.
5) Available, accessible.
6) Effective communication and listening skills.
7) Active involvement in a work group or served as a point of contact on a work group.

v. Nomination and Selection Process

1) Any stakeholder member interested in serving as Vice-Chair should notify Nominating Work Group Point of Contact (NWG-POC) about their interest in serving thirty (30) days before the last meeting of the calendar year.
2) Any stakeholder member may nominate a stakeholder member for Vice-Chair. Nominations should be sent to the NWG-POC. The NWG POC or his/her designee will contact nominees to confirm if they are interested in serving as Vice-Chair.
3) On the first day of the last MRRIC meeting of the calendar year, a slate of at least two (2) Vice-Chair nominees will be introduced. The Selection Process occurs on the second day of the MRRIC meeting.
4) Selection Process on Day Two
5) Each nominee shares why they are interested in serving as Vice-Chair. Members have a chance to ask questions of each nominee.
6) On slips of paper members are asked if there is any nominee they cannot live with serving as Vice-Chair and why? And to write down any questions they have of individual candidates. A comment/question box will be available to collect questions.
7) The questions and/or concerns are read before the full Committee. Nominees then answer questions in front of the Committee. Members may ask follow up questions
8) Committee members vote for nominees on slips of paper in

rounds until there is a majority. Each stakeholder, state, and tribal member present at the Committee meeting must vote or the ballot is spoiled. Between each round of voting, members may take a five (5) minute break. Questions may be asked of the candidates in front of the full Committee before each subsequent round of voting.

9) Once there is a majority preference, the Committee makes a consensus decision to select a Vice-Chair by show of hands.
10) If there is no consensus, the process starts again.

m) **Establishing MRRIC Meeting Agendas** (a*pproved by MRRIC October 20, 2011*)

The MRRIC meeting agendas are collaboratively developed by the MRRIC Chair and the Agenda Work Group (see sections 3(b)iii and 3 (f)iii(2)). MRRIC agenda items can originate in a number of ways by members:

i. Topics proposed by work groups and approved by MRRIC during the plenary meeting.
ii. Topics identified in the approved MRRIC work plan.
iii. New topics suggested by members, including lead agencies, at the conclusion of every meeting (during the Thursday morning plenary session)
iv. Emergent topics identified between meetings as suggested by members, Federal Working Group, lead agencies etc., and shared with Agenda Work Group and Chair
v. Discretion of Chair – often for topics in the Chair's hour

n) **MRRIC Work Plan Development Process and Implementation** *(approved by MRRIC October 20, 2011)*

Overview

There are two (2) documents that guide the annual work and product of MRRIC: the annual work plan and work group charges.

The purpose of the MRRIC work plan is to provide an overview of the Committee's work each year in fulfilling its duties as outlined in Section 5018 of the 2007 Water Resources Development Act (WRDA 2007). The work plan guides the more detailed work of MRRIC that is developed through work group charges approved by MRRIC at its meetings.

The work group charge documents provide more detailed information about the tasks of the work groups, the expected product and the timeline for completing the tasks. The work group charge documents are updated and approved by MRRIC at each meeting. In addition, the work group charge documents provide a mechanism for the Committee to work on issues that emerge in the year that were not anticipated in the work plan. New tasks not listed in the work plan can be added to the work of MRRIC during the year using the work group charge documents.

Topics in the work plan could, with MRRIC concurrence, be tabled. The work plan is created annually based on the calendar year and updated during the year as necessary. The steps below outline the approach to creating the plan.

1. Work group points of contact (POCs), lead agency staff of the work group, and work group members identify ongoing <u>work group tasks</u> expected to carry into the next year. They also identify and propose anticipated new tasks. As a part of this discussion the lead agencies share their priority needs relative to each work group for the upcoming year. The product from this discussion can be a list of current and anticipated work group charges and products and approximate time frame (e.g., at the winter, spring, summer, or fall MRRIC meeting).

2. Work group POCs, lead agency staff, MRRIC leadership and facilitation team meet to discuss <u>collective MRRIC tasks</u>, their relative priorities, and assess the distribution of work across the calendar year. At this meeting, the lead agencies confirm their priority needs from MRRIC for the year. Competing priorities between work groups or between MRRIC and the lead agencies are identified and addressed if possible between the work groups and lead agencies. If conflicting priorities cannot be resolved among the work groups, the MRRIC leadership may be consulted and when necessary, discussed with the full committee in order to achieve a resolution.

3. Leadership and Facilitation Team (LFT) draft a proposed work plan identifying the work of MRRIC, by work group, across the calendar year based on inputs and priorities from Step 2. The LFT circulate the draft proposed plan to the work groups for their review and comment.

4. The LFT revise the draft proposed work plan based on work group comments and circulate the revised to MRRIC members for review.

5. MRRIC reviews proposed work plan and provides comments to Chair and Vice-Chair.

6. MRRIC Leadership and Facilitation Team revise proposed work plan.

7. MRRIC reviews the revised proposed work plan, as a tool to guide the work of the committee, and approves the work plan as a process decision at the first MRRIC meeting of the calendar year. If the work plan includes anticipated tasks these tasks must have a MRRIC approved work group charge before work commences on the task.

8. The work plan maybe up updated during the calendar year to reflect the MRRIC approved work group charges not listed in the work plan at the time of its approval.

o) Work Group Decision Making (approved by MRRIC February 9, 2012)

Consensus will be used as the decision making standard in MRRIC work groups. In work group discussions, all work group members (i.e., agency staff, MRRIC members, non- MRRIC work group members) participate in the discussion and in developing a work group product. The consensus decision-making during the development of work group proposals is made by the current MRRIC members (or their alternates) seated on the work group. See paragraph 3b of the MRRIC Charter for a definition of consensus. In situations where a primary and an alternate MRRIC member sit on the same work group the individuals should coordinate their perspectives and speak with one voice as consistent with MRRIC.

If a work group does not reach consensus on a MRRIC task, or is not making timely progress on a task, the work group should inform MRRIC of the full status of the task such as the varying opinions, objections and perspectives. MRRIC should weigh-in, give guidance and further direction to the work group.

p) Stakeholder Membership (Approved by MRRIC January 31, 2013)

MRRIC member terms run on the federal fiscal calendar from Oct 1 to Sept 30. If a stakeholder member is appointed after October 1, his or her term will complete the current fiscal year and two additional years ending on Sept 30. For example:

If a member is appointed at the August 2013 meeting his or her term would end Sept 30, 2015.

q) Process for MRRIC Stakeholder Member Disclosure (*Approved by MRRIC May 23, 2013*)

SECTION I. WHAT SHOULD BE DISCLOSED

If any of the following are applicable they should be disclosed to MRRIC:

1. If a current stakeholder member or applicant is directly employed by a federal, state or tribal government agency or program.

OR

2. If a current stakeholder member's employment status changes (to # 1 above) from when you applied to MRRIC.

SECTION II. HOW TO DISCLOSE

1. Current stakeholder members who are renewing their MRRIC membership: disclose items 1 or 2 in Section I above in their renewal letter.

2. Current stakeholder members whose status changes during their three year term on MRRIC should make the disclosure immediately by:

   a. Preparing a letter to the MRRIC Chair that is included in the consent agenda of the next MRRIC meeting and the letter is posted to a folder for disclosures on the MRRIC Sharepoint site. (Goal is to ensure notice and transparency to MRRIC.)

   b. If a MRRIC member has a concern about a disclosure then the consent agenda procedures are followed (i.e., item is removed from consent agenda; Chair and individuals with the concern and the individual who made the disclosure meet to clarify and seek resolution of concerns; report back to MRRIC to affirm disclosure.)

3. Applicants for stakeholder membership: disclose on their MRRIC application. USACE should include the following language in the MRRIC stakeholder application materials:

Committee members are obligated to avoid and disclose any individual ethical, legal, financial or other conflicts of interest involving MRRIC. (From MRRIC Operating Procedures). Applicants must disclose on their MRRIC *application if they are directly employed by a government agency or program (Note: "government" encompasses state, tribal, and federal agencies and/or programs).*

The following question should be added to the stakeholder application to help the applicant understand what information is being sought:

"Are you currently directly employed by a government entity? If yes, please share the agency or program name, your position, and describe any decision-making roles or responsibilities that you have."

SECTION III. GUIDANCE FOR EVALUATING DISCLOSURES, ROLES of USACE and MRRIC

- Evaluate disclosures on a case-by-case basis.
- Preference will be given to stakeholder applicants who are not directly employed by state, tribal or federal government.

Scenarios that might not be acceptable for an individual to fill a stakeholder seat are:

- If stakeholder applicant/member is directly employed by a government and serves in a role appointed by a governor or executive branch (e.g., head of a state program or department).
- If stakeholder applicant/member is directly employed by a government and as a stakeholder member of MRRIC her/his decision making is influenced by his status as a government employee.

<u>Who Decides?</u>

Ultimately the ASA for Civil Works decides on stakeholder appointments to MRRIC.

<u>Role of MRRIC in evaluating disclosures;</u>

MRRIC members can weigh in on new and renewing stakeholder applicants through the online survey issued by USACE every summer. If a MRRIC member has a concern about stakeholder applicant, or members' disclosure, they can raise it using the survey. The USACE evaluation panel must then evaluate it.

<u>Can a MRRIC member stop a selection of a stakeholder member?</u>

If a single member has a concern about a disclosure that concern alone should not force a decision about the applicant/renewing/current member's status as a stakeholder. It was also noted that the Committee has in place in the MRRIC operating procedures (Section 3c) a dispute resolution process. If a member has a concern about another members' disclosure they use this process to address the concern. If the concern cannot be sufficiently addressed at the lowest level the process allows for issues to ultimately be resolved by the ASA.

Attachment A.3 – Alternatives Considered in the MRRMP and EIS

Note: This attachment presents a summary of the alternatives evaluated in the MRRMP-EIS. For a more detailed discussion of the alternatives, see Chapter 2 of the DEIS.

Table A.3.1 summarizes the features of each plan alternative carried forward for detailed evaluation in this draft MRRMP-EIS. Six plan alternatives were identified (the No-Action Alternative and five action alternatives). The names of each alternative correspond to the concept or feature that distinguishes them from all other alternatives. Some of the alternatives share management actions and these are discussed in the sections describing common actions.

Actions Common to All Plan Alternatives

The following management actions would be implemented as part of all plan alternatives carried forward for detailed evaluation in this draft MRRMP-EIS including the No-Action Alternative. However, the actual scale and extent of a particular action may vary.

Least Tern and Piping Plover

Mechanical ESH Creation

All alternatives include mechanical ESH creation as a management action; however, the amounts of ESH that would be created mechanically vary by alternative and those differences are described in the respective section for each alternative. Mechanical construction amounts vary because this management action would be used to create enough ESH to meet bird habitat targets after accounting for the amount of ESH created by a habitat-forming flow release in several alternatives. Therefore, because the amount of ESH created by the habitat-forming flow release varies by alternative, so does the amount of mechanical ESH construction needed to achieve targets. Methods to implement this action would occur as described in Section 2.5.1.6.

Vegetation Management, Predator Management, and Human Restriction Measures

Vegetation management, predator management, and human restrictions measures as described in Sections 2.5.1.8 through 2.5.1.10 would be implemented as part of all the plan alternatives including the No-Action Alternative.

TABLE A.3.1. SUMMARY OF FEATURES COMPRISING THE MRRMP-EIS ALTERNATIVES CARRIED FORWARD FOR DETAILED CONSIDERATION.

Management Actions	Alternative 1 No Action	Alternative 2 USFWS 2003 BiOp Projected Actions	Alternative 3 Mechanical Construction Only	Alternative 4 Spring Habitat-Forming Flow Release	Alternative 5 Fall Habitat-Forming Flow Release	Alternative 6 Pallid Sturgeon Spawning Cue
Least Tern and Piping Plover						
Mechanical ESH Creation	X	X	X	X	X	X
Vegetation Management	X	X	X	X	X	X
Predator Management	X	X	X	X	X	X
Human Restriction Measures	X	X	X	X	X	X
Flow Management to Reduce Take	X	X	X	X	X	X
Spring Habitat-Forming Flow Release				X		
Fall Habitat-Forming Flow Release					X	
Monitoring and Research	X	X	X	X	X	X
Pallid Sturgeon (both Upper and Lower River)						
Propagation and Augmentation	X	X	X	X	X	X
Pallid Sturgeon Population Assessment Project	X	X	X	X	X	X

Management Actions	Alternative 1 No Action	Alternative 2 USFWS 2003 BiOp Projected Actions	Alternative 3 Mechanical Construction Only	Alternative 4 Spring Habitat-Forming Flow Release	Alternative 5 Fall Habitat-Forming Flow Release	Alternative 6 Pallid Sturgeon Spawning Cue
Level 1 and 2[1] Studies			X	X	X	X
Upper River Pallid Sturgeon						
Monitoring and evaluation related to fish passage at Intake Diversion Dam	X	X	X	X	X	X
Lower River Pallid Sturgeon						
Spawning Habitat Construction			X	X	X	X
Early Life History Habitat Construction	X (SWH)	X (SWH)	X (IRC)	X (IRC)	X (IRC)	X (IRC)
Spawning Cue Flow	X	X				X
Low Summer Flow		X				
Floodplain Connectivity		X				
Habitat Development and Land Management	X	X	X	X	X	X

2003 BiOp (USFWS, 2003)

[1] Note that some level 2 studies would require additional NEPA compliance beyond the scope of this EIS.

Monitoring and Research

The USACE conducts annual productivity monitoring of least tern and piping plover populations on the reservoir and river reaches of the Missouri River mainstem. The monitoring focuses on an adult census, measurement of fledge ratios, and documentation of incidental take. The USACE also performs ESH habitat monitoring. Monitoring results are used to determine the effectiveness of management actions for least terns and piping plovers. In addition, the USACE funds focused research projects on various aspects of least tern and piping plover demographics and habitat use.

Pallid Sturgeon (Both Upper and Lower River)

Propagation and Augmentation

The pallid sturgeon propagation and augmentation program, as described in Section 2.5.2.2, would be implemented as part of all the plan alternatives including the No-Action Alternative. The Pallid Sturgeon Recovery Team and Basin Workgroups undertake annual reviews of data to ensure timely updates to stocking plans in the Upper and Lower River (e.g., USFWS 2007). A new Pallid Sturgeon Propagation Plan is being developed by the Pallid Sturgeon Recovery Team because of important concerns related to fish health/disease, genetics, stocking size, stocking practices, etc. This propagation plan examines hatchery practices and recommends changes to rearing practices that minimize disease occurrences and ensure appropriate levels of production. The plan will also address issues related to obtaining appropriate genetic representation in the stocked population. The USFWS plan will focus on hatchery practices, rather than the fate of fish after release from the hatchery. The authority and responsibility for hatchery management lie with the USFWS for those facilities operated by the USFWS; other entities (e.g., Montana Fish Wildlife and Parks) are responsible for the operation of their hatcheries.

Pallid Sturgeon Population Assessment Project

The Pallid Sturgeon Population Assessment Project (PSPAP) has been the primary fish monitoring element for the BiOp and the MRRP and would continue in some form under all plan alternatives including the No-Action Alternative. Data collected through the PSPAP are used to evaluate the Pallid Sturgeon Propagation and Population Augmentation management action and provide long-term assessment of fish metrics. The USACE is responsible for ensuring that these long-term assessment activities occur to meet BiOp required monitoring and evaluation. The USACE has developed partnerships with state and federal agencies already active on the Missouri and Kansas Rivers and has provided the funding, standardized protocols, and quality control oversight necessary to implement the monitoring strategy of the PSPAP. Some level of redesign of the PSPAP is anticipated in the future in order to achieve efficiencies and align the PSPAP to assist with evaluating management hypotheses.

Upper River Pallid Sturgeon

Under all plan alternatives, the USACE would conduct the monitoring and assessment complimentary of that for which Reclamation has responsibility to determine if modifications for fish passage at Intake Diversion Dam are meeting pallid sturgeon objectives. Reclamation is responsible for monitoring whether fish passage occurs at Intake following implementation of fish passage measures. The USACE would be responsible for ensuring that MRRP monitoring and assessment can determine if successful fish passage at Intake is contributing to the Upper River pallid sturgeon population.

Lower River Pallid Sturgeon

Channel Reconfiguration for Creation of Early Life History Habitat

All plan alternatives include channel reconfiguration for the creation of early life history pallid sturgeon habitat; however, the amounts and types of habitat that would be created vary by alternative and those differences are described in the respective section for each alternative. Methods to implement this action are described in Section 2.5.3.3.

Habitat Development and Land Management on MRRP Lands

All plan alternatives include habitat development on MRRP lands; however, the amount of land acquisition varies by alternative and so would the magnitude of this action. Those differences are described in the respective section for each alternative. Methods to implement this action are described in Section 2.5.4.

Adaptive Management

Adaptive Management (AM) Framework for Alternatives 1 and 2

Under Alternatives 1 and 2, the USACE would continue to implement the AM approach that has been in place since 2009. Under Alternative 1, the AM approach consists of two primary components; the AM Plan for ESH (USACE, 2011) and the AM strategy developed for SWH creation (USACE, 2012c). The AM approach developed for the SWH and ESH sub-programs was developed in accordance with the 2000 BiOp and the 2003 amendment, which called for establishing an AM process to evaluate species and habitat responses to management actions within the river and to continually provide knowledge for the decision-making process (USFWS 2000; 2003). Under Alternative 2, following the same AM approach as Alternative 1, AM strategies would be developed for additional specific management actions such as reservoir unbalancing and low nesting season reservoir releases. Under Alternatives 1 and 2, the individual AM strategies are driven by the management actions contained in the 2000 BiOp and its 2003 Amendment. Monitoring data would be compiled and analyzed on an annual basis to assess progress towards stated objectives for both ESH and SWH and to report results. These annual reports would include recommendations related to all or some of the following program decisions;

- Level of construction effort,
- Pilot projects,
- Site adjustments,
- Incorporation of new methodologies,
- Investigations.

Every five years, additional analyses would be conducted in order to assess whether the elements of the ESH AM Plan and SWH AM strategy are being met. If a decision is made to update the ESH AM Plan or SWH AM strategy document, a scope, schedule, and plan of action would be developed.

For additional detail regarding the Adaptive Management Framework that would be followed under Alternatives 1 and 2, see the MRRP Adaptive Management Framework, ESH AM Plan, and SWH AM Strategy which are public documents available on the MRRP website at www.moriverrecovery.org.

Adaptive Management Framework for Alternatives 3, 4, 5 and 6

Under Alternatives 3–6, the USACE would follow the Missouri River SAMP developed as part of this Management Plan process. The SAMP is rooted in the effects analysis (EA), which was an effort to synthesize and analyze existing scientific data and information that has accrued since the 2000 BiOp and its 2003 Amendment. The EA developed conceptual ecological models to facilitate visualization and organization of the current thinking about relationships between management actions and species response, developed hypotheses about the effects of different management actions, and assess the hypotheses with multiple lines of evidence. The AM Plan, based on this EA, includes elements of both active and passive adaptive management. Active AM emphasizes knowledge as an intermediate objective toward the fundamental objectives and uses experiments or alternative management strategies to better understand system behavior (i.e., it is typically hypothesis-driven). The knowledge gained is then fed back into the decision-making process, improving performance toward the fundamental objectives. Passive AM is strictly objective-driven, and embraces learning gained through monitoring as secondary to the achievement of the fundamental objectives.

The role of AM in managing the birds under this MRRMP is to improve decision-making in light of an uncertain future system state; a type of uncertainty that can never fully be resolved, and through improved understanding of how the system functions and responds to various management actions. As the AM program is implemented, what is learned about the actions included within its scope will be applied to increase their effectiveness and may also result in the addition or removal of management actions from consideration. For pallid sturgeon, lingering uncertainties regarding the scope and scale of the management actions necessary to address recruitment failure has led to an Adaptive Management strategy reliant upon a progressive AM approach to manage risks to the pallid sturgeon. Under Alternatives 3–6, the Adaptive Management strategy is driven by the hypotheses generated by the EA effort. For additional detail about the AM Framework, see the SAMP.

Alternative 1 – No Action

Under the No-Action Alternative, the MRRP would continue to be implemented as it is currently. The current program does not implement all RPAs included in the 2003 Amended BiOp (USFWS 2003). The following sections describe the actions that would be taken towards BiOp compliance in addition to those common actions identified in Section 2.8.1 and their projected level of intensity as part of the No-Action Alternative.

Least Tern and Piping Plover

Under the No-Action Alternative, the following management actions would be implemented in compliance with the BiOp for least tern and piping plover on the Missouri River. The geographic scope of these management actions include the Missouri River from Fort Peck reservoir downstream to Ponca, Nebraska.

Mechanical Emergent Sandbar Habitat Construction

Under the No-Action alternative, the USACE would mechanically construct ESH annually at a rate of up to 107 acres per year across the entire system. This amount (107 acres/year) is based on past average annual ESH construction in the Gavins Point Dam and upper Lewis and Clark Lake segments from 2004 through 2010.

The No-Action Alternative includes only mechanical construction and maintenance of ESH using earth moving equipment and hydraulic dredges. Under the No-Action

Alternative, there are no flow actions specific to managing ESH for terns and plovers. Current operations under the Missouri River Mainstem Reservoir System Master Water Control Manual (USACE 2006) would constitute the underlying base flows. Consistent with the Master Manual, flow management to reduce take of least tern and piping plover would continue.

The results of ESH availability modeling indicate that under the No-Action Alternative, the 107-acre-maximum construction cap would occur in 82 percent of years modeled. In the remaining years, the model indicates there would be sufficient ESH on the System that construction would not be necessary. On average, the 107 acres would be divided between the Garrison reach (47 acres) and the Gavins Point reach (61 acres).

Pallid Sturgeon – Lower River

Under the No-Action Alternative, the following management actions would be implemented in compliance with the BiOp for pallid sturgeon in the lower Missouri River. The geographic scope of these management actions to benefit pallid sturgeon in the lower Missouri River is downstream of Gavins Point Dam to the confluence of the Missouri and Mississippi Rivers near St. Louis, Missouri.

Propagation and Augmentation

Under the No-Action Alternative, the USACE support of pallid sturgeon propagation and augmentation efforts would continue at current levels. The USACE primary method of support is through the provision of annual funding, which is anticipated to continue at approximately $455,000 annually.

Early Life History Habitat Construction

Under the No-Action Alternative, construction of habitat to support early life history requirements of pallid sturgeon would occur as part of the SWH program. The SWH restoration goal as outlined in the 2003 Amended BiOp (USFWS 2003) is to achieve an average of 20–30 acres of SWH per river mile. Under the No-Action Alternative, the USACE would achieve the low end of this acreage target (i.e., 20 acres per river mile between Ponca, Nebraska, and the mouth). This equates to a total of 15,060 acres of SWH. Existing habitat on the system combined with SWH projects have created a total of 11,832 acres, leaving 3,999 acres to be created (Table A.3.2). For purposes of evaluating potential impacts to the human environment, modeling assumed that the additional SWH acreage would be created as follows (Table A.3.3):

- Approximately 3,519 acres of in-channel SWH created through channel or top-width widening. A conceptual width of 250 feet was assumed for projects between Ponca and Rulo (20 projects encompassing 48 river miles) and 300 feet for projects downstream of Rulo (24 projects encompassing 57 river miles). Actual project width and size will vary by site.
- Approximately 480 acres of off-channel backwaters, assuming 8 new backwaters with each creating 60 acres of SWH.

Table A.3.4 summarizes the amount of land acquisition that was assumed to be required to implement the identified amount of SWH.

TABLE A.3.2. SUMMARY OF PROJECTED SHALLOW WATER HABITAT CREATION UNDER THE NO-ACTION ALTERNATIVE.

River Reach	River Mile Start	River Mile End	Miles in Reach	20 acres per mile of SWH	Existing acres of SWH	Target Acres of SWH
Ponca to Sioux City	753	735	18	360	120	240
Sioux City to Platte River	735	595	140	2,800	1,779	1,021
Platte River to Rulo	595	498	97	1,940	1,268	672
Rulo to Kansas River	498	367	131	2,620	1,491	1,129
Kansas River to Osage River	367	130	237	4,740	3,803	937
Osage River to Mouth	130	0	130	2,600	3,371	0
		Total	**753**	**15,060**	**11,832**	**3,999**

TABLE A.3.3. PROJECTED COMPOSITION OF SHALLOW WATER HABITAT CREATION TYPE UNDER THE NO-ACTION ALTERNATIVE.

River Reach	Target Acres of SWH	Channel Widening[1]			Backwaters[2]	
		Acres	Miles	# of Projects	Acres	# of Projects
Ponca to Sioux City	240	180	5.9	2	60	1
Sioux City to Platte River	1,021	601	19.8	9	420	7
Platte River to Rulo	672	672	22.2	9	0	0
Rulo to Kansas River	1,129	1,129	31.1	14	0	0
Kansas River to Osage River	937	937	25.8	10	0	0
Osage River to Mouth	0	0	0	0	0	0
Total	3,999	3,519	105	44	480	8

[1] Acreage amounts assume a top width of 250 feet for projects between Ponca and Rulo and 300 feet for projects downstream of Rulo.

[2] Assumes 60 acres of SWH are created by each project.

TABLE A.3.4. LAND ACQUISITION REQUIREMENTS TO IMPLEMENT EARLY LIFE HISTORY OF PALLID STURGEON HABITAT UNDER ALTERNATIVE 1.

River Reach	Target Acres of SWH	Additional Land Required – Habitat Only (acres)	Additional Land Required – Total (acres)*
Ponca to Sioux City	240	240	1,848
Sioux City to Platte River	1,021	0	0
Platte River to Rulo	672	0	0
Rulo to Kansas River	1,129	675	5,198
Kansas River to Osage River	937	0	0
Osage River to Mouth	0	0	0
Total	**3,999**	**915**	**7,046**

* For estimating purposes, it was assumed that 7.7 acres of land acquisition are required for every 1 acre of habitat needed. This is based on historic implementation data and accounts for factors such as parcel size and other real estate acquisition considerations.

Spawning Cue Release

For purposes of modeling the No-Action Alternative, the USACE assumed continued implementation of the plenary spring pulse as described in the Master Manual (USACE 2006). The bimodal Gavins Point spring pulse plan was developed based on the following; the provisions of the 2003 Amended BiOp (USFWS 2003) including the Integrated Science Program (ISP), input from the 2005 spring pulse Plenary Group, and its associated technical working groups, Tribal consultations/meetings, and public comments received on the draft spring pulse plan presented in the fall of 2005. A description of the detailed features of the plan follows.

Gavins Point Spring Pulse Downstream Flows Limits

The magnitude of both the March and May Gavins Point spring pulses would be constrained by the Gavins Point spring pulse downstream flow limits. These downstream flow limits are established at the same locations as the current flood control constraint flow targets discussed in the Master Manual (USACE 2006) and shown in Table A.3.5. The downstream flow limits shown in Table 2-15 are the same values as the most conservative flood control constraint flow targets and therefore, would provide similar downstream flood control during the spring pulse periods. As an additional precaution, radar detected precipitation and National Weather Service quantitative precipitation forecasted (QPF) precipitation would continue to be used in forecasting the resultant downstream flows. Gavins Point releases would be adjusted as required during the spring pulse periods based on this forecast.

TABLE A.3.5. DOWNSTREAM FLOW LIMITS DURING THE SPRING PULSE UNDER THE NO-ACTION ALTERNATIVE.

Location	Flow Limit (cfs)
Omaha	41,000
Nebraska City	47,000
Kansas City	71,000

cfs = cubic feet per second

March Spring Pulse from Gavins Point

The March spring pulse below Gavins Point is a preclude based on System storage. If the actual System storage as computed on 1 March is at or below 36.5 MAF, a March pulse would not be implemented. After the first occurrence of a March pulse, the preclude would change to 40.0 MAF. The magnitude of the March pulse is defined as the combination of the Gavins Point release increase and the contribution of the James River. Assuming that System storage is above the March pulse preclude, the magnitude of the March pulse would be 5,000 cfs and would be implemented the day after System releases reach the level necessary to provide downstream flow support for the beginning of the navigation season. More specifically, the magnitude of the Gavins Point release at the peak of the March pulse would be 5,000 cfs minus the contribution of the James River measured at the Scotland, South Dakota, stream gage. Actual releases from Gavins Point dam would be set to the nearest 500 cfs increment. Also, the total Gavins Point release during the March pulse would not be set any higher than the Gavins Point powerplant capacity (35,000 cfs). The duration of the peak of the March pulse would be 2 days. Following the 2-day peak, the March pulse flows would be reduced each day over the next 5 days until non-spring pulse downstream flow support rates are achieved.

May Spring Pulse from Gavins Point

The May spring pulse from Gavins Point would also have a preclude based on actual System storage as computed on 1 May. If the actual System storage as computed on 1 May is at or below 36.5 MAF, a May pulse would not be implemented. The May pulse preclude would also initially be 36.5 MAF until the first time the May spring pulse is implemented. As with the March pulse, once the first May spring pulse has been implemented the May spring pulse preclude would change to 40.0 MAF.

The magnitude of the May pulse, as is the case for the March pulse, is defined as the combination of Gavins Point release increase and the contribution of the James River. Therefore, the magnitude of the Gavins Point release at the peak of the May pulse would be the result of the two-step proration computation described below, minus the contribution of the James River measured at the Scotland, South Dakota, stream gage. The total Gavins Point release during the May pulse would not be constrained to the

Gavins Point powerplant capacity, as is case for the March pulse. The two-step proration computation to determine the magnitude of the May pulse is as follows:

1. **First Step**: The May pulse magnitude is first computed based on 1 May System storage. The May pulse magnitude is prorated in a straight-line interpolation between 16,000 cfs and 12,000 cfs based on a System storage range between 54.5 and 40 MAF. The May pulse magnitude in this step is limited to 16,000 cfs if System storage is greater than 54.5 MAF. For the initial occurrence of the May pulse, if System storage is between 36.5 and 40 MAF, the resultant magnitude from this step is 12,000 cfs.
2. **Second Step**: The resultant May pulse magnitude from the first step is then further prorated based on the USACE 1 May data, Mainstem Calendar Year Runoff Forecast for the Missouri River basin above Sioux City, Iowa. The May pulse magnitude computed in the first step could be decreased or increased by as much as 25 percent in this step. The May pulse magnitude resulting from the first step is increased in a straight line interpolation from 0 to 25 percent for a calendar year runoff forecast that ranges from median to upper quartile. The May pulse magnitude from the first step is decreased in a straight line interpolation from 0 to 25 percent for a 1 May calendar year runoff forecast that ranges from median to lower quartile runoff. Use of both steps in this computational process produces a potential range of May pulse magnitudes from 9,000 cfs to 20,000 cfs. Actual releases from Gavins Point Dam would be set to the nearest 500 cfs increment.

The initiation of the May pulse would be between 1 May and 19 May, depending on Missouri River water temperature. The May pulse would be initiated after the second daily occurrence of a 16°C or higher Missouri River water temperature measured immediately below Gavins Point Dam. However, the final decision on the date of the initiation of the May pulse would take into account the potential for “take” of threatened and endangered bird species during the pulse period and downstream flow conditions.

Gavins Point releases would be increased at a rate of approximately 6,000 cfs per day from normal downstream flow support releases until the full May pulse magnitude (as calculated above), is achieved. The May pulse magnitude would be maintained for 2 days, after which releases would be decreased by 30 percent over the following 2 days. The remaining release reductions would be prorated over an additional 8 days until non-spring pulse downstream flow support rates are achieved. This would result in a recession length of 10 days from the peak of the May pulse. The length and magnitude of the recession may also be constrained by the downstream flow limits shown in Table A.3.5.

Monitoring and Research

Pallid sturgeon science efforts require a comprehensive approach when providing information to decision-makers. The USACE management actions require riverine monitoring to determine the species response, effectiveness of the action, and/or any unintended effects. These assessments are further developed through research activities that clarify critical uncertainties and focus on factors limiting recruitment. These elements, in combination with propagation and augmentation, seek to identify and remove bottlenecks to pallid sturgeon recruitment. Under the No-Action Alternative, the following monitoring and research activities would continue, in addition to the PSPAP, which is common to all plan alternatives.

- **Habitat Assessment and Monitoring Program (HAMP)**: The HAMP began in 2004 and was developed by representatives of state and federal agencies and academia that collectively possess knowledge and expertise on the Missouri River, pallid sturgeon, and other native Missouri River fishes, research, experimental design, and statistical analysis. The HAMP focuses on the endangered pallid sturgeon, other big river native fishes, and their habitats as recommended by the BiOp. The goal of the HAMP is to assess the physical and biological responses to habitat creation actions that are expected to benefit pallid sturgeon and related fish communities.
- **Focused Pallid Sturgeon Research**: The USACE annually funds focused research to address remaining critical pallid sturgeon information gaps including the identification and better understanding of key pallid sturgeon life history transitions and development of explicit pallid sturgeon objectives and prioritized hypotheses.

Alternative-Specific Adaptive Management Considerations

Under Alternative 1, the USACE would continue to implement the AM approach that has been in place since 2009. It consists of two primary components; the AM Plan for ESH (USACE 2011) and the AM strategy developed for SWH creation (USACE 2012c). The AM approach developed for the SWH and ESH sub-programs was developed in accordance with the 2000 BiOp and its 2003 amendment. These two documents called for establishing an AM process to evaluate species and habitat responses to management actions within the river and to continually provide knowledge for the decision-making process (USFWS 2000; 2003). In addition, the USACE released a technical memorandum describing implementation guidance for Section 2039 of the WRDA 2007 which called for monitoring and AM of ecosystem restoration projects and provided some specific direction on what should be addressed within AM plans. Finally, the National Research Council (NRC) called for AM efforts in their 2002 report *The Missouri River Ecosystem: Exploring the Prospects for Recovery* (NRC 2002). In 2008, a multi-agency team consisting of representatives from the USACE, USFWS, National Park Service (NPS), and experts in structured decision-making and model development initiated strategy development. In 2009, the strategy was updated by the MRRP Adaptive Management Work Group and the ESH Programmatic Environmental Impact Statement PDT, in coordination with cooperating agencies on the Programmatic Environmental Impact Statement (i.e., USFWS and NPS) before finalization and implementation in 2010.

Monitoring data would be compiled and analyzed on an annual basis to assess progress towards stated objectives for both ESH and SWH, and to report results. These annual reports would include recommendations related to all or some of the following program decisions; 1) level of construction effort, 2) pilot projects, 3) site adjustments, 4) incorporation of new methodologies, and 5) investigations. Every five years, additional analyses would be conducted in order to assess whether the elements of the ESH AM Plan and SWH AM strategy are being met. If a decision is made to update the ESH AM Plan or SWH AM strategy document, a scope, schedule, and plan of action would be developed.

MRRIC and other groups may choose to provide comments or recommend adjustments to AM strategies at any time during the implementation process. This could include changes to AM objectives, incorporation of additional management actions, input on anticipated benefits and tradeoffs, and other pertinent elements of the AM Plans.

Alternative 2 – U.S. Fish and Wildlife Service 2003 Biological Opinion Projected Actions

Alternative 2 represents the USFWS interpretation of the management actions that would be implemented as part of the USFWS 2003 Amended Biological Opinion (USFWS 2003). Whereas the No-Action Alternative only includes the continuation of management actions the USACE has implemented to date for BiOp compliance, Alternative 2 includes additional iterative actions and expected actions that the USFWS anticipates would ultimately be implemented through AM and as such, impediments to implementation were removed. This section describes the actions that would be taken towards BiOp compliance and their projected level of intensity as part of the Projected Actions alternative under the USFWS 2003 Amended Biological Opinion. The USFWS input on this alternative was formalized in a planning aid letter submitted to the USACE on 5 November 2015.

Least Tern and Piping Plover

Under Alternative 2, the following management actions would be implemented in compliance with the 2003 Amended BiOp (USFWS 2003) for least tern and piping plover on the Missouri River. The geographic scope of these management actions would include the Missouri River from Fort Peck reservoir downstream to Ponca, Nebraska. The Planning Aid Letter submitted to the USACE on 5 November 2015 reiterated the ESH goals included in the BiOp, which include a goal of 11,886 acres of ESH on the System subdivided as follows:

- Below Gavins Point Dam – 80 acres of ESH per river mile
- Below Garrison Dam – 50 acres of ESH per river mile

- Below Fort Randall Dam – 20 acres of ESH per river mile
- Lewis and Clark Lake – 80 acres per river mile

The USACE would have management discretion as to how those acreage goals are achieved (i.e., mechanical construction vs. flows) as using construction alone to reach acreage goals under this alternative would be cost prohibitive. The USACE would approach the acreage goals under this alternative incrementally; beginning with lower acreages, monitoring the bird response, and moving to higher acreages if birds are not achieving the desired biological metrics.set forth in the 2003 Amended BiOp (USFWS 2003).

Mechanical Emergent Sandbar Habitat Construction

Under Alternative 2, the USACE would mechanically construct ESH annually at an average rate of 191 acres per year across the entire system. This amount represents the acreage necessary to meet the 2003 Amended BiOp acreage goal after accounting for available ESH on the system resulting from system operations (including the spawning cue flows for pallid sturgeon). The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, and constructing new ESH. As with Alternative 1, ESH would be constructed using earth moving equipment and hydraulic dredges.

The results of ESH availability modeling indicate that under Alternative 2, ESH construction would occur in 69 percent of the years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Spring Habitat-Forming Flow Release

A spring reservoir release for the purposes of ESH creation is not included in Alternative 2. However, the timing and magnitude of the pallid sturgeon spawning cue release would provide ESH creating benefits. These benefits are accounted for in the habitat availability modeling that determined the amount of ESH that would be mechanically created.

Lowered Nesting Season Flows

The low summer flow described for pallid sturgeon would also serve as a lowered nesting season flow for the benefit of least terns and piping plovers under Alternative 2. The criteria for the flow implementation would be the same as described in Section 2.8.3.2 of the AMP.

Pallid Sturgeon – Lower River

Under Alternative 2, the following management actions would be implemented in compliance with the BiOp for pallid sturgeon in the lower Missouri River. The geographic scope of these management actions to benefit pallid sturgeon in the lower Missouri River is downstream of Gavins Point Dam to the confluence of the Missouri and Mississippi rivers near St. Louis, Missouri.

Propagation and Stocking

Under Alternative 2, the USACE' support of pallid sturgeon propagation and augmentation efforts would continue at current levels. The USACE primary method of support is through the provision of annual funding, which is anticipated to continue at approximately $455,000 annually.

Early Life History Habitat Construction

Under Alternative 2, construction of habitat to support early life history requirements of pallid sturgeon would occur as part of the SWH program. The SWH restoration goal as outlined in the 2003 Amended BiOp (USFWS 2003) is to achieve an average of 20–30 acres of SWH per river mile. Under Alternative 2, the USACE would achieve the upper end of this acreage target (i.e., 30 acres per river mile between Ponca, Nebraska, and the mouth). This equates to a total of 22,590 acres of SWH. Existing SWH projects have created a total of 11,832 acres, leaving 10,758 acres to be created (Table A.3.2). For the purposes of evaluating potential impacts to the human environment, modeling assumed that the additional SWH acreage would be created as follows (Table A.3.3):

- Approximately 9,858 acres of in-channel SWH would be created through channel widening. A conceptual width of 250 feet was assumed for projects between Ponca, Nebraska, and Rulo, Nebraska (60 projects encompassing 118.2 river miles) and 450 feet for projects downstream of Rulo (48 projects encompassing 115 river miles). Actual project width and size will vary by site.
- Approximately 900 acres of off-channel backwaters, assuming 15 new backwaters with each creating 60 acres of SWH.

Land acquisition to implement the SWH requirements described is summarized in Table A.3.4.

TABLE A.3.6. SUMMARY OF PROJECTED SHALLOW WATER HABITAT CREATION UNDER ALTERNATIVE 2

River Reach	River Mile Start	River Mile End	Miles in Reach	30 acres per mile of SWH	Existing acres of SWH	Target Acres of SWH
Ponca to Sioux City	753	735	18	540	120	420

Sioux City to Platte River	735	595	140	4,200	1,779	2,421
Platte River to Rulo	595	498	97	2,910	1,268	1,642
Rulo to Kansas River	498	367	131	3,930	1,491	2,439
Kansas River to Osage River	367	130	237	7,110	3,803	3,307
Osage River to Mouth	130	0	130	3,900	3,371	529
		Total	**753**	**22,590**	**11,832**	**10,758**

TABLE A.3.7. PROJECTED COMPOSITION OF SHALLOW WATER HABITAT CREATION TYPE UNDER ALTERNATIVE 2

River Reach	Target Acres of SWH	Channel Widening[1]			Backwaters[2]	
		Acres	Miles	# of Projects	Acres	# of Projects
Ponca to Sioux City	420	240	7.9	4	180	3
Sioux City to Platte River	2,421	1,761	58.1	32	660	11
Platte River to Rulo	1,642	1,582	52.2	24	60	1
Rulo to Kansas River	2,439	2,439	44.7	19	0	0
Kansas River to Osage River	3,307	3,307	60.6	25	0	0
Osage River to Mouth	529	529	9.7	4	0	0
Total	**10,758**	**9,858**	**233**	**108**	**900**	**15**

[1] Acreage amounts assume a top width of 250 feet for projects between Ponca and Rulo and 450 feet for projects downstream of Rulo.

[4] Assumes 60 acres of SWH are created by each project.

TABLE A.3.8. LAND ACQUISITION REQUIREMENTS TO IMPLEMENT EARLY LIFE HISTORY PALLID STURGEON HABITAT UNDER ALTERNATIVE 2

River Reach	Target Acres of SWH	Additional Land Required – Habitat Only (acres)	Additional Land Required – Total (acres)*
Ponca to Sioux City	420	420	3,234
Sioux City to Platte River	2,421	925	7,123
Platte River to Rulo	1,642	675	5,198
Rulo to Kansas River	2,439	1,985	15,285
Kansas River to Osage River	3,307	1,932	14,876
Osage River to Mouth	529	0	0
Total	**10,758**	**5,937**	**45,716**

* For estimating purposes, it was assumed that 7.7 acres of land acquisition are required for every 1 acre of habitat needed. This is based on historic implementation data and accounts for factors such as parcel size and other real estate acquisition considerations.

Spawning Cue Release

The USFWS determined in the 2003 Amended BiOp (USFWS 2003) that restoration of a normalized river hydrograph below Gavins Point Dam was necessary to avoid jeopardizing the continued existence of the pallid sturgeon. Several biologically relevant features were identified for a flow action below Gavins Point Dam including; 1) flows to cue spawning that are sufficiently high for an adequate duration, and 2) flows that provide for connection of low-lying lands adjacent to the channel.

The spawning cue release from Gavins Point Dam would be bimodal (i.e., consisting of two separate flow pulses) and would be implemented in every year if conditions are met. If System storage on 15 March is 31.0 MAF or less, equating to a "no service" navigation year, the spawning cue release would not be implemented. In addition, if downstream flood control targets are exceeded, the spawning cue release would not be initiated or it would be terminated if these targets are exceeded during implementation. The results of preliminary reservoir simulation modeling, based on an 82-year period of record, indicate that in practice the bimodal spawning cue flows would likely only meet the conditions for implementation once every eight years. The conditions and characteristics of the two pulses would include:

- In advance of the first pulse, the maximum winter Gavins Point release would be maintained at 16 kcfs.
- First pulse from Gavins Point Dam.
  - Implementation would occur if the conditions described previously are met; system storage on 1 March is at least 40.0 MAF and the System is not at storage evacuation service level on 15 March.
  - Implementation would begin with the typical increase in flow to provide for navigation around 15 March.
  - The rate of flow increase (i.e., the ascending limb of the pulse) would last 7 days until a peak of 31 kcfs is reached.
  - Once reached, the peak flow would be maintained for 7 days. After that, the rate of decrease (i.e., the descending limb of the pulse) would last 7 days and then return to FTT operations based on service level from the 15 March storage check.
- Second pulse from Gavins Point Dam.
  - Implementation would occur if the conditions described previously are met and system storage on 1 May is at least 40.0 MAF. Flood control constraints would be determined by adding the pulse magnitude to the existing flood control constraints as shown in Table VII-7 and VII-8 in Master Manual (USACE 2006). For example, if the pulse magnitude is 16 kcfs and the flood targets are 41 kcfs, 47 kcfs, and 71 kcfs at Omaha, Nebraska City, and Kansas City, respectively, the new flood targets would be 57 kcfs at Omaha (16 kcfs + 41 kcfs), 62 kcfs at Nebraska City (16 kcfs + 47 kcfs), and 87 kcfs at Kansas City (16 kcfs + 71 kcfs). The pulse would be terminated any time flood control constraints are exceeded.
  - Implementation would begin on 1 May.
  - The rate of flow increase (i.e., the ascending limb of the pulse) would last 7–10 days.
  - The pulse peak would be based on the 1 March forecast as follows but would never exceed a total Gavins Point Dam release of 60 kcfs:
    - Lower quartile or lower runoff = 12 kcfs rise over 1 May release and maintained for 14 days
    - Median = 16 kcfs rise over 1 May release and maintained for 25 days

        - Upper quartile or higher runoff = 20 kcfs rise over 1 May release and maintained for 35 days
    - The rate of decrease (i.e., the descending limb of the pulse) would last not less than 7 days until a return to “steady release” scenario is reached.

Low Summer Flow

The USFWS 2003 Amended BiOp (USFWS 2003) also called for modification to System operations to allow for flows that are sufficiently low to provide for SWH as rearing, refugia, and foraging areas for larval, juvenile, and adult pallid sturgeon. Alternative 2 includes a low summer flow that would be implemented as follows:

- Summer low flow would only be implemented in the two years following implementation of a complete bimodal spawning cue flow, meaning that both the first and second pulses as described in Attachment A.3 (Alternative 6) are implemented completely.
- From 23 June to 1 July, Gavins Point Dam release would be set to 25 kcfs
- On 1 July, the USACE would assess the navigation season length and operate as follows:
    - If there is a shortened navigation season as determined by the existing Master Manual (USACE 2006):
        - Gavins Point Dam releases would be determined based on meeting water supply targets (open channel non-navigation season).
        - The duration of those releases would be equivalent to that of the number of days the season is shortened less the 8 days in June (e.g., if season is shortened 30 days).
        - Following that duration, flows would be set to 25 kcfs until 15 July at which time release would be dropped to 21 kcfs until 15 August. As of 15 August, releases would return to 25 kcfs until 1 September.
        - FTT operations would resume from 1 September until 1 December.
    - If there is not a shortened navigation season:
        - Releases of 25 kcfs would continue from 1 July to 15 July then drop to 21 kcfs until 15 August. After 15 August, releases would return to 25 kcfs until 1 September.
        - FTT operations would resume from 1 September until 1 December or 10 December if a ten-day navigation season extension is determined.

Floodplain Connectivity

The USFWS 2003 Amended BiOp (USFWS 2003) stated the following in regard to floodplain connectivity: “*Floodplain inundation and connectivity is essential in order to maximize the production of the forage base for pallid sturgeon. The forage base production must occur at a time that coincides with larval sturgeon becoming active, free-swimming feeders. Floodplains are highly productive habitat in the late spring* *and early summer when warm, shallow water floods over the area and produces a bloom of forage that is of appropriate size for larval fish to eat. Additionally, low-lying lands are an extremely important source for floodplain spawning fish which subsequently support the forage base for adult pallid sturgeon. Highly productive floodplains are necessary on a frequent annual basis to provide necessary life requisites for pallid sturgeon survival.*"

The USACE coordinated with the USFWS during alternatives development to identify criteria for clarification of the floodplain connectivity management action for Alternative 2. These criteria were included in a Planning Aid Letter submitted to the USACE on 5 November 2015. The criteria stated that this management action should maximize floodplain habitat by ensuring that 77,410 acres of connected floodplain are inundated at a 20 percent annual chance exceedance. The USACE conducted HEC-GeoRAS mapping to determine the acres of existing floodplain connectivity in the lower Missouri River. The mapping results indicated that 156,480 acres of floodplain connectivity are currently present, not including the area of the main channel. Under Alternative 2, the USACE would continue management of the System for a minimum of 77,410 acres of floodplain connectivity.

Monitoring and Research

Monitoring and research efforts under Alternative 2 would be the same as described for Alternative 1.

Alternative-Specific Adaptive Management Considerations

The AM approach for Alternative 2, is similar to the AM approach that the USACE has been implementing since 2009 and described for Alternative 1. The AM approach for Alternative 2 would be the same as for Alternative 1 but would be modified to address specific alterations in proposed management actions as described in the 5 November 2015 Planning Aid Letter from the USFWS. Management actions implemented by the USACE as part of Alternative 2 would be modified and continually improved upon through AM and in cooperation with the USFWS. Due to changing river conditions, methods of implementing management actions may vary over time, and modifications to management actions would be based on an evaluation of habitat, flow, climate, species response, and any other new information available each year. Under Alternative 2, monitoring would remain a key component to the AM approach to document how management actions were implemented and their effects within the river and on the listed species. The USACE and USFWS would jointly define what is considered to be sufficient progress for each management action within specified timeframes to avoid jeopardy.

Actions Common to Alternatives 3–6

Active Adaptive Management

Under alternatives 3–6, the USACE would implement an AM program. AM promotes collaboration and flexible decision-making through deliberately designing and implementing management actions to test hypotheses and maximize learning about critical uncertainties that better inform management decisions (Williams et al. 2009). The AM Plan, based on the EA, includes elements of both active and passive adaptive management. Active AM emphasizes knowledge as an intermediate objective toward the fundamental objectives and uses experiments or alternative management strategies to better understand system behavior (i.e., it is typically hypothesis-driven). The knowledge gained is then fed back into the decision-making process, improving performance toward the fundamental objectives. Passive AM is strictly objective-driven and embraces learning gained through monitoring as secondary to the achievement of the fundamental objectives. Alternatives 3–6 would implement the active form of adaptive management, which employs management actions in an experimental design aimed primarily at learning to reduce uncertainty; near-term benefits to the resource are secondary. Specific AM actions would be implemented focused on understanding limiting factors associated with least terns and piping plovers, as well as pallid sturgeon.

Level 1 and 2 Studies

As part of the AM program described above, the USACE would implement level 1 and 2 studies under Alternatives 3–6 for better understanding limiting factors associated with pallid sturgeon. Level 1 studies are research focused and do not change the system (Laboratory studies or field studies under ambient conditions). Level 2 studies would focus on in-river testing of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response. Some level 2 studies would be outside the scope of this EIS and require additional compliance with NEPA. For additional information on the types of studies that could be implemented under alternatives 3–6 see Section 4.2.4 of the SAMP.

Spawning Habitat

Under Alternatives 3–6, the USACE would create three, high-quality spawning habitat sites. Monitoring the effectiveness of these actions in terms of the relative use of these sites compared to other control areas, and the relative spawning success, as determined by hatch rate, catch per unit effort of free embryos and other indicators will be conducted. Sufficient understanding to characterize the necessary features of high quality pallid sturgeon spawning habitats does not exist. These sites would be constructed following initial studies that further clarify habitat specifications. An early emphasis would use information from the Yellowstone River as the best natural reference condition to inform the design of these pilot projects on the Lower Missouri River, while also continuing to examine the habitat characteristics of spawning sites on the Lower Missouri River.

Channel Reconfiguration for Interception and Rearing Complexes

Under Alternatives 3–6, construction of habitat to support early life history requirements of pallid sturgeon would occur following the IRC (interception and rearing complexes) concept. Best available science indicates that future acreage required to construct IRCs would most likely be achieved through channel widening. For the purposes of evaluating potential impacts to the human environment, modeling assumed that about 3,380 acres of channel widening would be implemented to create IRCs under Alternatives 3–6 (Table A.3.9). A conceptual width of 250 feet was assumed for projects between Ponca and Rulo and 300 feet for projects downstream of Rulo. Land acquisition to implement the requirements described is summarized in Table A.3.10.

TABLE A.3.9. SUMMARY OF PROJECTED IRC CREATION UNDER ALTERNATIVES 3–6

River Reach	River Mile Start	River Mile End	Miles in Reach	Target Acres of IRC habitat[1]
Ponca to Sioux City	753	735	18	0
Sioux City to Platte River	735	595	140	276
Platte River to Rulo	595	498	97	585
Rulo to Kansas River	498	367	131	670
Kansas River to Osage River	367	130	237	1,389
Osage River to Mouth	130	0	130	460
			Total	**3,380**

[1] All acreage achieved through channel widening. Acreage amounts assume a top width of 250 feet for projects between Ponca and Rulo and 300 feet for projects downstream of Rulo.

TABLE A.3.10. LAND ACQUISITION REQUIREMENTS TO IMPLEMENT IRC UNDER ALTERNATIVES 3–6

River Reach	Target Acres of SWH	Existing Public Lands Available for Habitat Development (acres)[1]	Additional Land Required – Habitat Only (acres)	Additional Land Required – Total (acres)[2]
Ponca to Sioux City	0	420	0	0
Sioux City to Platte River	276	276	0	0
Platte River to Rulo	585	585	0	0
Rulo to Kansas River	670	454	216	1,664

Kansas River to Osage River	1,389	1,375	14	108
Osage River to Mouth	460	460	0	0
Total	**3,380**	**3,150**	**230**	**1,772**

[1] Existing public lands includes USACE, USFWS, and state conservation owned lands. Acreage was based on identifying government owned lands that may be appropriate for habitat development; however, these areas do not necessarily represent actual locations of future habitat development.

[2] For estimating purposes, it was assumed that 7.7 acres of land acquisition are required for every 1 acre of habitat needed. This is based on historic implementation data and accounts for factors such as parcel size and other real estate acquisition considerations.

Alternative 3 – Mechanical Construction Only

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 3, the USACE would only create ESH habitat through mechanical means at an average rate of 391 acres per year across the entire system. This amount represents the acreage necessary to meet bird habitat targets after accounting for available ESH resulting from system operations. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 3, ESH construction would occur in 75 percent of the 50 years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Alternative 4 – Spring Habitat-Forming Flow Release

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 4, the USACE would mechanically construct ESH annually at an average rate of 240 acres per year across the entire system. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of a Spring ESH-creating reservoir release. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 4, ESH construction would occur in 49 percent of the 50 years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Spring Habitat-Forming Flow Release

Alternative 4 reservoir operations would be similar to Alternative 1 (current operations), with the addition of a high spring release designed to create ESH for the least tern and piping plover. In any year, the implementation of this habitat-forming flow release would occur if System storage is at 42 MAF or greater on 1 April. Natural flows creating 250 acres of ESH have not occurred in the previous four years and downstream flow is below identified flood control constraints specific to this alternative (Table A.3.11). If those conditions are met, the habitat-forming flow release would be implemented on 1 April with a release of up to 60 kcfs out of Gavins Point Dam, and occur as often as every four years. To achieve the Gavins Point Dam release, Fort Randall Dam releases would be increased a similar amount as Gavins Point and releases from Garrison Dam would be approximately 17.5 kcfs less than the Gavins Point release.

TABLE A.3.11: FLOOD TARGETS.

Location	Kilo Cubic Feet Per Second (kcfs)
Omaha	71
Nebraska City	82
Kansas City	126

The duration of the release would increase as release magnitude is decreased. Table A.3.12 shows the duration (number of days) required for the habitat-forming flow release at various discharges.

TABLE A.3.12: ESTIMATED DURATIONS OF HABITAT-FORMING FLOW RELEASE.

Kilo Cubic Feet Per Second (kcfs)	Required Number of Days
60	35
55	49
50	77
45	175

If flood targets are exceeded, the Gavins Point release would be reduced by 5 kcfs until flood targets are no longer exceeded. In instances where the Gavins Point release falls below 45 kcfs, the release would be terminated. Modeling indicates that over the 82-year period of record, the spring habitat-forming flow release as defined here would have been implemented 10 times and would have been partially implemented 5 times. Partial implementation means that the criteria were met in that year to initiate the flow release but it was terminated before completion.

Under current operations, navigation releases are computed based on the current service level prior to flood targets being assessed. Flow support for navigation and other downstream purposes is defined based on service level. A “full-service” level of 35,000 cfs results in target flows of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Similarly, a “minimum-service” level of 29,000 cfs results in target flow values of 6,000 cfs less than the full-service levels. If system storage is high enough to warrant evacuation of flood storage, the service level will be greater than 35,000 cfs.

The following example assumes a service level of 40,000 cfs is the operations target. Navigation discharges for each of the target locations are computed based on Table A.3.13 (Table VII-1 in the Master Manual [USACE 2006]). These navigation discharges are the required discharges at the four target locations to support navigation. For a 40,000 cfs service level, the required navigation discharges at Sioux City, Omaha, Nebraska City, and Kansas City are; 36,000 cfs (40,000 - 4,000); 36,000 cfs (40,000 - 4,000); 42,000 cfs (40,000 + 2,000); and 46,000 cfs (40,000 + 6,000), respectively.

TABLE A.3.13. RELATION OF TARGET DISCHARGES TO SERVICE LEVEL.

Control Point Location	Flow Target Discharge Deviation from Service Level
Sioux City	-4,000 cfs
Omaha	-4,000 cfs
Nebraska City	+2,000 cfs
Kansas City	+6,000 cfs

Source: Master Manual, Table VII-1 (USACE 2006)

cfs = cubic feet per second

Once navigation discharges are calculated, two tiers of flood target discharges are calculated and forecasted discharges are checked against the flood discharges. The first tier is based on the criteria in Table A.3.14 (Table VII-7 in the Master Manual [USACE 2006]) and represents a full-service flood target. The second tier is based on the criteria in Table A.3.15 (Table VII-8 in the Master Manual [USACE 2006)] and represents a minimum-service flood target.

TABLE A.3.14. CRITERIA FOR MODIFYING TARGET FLOWS – FULL SERVICE.

Target flows will be reduced to those consistent with full-service level of 35,000 cfs when one or more of the anticipated downstream flows exceed the current service level flow values by more than:

6,000 cfs at Omaha	(target flow + 10,000 cfs)
12,000 cfs at Nebraska City	(target flow + 10,000 cfs)
36,000 cfs at Kansas City	(target flow + 30,000 cfs)

Source: Master Manual, Table VII-7 (USACE 2006)

cfs = cubic feet per second

TABLE A.3.15. CRITERIA FOR MODIFYING TARGET FLOWS – MINIMUM SERVICE.

Target flows will be reduced to those consistent with minimum-service level of 29,000 cfs when one or more of the anticipated downstream flows exceed the current service level flow values by more than:	
11,000 cfs at Omaha	(target flow + 15,000 cfs)
22,000 cfs at Nebraska City	(target flow + 20,000 cfs)
66,000 cfs at Kansas City	(target flow + 60,000 cfs)

Source: Master Manual, Table VII-8 (USACE 2006)

cfs = cubic feet per second

Using Table A.3.16 for a 40,000 cfs service level, full-service flood target discharges at Omaha, Nebraska City, and Kansas City are 46,000 cfs (36,000 + 10,000); 52,000 cfs (42,000 + 10,000); and 76,000 cfs (46,000 + 30,000), respectively. When downstream discharges are forecasted, if discharges at Omaha, Nebraska City, or Kansas City exceed their full-service flood targets, the system is operated as if at full-service. Navigation discharges become; 31,000 cfs (35,000 - 4,000); 31,000 cfs (35,000 - 4,000); 37,000 cfs (35,000 + 2,000); and 41,000 cfs (35,000 + 6,000). Gavins Point releases are then decreased until the full-service flood targets of 46,000 cfs, 52,000 cfs, and 76,000 cfs are no longer exceeded while still maintaining at least full-service discharges at each of the target locations.

Using Table A.3.16 for a 40,000 cfs service level, minimum-service flood target discharges at Omaha, Nebraska City, and Kansas City are 51,000 cfs (36,000 + 15,000); 62,000 cfs (42,000 + 20,000); and 106,000 cfs (46,000 + 60,000), respectively. When downstream discharges are forecasted, if discharges at Omaha, Nebraska City, or Kansas City exceed their minimum-service flood targets, the system is operated as if at minimum service. Navigation discharges become 25,000 cfs (29,000 - 4,000); 25,000 cfs (29,000 - 4,000); 31,000 cfs (29,000 + 2,000); and 35,000 cfs (29,000 + 6,000). Gavins Point releases are then decreased until the minimum-service flood targets of 51,000 cfs, 62,000 cfs, and 106,000 cfs are no longer exceeded while still maintaining at least minimum-service discharges at each of the target locations. These calculations are summarized in Table A.3.16.

The habitat-forming flow release of 60 kcfs from Gavins Point could not occur under current operations because of how the flood target criteria are operationally applied. If 60,000 cfs were released from Gavins Point and it was assumed that all tributaries between Gavins Point and Omaha were dry, there would still be 60,000 cfs at Omaha due to releases from Gavins Point. A 60,000 cfs discharge at Omaha exceeds both the full-service flood target of 46,000 cfs and the minimum-service flood target of 51,000 cfs for a 40,000 service level. If the current flood target operations were used, the habitat-forming flow release would never have a chance to occur until the service level exceeded 49,000 cfs; therefore, in order to allow this high release from Gavins Point, it was necessary to modify how the flood target criteria are applied during times when a habitat-forming flow release is attempted. This revision results in the flood targets presented in Table A.3.16.

TABLE A.3.16 EXAMPLE NAVIGATION AND FLOOD TARGET DISCHARGES FOR A 40 KCFS SERVICE LEVEL UNDER CURRENT OPERATIONS.

Location	Navigation Discharge for 35,000 Service Level (Full-service) (cfs)	Navigation Discharge for 29,000 Service Level (Minimum-service) (cfs)	Navigation Discharge for Example 40,000 Service Level (cfs)	Full-service Flood Target (cfs)	Minimum-service Flood Target (cfs)
Sioux City	31,000	25,000	36,000	--	--
Omaha	31,000	25,000	36,000	46,000	51,000
Nebraska City	37,000	31,000	42,000	52,000	62,000
Kansas City	41,000	35,000	46,000	76,000	106,000

cfs = cubic feet per second

Alternative 5 – Fall Habitat-Forming Flow Release

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 5, the USACE would mechanically construct ESH annually at an average rate of 309 acres per year across the entire system. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of a Fall ESH-creating reservoir release. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 5, ESH construction would occur in 63 percent of the 50 years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Fall Habitat-Forming Flow Release

Alternative 5 reservoir operations would be similar to Alternative 1 (current operations), with the addition of a high fall release designed to create ESH for the least tern and piping plover. In any year, the implementation of this habitat-forming flow release would occur if the service level is at 35 kcfs or greater (54.5 MAF System storage) on 17 October. Natural flows creating 250 acres of ESH have not occurred in the previous four years and downstream flow is below identified flood control constraints. Downstream flood control constraints for Alternative 5 would be the same as that for Alternative 4 (Table A.3.11). If those conditions are met, the habitat-forming flow release would be implemented on 17 October with a release of up to 60 kcfs out of Gavins Point Dam, and as often as every four years. To achieve the Gavins Point Dam release, Fort Randall Dam releases would be increased a similar amount as Gavins Point and releases from Garrison Dam would be approximately 17.5 kcfs less than the Gavins Point release. As with Alternative 4, the duration of the release would increase as release magnitude is decreased (Table A.3.12).

If flood targets are exceeded, the Gavins Point release would be reduced by 5 kcfs until flood targets are no longer exceeded. In instances where the Gavins Point release falls below 45 kcfs, the release would be terminated. Modeling indicates that over the 82-year period of record, the fall habitat-forming flow release as defined here would have been implemented 7 times and would have been partially implemented 2 times.

Alternative 6 – Pallid Sturgeon Spawning Cue

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 6, the USACE would mechanically construct ESH annually at an average rate of 303 acres per year across the entire system. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from System operations, which includes a spawning cue flow for pallid sturgeon. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 6, ESH construction would occur in 71 percent of the 50 years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system such that construction would not be necessary.

Spawning Cue Release

Under Alternative 6, the USACE would attempt a spawning cue release every 3 years consisting of a bimodal pulse in March and May. These spawning cue releases would not be started or would be terminated whenever flood targets are exceeded. ResSim modeling indicates that over the 82-year period of record, the spawning cue release as defined here would have been implemented 11 times and would have been partially implemented 33 times.

March Pulse

The USACE would initiate a March pulse once navigation releases were met at downstream target locations. This could result in increases of 2,200 cfs per day until the pulse magnitude is achieved. Peak pulse magnitude is equal to the navigation release that occurs on the day the pulse is initiated. In the case of Gavins Point, the peak release is double the navigation release that occurs on the day the pulse is initiated. The peak would be maintained for two days. Once peak duration is met, the USACE would reduce the pulse by 1,700 cfs per day until flow-to-target navigation releases are reached. Table 2-27 below provides flood targets associated with a March pulse. After the first occurrence of a March pulse, the preclude for System storage would change to 40.0 MAF. Based on ResSim POR simulations, Gavins Point releases during the March spawning cue would be 39-61 kcfs.

TABLE A.3.17: FLOOD TARGETS

Location	Kilo Cubic Feet Per Second (kcfs)
Omaha	41 + Pulse Magnitude
Nebraska City	47 + Pulse Magnitude
Kansas City	71 + Pulse Magnitude

May Pulse

The USACE would initiate the pulse on 18 May each year. A varied initiation date based on water temperature was specified by the USFWS; however, 18 May was used for modeling purposes. The USACE would increase the pulse by 2,200 cfs per day until the pulse magnitude is achieved. The peak pulse magnitude would be equal to the steady release on 18 May. The peak Gavins Point release would be double the steady release that occurs on the day the pulse is initiated (18 May). The USACE would maintain the peak for two days, and then reduce the pulse by 1,900 cfs per day until steady release is reached. Table A.3.17 provides flood targets associated with a May pulse. Based on ResSim POR simulations, Gavins Point releases during the May spawning cue would range from 50-67 kcfs.

TABLE A.3.18: FLOOD TARGETS

Location	Kilo Cubic Feet Per Second (kcfs)
Omaha	41 + Pulse Magnitude
Nebraska City	47 + Pulse Magnitude
Kansas City	71 + Pulse Magnitude

Preferred Alternative

Alternative 3 has been identified as the preferred alternative in this MRRMP-EIS. Alternative 3 is a complete plan in that it meets the USFWS probability of persistence targets for piping plover and least terns. Alternative 3 would continue ongoing pallid propagation activities, build spawning habitats (as in-river test projects will learn if this action is effective), and build IRC habitats thru structure modification and channel widening. It would also provide (in common with Alternatives 4, 5, and 6) a foundational active AM program.

Although Alternative 3 would not be the most efficient alternative from an overall National Economic Development (NED) standpoint; when compared to alternative 1, the lack of adverse NED impacts is a good balance between overall efficiency and impacts to specific NED resources. Although there are uncertainties associated with the effectiveness in meeting the species objectives (in common with Alternative 4, 5, and 6), Alternative 3 would be the least impactful means of meeting species objectives across the full range of interests.

Attachment A.4 – Water Management Technical Criteria

Note: This attachment reflects the current Water Management Technical Criteria as presented by the USACE in the Missouri River Mainstem Reservoir System - System Description and Regulation (USACE 2007). Future updates to the criteria should be reflected in this attachment and the appropriate reference.

Summary of Master Manual Technical Criteria

Missouri River Mainstem Reservoir System - System Description and Regulation (USACE 2007)

NAVIGATION TARGET FLOWS

Location	Minimum Service (kcfs)	Full Service (kcfs)
Sioux City	25	31
Omaha	25	31
Nebraska City	31	37
Kansas City	35	41

RELATION OF SYSTEM STORAGE TO NAVIGATION SERVICE LEVEL

Date	System Storage (MAF)	Navigation Service Level
March 15	54.5 or more	35,000 cfs (full-service)
March 15	49.0 to 31	29,000 cfs (minimum-service)
March 15	31.0 or less	No navigation service
July 1	57.0 or more	35,000 cfs (full-service)
July 1	50.5 or less	29,000 cfs (minimum-service)

RELATION OF SYSTEM STORAGE TO NAVIGATION SEASON LENGTH

Date	System Storage (MAF)	Final Day of Navigation Support at Mouth of the Missouri River
July 1	51.5 or more	November 30 (8-month season)
July 1	46.8 through 41.0	October 31 (7-month season)
July 1	36.5 or less	September 30 (6-month season)

RELATION OF SYSTEM WINTER RELEASE TO SYSTEM STORAGE

September 1 System Storage (MAF)	Average Winter Release for Gavins Point
58.0 or more	17,000 cfs
55.0 or less	12,000 cfs

GAVINS POINT RELEASES NEEDED TO MEET TARGET FLOWS

1950 to 1996 Data (kcfs)

Median, Upper Quartile, Upper Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full Service	26.7	28.0	27.9	31.6	33.2	32.6	32.0	31.1
Minimum Service	20.7	22.0	21.9	25.6	27.2	26.6	26.0	25.1

Lower Quartile, Lower Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full Service	29.8	31.3	31.2	34.3	34.0	33.5	33.1	31.2
Minimum Service	23.8	25.3	25.2	28.3	28.0	27.5	27.1	25.2

RESERVOIR UNBALANCING SCHEDULE

	Fort Peck		Garrison		Oahe	
Year	*March 1*	*Rest of Year*	*March 1*	*Rest of Year*	*March 1*	*Rest of Year*
1	High	Float	Low	Hold Peak	Raise & hold during spawn	Float
2	Raise & hold during spawn	Float	High	Float	Low	Hold peak
3	Low	Hold peak	Raise & hold during spawn	Float	High	Float

Notes: **Float year:** Normal regulation, then unbalance 1 foot during low pool years or 3 feet when System storage is near 57.0 MAF on March 1.

Low year: Begin low, then hold peak the remainder of the year.

High year: Begin high, raise and hold pool during spawn, then float.

MRNRC RECOMMENDED RESERVOIR ELEVATION GUIDELINES FOR UNBALANCING

	Fort Peck	Garrison	Oahe
Implement unbalancing if March 1 pool is above this level.	2234 feet msl	1837.5 feet msl	1607.5 feet msl
Implement unbalancing if March 1 pool level is in this range **and** the pool is expected to raise more than 3 feet after March 1.	2227-2234 feet msl	1827-1837.5 feet msl	1600-1607.5 feet msl
Scheduling Criteria	Avoid pool level decline during spawn period which ranges from April 15 – May 30	Schedule after spawn period of April 20 – May 20	Schedule after spawn period of April 8 – May 15

TECHNICAL CRITERIA FOR SPRING PULSES FROM GAVINS POINT DAM

<u>Criteria Applicable to Both the March and May Spring Pulses</u>

Flood Control Constraints	No change from current levels

<u>Criteria Applicable to the March Spring Pulse</u>

Drought Preclude	40.0 MAF or below measured on March 1.
Drought Proration of Pulse Magnitude*	None, 5 kcfs added to navigation releases, but no greater than 35 kcfs.
Initiation of Pulse	Extend the stepped System release increases that precede the beginning of the navigation season.
Rate of Rise before Peak	Approximately 5 kcfs for 1 day.
Duration of Peak	Two days.
Rate of Fall after Peak	Drop over 5 days to navigation target release.

<u>Criteria Applicable to Time Period Between the Bimodal Pulses</u>

Release	Existing Master Manual Criteria

<u>Criteria Applicable to the May Spring Pulse</u>

Drought Preclude	40.0 MAF or below measured on May 1.
Proration of Pulse Magnitude Based On System Storage*	Prorated from 16 kcfs based on a May 1 System Storage check; 100% at 54.5 MAF; straight line interpolation to 75% at 40.0 MAF.

Proration of Pulse Magnitude Based On Projected Runoff*	After the proration of the spring pulse magnitude for System Storage, the resultant magnitude would be further adjusted either up or down based on the May CY runoff forecast; 100% for Median; straight-line interpolation to 125% at Upper Quartile runoff; 125% for runoff above Upper Quartile; straight-line interpolation to 75% at Lower Quartile runoff; 75% for runoff below Lower Quartile.
Initiation of Pulse	Between May 1 to May 19, depending on Missouri River water temperature immediately below Gavins Point Dam. If possible, pulse will be initiated after the second daily occurrence of a 16 degree Celsius water temperature; however, the decision will be informed by the potential for 'take' of Threatened and Endangered bird species.
Rate of Rise before Peak	Approximately 6 kcfs per day.
Duration of Peak	Two days.
Rate of Fall after Peak	Approximately 30% drop over 2 days followed by a proportional reduction in releases back to the existing Master Manual criteria over an 8-day period.

<u>Spring Pulse Downstream Flow Limits</u>

Omaha	41,000 cfs
Nebraska City	47,000 cfs
Kansas City	71,000 cfs

* Spring pulse magnitudes will be determined by taking the difference between pre-pulse Gavins Point releases and the peak pulse Missouri River flows measured just downstream of the mouth of the James River.

Attachment A.5 – Procedures to Adjust Water Management Technical Criteria

Note: This attachment will be prepared by Water Management. Materials below are summary points already made in presentations to MRRIC.

The water control plan and technical criteria that guide the operation of the six mainstem reservoirs on the Missouri River, as well as their operation as a system are presented in a set of seven Water Control Manuals, one for each of the individual reservoir projects and the Missouri River Basin Mainstem Reservoir System Master Water Control Manual (Master Manual) for the entire system.

Policies and procedures for the preparation, review, update, and adjustment of water control manuals, including "master" water control manuals, are provided in the following USACE Engineer Regulations and Engineer Manuals:

- ER 1110-2-240 WATER CONTROL MANAGEMENT
- ER 1110-2-8156 PREPARATION OF WATER CONTROL MANUALS
- ER 1110-2-1400 RESERVOIR/WATER CONTROL CENTERS
- EM 1110-2-3600 MANAGEMENT OF WATER CONTROL SYSTEMS

Periodic updates and adjustments to the manuals are encouraged as a policy of the Chief of Engineers to ensure that the best use is made of available water resources. Actions are taken to keep approved water control plans up-to-date and plans are subject to continuing study. Consequently, water control manuals are revised as necessary to conform with changing requirements resulting from developments in the project area and downstream, improvements in technology, new legislation and other relevant factors provided such revisions comply with existing Federal regulations and established USACE policy.

Updates to the Master Manual or any of the Water Control Manuals for the individual projects that might be required as a consequence of the MRRP would be undertaken following the policies and practices outlined in the above references. These include requirements for public engagement in the process. Revisions to water control manuals that are administrative or informational in nature and that do not change the water control plan do not require public meetings (ER 1110-2-240). Conditions that require public involvement and public meetings include revision or update of a water control manual that changes the water control plan. These changes would also involve coordination with MRRIC as described in the sections below.

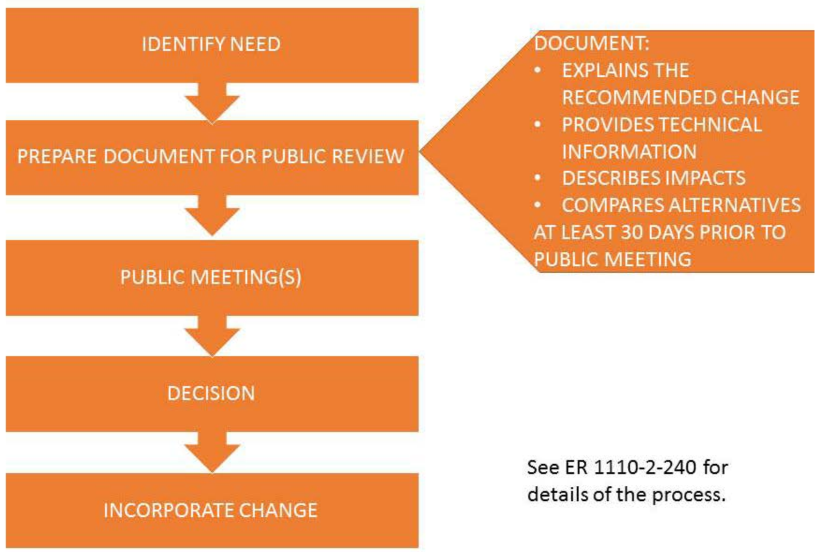

Figure A 1. Process for modifying the Master Manual.

Changes to the plan or manual would be prepared only after the associated public involvement process is complete. The USACE will provide information to the public concerning proposed changes at least 30 days in advance of a public meeting. A separate document(s) should be prepared that a) explains the recommended water control plan or change, b) provides technical information explaining the basis for the recommendation, c) includes a description of its impacts (both monetary and nonmonetary) for various purposes, and d) includes the comparisons with alternative plans or changes and their effects.

[Note: Remaining text under development.]

Attachment A.6 – Procedures for Adjustments to Significant Components of the AM Plan

Note: This attachment has not yet been prepared. It will address the process for adjustments to the MRRP AM Plan, including interactions with MRRIC.

Attachment A.7 – Agendas for Annual AM Workshop and the Fall Science Meeting

Note: This section is subject to change as plans for the Fall Science Meeting and AM Workshop are under development in collaboration with the AM ad Hoc.

Draft Agenda

MRRP Annual AM Workshop

XX-XX February, 20XX

Location

Day 1 (date)

I. Introduction and Purpose (Facilitator)
   a. Logistics and schedule
   b. Introductions
   c. Role of meeting within MRRP Process
   d. Purpose and expected outcomes

II. Status Updates
   a. MRRP – Multi-year and Annual Work Plan status; Current FY appropriations and President's Budget for FY+1 (MRRP PM)
   b. MR system –AOP; past & projected storage, run-off (WM)
   c. Updates to the Effects Analysis (EA Team Lead)
   d. Birds – existing conditions (ISP)
   e. Fish – existing conditions (ISP)
   f. Summary of major action items/lessons from Fall Science Meeting

III. Bird Session I – Status and Trends; What's happening?
   a. Context- Conceptual model
   b. Species monitoring, modelling and population trends
      i. Advances in monitoring
      ii. Advances in modelling and decision criteria

iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
iv. Performance towards objectives
v. Model predictions of trend

IV. Bird Session II – What are we doing, might do, shouldn't do?
a. Context- Conceptual model and hypotheses
b. Constructed Habitat Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
c. Flow Management Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
d. Other Actions (e.g. predator control; vegetation management; etc.,)
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments

V. Bird Session III - Research findings and new information
a. Report on Bird Research Activities
i. Research effort #1
ii. Research effort #2
iii. Etc.,
b. New Information
c. Needs Assessment, Research Prioritizations, Calls for Proposals

VI. Bird Session III - Synthesis: Progress Towards Objectives and Learning (ISP)
a. New Insights on Habitat
b. Learning About Actions; Answers to Original Big Questions and Hypotheses
c. Updates to Big Questions, Hypotheses, and CEMs

Day 2 (date)

VII. Pallid Sturgeon Session I – Status and Trends; What's happening?
   a. Context- Conceptual model
   b. Species monitoring, modelling and population trends
      i. Advances in monitoring
      ii. Advances in modelling and decision criteria
      iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
      iv. Performance towards objectives
      v. Model predictions of trend

VIII. Pallid Sturgeon Session II – Upper Missouri; What are we doing, might do, shouldn't do?
   a. Upper Missouri Big Questions, and Hypotheses
      i. Propagation Program Status of Implementation
      ii. Performance monitoring and evaluation
      iii. Possible adjustments
   b. Intake Dam
      i. Planning, Analysis and Design (Level 1 and Level 2)
      ii. Status of Implementation of Level 3 Actions
      iii. Performance monitoring and evaluation (including HCs)
      iv. Possible adjustments
   c. Other Actions (e.g. temperature control at Fort Peck; flow management; Lake Sakakawea drawdown, etc.,)
      i. Planning, Analysis and Design (Level 1 and Level 2)
      ii. Next Steps

IX. Pallid Sturgeon Session III – Lower Missouri; What are we doing, might do, shouldn't do?
   a. Lower Missouri Big Questions, and Hypotheses
   b. Propagation Program
      i. Status of Implementation
      ii. Performance monitoring and evaluation
      iii. Possible adjustments
   c. Channel Reconfiguration Actions (IRCs, Spawning Habitat)
      i. Planning, Analysis and Design (Level 2 and 3)
      ii. Status of Implementation of Level 3 Actions
      iii. Performance monitoring and evaluation (including HCs)

iv. Possible adjustments

d. Other Actions (e.g. Temperature control at Gavins Point; Flow releases; sediment management, etc.,)

i. Planning, Analysis and Design (Level 1 and Level 2)

ii. Next Steps

X. Pallid Sturgeon Session IV – Research and New Information (ISP)

a. Report on Pallid Sturgeon Research Activities

i. Research effort #1

ii. Research effort #2

iii. Etc.,

b. New Information

c. Needs Assessment, Research Prioritizations, Calls for Proposals

XI. Pallid Sturgeon Session V - Synthesis: Progress Towards Objectives and Learning (ISP)

a. New Insights on Habitat

b. Learning About Actions; Answers to Original Big Questions and Hypotheses

c. Updates to Big Questions, Hypotheses, and CEMs

Day 3 (date)

XII. Program Summary Results and Discussion (Facilitator)

a. Bringing it all together- actions

b. Bringing it all together- monitoring and research

c. Bringing it all together- species

XIII. Breakout Meetings (Team Leads)

a. Bird Team

i. Results in Context of system status and 5 year trajectory

1. Habitat
2. Flow
3. Monitoring- habitat, species, HC

ii. Concerns, learning, or new information

iii. Review of prioritized proposed actions and research

iv. Review of AWP and 5 year plan

v. Conclusions:

1. Action- up, down, same

            2. Flow- yes/no
            3. Research- continue/end, new start, rankings

    b. Fish Team
        i. Results in Context of system status and 5 year trajectory
            1. Habitat
            2. Flow
            3. Monitoring- habitat, species, HC
            4. Modelling
        ii. Concerns, learning, or new information
        iii. Review of prioritized proposed actions and research
        iv. Review of AWP and 5 year plan
        v. Conclusions:
            1. Action- up, down, same
            2. Flow- yes/no
            3. Research- continue/end, new start, rankings

Day 4 (date)

XIV. Close out Session (Facilitator)
    a. Bird Team Report out
    b. Fish Team Report out
    c. System Considerations
    d. Recommendations
    e. Next Steps

Draft Agenda

MRRP Annual Fall Science Meting

XX-XX October, 20XX

Day 1 (date)

I. Research Program IPR (ISP Manager)
   a. Report on Bird Research Activities
      i. Research effort #1
      ii. Research effort #2
      iii. Etc.,
   b. Report on Fish Research Activities
      i. Research effort #1
      ii. Research effort #2
      iii. Etc.,
   c. Report on System Research Activities
      i. Research effort #1
      ii. Research effort #2
      iii. Etc.,
   d. New Information

II. Day 2 (date)

III. Introduction and Purpose (Facilitator)
   a. Logistics and Introductions
   b. Role of meeting within MRRP Process
   c. Expected outcomes

IV. Status Updates
   a. MR system –AOP; past & projected storage, run-off (WM)
   b. Updates to the Effects Analysis (EA Team Lead)
   c. Review of scheduled activities in AWP

V. Bird Session I – Status and Trends; What's happening?
   a. Species monitoring, modelling and population trends
      i. Advances in monitoring

ii. Advances in modelling and decision criteria
iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
iv. Performance towards objectives
v. Model predictions of trend

VI. Bird Session II – What are we doing, might do, shouldn't do?
a. Context- Conceptual model and hypotheses
b. Constructed Habitat Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
c. Flow Management Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
d. Other Actions (e.g. predator control; vegetation management; etc.,)
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments

Day 3 (date)

VII. Pallid Sturgeon Session I – Status and Trends; What's happening?
a. Context- Conceptual model
b. Species monitoring, modelling and population trends
i. Advances in monitoring
ii. Advances in modelling and decision criteria
iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
iv. Performance towards objectives
v. Model predictions of trend

VIII. Pallid Sturgeon Session II – Upper Missouri; What are we doing, might do, shouldn't do?
a. Upper Missouri Big Questions, and Hypotheses

      i. Propagation Program Status of Implementation
      ii. Performance monitoring and evaluation
      iii. Possible adjustments
   b. Intake Dam
      i. Planning, Analysis and Design (Level 1 and Level 2)
      ii. Status of Implementation of Level 3 Actions
      iii. Performance monitoring and evaluation (including HCs)
      iv. Possible adjustments
   c. Other Actions (e.g. temperature control at Fort Peck; flow management; Lake Sakakawea drawdown, etc.,)
      i. Planning, Analysis and Design (Level 1 and Level 2)
      ii. Next Steps

IX. Pallid Sturgeon Session III – Lower Missouri; What are we doing, might do, shouldn't do?
   a. Lower Missouri Big Questions, and Hypotheses
   b. Propagation Program
      i. Status of Implementation
      ii. Performance monitoring and evaluation
      iii. Possible adjustments
   c. Channel Reconfiguration Actions (IRCs, Spawning Habitat)
      i. Planning, Analysis and Design (Level 2 and 3)
      ii. Status of Implementation of Level 3 Actions
      iii. Performance monitoring and evaluation (including HCs)
      iv. Possible adjustments
   d. Other Actions (e.g. Temperature control at Gavins Point; Flow releases; sediment management, etc.,)
      i. Planning, Analysis and Design (Level 1 and Level 2)
      ii. Next Steps

Day 4 (date)

X. Close out Session (Facilitator)
   a. Bird Team Report out
   b. Fish Team Report out
   c. System Considerations
   d. Recommendations
   e. Next Steps

Attachment A.8 – Fact Sheet Requirements/Template

Attachment A.9 – Requirements and Procedures for the Independent Science Advisory Committee

Attachment A.10 – Requirements and Procedures for External Peer Review

The objectives and general requirements for peer review are presented in Section 2.6.5 of the AMP. Quality Assurance and Quality Control (QA/QC) requirements are outlined in Section 6.5 of the AMP. This attachment specifies the requirements and procedures for Type I and Type II Independent External Peer Review (IEPR) not involving the use of the ISAP. Details regarding the use of the ISAP are presented in Attachment 12. The following references apply:

- ER 1105-2-100, Planning Guidance Notebook, 22 April 2000
- ER 1110-1-12, Engineering and Design Quality Management, 30 September 2006
- REF8008G, Quality Management Plan, 15 October 2002
- EC 1105-2-408, Peer Review of Decision Documents, 31 May 2005
- EC 1165-2-209 Change 1, Civil Work Review Policy, 31 January 2012
- Memorandum signed MG Don Riley, Peer Review Process, 30 March 2007
- 08502-CENWD-RBT EC 1165-2-209 Civil Works Review Policy Guidance, 29 September 2011

A.10.1. Requirements and Procedures for assembling an IEPR Panel

A.10.2. Requirements and procedures for conducting an IEPR

A.10.3. Reporting on an IEPR

[Note: Section to be completed]

Attachment A.11 – MRRP Health and Safety Requirements for Contractor Activities

Safety Requirements

Safety is the primary concern for all on-site activities. A government representative is required to monitor contractor activities from a QA viewpoint, including the contractor's safety program. Under the terms of the contract, Federal Acquisition Regulations (FAR) 52-212-3 Stop-Work Order clause of the basic contract, the contracting officer has full authority to require the contractor to take any steps deemed necessary for maintaining safe operating conditions.

The contractor is obligated by the terms of the contract to protect the lives and health of persons exposed to their operations and to safeguard property and equipment from accidental loss or destruction. All work must be performed in accordance with the safety and health provisions of the contract, Engineering Manual (EM) 385-1-1 (U.S. Army Corps of Engineers Safety and Health Requirements Manual), and federal, state, and local codes and standards. When a difference in standards exists, the most stringent standard applies.

In addition to being a contract requirement, a well-planned and conscientiously applied accident prevention program is essential to the efficiency, quality, and scheduling of work and the minimization of costs. The prime contractor is responsible for informing their subcontractors of the safety provisions under the terms of the contract and the penalties for noncompliance. The prime contractor is responsible for coordinating the work to prevent one craft from interfering with, or creating hazardous working conditions for other crafts, and inspecting subcontractor operations to ensure that accident prevention responsibilities are being fulfilled. Public safety is paramount, all sites must be secured from public access.

Unsafe practices will not be tolerated. Reckless behavior or disregard of safety and health requirements will not be tolerated on USACE projects. If any contractor employee endangers his own life, the lives of others or property by disregard of safety and health requirements, the contractor shall be informed of the employee and their unacceptable attitude/performance towards accident prevention. The contractor will be reminded of the contract requirements and be instructed to immediately resolve the problem.

Should a USACE employee identify an immediate endangerment to life or health, a Stop-Work Order may be issued. Situations in this category include, but are not be limited to, workers being crushed, buried, electrocuted, suffocated, thrown from moving equipment, falling, drowning, and being blown up. If any of the aforementioned safety concerns should arise, the following steps shall be taken; the PM or USACE employee(s) on-site will instruct the contractor to immediately remove workers from the area of danger or to desist from the dangerous operation or practice. If a representative of the contractor is not at the site, the PM or USACE employee(s) on-site will order the workers to remove themselves from the dangerous location or to cease the dangerous operation or practice. The PM or USACE employee(s) onsite will ensure that the work would not be resumed in the area of danger and that workers would not be involved in the operations or practices until recommendations for corrections had been complied with fully. Defective equipment will not be operated until all deficiencies are corrected and the equipment meets inspection and testing requirements.

Safety Reporting

It is necessary that the safety offices of both the NWO and NWK receive monthly contractor man-hours in order to determine the lost time frequency rates. This data will be required to be received telephonically, electronically, or by mail by the fifth of every month. The information needed will be the number of man-hours worked by the prime and subcontractors at any particular project for the previous month. The Safety Office of the Omaha District (CENWO-SO) will only need the total labor hours (not separated by contracts). The existing office safety plan will be used. Onsite personnel safety plans will be developed for each subprogram and included in the PMP. The Implementation PM for each USACE district will be responsible for ensuring these reports are completed in a timely manner.

Attachment A.12 – Cultural Resources Plan

Note: This attachment will reference appropriate policies, agreements, etc. (e.g., the 2004 Programmatic Agreement for operation and management of the Missouri river mainstem system for compliance with the national historic preservation act, as amended). It will also summarize key provisions as they pertain to implementation of the MRRP AMP.

Attachment A.13 – MRRP Program Management Plan

To be developed/provided by the USACE

Attachment A.14 - ISP Program Management Plan

Important components of an ISP Program Management Plan have been developed, at least in part, throughout the AMP. The AMP will now be used as a guide to revise the ISP PMP to ensure the ISP is structured to best serve the many adaptive management, agency, and stakeholder needs. Due to time constraints, other priorities, and need to develop AMP components first, this task has yet to be completed but will be completed in coming months by ISP staff with additional input from outside experts, agency leadership, and partners as appropriate.

Attachment A.15 the TPSN and the Independent Advisory Panel process

Third Party Science Neutral Support to Establish an Independent Science Advisory Panel for the Missouri River Recovery Program

Approved by MRRIC on July 21, 2010

Attachment A

ISP WG Involvement in ISAP Information/Presentation Requests

Approved by MRRIC on February 17, 2011

I. BACKGROUND AND INTRODUCTION

The US Army Corps of Engineers (Corps) - Missouri River Recovery Program (MRRP) are engaged in large scale ecosystem management on the Missouri River, with significant efforts to restore ecosystem functions and recover threatened and endangered species. This effort relies on collaborations with a wide range of governmental, academic, and private organizations that are working to deliver products, including extensive scientific analyses and syntheses. The Missouri River Recovery Implementation Committee (MRRIC), a group of 69 members representing various interests, tribes, and agencies, assists these efforts by developing recommendations for the agencies implementing the ecosystem management efforts.

The desire and need for well thought out science and independent scientific advice and recommendations to support decisions and directions taken by the Corps has increased, and is also desired by the MRRIC. As a result, the MRRP Integrated Science Program (ISP) is working to ensure the quality, completeness, and application of scientific information in use, and is following the Office of Management and Budget's "Final Information Quality Bulletin for Peer Review" (2005). This approach is also consistent with Corps civil works review policy guidance EC 1165-2-209.

This document describes the Corps' intent to establish a standing independent Science Advisory Panel for the MRRP and the MRRIC, utilizing the Third Party Science Neutral (TPSN) contracted by the US Institute for Environmental Conflict Resolution (USIECR), as a lead advisor for the management of scientific advisor selection, panel processes, and panel products.

General support tasks of the independent Science Advisory Panel could include but are not limited to the following:

- Synthesis of all available information on a specific topic which may include meetings with scientists, agency personnel and stakeholders and culminates in a written report providing independent advice and recommendations to the Corps or MRRIC.
- Scientific or technical services to gather, evaluate, and synthesize the best available information/data on a scientific topic resulting in a report to the Corps. Providing independent opinion and recommendations on the topics presented.
- Evaluation of scientific proposals and making recommendations on how to proceed.
- A standing program of independent opinions and recommendations for the overall MRRP-ISP.
- Assessment of documents (models, data, monitoring plans, management plans, and recovery actions) for contextual clarity and their application to a specific project planning effort, resulting in a letter report to the Corps.
- Responding to scientific questions from the Corps, USFWS, or MRRIC.

II. MRRP SCIENCE ADVISORY PANEL

1. A standing panel of up to 6 science advisors who will meet at least annually (and more often in the initial stages of setting up the panel and as required by specific scope of tasks). This panel will be charged with overall independent science support and technical oversight of the ISP program. In addition, the panel will be charged to provide advice on specific topics as needed. The general disciplines of expertise desired on the standing panel will be from the following areas of science including:
    a. Aquatic/Riverine Ecologist: Expertise in energy flow dynamics; flora and fauna community assembleges; river/floodplain dynamics; and knowledge of biological/physical drivers and processes.
    b. River Hydrologist/Geomorphologist: Expertise in dynamics of river and associated landforms; sediment dynamics/transport; large dryland river physical processes; and flow modeling.
    c. Least Tern/Piping Plover Specialist: Ornithological expertise in least tern and piping plover population dynamics; ecological threats; habitat, energy, and security requirements; and status of population and productivity within the interior population of least tern and Great Plaines population of piping plovers.
    d. Sturgeon Specialist: ichthyological expertise in scaphirhynchus sturgeon population dynamics; ecological threats; habitat, energy, and security requirements; knowledge of the current understanding of life history needs; and status of population and productivity within the pallid sturgeon range.
    e. Quantitative Ecologist/Statistician: Expertise in biostatistical methods, analytical tools, and the interpretation of ecological data sets; mathematical modeling; and presentation of complex analysis.

   f. Conservation Biologist: Expertise in ecological community interations with emphasis on large river form and function; restoration and recovery at the population/ landscape scale.

2. Ad hoc specialists may be added to the standing panel, as needed, to provide expertise not represented by standing panel members for a particular topic. These individuals would serve only for the duration of the topical study for which they are selected. The type of expertise needed may be identified by the Corps or MRRIC as they develop questions to be considered by the standing panel, or by the standing panel itself if it convenes around a topic and determines additional expertise is needed. In either case, the TPSN would select a candidate and potential alternates qualified in that expertise for the panel following the criteria and selection process for the standing panel.

3. Standing panel members are expected to commit to a three year term, renewable upon review by the TPSN.

III. SELECTION OF SCIENCE ADVISORS

1. When selecting science advisors, the TPSN shall comply with the National Academy of Science's "Policy and Procedures on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports" (2003) and the Office of Management and Budget's "Final Information Quality Bulletin for Peer Review" (2005). The TPSN shall strive to establish a panel of science advisors that demonstrates:
   a. Expertise. Varied knowledge, experience and skill.
   b. Balance. A diversity of scientific perspectives.
   c. No Conflict of Interest. No financial or other interest that impairs the panel's objectivity or gives an unfair competitive advantage to a person or organization.

2. The TPSN shall undertake a structured search process whereby they shall select science advisors that represent a broad spectrum of scientific expertise within their discipline and that have established high-caliber scientific credentials including:
   a. Widely recognized by peers for expertise in their field
   b. Strong publication record or record of scientific leadership
   c. Willingness to participate with objectivity and professionalism
   d. Track record of fair and unbiased, yet constructive, criticism
   e. Ability to function within a team and an interdisciplinary setting
   f. High standard of scientific integrity, independence, and objectivity
   g. Demonstrated ability to forge creative solutions to address identified topics or problems
   h. Knowledge and understanding of adaptive management process and application (represented in at least some members)

3. The TPSN will provide a proposed list of panelists for each position to the full MRRIC. The ISP Work Group (and any other MRRIC members who choose to participate), Corps, and USIECR will have the opportunity to review and collaboratively provide input (through a joint facilitated conference call or meeting) on the proposed panelists. All MRRIC members will also have the opportunity to provide comments to the ISP Work Group Points of Contact to bring into the conversations. The TPSN will select the standing panel members representing the general disciplines using the criteria identified above.

4. The TPSN shall recognize and provide clear direction to prospective panel members that the independent science advice/reviews required are scientific in nature and that decision making and policy interpretation are left to the Corps after consideration of any consensus recommendations from MRRIC.

IV. HOW THE INDEPENDENT SCIENCE ADVISORY PANEL WORKS

1. Task Orders/Charge Questions: Topics for the Science Advisory Panel may originate from either the Corps or MRRIC (or collectively). For each topic, initial charge questions will be drafted by the proposing entity for review and discussion. If the Corps develops the initial questions, MRRIC members will have an opportunity to provide questions they would like

addressed through the ISP WG for consideration as part of the initial questions to be presented to the Science Advisory Panel for their evaluation. Ideally, the ISP WG and the Corps will agree on the questions to be delivered to the TPSN. Where there is not agreement, both the ISP WG and Corps have the option to provide questions to the TPSN.

2. Charge Description: The description of the charge to the Science Advisory Panel shall be developed as follows:
    a. The TPSN shall expeditiously develop a proposal containing specific instructions to the science advisors including:
        i. Description of topic.
        ii. Expected products and ground rules for operation.
        iii. How panel deliberations will be conducted, either sessions open to the general public and/or restricted to only the panel; and how findings will be presented.
            1. The TPSN shall make the science advisors aware that key agency staff and members of MRRIC are available to provide input as necessary when requested by the panel.
            2. A panel chair (and/or the full panel if desired) shall present findings to MRRIC via video teleconference or at a regularly scheduled meeting.
        iv. Schedule/timeline.
    b. The ISP WG, USACE, and USIECR will review and collaboratively provide input on the TPSN proposed description of the charge.
    c. The TPSN will provide the final charge description to the MRRIC, USACE, and USIECR.

3. Implementation: In coordination with the Corps and the ISP WG, the TPSN shall schedule the review and coordinate all logistical issues associated with carrying out the panels' charge including, but not limited to, travel, facilities, equipment, facilitators, panelists, arranging for transcription of panel discussions (if necessary), and public access (as necessary). Also see Attachment A for additional information on ISP WG involvement in information and presentation requests from the ISAP.

4. Panel Chair: A panel chair will be chosen to ensure consideration of all technical matters amongst panelists and coalesce a final report. The method for choosing the chair will be determined by the panel members with the assistance of the TPSN. Possible options include, but are not limited to, a different chair for each topic, a chair for the full period of time, and a rotating chair.

5. Facilitation: The TPSN will facilitate selection of panel chair, all panel deliberations, external panel interaction, and report preparation and dissemination. The TPSN will also provide other project management duties including ensuring product completion per schedule and budget.

6. Standing Ground Rules: To facilitate consideration of multiple perspectives on the issues, a structured process has been developed to avoid bias and guide communications between Science Advisory Panel members and the Corps, MRRIC, and other interested parties including the public. The TPSN may add to or refine these in certain situations as necessary (see How the Independent Science Advisory Panel Works, 2.a.ii. above).
    - The TPSN will coordinate all contact between candidate or selected panelists and interested parties.
    - There will be no direct communication between interested parties and candidate or selected panelists, except as invited by the Science Advisory Panel through the TPSN.
    - All communication regarding the topics under consideration, between the Corps, MRRIC members, and candidate or selected panelists, will be coordinated through the TPSN. Communications between the Corps and/or MRRIC members and the candidate or selected panelists outside of the MRRIC process are inappropriate.
    - Questions or information received after the initial questions have been delivered to the Science Advisory Panel (including from the Institute's Independent Science Advisory Panel web site) will be routed to the Institute and TPSN. The Institute and TPSN will assess the information/ questions received. The TPSN will forward to the panel information and questions determined pertinent to the proceedings. To ensure the transparency of the process the Institute and TPSN will inform the Corps and ISP Work Group and MRRIC of any information/questions received and the disposition of these items.
    - During their deliberations, science advisors may access and reference any peer reviewed literature in their review deliberations and report(s). They also may reference other information that the panel deems credible, and include a copy of the other information with their report(s).
    - The panel may make on-site visits to gain understandings in topics being addressed and to see, first-hand, the challenges and successes.
    - During their deliberations science advisors may (through the TPSN) invite presentations and/or request information through the Institute from MRRIC including member agencies, Corps, or any source that they believe may be of value to their deliberations. The presenters and content of the presentations or information received will be included with their report(s).
    - Science advisors may recommend the need for ISR.
    - It is anticipated that the Science Advisory Panel will meet with the ISP WG and the Corps periodically during the advisory process and in some cases the MRRIC. These meetings will be open to MRRIC members and the public. Additional questions may be agreed to by the ISP WG/MRRIC and the agencies as the process iterates.

7. Interaction with MRRIC: The Science Advisory Panel will interact directly with the MRRIC at the beginning (soon after the charge is given to the Advisory Panel) of their work on a particular topic and when they are ready to present their draft report and recommendations.

The presentations and panel interaction with MRRIC will occur at a regular MRRIC meeting.

8. MRRIC Input/Recommendations: Once the Advisory Panel recommendations are final MRRIC will have the opportunity to develop recommendations on: 1) implementation of the Advisory Panel recommendations; and 2) the socio/economic and Tribal impacts from implementing the recommendations/alternatives presented by the Advisory Panel.

The MRRIC, Corps, the public, the Institute, TPSN, and candidate and selected advisory panelists will follow the above ground rules and communication protocols. The Institute and TPSN should be alerted to possible violations of the protocols, or to other undue biases or influences immediately. When the violations are related to a panel member's conduct, the Institute and TPSN will assess the situation and act accordingly and then the report back to MRRIC on disposition of the issue. If the violations are related to the MRRIC, the Charter and Operating Procedures will be used to address the situation.

V. FINAL REPORT

The Panel Chair shall be responsible for writing and editing any initial, draft, and/or final reports that are required under the task order. The TPSN should ensure that the report addresses all task order requirements, is thorough, and is understandable.

The TPSN shall deliver a final report. In general, the final report for each task order shall:

1. Summarize the goals and objectives of the charge to the panel, the process undertaken to select any additional advisory panel participants, the participants selected, a brief summary of their qualifications, the information considered by the panel, the exercises completed as part of the process, summary of panel discussion and the results.

2. Include an analysis of the findings including observations of the strengths and weaknesses of the findings and any dissenting opinions.

3. Provide independent opinions and recommendations regarding each task request or question as assigned.

4. Accurately present the views of the entire panel.

5. Be delivered in electronic format as a text selectable "pdf" file (portable document format created with Adobe Acrobat) within the dates established in the task order schedule.

VI. LITERATURE CITED

National Academy of Sciences. 2003. Policy and Procedures on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports. May 2003. Available online at: http://www.nationalacademies.org/coi/index.html

Office of Management and Budget. 2005. Final Information Quality Bulletin for Peer Review. December 16, 2004. Available online at: http://www.whitehouse.gov/omb/memoranda/fy2005/m05-03.pdf

Attachment A.15. Examples of decisions required for the MRRP

Examples of decisions needed for the MRRP, sorted by category or action type. For each decision, the step in the AM cycle in which it occurs is identified, and the typical recommending entity and primary decision level is indicated[1].

Category/ Action	Decision	Step in AM Cycle	Recommendi Entity
Plan design	What are the objectives?	Plan/design	USFWS
	What are the targets?	Plan/design	USFWS
	How will decisions be made?	Plan/design	Management
	What actions are included?	Plan/design	Management
	What are the criteria for implementing the actions?	Plan/design	Bird or Fish Tea
	What monitoring will be conducted?	Plan/design	Bird or Fish Tea
	How will research be prioritized?	Plan/design	Bird or Fish Tea
	How will learning be incorporated into decisions?	Plan/design	Bird or Fish Tea
	How will status and decisions be reported and communicated?	Plan/design	Bird or Fish Tea
	How will conflicts be resolved?	Plan/design	Management
Program-scale	How will resources be allocated to program components?	Adjust/continue	Bird or Fish Tea
	If objectives cannot be met, what are the implications for compliance?	Adjust/continue	Management
	How will flows be managed to meet objectives for both species?	Adjust/continue	Management/ Water Mgt.
Habitat construction	What are the criteria for implementing habitat construction?	Plan/design	Bird or Fish Tea
	How much new habitat should be constructed?	Adjust/continue	Bird or Fish Tea
	Where and how should it be constructed?	Adjust/continue	Bird or Fish Tea
	Should ESH be created using construction or flows?	Adjust/continue	Bird or Fish Tea
	Should construction be implemented with experimental design and/or additional monitoring to increase understanding?	Adjust/continue	Technical Team
	Should adjustments be made to project design due to unanticipated field conditions?	Implement	Bird or Fish Tea
	Should construction methods or design be changed to improve effectiveness?	Adjust/continue	Bird or Fish Tea

[1] Entities in the columns at the right are described in Section 2.3. The indicated entity/decision level is provisional – discussions are underway regarding these issues.

Category/ Action	Decision	Step in AM Cycle	Recommendi Entity
Non-routine flow modification[1]	What are the criteria for implementing non-routine flows?	Plan/design	Technical Team Water Mgt.
	If ESH is to be created using flows, what should the duration, magnitude, and timing be?	Adjust/continue	Technical Team Water Mgt.
	Will flows be implemented in a way to increase understanding?	Adjust/continue	Technical Team
	What additional monitoring and/or research will accompany a non-routine flow action?	Adjust/continue	Technical Team
	Should non-routine flows be changed or terminated during implementation?	Implement	Water Management
	Should non-routine flow releases be implemented in the same way (magnitude, duration, timing) in the future, or should they be adjusted to reduce impacts, increase effectiveness or improve learning?	Adjust/continue	Water Management; Technical Team
	Should non-routine flow releases be attempted more or less often as a result of past outcomes?	Adjust/continue	Technical Team Management
	Are there additional ways to improve the effectiveness of non-routine flow actions within the current constraints?	Adjust/continue	Technical Team Water Mgt.
	Should constraints on non-routine flow releases be increased or decreased?	Adjust/continue	Technical Team Water Mgt.
Routine flow management[1]	What are the criteria for implementing routine flow management?	Plan/design	Water Mgt.
	How will flows be managed during the nesting season to reduce incidental take (inundation of nests or chicks)?	Adjust/continue	Technical Team USFWS
	Will flows be implemented in a way to increase understanding?	Adjust/continue	Technical Team
	Should routine flow management be changed during implementation because of HC or species impacts?	Implement	Bird or Fish Tea Management
	Should routine flow management be implemented in the same way (magnitude, duration, timing, etc.) in the future, or should they be adjusted to reduce impacts or increase effectiveness?	Adjust/continue	Bird or Fish Tea
	Are there additional ways to improve the effectiveness of routine flow management within the current constraints?	Adjust/continue	Bird or Fish Tea Technical Team

[1] Decisions regarding reservoir releases are made by the USACE Northwest Division Water Management, and does so in accordance with guidance and criteria in the Master Manual and consistent with relevant policies, laws, and court decisions. Recommendations and/or analytical support from the Technical or Management Teams and public/stakeholder input are typical for non-routine flows, which are subject to Oversight approval.

Category/ Action	Decision	Step in AM Cycle	Recommendi Entity
	Do constraints on routine flow management needed to be increased or decreased?	Adjust/continue	Bird or Fish Tea Management
Habitat modification	What are the criteria for implementing habitat modification?	Plan/design	Technical Team
	Should current habitat be modified?	Adjust/continue	Bird or Fish Tea
	What habitat should be modified, and how?	Adjust/continue	Bird or Fish Tea
	Should modification be implemented with experimental design and/or additional monitoring to increase understanding?	Adjust/continue	Technical Team
	Should adjustments be made to project design due to unanticipated field conditions?	Implement	Bird or Fish Tea
	Should modification methods be changed to improve effectiveness?	Adjust/continue	Bird or Fish Tea
Population intervention[1]	What are the criteria for implementing population interventions?	Plan/design	Bird or Fish Tea Technical Team
	Should population interventions be implemented? Where?	Adjust/continue	Bird or Fish Tea
	Should population interventions include experimental design and/or additional monitoring to increase understanding?	Adjust/continue	Bird or Fish Tea Technical Team
	Should population interventions be made to implementation due to unanticipated field conditions?	Implement	Bird or Fish Tea
	Should population interventions methods be changed to improve effectiveness?	Adjust/continue	Bird or Fish Tea
Research	Should an active hypothesis be rejected?	Adjust/continue	Technical Team
	Should a reserve hypothesis be activated?	Adjust/continue	Technical Team
	Is additional basic research (demographics, behavior, habitat quality, etc.) needed?	Adjust/continue	Technical Team
	Should existing research programs be continued or should resources be used elsewhere?	Adjust/continue	Technical Team
Monitoring	Should the level of effort and/or protocols of the current monitoring program be changed?	Adjust/continue	Bird or Fish Tea
	Should additional monitoring be conducted beyond the existing program in the long term (current metrics are insufficient)?	Adjust/continue	Bird or Fish Tea
	Should additional monitoring be conducted in the short- or moderate-term because of unusual conditions or natural events?	Adjust/continue	Bird or Fish Tea

[1] i.e.., stocking, predator control, etc. See Sections 3.2.4.1.5 and 4.2.6.2 for additional descriptions.

Appendix B. Conceptual Ecological Models, Hypotheses, and Key Findings of the Effects Analysis

B.1. Overview

This appendix presents the Conceptual Ecological Models (CEMs) from the Effects Analysis (EA) for the MRRP and includes requirements for updates to the initial products. Updated information is presented in the first section of each chapter in the appendix. All updates are noted in the header. Note that only the diagrams for the CEMs are presented in this Appendix, the accompanying narratives in the EA reports provide important contextual information and the full suite of EA Products describe how the CEMs apply to other aspects of the science underpinning this AMP.

Buenau, K.E., C.J. Huber, V. Cullinan, and C.R. Vernon. In review. Draft Interim Effects Analysis Integrated Report; Piping Plovers and Least Terns. Pacific Northwest National Laboratory. Richmond, WA. October 2014 Draft.

Buenau, K.E., C.J. Huber, V. Cullinan, C.R. Vernon, and C. Huber. In review. Missouri River Effects Analysis Deliverable 2: Compilation of existing data, literature, and models for plovers and terns Pacific Northwest National Laboratory. Richmond, WA. October 2014 Draft.

Buenau, K.E., C. Aron, C.J. Huber, V. Cullinan, C.R. Vernon, C. Huber, J. Ledwin and T. Swannack. In review. Conceptual Ecological Models for Interior Least Terns And Piping Plovers on the Missouri River. Pacific Northwest National Laboratory. Richmond, WA. January 2014 Draft.

Fischenich, J.C., in review, Hydrologic, hydraulic, and geomorphic models and analyses to support the Missouri River Effects Analysis. ERDC Technical Report TR-16-X. Engineer Research and Development Center Environmental Laboratory. Vicksburg, MS. (In Review)

Fischenich, J.C., R. McComas, D. Meier, J. Tripe, D. Pridal, P. Boyd, S. Gibson, J. Hickey, T. Econopouly, and L. Strong. In Review. Habitat Analyses for the Missouri River Effects Analysis – Geomorphic Team Integrative Report. ERDC Technical Report TR-16-X. Engineer Research and Development Center Environmental Laboratory. Vicksburg, MS. (In Review)

Jacobson, R.B., Annis, M.L., Colvin, M.E., James, D., Welker, T.L., and Parsley, M.J., 2016, Missouri River *Scaphirhynchus albus* (Pallid Sturgeon) Effects Analysis—Integrative Report 2016: U.S. Geological Survey, Scientific Investigations Report 2016-5064, 154 p. 10.3133/sir20165064.

Jacobson, R.B., Parsley, M.J., Annis, M.L., Colvin, M.E., Welker, T.L., and James, D.A., 2016, Development of working hypotheses linking management of the Missouri River to population dynamics of

Scaphirhynchus albus (pallid sturgeon): U.S. Geological Survey, Open-file Report 2015-1236, 33 p. 10.3133/ofr20151236.

Jacobson, R.B., Annis, M.L., Parsley, M.J., James, D.A., Colvin, M.E., and Welker, T.L., 2015, Science information to support Missouri River Scaphirhychus albus (pallid sturgeon) effects analysis: U.S. Geological Survey, Open-file Report 2015-1226, 78 p. 10.3133/ofr20151226.

Jacobson, R.B., Parsley, M.J., Annis, M.L., Colvin, M.E., Welker, T.L., and James, D.A., 2015, Development of conceptual ecological models linking management of the Missouri River to pallid sturgeon population dynamics: U.S. Geological Survey, Open-File Report 2015-1038, 47 p. 10.3133/ofr20151038.

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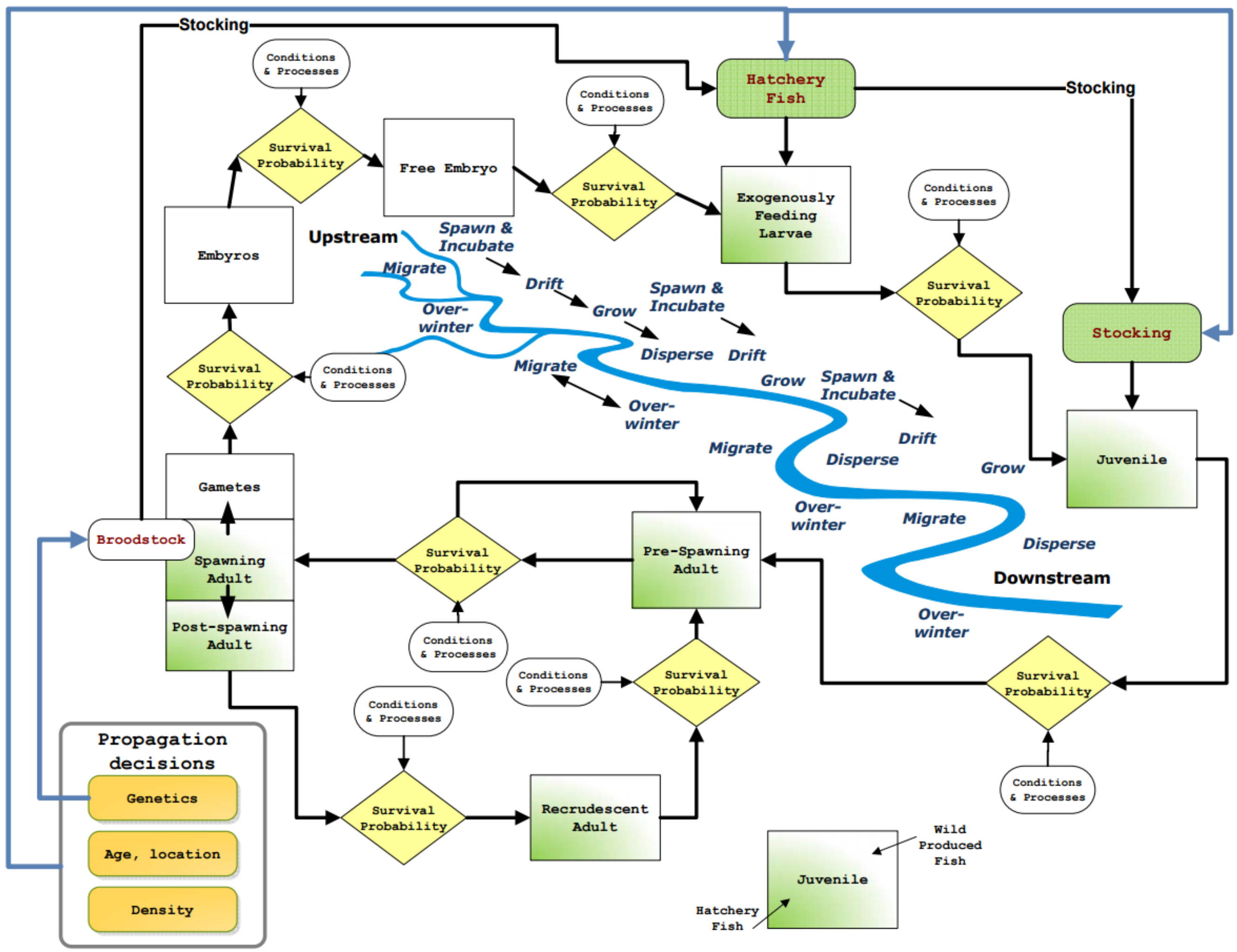
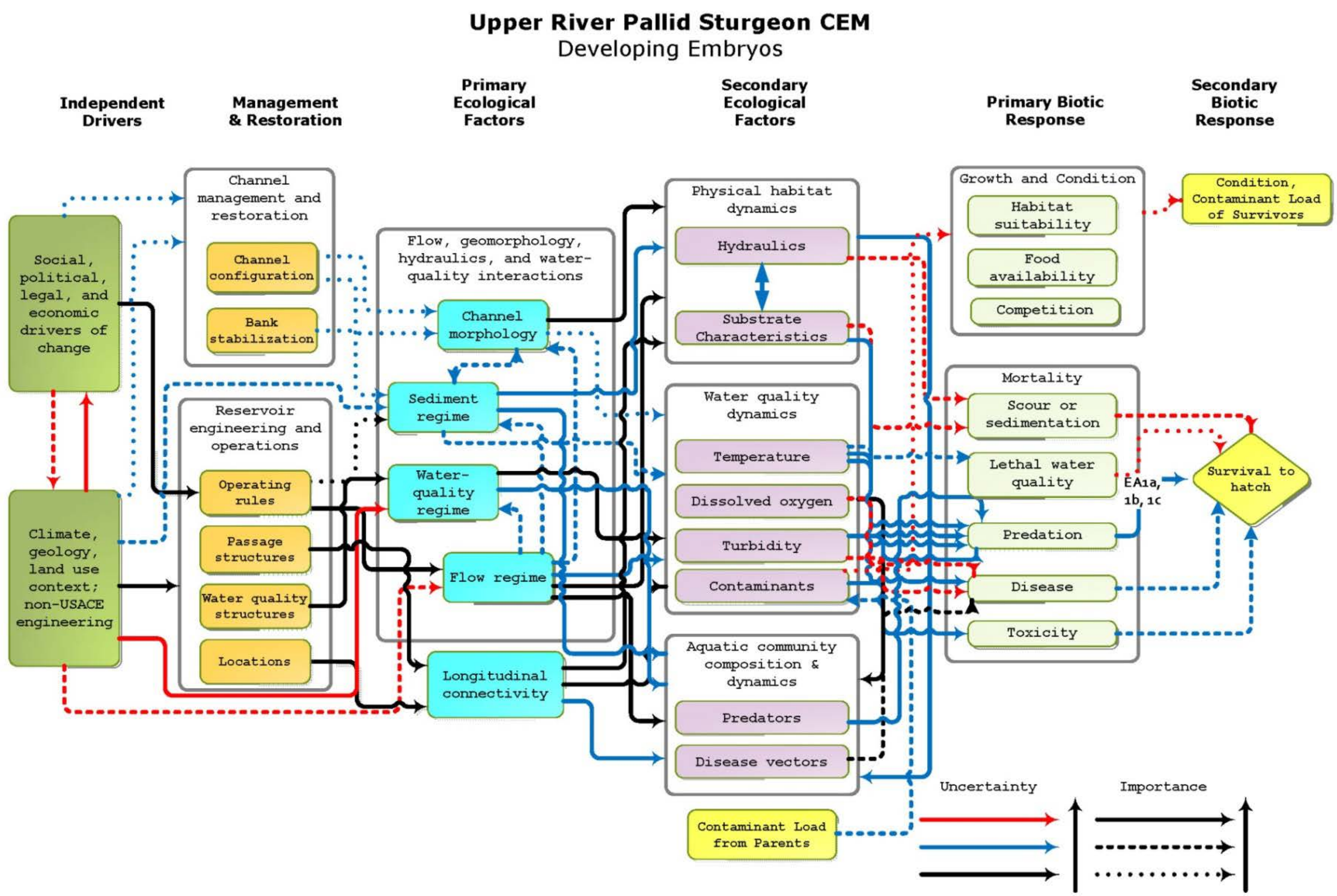
B.1 Pallid Sturgeon

Figure B 1. Population-level conceptual ecological model for pallid sturgeon. From Wildhaber et al (2007; 2011).

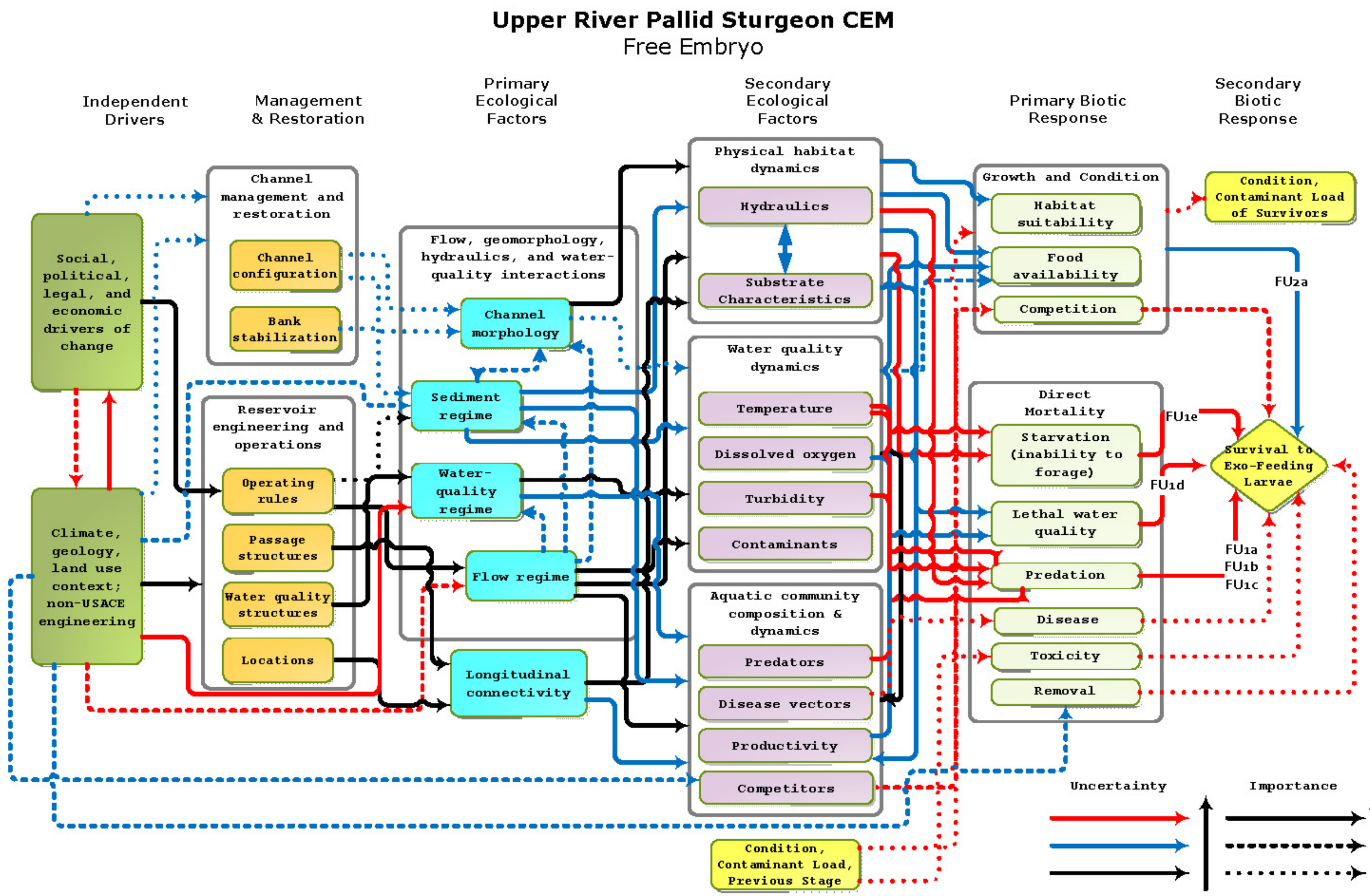


Upper River

Figure B 2. Upper River Pallid Sturgeon CEM – developing embryos.

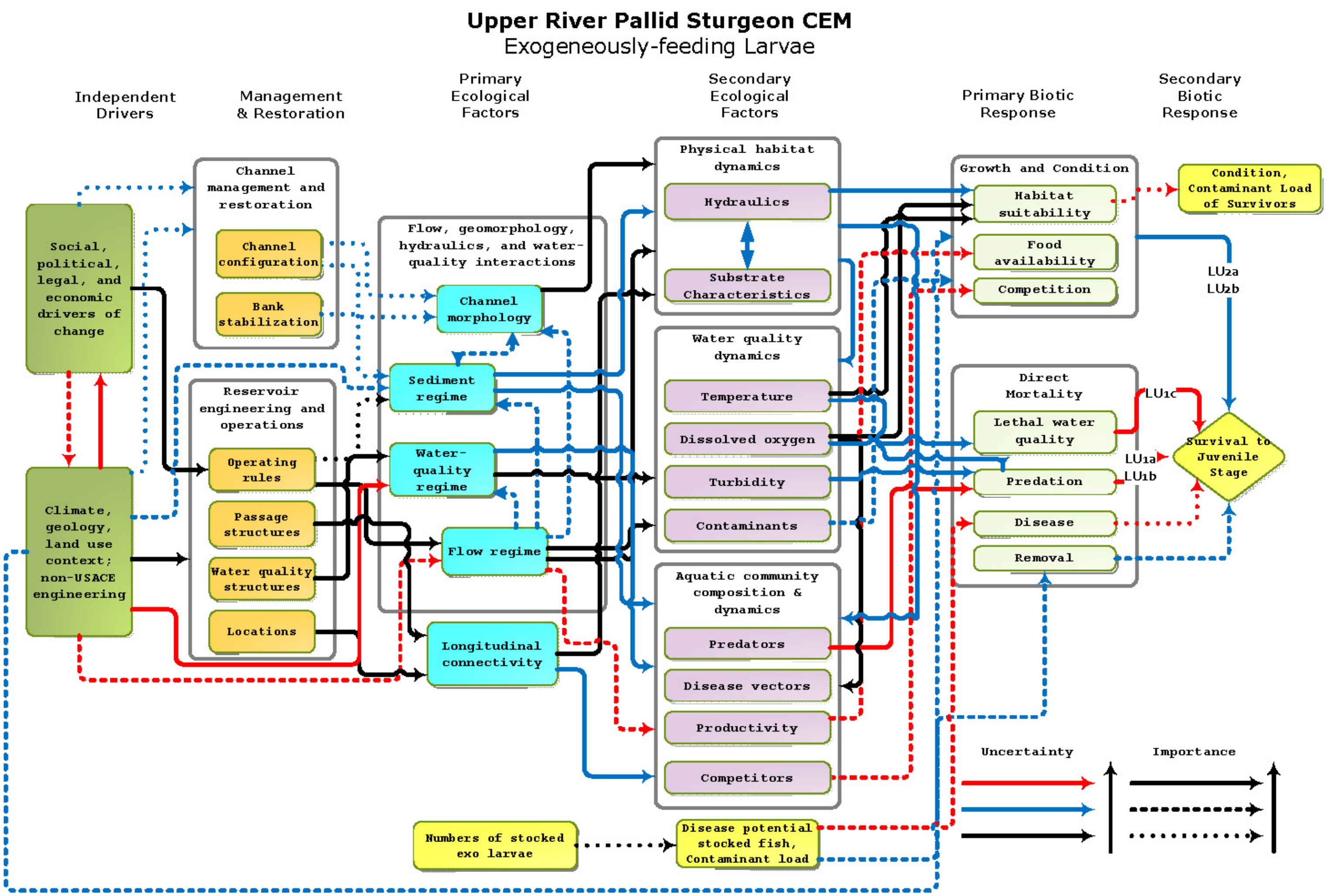


1 Figure B 3. Upper river pallid sturgeon CEM – free embryo.



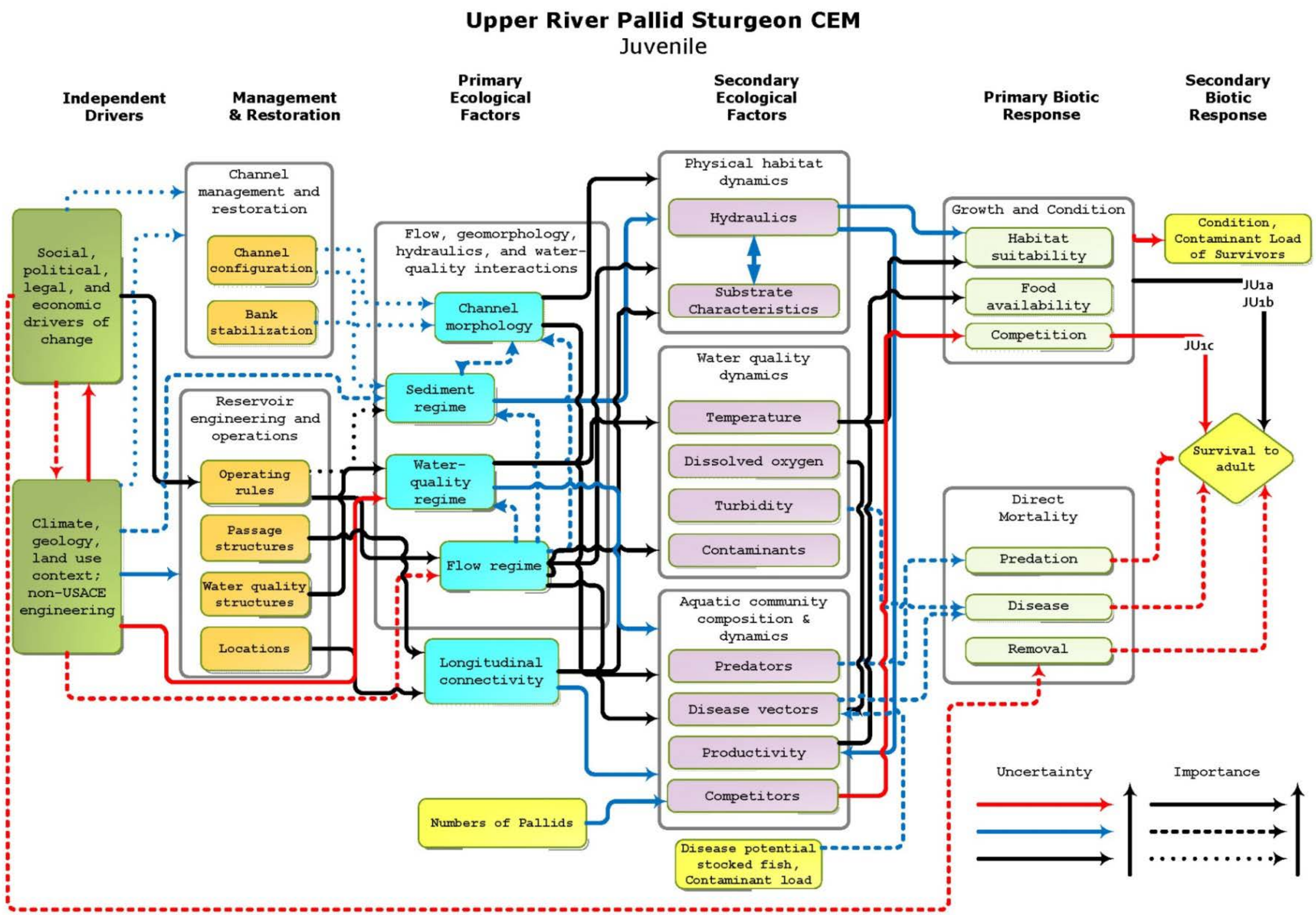
2

1 Figure B 4. Upper river pallid sturgeon CEM – exogenously-feeding larvae.



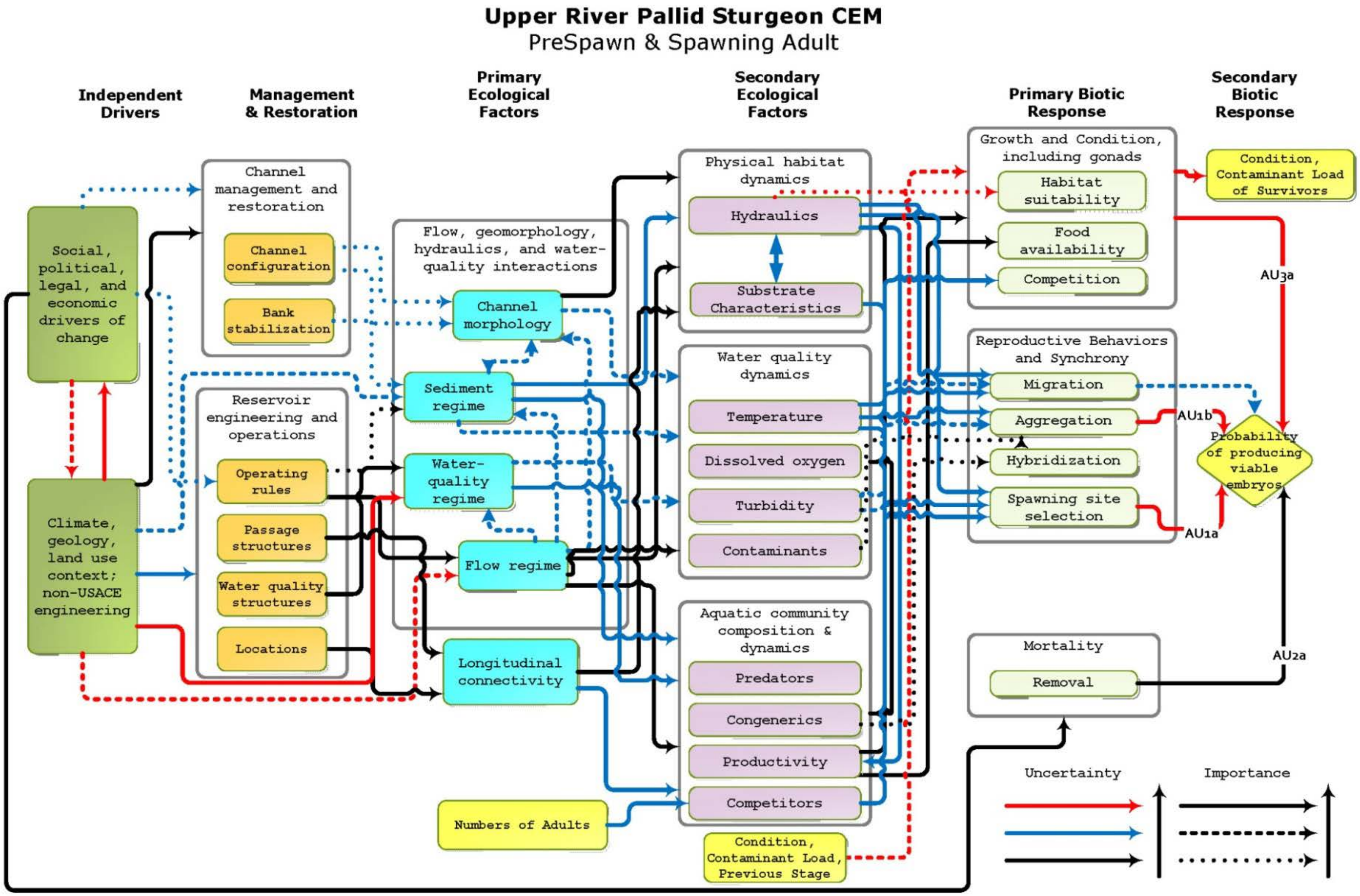
2

1 Figure B 5. Upper river pallid sturgeon CEM – juvenile.



2

Figure B 6. Upper river pallid sturgeon CEM – pre-spawn and spawning adult.



Lower River

Figure B 7. Lower river pallid sturgeon CEM – developing embryos.

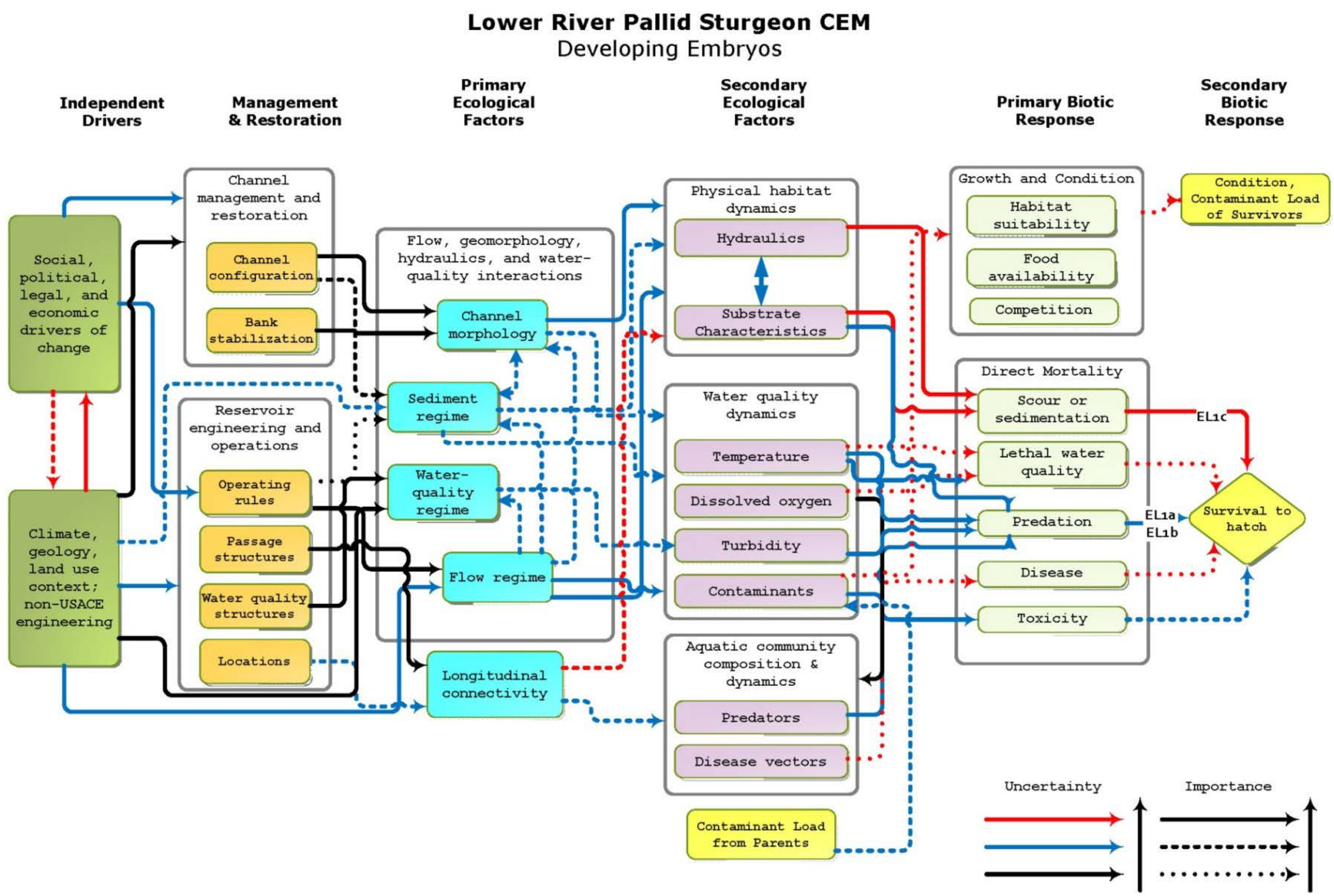


Figure B 8. Lower river pallid sturgeon CEM – free embryo.

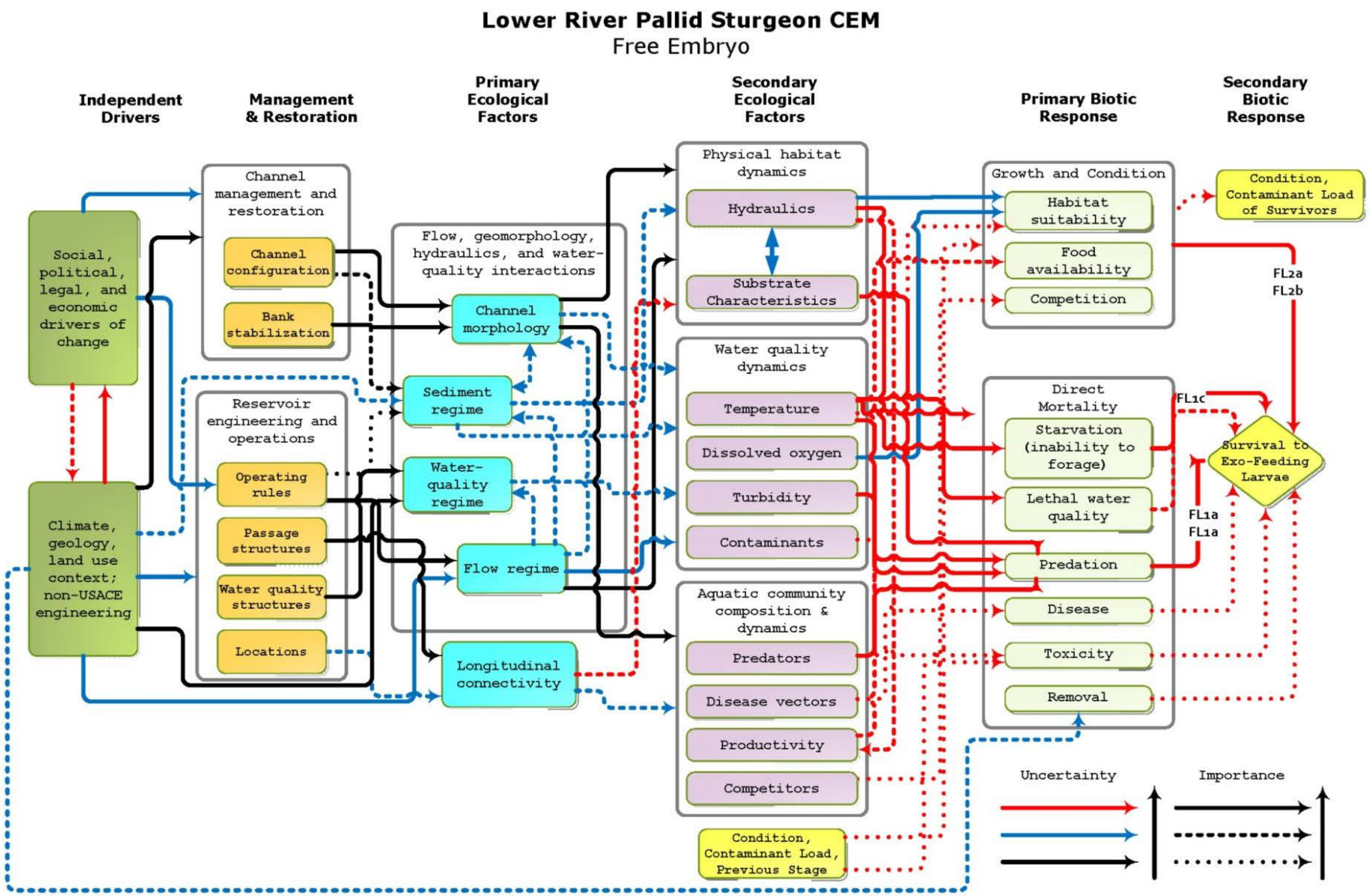


Figure B 9. Lower river pallid sturgeon CEM – exogenously-feeding larvae.

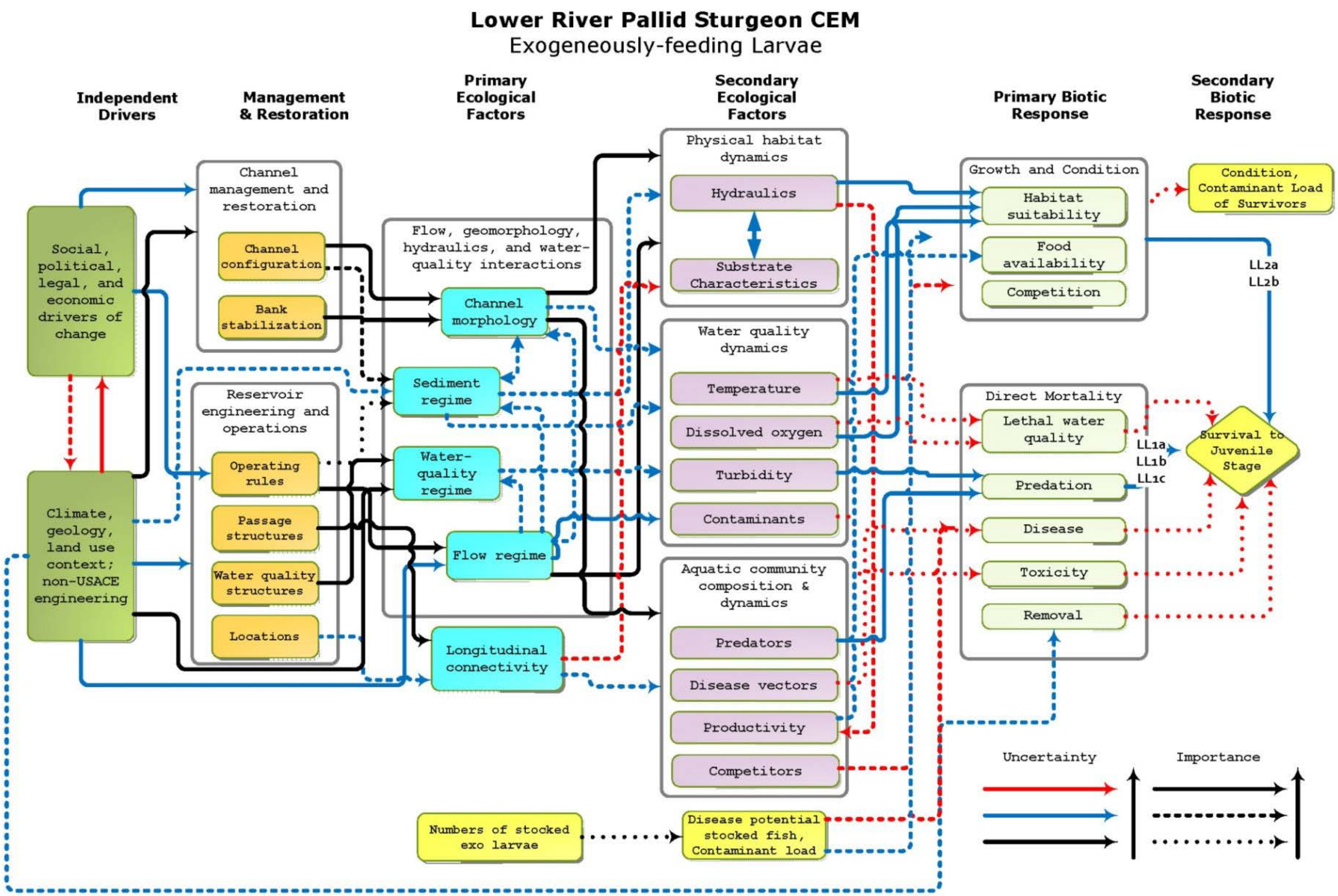


Figure B 10. Lower river pallid sturgeon CEM – juvenile.

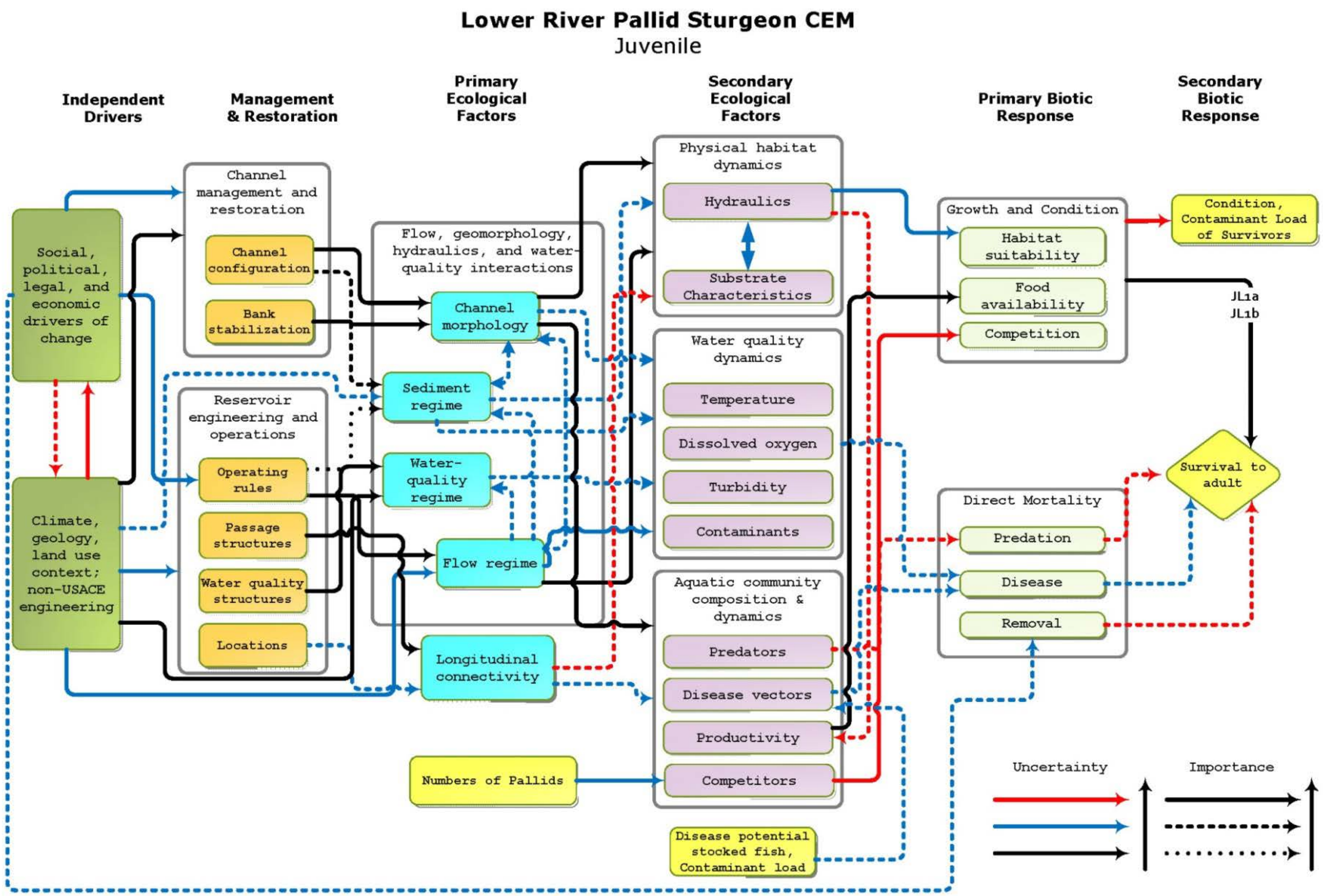
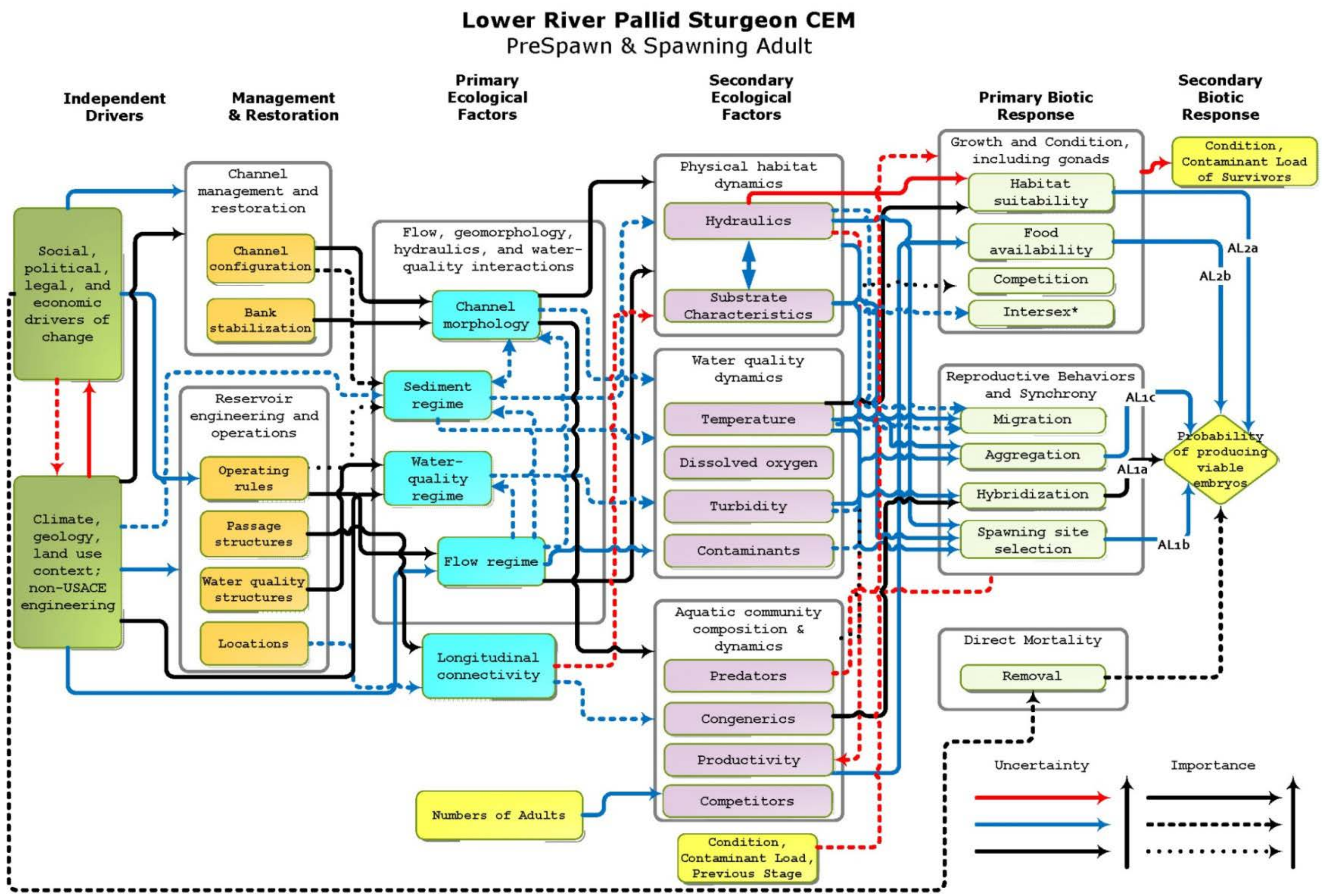


Figure B 11. Lower river pallid sturgeon CEM – pre-spawn and spawning adult.



1 ## B.2 Piping Plover CEMs

2 *Without Management Action*

3 Figure B 12. Piping plover ecological effects model (drivers → habitat) without management action.

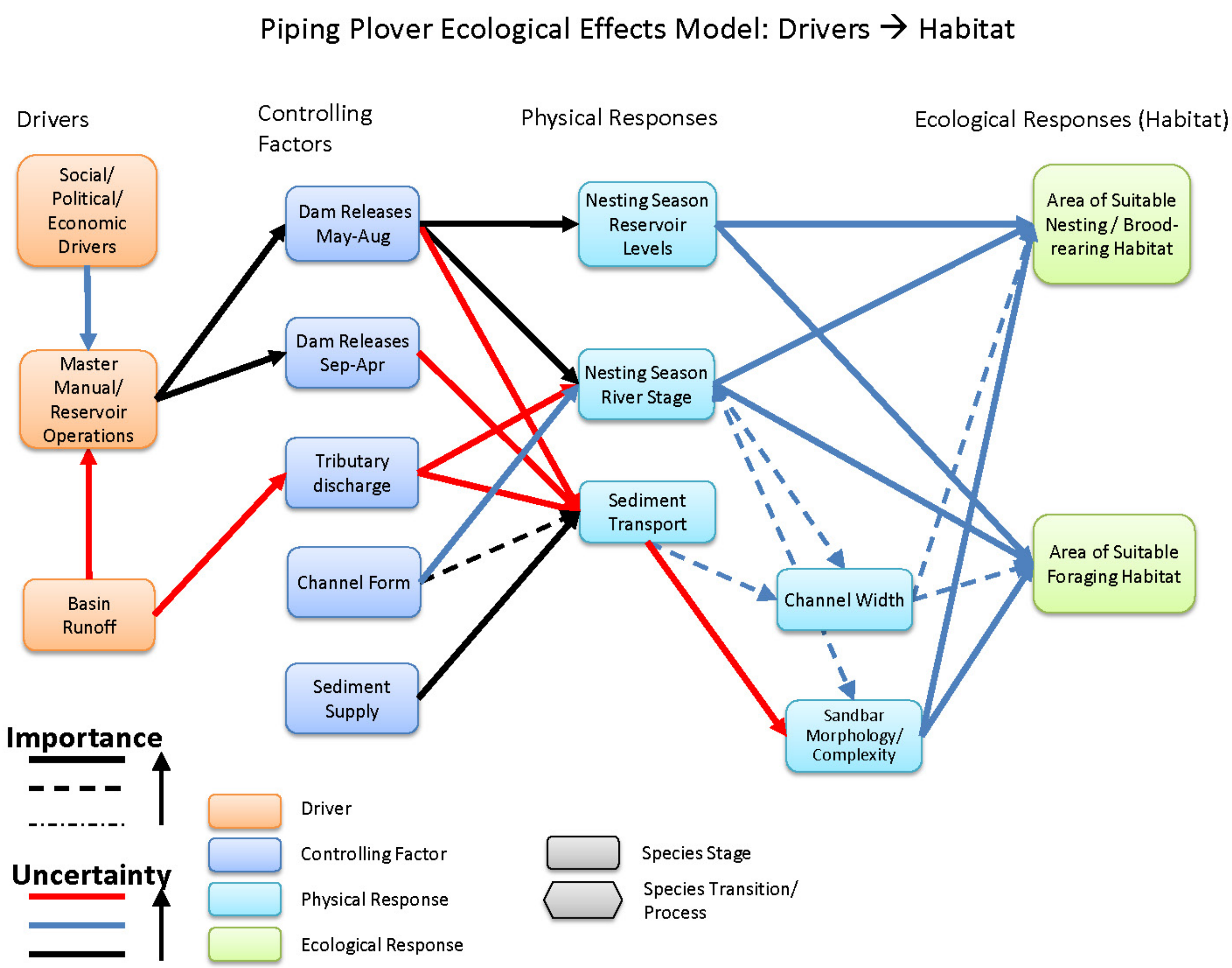
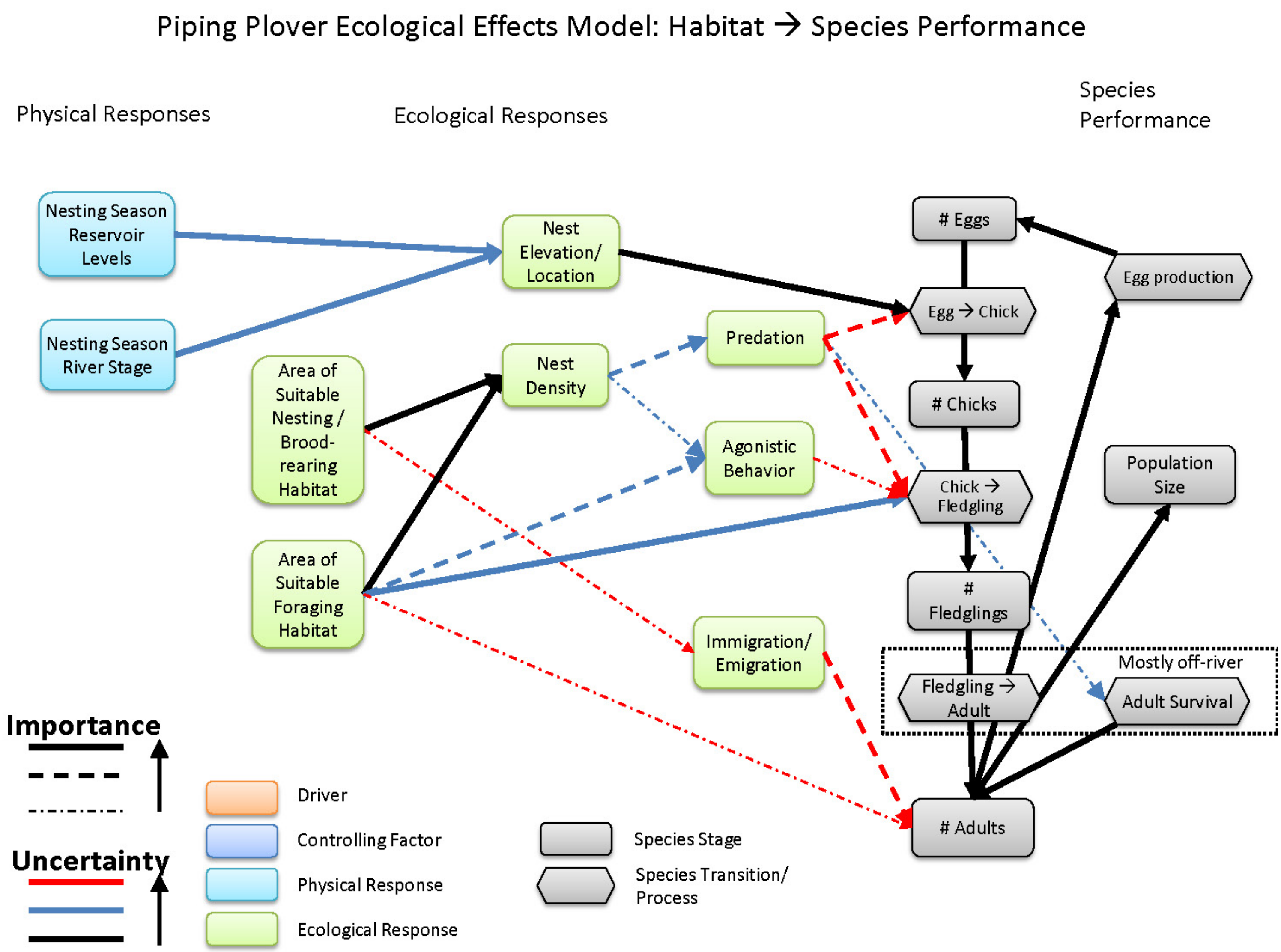
4 

Figure B 13. Piping plover ecological effects model (habitat → species performance) without management action.



With Management Action

Figure B 14. Piping plover ecological effects model (drivers → habitat) with management action.

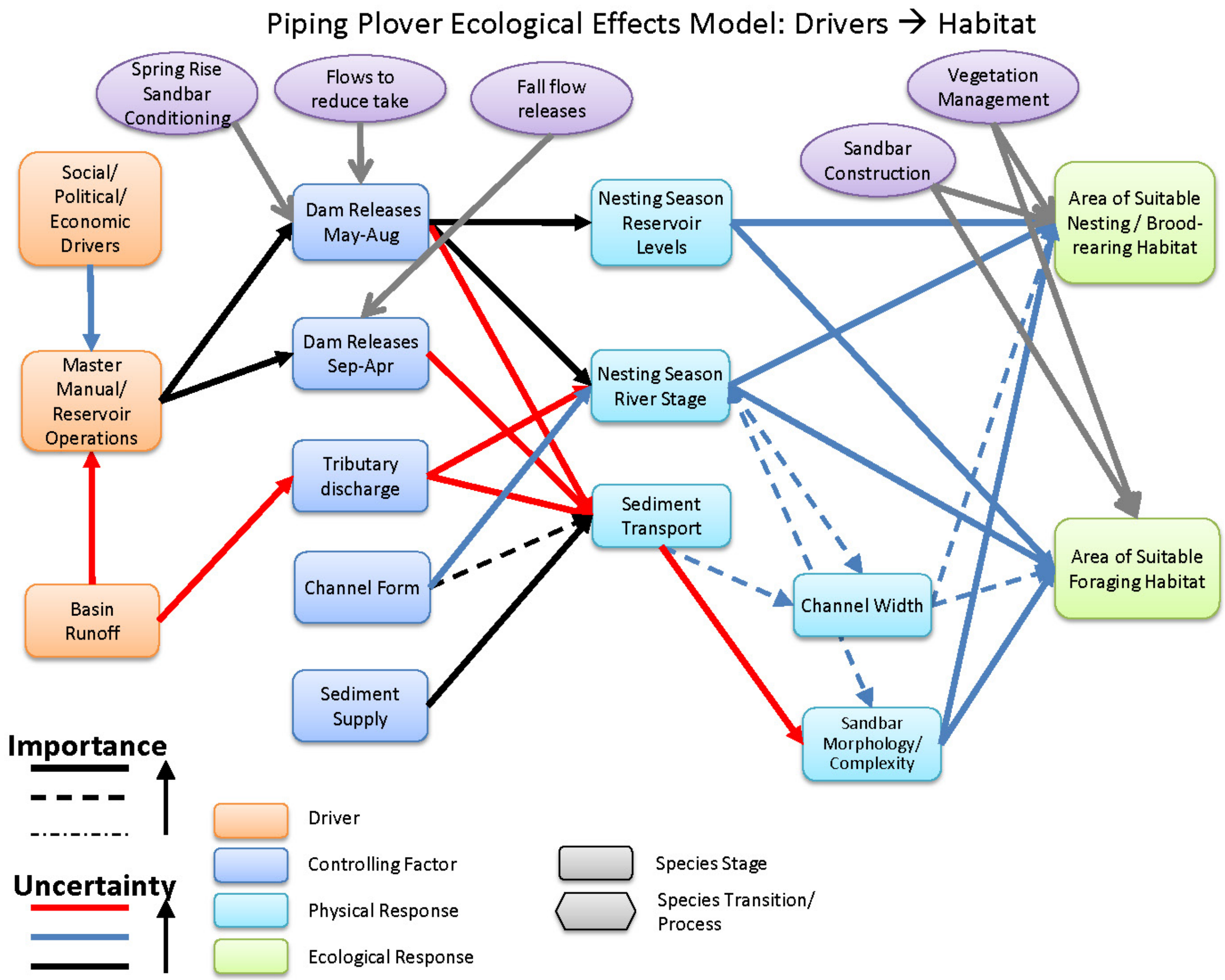
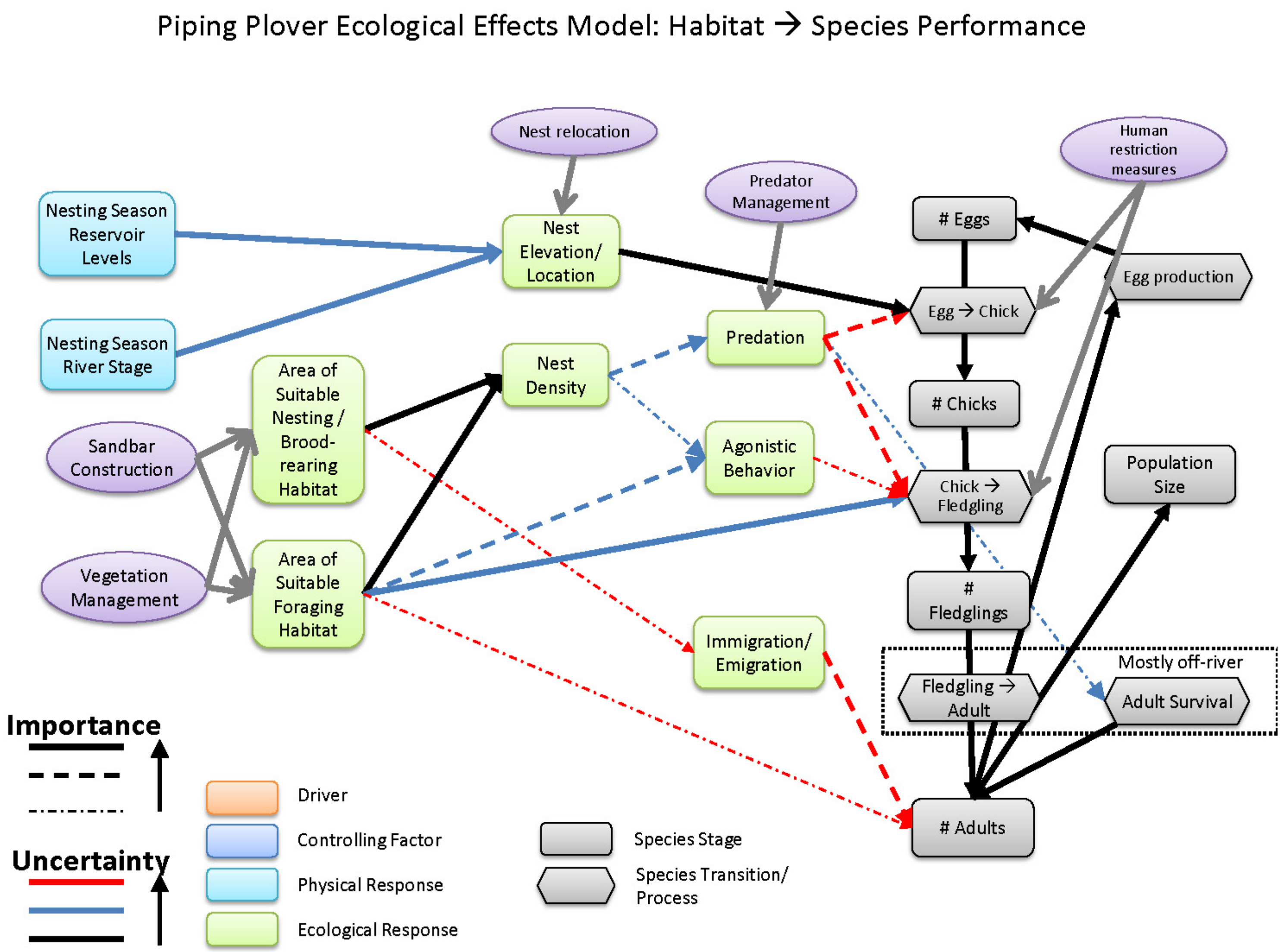


Figure B 15. Piping plover ecological effects model (habitat → species performance) with management action.



B.3 Least Tern CEMs

Without Management Action

Figure B 16. Least tern ecological effects model (drivers → habitat) without management action.

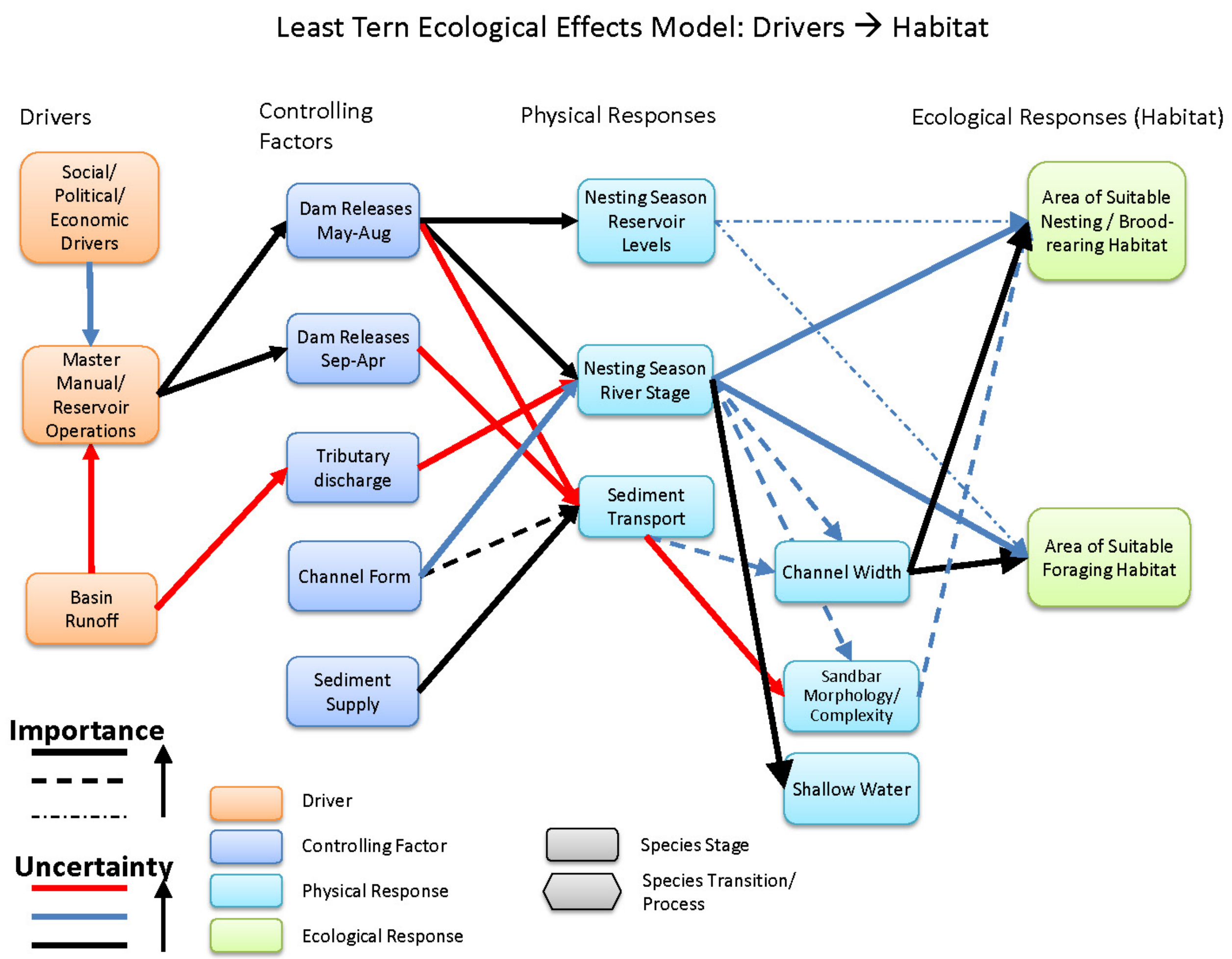
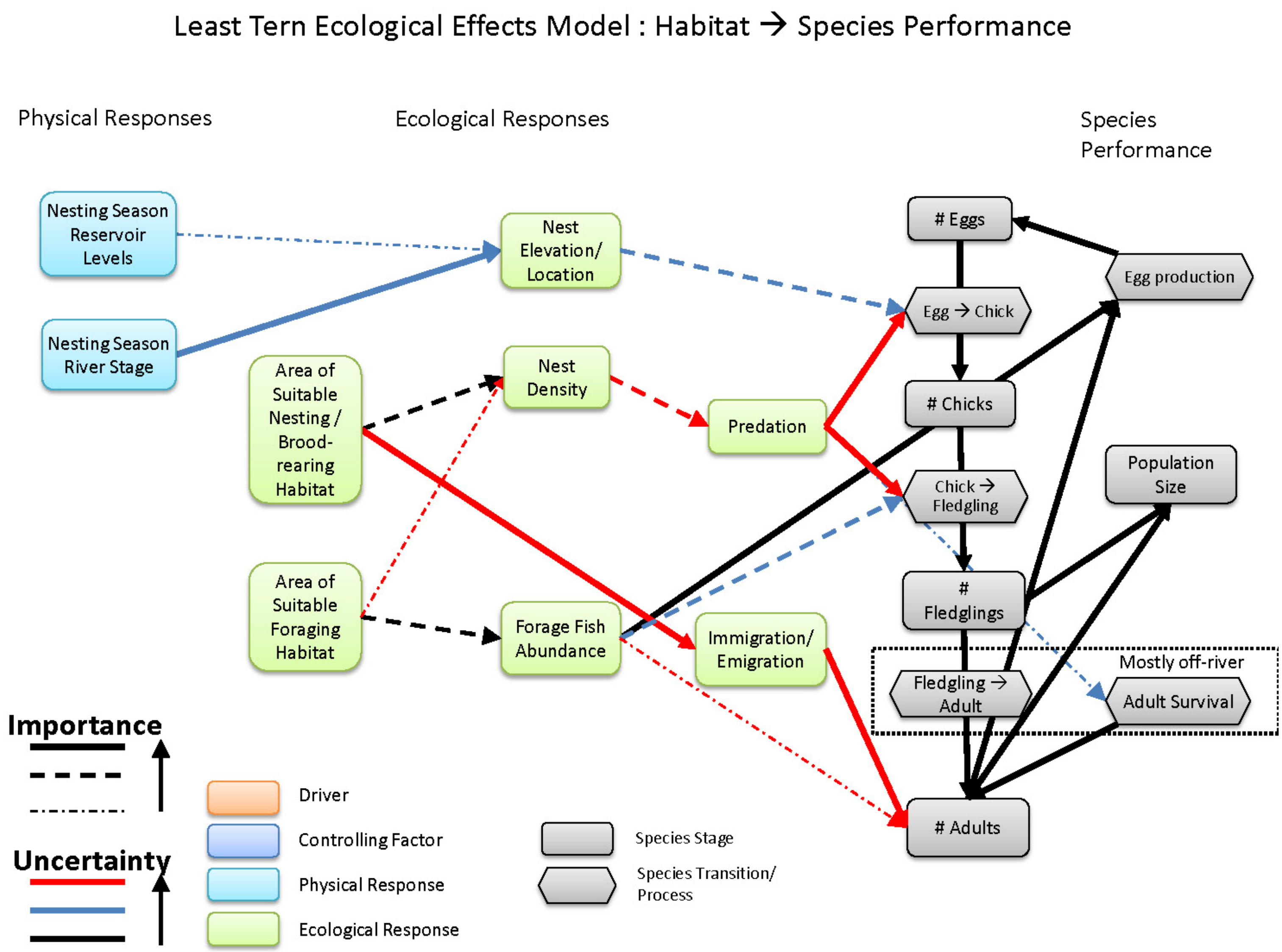


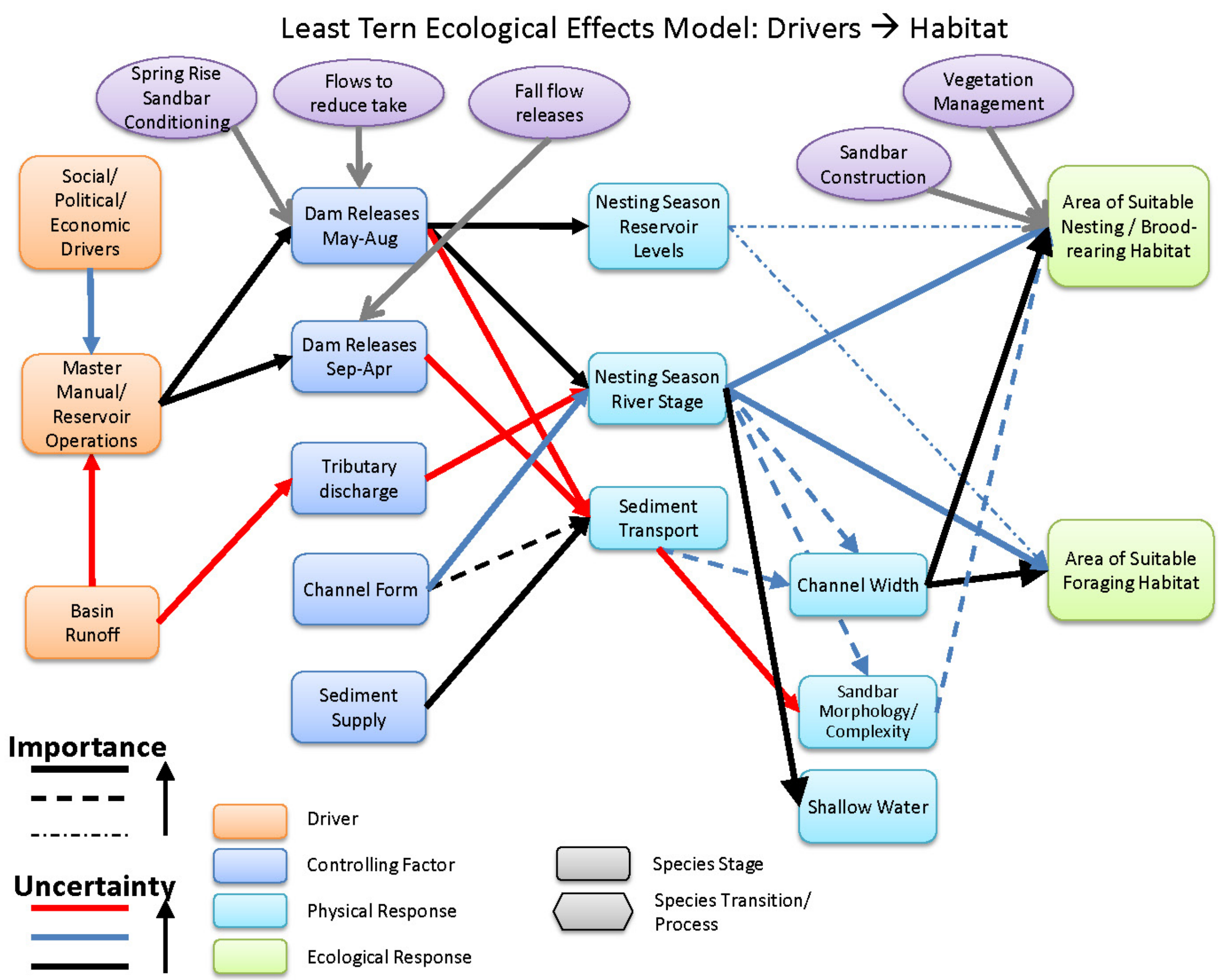
Figure B 17. Least tern ecological effects model (habitat → species performance) without management action.



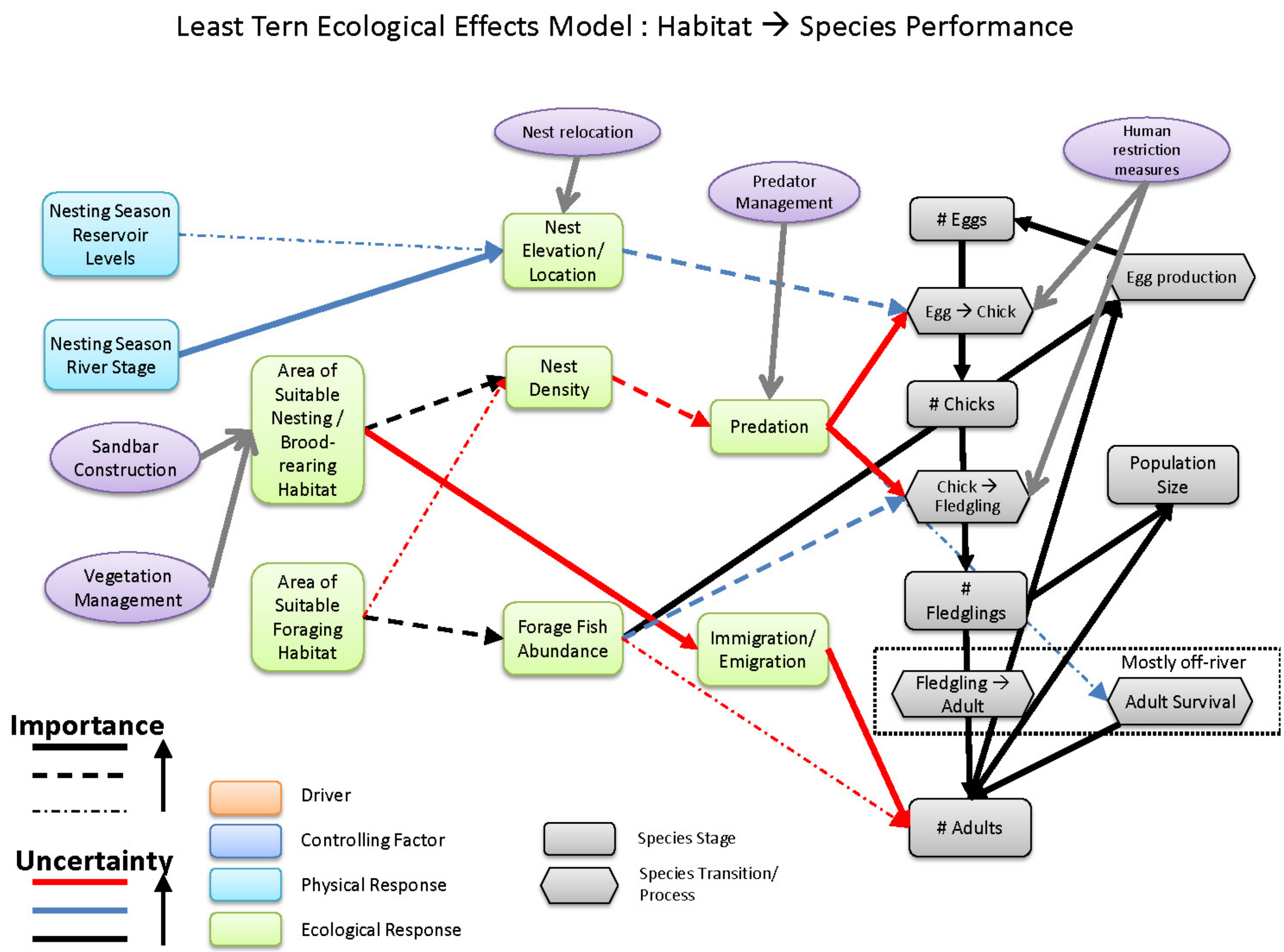
1 *With Management Action*

2 Figure B 18. Least tern ecological effects model (drivers → habitat) with management action.

3



1 Figure B 19. Least tern ecological effects model (habitat → species performance) without management action.

2 

B.2. Updating the CEMs

The CEMs are reviewed annually by the technical team and updates made as warranted. Updated CEMs are presented to the appropriate implementation team (i.e., bird team or fish team) and other attendees at the Fall Science Meeting or the AM Workshop. Reviews of any proposed changes are required from the ISAP. Pending the ISAP review and comments/recommendations from the appropriate implementation team, the proposed changes are presented to the MRRIC and the Agency senior leadership (USACE and USFWS) and discussed at the next MRRIC meeting. If approved at the Oversight level, the proposed changes are implemented and the revised CEMs are placed in this appendix, labeled as Updated and contain the approval date for reference.

Appendix C. Detailed Description of Level 1 and 2 Science Components for Pallid Sturgeon

C.1 Introduction

This appendix presents a series of scientific components intended to provide a foundation for the Adaptive Management (AM) of pallid sturgeon in the Missouri River. The components address the 21-hypotheses generated in the pallid sturgeon effects analysis (EA) (Jacobson et al. 2016a). These components provide an initial understanding of how management actions may affect pallid sturgeon recruitment and population dynamics.

The study components are broadly defined to address key information needs; however, the decision to pursue certain components, in certain sequences, will be based on evolving understanding, progress on competing hypotheses, trade-offs with socio-economic values, relevance to pending decisions, and estimated costs and benefits. Therefore, the components should be viewed as a set from which pieces can be selected as needed. The big questions and associated study components are not prioritized in this appendix and numbering does not reflect a priority or preference. A discussion about criteria for prioritization, a potential initial set of science components, and associated costs are provided in Appendix F.

This appendix is organized first by geography, separating the upper river and lower river, and then by *big questions*. For each big question, science components are provided for level 1 and level 2 (where level 1 is defined as *foundational research* needed to understand how pallid sturgeon populations will respond to a management action, and level 2 is defined as *field experimentation* to test efficacy of a management action). Additionally, study components are classified as:

- **Engineering/technology:** studies needed to a) develop technology to measure pallid sturgeon responses to a management action (e.g., new telemetry technology, new population modeling approaches) or b) develop engineering approaches to achieve the management action (e.g., engineering designs capable of increasing interception of drifting free embryos).

- **Biological screening:** studies to screen a management hypothesis for biological relevance (e.g., biological screening could describe a study to determine whether growth or survival of age-0 pallid sturgeon is food limited). These studies would proceed to quantify functional relationships between the management action and the population response; if not applicable, the management hypothesis might be placed in reserve until the biological relevance was established. Screening studies may include mining of existing data or establishing new studies to address whether limitations exist.

- **Level of biological effect:** studies to quantify the functional relationships between the levels of management action and biological responses (e.g., determine the level of change in survival per increment of food-producing habitat). Understanding the level of biological effect that a management action produces is critical to modeling and projecting the effects of management actions on the species.

In addition, biological-screening and biological-effect studies are classified by approach. Because the sturgeon life cycle is complex and critical parts of it involve very small fish in a fast, deep, and turbid river, improvements in scientific understanding are likely to require a combination of approaches. Approaches range from laboratory studies which provide highly controlled, but unrealistic conditions to field-gradient studies, which typically lack experimental controls and replication, but take place under realistic conditions.

- **Laboratory experiment** – a controlled experiment at the laboratory scale typically involves randomization and replication for statistical rigor and may include experiments to determine fundamental biological rates (e.g., rate of embryo development as a function of temperature) and behavioral experiments (e.g., drift studies in racetrack flumes).

- **Mesocosm experiment** – experiments outside of the strict controls of laboratories, but at less than field scale. Examples include experiments in controlled flume, stream, or pond environments. These conditions are incrementally closer to field conditions when compared to laboratory experiments; however, they lack the full dynamism of the field example and typically involve somewhat less statistical rigor and precision of measurements when compared to laboratory experiments.

- **Field-gradient experiment -** using existing measured gradients of hydrologic, geomorphic, and biotic conditions to identify and/or quantify biological effects. These experiments often substitute space for time, or for treatment level. Field gradient experiments take advantage of existing conditions and offer to provide results under realistic conditions; however, they often lack replication and statistical rigor. Gradient studies require care to reduce or eliminate effects of interacting variates.

- **Monitoring/assessment** – as used in this document, monitoring/assessment denotes data collection of physical and/or biological data, but not necessarily in a hypothesis-testing or adaptive-management framework (field experiments include hypothesis-driven monitoring/assessment in an adaptive management framework). Monitoring often provides critical contextual or covariate information, (e.g., water quality or discharge, or population indices or metrics).

- **Modeling** – numerical experiments with computational models to test sensitivity of habitats or population dynamics to changing parameter values and to explore system dynamics (e.g., using a well-calibrated population model to test population responses to variable stocking levels).

- **Field experiment** – manipulative field experiment to quantify responses to management actions and to test hypotheses (e.g., pulsed-flow experiments to elucidate effects of spawning cues, or controlled experiments on varied channel reconfigurations to document effects on foraging habitat availability). Although these are planned experiments, they fit the definition of quasi-experiment because they typically lack randomization, replication, and/or independence of treatments.

It is important to understand that biological-effect science components are designed ultimately to provide survival probabilities at critical life-stage transitions. Quantitative estimates of survival probabilities will be challenging to derive, but they are critical numbers needed to link management actions to population responses through the collaborative population model (Appendix D). Field-gradient studies and field-based experiments may provide useful information to evaluate aspects of performance of management actions, but laboratory and mesocosm experiments will likely be necessary to estimate associated survival probabilities.

Study components in the following sections are arranged by big questions that serve to group management hypotheses that require similar scientific approaches. Individual components (or discrete studies) are presented for level 1 and level 2 efforts for the upper river and lower river. The description of each component includes metrics, timelines and contingencies, and decision criteria for application of information from the component. For each big question, information is provided on critical uncertainties, utility of the component, risks, and associated adaptive actions.

The objective of this listing is to provide a general framework for the types and sequences of scientific studies that are envisioned for level 1 and 2 phases for the Lower Missouri River pallid sturgeon alternatives. The intent is for these studies, in aggregate, to provide the scientific foundation needed to implement an action, or actions, at level 3, which would be intended to create a positive population response. Information developed during level 1 and level 2 studies may indicate that some hypotheses are invalid and associated management actions should be dropped from consideration, or that new hypotheses and actions need to be developed to address pallid sturgeon population needs.

Level 3 monitoring and assessment are not included in this appendix; specific monitoring and assessment protocols for level 3 implementations will be included with descriptions of those implementations (e.g., in IRCs monitoring design in Appendix E). However, it is clear that knowledge gained in level 1 and 2 components will be useful in design of monitoring for many level 3 assessments by providing technical insights and by directing monitoring efforts toward the most effective metrics for evaluating process- and population-level responses. There will also be complementarity between population-level monitoring/modeling (Appendix D) and some efforts at levels 1–3. Metrics used at levels 1–3 should ultimately provide information to estimate critical population parameters (particularly survival of early life stages). Age-0 CPUE monitoring, envisioned as part of population-level monitoring, may also be designed to complement level 1 and 2 science components related to dispersal and retention of larval pallid sturgeon.

C.1.1 Decisions about quality of science information

As information is developed during implementation of level 1 and level 2 efforts, decision points will be reached where the AM program will need to determine whether to pursue alternate paths. Decisions might be:

- accept that the scientific information supports the hypothesized action and:
    - move to the next most important science question pending for each big question; or
    - move to implementation of level 3 actions intended to promote a measurable, positive biological response to the species;
- determine that the scientific information does not support the hypothesized action; and
    - refine the hypothesis and continue scientific investigations; or

- reject the hypothesis and promote an alternative hypothesis that better explains observed information.

In some science components, rigorous hypothesis testing may be possible, especially in well-constrained laboratory or mesocosm experiments. In this case, specific and quantitative decision criteria can be applied. When results are investigated in the field under realistic conditions, it is likely that statistically robust results will not be produced because of the inherent challenges in designing field experiments with sufficient randomization and replication. Under these conditions, a lines-of-evidence approach may be necessary in which multiple types of information are evaluated and judged. A lines-of-evidence approach may require a specific process for using experts to provide judgments in these decisions as well as independent review (e.g., ISAP).

C.1.2 Geographic areas

The geographic scope of the pallid sturgeon framework is the Upper Missouri River mainstem from Fort Peck Dam to the headwaters of Lake Sakakawea, the Yellowstone River upstream of the confluence with the Upper Missouri River for an unspecified distance (Figure C 1, Figure C 2), the Lower Missouri River mainstem from Gavins Point Dam to confluence with the Mississippi River at St. Louis, tributaries used by pallid sturgeon, and an unspecified distance downstream in the Mississippi River (Figure C 2). The geographic scope is constrained, in part, by decision-making authority of the USACE and in part, by present understanding of the geographic distribution of pallid sturgeon. The reservoirs and inter-reservoir reaches (from Lake Sakakawea to Lewis and Clark Lake) presently are excluded from the analysis based on the assumption that these habitats are unlikely to sustain reproductive populations of pallid sturgeon. The upstream distance on the Yellowstone River is unspecific because of limited knowledge about how far pallid sturgeon might migrate and whether they may use tributaries for spawning. The distance in the Mississippi River is unspecified because presently available information (2016) is ambiguous about the extent to which Missouri and Mississippi river populations mix through migrations and dispersal.

Figure C 1. Location of Upper Missouri and Yellowstone River segments.

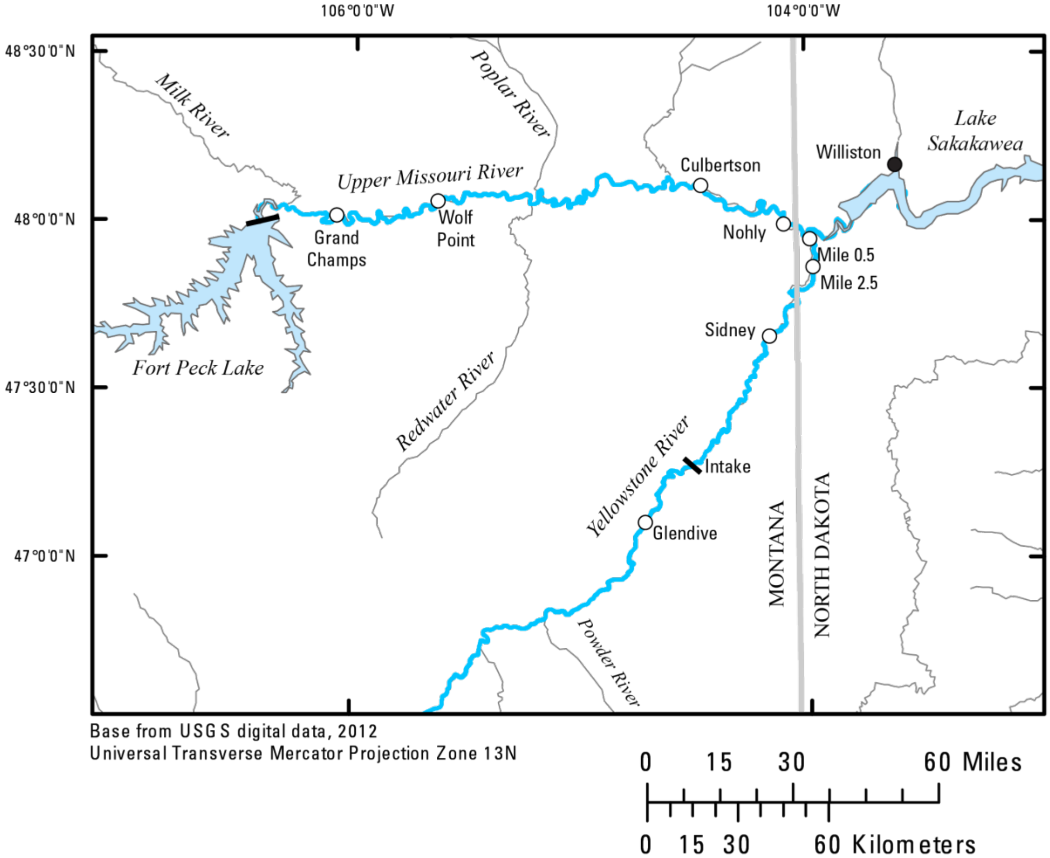
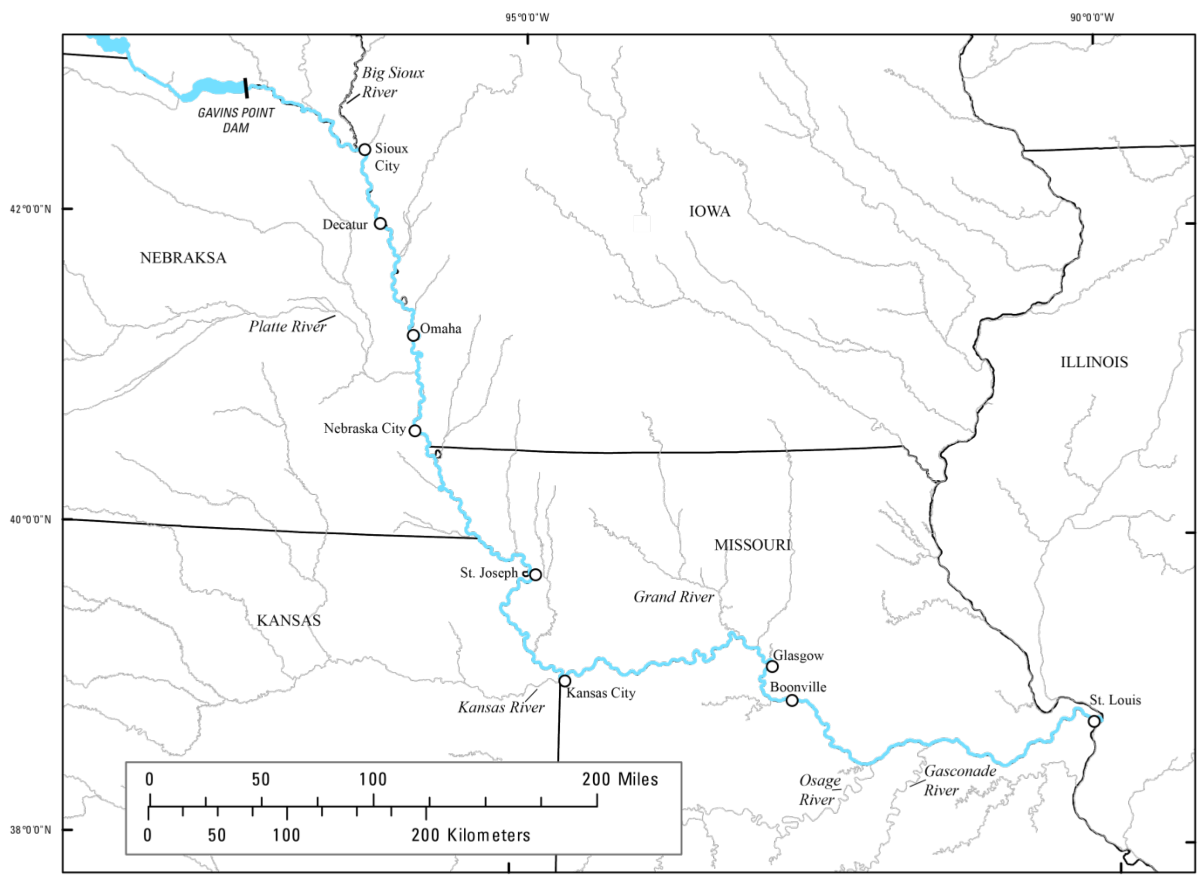


Figure C 2. Location map for the Lower Missouri River.



Base from USGS digital data, 2012
Albers Equal Area Projection

C.1.3 Breadth and staging of science components

The large breadth of components presented here represents a view of the information content necessary to inform management decisions. The components are designed to be decision-critical, cost effective, and flexible. In addition, the components are intended to develop sufficient understanding of cause and effect to support adaptive management of the river and the species. The selection of components is not prioritized in this appendix, but is instead presented as a superset of components from which prioritized components can be selected as required. An initial set of prioritized science components is presented in Appendix F.

The staging (sequence) of components and cost estimates, based on current priorities, are presented in Appendix F. This staging assumes that all level 1 components can be pursued effectively in parallel and level 2 components can be substantially overlapped in time, although level 2 components generally follow the completion of level 1.

The staging of science components has implications for costs and how information is developed to support decision making. In a purely sequential approach, science components would be staged and prioritized so the next component is only addressed when the previous ones have been completed with satisfactory results; that is, with results providing relevant information to frame the next component. In a parallel approach, multiple science components may be pursued simultaneously. The parallel approach involves more financial risk compared to the sequential approach in that it may expend resources on science components whose relevance could be negated by other components. Hence, the parallel approach would have higher annual budget needs than the sequential and could potentially be less cost effective. The parallel approach is less risky to the species, however, in that relevant information will be developed more rapidly and the more definitive field experiments of level 2 (and potential implementation of level 3) would occur sooner.

In general, the parallel staging scenario presented maintains a sequential approach to moving from level 1 to level 2. This recognizes the considerable cost that may be incurred with level 2 implementation of field experiments and the perceived need to justify that cost with strong support for hypotheses that are developed during level 1.

It should be noted that time frames estimated for the science components are highly contingent on what is learned and how rapidly. Some components that would require long time-intervals may be dropped from consideration if information indicates that the hypotheses should be rejected, whereas others may expand in time if the logistics of carrying out the science require it. Moreover, estimated total time required varies considerably among the hypotheses. Importantly, the decision criteria for ending science components are subject to considerable judgement concerning how reliable the information needs to be to either proceed or abandon a hypothesis. The need for judgement should provide ongoing flexibility for the management team to adjust the times devoted to these components.

Several significant management actions on the Missouri River are in progress or are near the completion of the planning process. These actions include some aspects of the shallow-water habitat program that correspond closely to the IRC concept, population augmentation, and the Yellowstone River Intake Diversion Dam Passage Project. This document assumes that although decisions have already been made to move forward with these actions (essentially at level 3), additional level 1 and level 2 science components are needed to backfill the scientific foundation of the actions. Although performance of these ongoing level 3 actions may be assessed using various monitoring metrics, the level 1 and 2 components are designed to impart more controlled, quantitative analysis of ecological processes than will be possible with monitoring of level 3 actions alone. The level 1 and 2 components will provide important cause/effect understanding to explain performance; such understanding is essential to design adaptive responses if performance is not as expected.

The Intake Passage Project presents a special challenge to staging and adaptive management because of the legal and multi-agency framework. The Intake Project is at least a level 3 implementation that was pursued with incomplete implementation of level 1 and level 2 components. For the purposes of this appendix, level 1 and level 2 components are presented that address fundamental, underlying science questions to help guide decisions related to the Intake Project. Chapter 4 of the main document presents a level 3 monitoring plan for the Intake Project that is intended to complement the Bureau of Reclamation Adaptive Management Plan (U.S. Bureau of Reclamation 2014) and extend relevance to decision making for the Upper Missouri River.

C.2 Upper River

The upper river refers to the Upper Missouri River mainstem from the headwaters of Lake Sakakawea to Fort Peck Dam, major tributaries to the Upper Missouri River, and the Yellowstone River and its tributaries for an undetermined distance upstream from the Yellowstone/Missouri confluence (Figure C 1). The level 1 and level 2 adaptive management actions are referred to below by upper big questions.

Upper big questions 1–6 relate mostly, or in part, to management actions on the Upper Missouri River that would be intended to increase natural recruitment of pallid sturgeon. At the same time, significant Federal action is underway on the Yellowstone River to increase fish passage at Intake Diversion Dam near Glendive, Montana. As documented in the EA, the prospect of successful passage around Intake Diversion Dam, combined with upstream migration of sufficient numbers of reproductive fish to suitable spawning habitat in the Yellowstone River or tributaries, is related to Upper Missouri management actions. If spawning occurs at locations in the Yellowstone that allow free embryos sufficient distance for transition to first feeding upstream of Lake Sakakawea, actions on the Upper Missouri River may not be necessary to recover the subpopulation. However, if passage on the Yellowstone is not documented to result in sufficient successful recruitment, there is a logical need to evaluate whether actions on the Upper Missouri River could increase probability for recruitment. These could include decreases in flows from Fort Peck Dam to decrease downstream transport rates, increases in water temperatures from Fort Peck Dam to increase developmental rates, drawdown of Lake Sakakawea to increase available dispersal distance, or some combination thereof.

Although contingencies based on evolving information might dictate a sequential approach to science components and eventual management actions, the staging assumed here (Appendix F) infers all level 1 components are simultaneous and will be followed by appropriate level 2 field experiments. Appendix F presents additional discussion of prioritization.

C.2.1 Upper big question 1; can spring pulsed flows from Fort Peck synchronize reproductive fish, increasing chances of reproduction and recruitment?

C.2.1.1 Objective of study components

The objective of these study components is to determine if water flow, or changes in flow, from Fort Peck Dam during the spring influences spawning behavior and successful reproduction of pallid sturgeon in the Upper Missouri River. The value of these study components would accrue in the event that recruitment from spawning on the Yellowstone River is not sufficient to sustain population size.

C.2.1.2 Description of study components

Water discharge is thought to influence pallid sturgeon migration behavior, reproductive readiness, and possibly spawning site selection prior to spawning. By providing attractant flows from the dam during the spring, reproductive pallid sturgeon may be cued to migrate in synchrony, leading to increased aggregations at spawning locations. This could increase the chances of successful reproduction.

C.2.1.3 Relation to Effects Analysis

These study components directly support EA hypothesis 2; attractant flow releases at Fort Peck will result in increased reproductive success through increased aggregation and spawning success of adults.

C.2.1.4 Approaches

Two levels could be implemented to test this hypothesis. Level 1 includes opportunistic field testing in the river and experiments in a constructed mesocosm in order to evaluate behavioral responses under more controlled conditions. Level 2 includes an engineering study to determine the associated effects of flow pulses and implementation of experimental flow releases to test fish reproductive behaviors.

C.2.1.5 Level 1

C.2.1.5.1 Component 1

This component is a technology development study to design, optimize, and implement a passive, fixed-station telemetry receiver network to complement intensive, boat-based tracking through the Upper Missouri and Yellowstone study area. The study is intended to support component 2 and upper big question 5 (drift/dispersal). This is delineated separately because of the potential challenges in design and implementation in the dynamic Missouri River system.

Metrics

Metrics for this technology development study will be; performance metrics for detectability of tags, variation of detectability with discharge-related characteristics, cost, and reliability.

Timelines and contingencies

The technology developed and tested in this component would contribute to the success and cost effectiveness of subsequent components (components 2 and 5) and will be especially useful in upper big question 5 (evaluate spawning locations). Development and testing could be accomplished in one year. It is expected to begin in 2017 under the parallel staging scenario.

Decision criteria for application of component

If testing proves successful, the decision may be made to deploy passive telemetry receivers in a network that will contribute to sample designs for evaluating sturgeon responses to flow pulses. Success will be determined by the ability to detect fish movements past strategic locations.

C.2.1.5.2 Component 2

This study component involves opportunistic monitoring of water discharge, pallid sturgeon movement, and pallid sturgeon location data. Flows would need to be measured continuously at multiple locations downriver from Fort Peck Dam and on the lower Yellowstone River. A range of opportunistic flows (low to high) would be needed to bracket ecologically ineffective and effective flows. Without intentional flow releases, variation between the Upper Missouri River and the Yellowstone River will still provide a strong experimental contrast. Pallid sturgeon in reproductive condition would need to be tracked via telemetry methods to determine movement patterns. Telemetry would include documenting reproductive behavior (aggregation, spawning) and spawning success as measured by production of free embryos. Statistical relationships of flow-regime components (e.g., mean discharge, change in discharge) and covariates (e.g., turbidity and temperature) to pallid sturgeon behavior would be evaluated.

Metrics

Metrics for this component will include the degree of association of reproductive migrations and successful spawning with monitored hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, and water quality). Extensive tracking by way of the passive telemetry network (component 1) will be complemented with intensive, boat-based tracking. Tracking information for reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes.

Timelines and contingencies

This component is an extension of existing research. This 8-year effort in understanding reproductive ecology of the pallid sturgeon has not been sufficient to associate reproductive success with hydrologic characteristics with confidence. More tagged fish, a longer record, more-intensive manual tracking, and a denser passive telemetry network will contribute to a significantly improved understanding of whether hydrologic links exist and are important to the pallid sturgeon population. It is anticipated that an additional 8 years of data collection will be necessary. Success of the study will depend in part on the development of passive receiver networks (component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program. This component would progress in parallel with component 1 and the mesocosm experiments in component 3.

Information on spawning locations collected in this component will be essential for evaluations of drift and dispersal under upper big question 5, as the spawning locations determine the upstream extent of dispersal. Tracking of reproductive pallid sturgeon on the Yellowstone River would be highly complementary to the monitoring and assessment of Intake Project performance.

Decision criteria for application of component

Based on past research, it is unlikely that this component will result in a statistically rigorous decision. Instead, a decision to accept information as useful to decision making will most likely be based on the judgement of multiple lines-of-evidence from components 1, 2, and 3.

C.2.1.5.3 Component 3

Many of the same aspects of component 2 would be measured in component 3 except at a smaller scale in a controlled environment. The objective is to develop a precise understanding of what characteristics of flow are instrumental in producing a fish response and how can those characteristics be optimized in flow releases from Fort Peck to draw fish up the Missouri River for successful reproduction. Possibilities for mesocosm experiments include very large circulating tanks, circulating ponds, or constructed side channels to the Missouri River. Mesocosm experiments would ideally vary water velocity, temperature, and turbidity (and rates of change) to evaluate behavioral responses of reproductive adults. Acoustic video and 3-dimensional telemetry arrays would allow for detailed characterization of behaviors.

Metrics

Metrics for this component will include the degree of association of reproductive behaviors with manipulated hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, and water quality). Intensive, fine-scale telemetry tracking data of reproductive adults (males and females) will be evaluated in trials with varying discharge, temperature, and turbidity. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes. The ultimate metric will be probability of successful spawning as a function of abiotic variables.

Timelines and contingencies

This component is anticipated to progress in parallel with field-scale telemetry in component 2, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Implementation of this component will require construction of a mesocosm (large flume or pond facility) that is capable of a creating a wide range of hydrologic and water-quality conditions; in addition, the facility will need to be large enough to accommodate multiple full-sized adult fish (see discussion of lower big question 2, component 3). This facility could be a semi-controlled side channel of the Missouri River or a highly controlled experimental flume similar to the USACE-ERDC cognitive fish flume (http://el.erdc.usace.army.mil/emrrp/nfs/facilities.html). The mesocosm studies are identical with those discussed under lower big question 1, component 3.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to accept information as being useful in decision making and moving forward to level 2. Controlled mesocosm studies may provide statistically rigorous results indicating the presence or absence of hydrologic effects on reproductive success and the strength of any association that exists. Such information would likely be an incomplete assessment of field-scale conditions; and therefore, would be evaluated in a lines-of-evidence approach along with component 2 information.

C.2.1.5.4 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is, or is not, a likely relation between actionable hydrologic characteristics and reproductive success. The judgement should be based on the strength and replicability of relations between flow pulses (and associated water quality characteristics) and reproductive migrations, spawning, and spawning success demonstrated by capture of free embryos.

C.2.1.6 Level 2

Although level 2 components are included in this compilation, they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.1.6.1 Component 4

In anticipation of intentional experimental flow releases in component 5, an engineering study may be implemented to evaluate effects of experimental flow releases for other impacts such as bank stability and flood control. This study would also be used to design monitoring of ancillary effects during intentional flow releases.

Metrics

Metrics for this component will include measures of the effects of flow pulses on other authorized purposes. Some of the elements of these studies will have been developed in earlier planning efforts, such as human consideration proxies and metrics in the MRRMP-EIS. New studies on the specific effects of the experimental releases will provide similar metrics (e.g., days above flood stage), but specific to the planned experiments.

Timelines and contingencies

This component is expected to take 2 years and is contingent on completing all of the level 1 analyses so the results of the experimental design parameters can be evaluated. Although this experiment is included in this compilation, it is not currently planned for implementation (the timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first).

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 5. That decision will be based on development of functional relations between experimental flow pulses, effects on reproductive behaviors, and other authorized purposes. If experimental flow pulse characteristics thought to be biologically significant (magnitude, duration, frequency, timing, rate of change) reach a threshold wherein impacts to other authorized purposes are a concern and/or are beyond levels previously given NEPA coverage, then additional analysis and approval may be needed to move to component 5. If experimental flow pulse hydrologic characteristics are within previously approved levels, then the decision to move to component 5 field experimentation would be based on anticipated biological results.

C.2.1.6.2 Component 5

This study, while similar to level 1, component 2, also uses experimental flow releases from Fort Peck Dam to exert more experimental control. Flows from Fort Peck Dam would be deliberately manipulated over a range of magnitude, duration, timing, and rate of change to evaluate the reproductive behavior of pallid sturgeon. Parameter values for the experiments would be developed from preceding opportunistic and mesocosm experiments. Years with flow pulses should also be tested against control years without flow pulses.

Metrics

Metrics for this component will be very similar to component 2 and will include the degree of association of reproductive migrations and successful spawning with monitored experimental flow pulses. Intensive and passive network telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes and through capture of genetically identified free embryos. The experiment will be a series of experimental releases over several years; the series will result in a functional relationship between flow-pulse characteristics, migrations, and probability of producing viable gametes.

Timelines and contingencies

For the experiment to be successful there will need to be a substantial number (12 or more) of tagged, reproductive adult fish identified and tracked each experimental year. Assuming a minimum of four pulse levels, one replicate year, and two control years, seven years will be necessary for completion of this component. Success of the study will depend in part on development of passive receiver networks (component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program. Success will also depend on experimental parameters thought to elicit a biologically useful result while minimizing negative effects on other authorized purposes. These flow releases would need to be coordinated with upper big questions 2 and 3; releases under this big question would likely be accommodated with naturalization under big question 2; however, if temperature treatments are added, then accommodation of temperature/flow combinations may require additional experimental years.

Although this experiment is included in the compilation, it is not currently planned for implementation. The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

Decision criteria for application of component

Experimental control imposed in this component will add to the ability to detect and quantify reproductive behavioral changes related to flow pulses; however, the experiments will still take place within a system where many sources of variability are not controlled (e.g., weather systems and tributary inputs). It is therefore unlikely that these experiments will result in a statistically rigorous result. Instead, a decision to accept the value of manipulated flow pulses in increasing pallid sturgeon reproductive success, or to reject it, will probably be based on judgement of multiple lines of evidence, including consideration of whether there is evidence of sufficient drift/dispersal distance.

C.2.1.7 Critical scientific uncertainties and constraints

Several components under this big question require the ability to tag and monitor a large population of pallid sturgeon in the Upper Missouri River and Yellowstone River; therefore, reproductive condition and history of subject fish will be known. Implementation of mesocosm studies will require a facility that can culture reproductive adult fish for experiments and construction of a mesocosm large enough to accommodate ecologically significant velocity, temperature, and turbidity pulses. Locations of fish in the field and mesocosms must be established with high spatial and temporal frequency during spawning season in order to infer with confidence that behaviors are relatable (or not) to flow pulses. Data on flow-related covariates (water temperature and turbidity) are also necessary to discriminate cause and effect. Implementation of field experiments will require buy-in from agencies and stakeholders to accept risks from providing flow pulses of a magnitude that are likely to be measurable and effective. Evaluation of spawning success will require additional investment in technology to image spawning behaviors, egg release, and fertilization in challenging environments.

C.2.1.8 Utility of study components

These study components will provide critical information to determine if pallid sturgeon in the upper river require flow cues that ultimately lead to successful reproduction. If flow cues are apparently successful, the study component will provide guidance about flow thresholds, changes in flow, or other aspects of flow influencing spawning behavior.

C.2.1.9 Ancillary information benefit

The results of the study components will provide ancillary information applicable to habitat use, spawning locations, reproductive ecology, and migration routes of pallid sturgeon.

C.2.1.10 Risks

Manipulating discharge from Fort Peck Dam (component 5) imposes the greatest risk for this big question. Impacts on stakeholders could be considered high, depending on the magnitude of flow changes. Manipulated flows that are too low or too high could lead to problems with bank stability, irrigation, or flooding. Little risk to stakeholders is associated with other components. Risk to pallid sturgeon is minimal as telemetry on the species has been practiced for many years without issue.

C.2.1.11 Adaptive actions

Results of these study components could provide information to optimize releases from Fort Peck Dam in the spring, or potentially to indicate that flow manipulations are not necessary to elicit a reproductive behavioral response from pallid sturgeon. The hydrologic characteristics of the flow pulses (magnitude, duration, frequency, timing, rate of change) can be adaptively managed to elicit an optimal biological response while minimizing effects on other authorized purposes.

C.2.1.12 Estimated costs

The estimated cost of these study components is medium to high. Maintenance of a telemetry tagged population, enhancement of the passive telemetry array, intensive telemetry tracking, and construction of a large-scale mesocosm would all require substantive investments on the order of several million dollars per year.

C.2.2 Upper big question 2: Can naturalization of the flow regime from Fort Peck contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?

C.2.2.1 Objective of study components

This big question addresses the hypothesis that naturalization of the flow regime from Fort Peck would result in increased productivity, foraging habitat, and survival of age-0 pallid sturgeon. Naturalization refers to the process of using characteristics of the natural ecosystem to guide elements of river restoration, but constrained by social and economic values (Rhoads et al. 1999; Jacobson and Galat 2008). The study components are intended to provide the scientific basis for understanding how flow regime and channel reconfiguration can interact to provide food-producing and foraging habitats supportive of increased growth and survival. The value of these study components would accrue mainly in the event that recruitment from spawning on the Yellowstone River is not sufficient to sustain population size and free embryos are successfully retained in the Upper Missouri River.

C.2.2.2 Description of study components

The hypothesis states naturalized flow releases at Fort Peck will result in increased productivity through increased hydrologic connections with low-lying land and floodplains in the spring, and decreased velocities and bioenergetic demands on exogenously feeding larvae and juveniles during low flows in summer and fall. Hence, naturalization may include elements of both high and low flows. Unlike the lower river, the assumption is made that the channel morphology is near natural so channel configuration would not be an interacting management action. Study components at level 1 will focus on engineering, technology development, and field-gradient/mesocosm studies that would establish whether habitats are limiting and how habitats vary within the Upper Missouri River. Contingent on results of level 1 components, study components at level 2 will involve design and implementation of field-scale experiments to quantify linkages from flow naturalization to habitat availability, growth, and survival.

Productivity may relate to pallid sturgeon population dynamics in two different ways. Under a scenario of population augmentation, with or without natural reproduction and recruitment, increased productivity may be necessary to maintain growth of juveniles and adults. When stocked fish reach reproductive age, their reproductive potential (fecundity) may then also depend on increased productivity (carrying capacity) in the river. However, productivity may also be limiting in terms of food production for age-0 fish that could be naturally produced in the system. In the latter case, the importance of productivity is contingent on adequate drift/dispersal distance as discussed in upper big question 5 and hypotheses 3, 7, and 10. Although productivity for all life stages may be important for population growth, the immediate emphasis is on survival of age-0 sturgeon, if they are provided adequate dispersal distance.

C.2.2.3 Relation to effects analysis

Study components address hypothesis 2 from the EA. This hypothesis includes both food productivity and bioenergetic demands of foraging habitats.

C.2.2.4 Approaches

Two levels with six different components could be implemented to evaluate the hypothesis. Level 1 is proposed to include methods development and engineering studies to understand how flow naturalization would interact with other authorized purposes. Level 1 will also include screening studies to determine whether food or foraging habitats are limiting to age-0 pallid sturgeon, field-gradient studies to quantify relations between flow naturalization and habitat and food availability, and mesocosm studies to attempt to develop quantitative relations between abiotic variables and growth and survival. If level 1 results are supportive, level 2 components would include design and implementation of controlled, field-scale experiments to validate quantitative relations from flow naturalization to growth and survival. This level 1 experiment is not currently planned for implementation (Appendix F). This is because the timeline is likely beyond the current MRRMP planning process and because contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.2.5 Level 1

D.1.1.1.1 Component 1

Engineering studies are anticipated to address how ranges of flow naturalization, provision of high and low flows mimicking timing of natural flows, will interact with other authorized purposes. Some of this data will have been completed by other NEPA study components; however, some will likely require testing of new ranges of high and low flows that have not been previously addressed. In the Fort Peck reach there is likely to be some emphasis on how high flows will affect agricultural production, groundwater levels, and bank stability. Modeling may include 1-, 2-, and 3-dimensional models, including groundwater effects, to address these concerns.

Metrics

Metrics for this group of studies includes measures of costs or foregone services as a result of flow naturalization. Some emphasis will be placed on effects of floodplain connectivity with agricultural production, groundwater effects, and bank stability. The studies are expected to illustrate a cost function associated with the attainment of different levels of naturalized flow.

Timelines and contingencies

The measurements and models anticipated in this component would require three years for development. Under a parallel staging, this work could proceed simultaneously with components 1 and 3 to provide mutually supportive information. The time for this component depends as well on the need for more or less complex models; models involving groundwater and bank stability may require longer times.

Decision criteria for application of component

Results of the measurement and modeling should help in understanding the functional relationships between levels of naturalized flows and effects on authorized purposes. This information will be fundamental for deciding whether to proceed to components 5 and 6. If measurement and modeling demonstrate acute costs to other authorized purposes there may be need for additional NEPA coverage before moving to subsequent levels.

D.1.1.1.2 Component 2

Component 2 studies are biological screening studies to determine, if possible, whether food production or foraging habitats are likely to be limiting to pallid sturgeon. These studies may be very powerful in determining whether flow naturalization is necessary for survival of the pallid sturgeon in the upper river. These studies could be based on sampling a gradient of assumed habitat quality or as a randomized design and would involve assessing age-0 sturgeon for indications of starvation or growth. Because of dietary overlap between shovelnose and pallid sturgeon at this life stage, shovelnose sturgeon may be used to some extent as a surrogate.

Metrics

The metrics for this study are indicators of starvation or impending death of age-0 sturgeon in conjunction with possible explanatory abiotic variables. Such indicators may be based on stomach contents (percentages of empty/full stomachs) or physiological indicators (lipid content). Because it is extremely rare to catch dead age-0 fish, these metrics are useful to characterize the surviving population but may fail to address actual mortality rates, that is, sampling will be biased toward live fish. Because these metrics are likely to measure the net bioenergetic effects of a combination of food availability (food-producing habitat) and energy expenditures (foraging habitats), additional studies may be needed to address cause and effect.

Timelines and contingencies

Similar studies started in 2013 in the lower river and are likely to provide useful comparative results by 2017. In addition, some ongoing studies concerning carrying capacity of the upper river are under way, and results should address productivity of food items for juveniles and adults, and spatial gradients in productivity. The question of whether bioenergetic conditions are limiting to age-0 survival is contingent on avoidance of mortality by other sources, and so this science component could be delayed until adequate drift/dispersal distance is documented. Component 2 will occur simultaneously or with substantial overlap with components 1, 3, and 4.

Decision criteria for application of component

Results from this component may be indicative of bioenergetic constraints, but may not be statistically robust. Most of the age-0 sturgeon evaluated will be shovelnose, and although there is evidence to support the notion that the pallid and shovelnose diets and bioenergetic demands are very similar at this life stage, there is residual uncertainty about how well the surrogate species represents pallid sturgeon. If results indicate that age-0 sturgeon have full stomachs and healthy lipid content, it indicates that current bioenergetic conditions are not limiting, but additional science components may still be justified in order to evaluate future conditions when the population is larger and either food or forage could become limiting. If results indicate that stomachs are not full and/or lipid content is not healthy, it will not necessarily be clear whether this is attributable to food availability or energetic demands. Therefore, a decision to proceed or continue with level 2 science components may require multiple lines of evidence.

D.1.1.1.3 Component 3

The information value of this study component is closely tied to component 2 regarding limitations of food, forage habitat, or both, on survival of age-0 pallid sturgeon. The objective will be to develop quantitative links from flow manipulation actions to the amount and quality of food-producing and foraging habitat. The study will incorporate information from component 2 to improve definition of food-producing habitats through understanding of spatial linkages and geometries. It can be pursued on a field-gradient design by evaluating food and forage habitat conditions along existing ranges of habitat conditions (flow variability and channel complexity) along the river. For food, the study would include repeated measures sampling of biota judged to be food items for larval and juvenile pallid sturgeon. For foraging habitat, the study would include habitat selection based on catch rates from trawling for age-0 sturgeon in comparison to well-characterized habitat conditions. Habitat characterization at the scale of age-0 sturgeon will be challenging and may require innovative applications of acoustic Doppler current profilers, acoustic velocity meters, and/or benthic imaging technologies to establish bioenergetic conditions experienced by larval fish.

Metrics

Habitat metrics (potential explanatory variables) will be statistical measures of depths, velocities, and substrate, including means and variances, potentially complemented with metrics of spatial complexity like patch dimensions and spatial relations. Metrics for this study would include measures of habitat selection for food items (chironomids) and foraging (age-0 sturgeon), based on habitats occupied and unoccupied.

Timelines and contingencies

The measurements and models anticipated in this component would require four years for development, although some of this work is already underway. This component may proceed simultaneously with components 1, 2, and 4 to provide mutually supportive information.

Decision criteria for application of component

Results of the measurement and modeling should help develop quantitative statistical associations between habitat characteristics and selection by food sources and age-0 fish. The statistical analysis is likely to include substantial uncertainty and a lines-of-evidence approach that includes data from mesocosm experiments in component 4. This will further refine understanding of functionality of these habitats and help determine if evidence supports moving to level 2 experiments.

D.1.1.1.4 Component 4

This study component would attempt to develop quantitative relations between the range of habitat conditions identified in component 3 with quantitative productivity rates and growth and survival of pallid sturgeon, using mesocosms. This component would provide parameter values for integrated bioenergetic and population models that could be used to predict results of flow naturalization.

Metrics

Habitat metrics (potential explanatory variables) will be statistical measures of depths, velocities, and substrate, including means and variances, potentially complemented with metrics of spatial complexity like patch dimensions and spatial relations. Metrics for this study would be relative growth rates and survival as a function of habitat characteristics.

Timelines and contingencies

The measurements and models anticipated in this component would require four years for development. It would be most effective to wait for completion of component 3 so the range of conditions needed in mesocosm experiments would be known and hypotheses would be rigorously formulated.

Decision criteria for application of component

Results of the mesocosm experiments will quantify relations between abiotic variables and growth and survival. These are likely to be relations that show a peak of growth and survival at some interval, with decreasing growth/survival at higher and lower values. If growth/survival does not show a systematic relation to abiotic variables, the concept of flow naturalization would need to be substantially refined or abandoned. If there is a systematic relation, the supportive range of abiotic variables would be used to justify and to design field experiments in components 5 and 6.

C.2.2.5.1 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is, or is not, a systematic relation between flow naturalization and increases in growth and survival of age-0 sturgeon. The judgement should be based on the strength and replicability of relations between abiotic habitat variables describing food and forage habitats, and growth and survival of age-0 sturgeon. Movement to level 2 would not be recommended if drift/dispersal continues to be limiting.

C.2.2.6 Level 2

Level 2 components are included in this section, but they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first

C.2.2.6.1 Component 5

Components 5 and 6 will be contingent on the type and quality of information provided from previous components. The objective of component 5 will be to use quantitative relations gleaned from the gradient and mesocosm studies (components 3 and 4) to design flow naturalization experiments and to assess associated effects. This component would make use of the integrative hydrodynamic-bioenergetic models to test alternative flow regimes for the ability to provide effective amounts of both food-producing and foraging habitats.

Metrics

Metrics for this component will be relative performance of designs, measured as areas of functional habitat, flux of food items, predicted growth, and survival.

Timelines and contingencies

This component is expected to take two years under the assumption that hydrodynamic modeling reaches will already be established. If this is not the case, additional time would be required and an earlier start might be anticipated, especially if the spatial variability in the Upper Missouri is not adequately represented in the existing models.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 6. That decision will be based on lines of evidence from components 1–4 and success in developing designs in component 5. The decision to proceed with component 6 would be based on the demonstrated ability to predict increases in productivity, growth, and survival from naturalization of the flow regime without unacceptable risk to other authorized purposes.

C.2.2.6.2 Component 6

The objective of component 6 will be to evaluate the functions of food-producing and foraging habitats under controlled, experimental conditions. It will involve a sample design that will evaluate specific metrics of productivity over a range of flow regimes. Responses can be measured in terms of hydraulic conditions, functional habitat area, and food production; responses in terms of growth and survival of age-0 sturgeon would need to be calculated from mesocosm results and bioenergetic models because of the difficulties in assessing these metrics in the field. The role of flow manipulations can be evaluated against interspersed, non-manipulated years.

Metrics

The study design will incorporate a gradient of flow regimes with varying amounts of naturalization of the flow regime, indicated by quantiles of ecological flow components (for example, 25^{th}, 50^{th}, and 75^{th} percentiles of flow pulses, low flows). Because growth and survival probably cannot be measured reliably under field conditions, the metrics will need to be indirect and may include area of food-producing habitat, area of foraging habitat, catch per unit effort of age-0 sturgeon, stomach contents, and lipid content.

Timelines and contingencies

This component is expected to take seven years to complete, assuming four treatment years, one treatment replicate year, and two control years. The component is contingent on results from component 5. This component has a high degree of interaction with science components or implementations that alter the flow and temperature regimes (e.g., components under upper big questions 1, 3, and 5). Although the component does not directly relate to productivity to support juveniles and adults, the hydrodynamic modeling results will be useful for inferring general productivity (carrying capacity) of the river system as a function of flow regime.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward to level 3 implementation. Statistical relations will likely not be robust, and the decision will therefore require a judgement based on lines of evidence presented in components 1–6. If experimental results in component 6 fail to support systematic increase in habitat and fish condition, then the hypothesis may need to be refined or abandoned. If the experimental results support the hypothesis that flow naturalization can provide increased food-producing and foraging functional habitats, and if evidence from level 1 and 2 studies under upper big question 5 indicates that there is adequate drift / dispersal distance, then the decision would be to move toward level 3 implementation.

C.2.2.7 Critical scientific uncertainties and constraints

Critical scientific uncertainties include the food base for age-0, exogenously feeding pallid sturgeon, and relation of that food base to habitat conditions. Additional critical uncertainty relates to foraging behaviors of age-0 sturgeon and the extent to which foraging habitat can be measured and modeled at appropriate scale. In addition, the linkage from habitat variables to survival is critical to link management actions to population-level responses. Finally, the uncertainty about whether free embryos have adequate drift/dispersal distance is a fundamental uncertainty that could overwhelm the importance of this big question.

C.2.2.8 Utility of study components

These study components will provide scientific information bearing on whether flow manipulation will be effective in increasing survival and recruitment of age-0 pallid sturgeon. If successful, the study components will provide functional relations indicating how much flow naturalization is needed to increase survival, which can then be accommodated in population models.

C.2.2.9 Risks

Level 1 components present little risk to stakeholders, authorized purposes, or pallid sturgeon. At level 2, field experimentation would require flow manipulations that could be perceived as risks to flood control, power generation, water supply, navigation, and floodplain farming.

C.2.2.10 Adaptive actions

The results of these will have a bearing on decisions regarding extent of flow-management at Fort Peck Dam. The relations provided in component 6 will allow for incremental naturalization of flows toward greater survival.

C.2.2.11 Estimated costs:

Estimated costs of level 1 components are relatively small. Field-gradient studies will rely on existing gradients of flow regime and channel reconfiguration. Mesocosm studies may require some investment in laboratory facilities to provide ecologically meaningful conditions, but much of the culture and laboratory investment already exists. Level 2 studies with field experiments will be more costly, and may involve substantial investments in land and construction.

C.2.3 Upper big question 3; can water-temperature manipulations at Fort Peck contribute significantly to increased chance of reproduction and recruitment?

C.2.3.1 Objective of study components

The objective of these study components is to determine if increased water temperature from Fort Peck Dam during the spring can significantly increase productivity and developmental rates. These two aspects were combined in this big question because both depend on the same action, implementation of increased water temperatures at Fort Peck. The productivity components relate strongly to upper big question 2 and the development rates components relate strongly to upper big question 5. Aspects of scientific approaches presented here may be accommodated in close coordination with those questions.

C.2.3.2 Description of study components

Water temperature may influence productivity of the river system downstream from Fort Peck as well as increasing the development rate of free embryos. The first of these hypotheses relates water temperature to productivity of food which will eventually be consumed by the pallid sturgeon; this hypothesis is highly correlated with flow naturalization under upper big question 2. The second of these hypotheses is highly related to drift/dispersal hypotheses under upper big question 5, but is included here because of the relation to temperature controls at the dam. Water temperature may also interact with flow pulses (upper big question 1) to influence spawning cues.

C.2.3.3 Relation to Effects Analysis

The study components directly address action hypotheses 4 and 5 in that increased temperatures may increase productivity and development rates. These hypotheses are interrelated with hypotheses 1, 3, and 10, which also involve changes in flow regime.

C.2.3.4 Approaches

Two levels with six different components could be implemented to evaluate these hypotheses. For some components, it is convenient to separate sub components related to temperature-mediated productivity (‘a’ components) and those related to temperature-mediated development during drift/dispersal (‘b’ components). Level 1, component 1 includes feasibility studies and modeling temperature elevations as a function of water releases from Fort Peck. Component 2a is a biological screening component that will document whether temperature-mediated productivity is limiting to population growth (similar to upper big question 2, component 2). Component 2b will similarly document whether the temperature-mediated developmental rate is relevant given other constraints on drift/dispersal and survival. Component 3a is a field-gradient study to document whether productivity varies significantly across existing gradients of water temperature along the Upper Missouri River and in comparison between the Upper Missouri and the Yellowstone. Component 3b is a field experiment to validate simple advection/dispersion models for drift of free embryos, with emphasis on including temperature-mediated development rates to add biological realism. Component 3b is essentially identical to upper big question 5, component 3 and these would be coordinated. Components 4a and 4b depend on controlled mesocosm studies to develop quantitative relations between water temperature and productivity and developmental rate. Component 5 is an engineering study to test temperature control structures and validate downstream variation in water temperature. Component 6a is a series of field experiments to test sensitivity of productivity to water temperature whereas component 6b does the same to test sensitivity of development rate and survival to water temperature.

C.2.3.5 Level 1

C.2.3.5.1 Component 1

This component includes an engineering study to investigate the feasibility of temperature mediation at Fort Peck and a technology development study that would merge a temperature-mediated development model with advection/dispersion modeling of free embryo drift/dispersal. The feasibility study would update previous study results on costs, practicality, and reliability of different approaches to mediating temperature of releases at Fort Peck (modification to the existing intake, new intake and tunnel, pumped discharge over spillway, or submerged weir), and determine the range of water temperatures that could be attained. The developmental drift/dispersal model would indicate whether the resultant temperature increase would likely increase developmental rate sufficient to retain larvae in the free-flowing river. Previously completed feasibility studies will provide a useful foundation for this component.

Metrics

Metrics for this component will be costs, temperature increases, achieved development stages, increased productivity, and length of the river that would be needed to attain retention of larvae before transport into Lake Sakakawea. These metrics may be analyzed to reach conclusions about the cost effectiveness of alternative designs.

Timelines and contingencies

The models developed in this component will provide; 1) quantitative understanding of need and efficacy for water temperature control and 2) an estimate of costs. As such, this component will provide foundational information to determine whether the hypothesized action is necessary and practical. Components 1, 2, and 3 would start at the same time (as early as 2017).

Decision criteria for application of component

Results of the modeling will demonstrate whether operations of temperature mediation strategies at Fort Peck may increase water temperatures in the Upper Missouri River to the point where sufficient development can take place before larvae are dispersed into Lake Sakakawea, and whether such manipulations would be expected to significantly increase productivity. If the models indicate that water temperatures will contribute significantly to recruitment or productivity, alone or in combination with manipulated flows and drawdown of Lake Sakakawea, this will support moving to level 2 science components related to temperature management.

C.2.3.5.2 Component 2

The science component includes two subcomponents related to biological screening to determine whether water temperatures may be limiting in recruitment. Component 2a addresses the fundamental question of whether food is limiting to recruitment of age-1 pallid sturgeon and component 2b addresses whether conditions in Lake Sakakawea are necessarily fatal to age-0 sturgeon. Studies currently (2017) underway to address food limitation on the lower river will provide some framework for 2a; in this component randomized sampling for age-0 sturgeon (presumed to be shovelnose in this case) will indicate whether young fish are starving through stomach content and whole body lipid analyses. For component 2b, studies currently (2017) underway to assess anoxia in the headwaters of Lake Sakakawea may provide substantive results by 2017; additional study may be needed to refine understanding of the spatial and temporal patterns of anoxia.

Metrics

Metrics for component 2a will be numbers of age-0 sturgeon with full or empty stomachs, plus an inventory of stomach contents to define where food items originate. Whole-body lipid content of the age-0 sturgeon should also provide a metric for the extent to which food availability limits fish health and potential for survival. For component 2b, metrics will be the spatial extent and temporal persistence/variability of anoxic conditions that would be fatal to benthic dwelling larval fish.

Timelines and contingencies

Components 1 and 2 can be pursued simultaneously. Component 2a is expected to require three years to complete starting in 2017 and component 2b is shown starting in 2015 and extending four years to 2019. Because the temperature mediation advection/dispersion modeling is central to Upper Big Question 5, these science components would be highly coordinated. Note that essential validation of the advection/dispersion modeling approach is addressed in component 3b and is identical to component 3 for Upper Big Question 5.

Decision criteria for application of component

It is unlikely that component 2a will result in a statistically rigorous result due to interactions with uncontrolled variables, and the dependence on shovelnose sturgeon as a surrogate species. The decision to accept or reject results may need to be based on judgement of multiple lines of evidence. This determination will depend a great deal of the strength of the results and may be complicated by spatial variability in productivity (productivity may not be limiting downstream of the Yellowstone confluence, but may also be much less amenable to management). Results from component 2b may indicate a continuum from presence of a persistent, spatially homogeneous area of anoxia with no potential for supportive habitats to presence of little area or patchy areas of anoxia among non-anoxic patches that may retain potential for supportive habitats. If the result is more like the former, it will document a fundamental constraint on pallid sturgeon recruitment as it will validate the assumption that transport into the headwaters of Lake Sakakawea is fatal. If lethality of Lake Sakakawea is validated, decisions could still be made to move forward with level 2 science components under this big question if advection/dispersion modeling presents positive or equivocal results that temperature, flow, passage, and or drawdown may be sufficient to keep free embryos from dispersing into the anoxic zone. Component 3b addresses the essential need to validate the advection/dispersion model on the Upper Missouri.

C.2.3.5.3 Component 3

Similar to the previous component, component 3 is split into 3a, a field gradient study of the association between productivity and water temperature and 3b, a field study to validate advection/dispersion models as a predictive tool for dispersal of free-embryos. Component 3a will assess food (indexed by chironomid larvae) availability along temperature gradients on the Upper Missouri and in comparison between the Upper Missouri and Yellowstone River. The relevance of this study depends on; a) whether age-0 pallid sturgeon can be expected to be retained in the Upper Missouri River and b) whether water temperatures can be practically managed at Fort Peck. Component 3b is envisioned as a field experiment using tracking of dispersal of free embryos and surrogate tracers, combined with robust characterization of flow fields and dispersion coefficients, to test/validate/refine the advection/dispersion model developed as part of the EA process. Because of the importance placed on advection/dispersion modeling in the EA process for both the upper and lower river, validation of the model is presented as a high priority and initial experimentation began in 2016.

Metrics

Metrics for component 3a will be densities of chironomid larvae and associated abiotic habitat variables (depth, velocity, temperature, and derivatives). The abiotic variables will quantify relations between flow conditions, channel configurations, and food availability that will be useful to parameterize predictive models. Metrics for component 3b will be space and time distributions of larvae and surrogate tracers developed through Eulerian sampling during the experiment. Free embryos will have known genetics to allow for discrimination from wild-produced sturgeon. Metrics will include Lagrangian evaluation of the flow fields experienced by the tracers to characterize mean velocities, variance, and longitudinal dispersion coefficients; these data will be collected by acoustic Doppler current profile mapping from boats floating with the tracers. Areas identified with increased loss of tracers will be identified for subsequent, high-resolution measurement and modeling of the flow field to determine conditions that retard or retain drifting larvae.

Timelines and contingencies

Carrying capacity studies are already underway in the Upper Missouri River; therefore, component 3a is shown beginning in 2014 and extends to 2018. Component 3b is fundamental to acceptance of information from advection/dispersion modeling in the decision making process. Component 3b is shown starting in 2017 in parallel with components 1, 2, and 4. A minimum of two experiments are anticipated to establish some confidence in replicability (additional controlled experimentation would occur under level 2). To allow for variability in years and availability of sufficient numbers of free embryos, four years are indicated for the component. It should be noted that availability of a large number of free embryos and agreement about prevailing releases from Fort Peck during the experiments are necessary conditions for success.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to accept the science information as useful to decision making. The quality of information developed in these components will depend to a large extent on how well the field studies control ancillary variables. The cumulative results from components 1–3 are likely to be less than statistically rigorous and the decision to accept the information may require judgement from multiple lines of evidence.

C.2.3.5.4 Component 4

Component 4 is similarly divided into 4a and 4b. Component 4a is a mesocosm-based study of water temperature, food production, and growth intended to develop the quantitative relations that will indicate how much additional food production will result in how much growth of exogenously feeding larvae, assuming they have been retained before entering Lake Sakakawea. These relations would be essential to parameterize bioenergetics and population models to link temperature manipulations and recruitment to age-1. Component 4b is a laboratory study that will document developmental rates of embryos, free embryos, and exogenously feeding larvae as a function of water temperature. Some of these relations already exist, but they need to be confirmed and expanded to a wider temperature range to apply to Yellowstone River temperatures. Component 4b is placed here logically because it is a laboratory/mesocosm study that is critical to understanding the role of temperature in development and dispersal.

Metrics

Metrics for component 4a will be densities of chironomid larvae as a function of water temperature and associated growth rates of exogenously feeding pallid sturgeon larvae. These experiments will be most useful if carried out in mesocosms that can vary abiotic variables (velocities, bed configurations) so they will include behavioral (foraging) metrics associated with those variables. Metrics for 4b will be descriptions of developmental stages of embryos through exogenously feeding larvae as functions of water temperature (parameterized as cumulative thermal units). Because shovelnose sturgeon are used in many related science components as surrogates, it will be valuable to have parallel information on shovelnose sturgeon development rates for comparative purposes. This information applies to the upper and lower river, so temperature ranges and genetic diversity associated with the two river sections should also be represented.

Timelines and contingencies

Mesocosm studies could start in 2017 and progress concurrently with other level 1 studies in order to minimize total time frame. Construction of mesocosms and supportive propagation facilities may require some lead time depending on complexity of the experiment.

The fundamental nature of component 4b supports an earlier staging; as some of this work has already been published (Kappenman et al. 2013), it is shown as starting in 2014 and concluding in 2017.

Decision criteria for application of component

The decision at this stage for component 4a and 4b is whether to accept information as valuable to decision making. Results from mesocosm experiments are likely to be statistically rigorous, but their relevance to decision making depends on how the experimental results apply to the capacity of the river system and the ability to manage it. Hence, decisions to move forward with level 2 may require judgements based on multiple lines of evidence (more in next section). Results from the developmental rate experiments are likely to be statistically rigorous and the data will contribute critical context to results of advection/dispersion modeling. Based on existing data, these new information on developmental rates will not likely influence the decision to level 2 alone; rather, it is the context of management capacity (temperatures, flows, drawdown) and the accuracy of the advection/dispersion models that will likely influence this decision.

C.2.3.5.5 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is a likely relation between feasible temperature mitigation and recruitment, whether constrained by productivity or dispersal distance. The experiments envisioned in component 6 are highly interdependent with experiments envisioned under Upper Big question 5. These are related to other questions about drift/dispersal and therefore, the decision to move forward to level 2 may not be based solely on information developed in this Big Question. The decision to move to level 2 would be based on the strength and replicability of relations between temperature variation (and associated abiotic characteristics) and productivity, growth, and survival, assuming the survival of dispersing free embryos has been shown to be sufficient to sustain population targets and assuming there is sufficient drift/dispersal distance. Because of the high cost anticipated for construction of many of the mechanisms to manipulate water temperature ($10’s–$100’s of millions), the decision to invest in temperature management is likely to require a very high level of confidence of success, thereby placing high reliance on the quality of information developed in components 1–4.

C.2.3.6 Level 2

Although level 2 components are included in the staging, they are not currently planned for implementation. The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.3.6.1 Component 5

This study component would consist of field tests of water temperature manipulation structures or managed water releases to determine if expected river water temperatures are realized downstream. Water temperature would be controlled by one or more of the mechanisms determined during the feasibility study in component 1a. Controlled releases of warm water into the river would be measured and monitored. A longitudinal series of temperature monitors would need to be placed downstream to evaluate the effectiveness of water temperature manipulations.

Metrics

Metrics for this component will be increase of water temperatures above those that would have prevailed without the temperature mitigation. This will necessitate well-calibrated water-temperature models to be able to simulate what temperatures would have been in the absence of the mitigation. Field tests may include a range of implementations that would have a range of temperature effects. Field tests would also evaluate whether water temperature effects were adverse for other authorized purposes.

Timelines and contingencies

Construction would likely require four years, and the study part of the component is expected to take four additional years after construction to address climatic variability. It is contingent primarily on component 1a results that will indicate feasibility but also on components 2, 3, and 4 which will together indicate the expected biological benefits of water temperature manipulations. If results for components 1–4 are negative, components 5 and 6 would be abandoned.

This component is highly related to Upper Big Question 5 experiments because water temperature, velocities, fish passage at Yellowstone, and drawdown of Lake Sakakawea may all contribute in some proportion to recruitment.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 6. That decision will be based on lines of evidence from components 1–4 and information developed during component 5 that temperature mitigations can be effective. The decision to proceed with component 6 would be based on the demonstrated ability to raise water temperature by an increment thought to be biologically significant.

C.2.3.6.2 Component 6

This component is a field-based experiment based on manipulated water temperatures. The primary goal of the experiment is to validate that increased water temperature contributes substantially to free-embryo survival and recruitment under real-world conditions. It would require free-embryo tracer experiments similar to component 3b, but with alternating years of cold (normal operations) and a series of elevated water temperatures. The developmental rate of tracer free embryos placed in the river at suitable locations would be determined at sampling sites along the river and would be compared to model predictions and among years. Results for altered productivity could also be evaluated in these experiments by repeated sampling of chironomid-producing habitats (identified in component 2a) during the experiments to evaluate effects of temperature. Multiple experimental events in time would be necessary to establish replicability, and the role of covariates of discharge, turbidity, and genotype (of tracer free embryos).

Metrics

Metrics for this component will be primarily the developmental rate of free embryos as a function of water temperature achieved on the river and the location of developmental stages relative to Lake Sakakawea headwaters. Metrics could also include costs of the experimental operations and impacts to other authorized purposes. Secondary metrics would be densities or fluxes (productivity) of chironomid larvae in parts of the river where free embryos may be retained.

Timelines and contingencies

These experiments are contingent on successful validation tests (component 5). For the experiment to be successful there will need to be a substantial number of free embryos available and strong agreement to an experimental release schedule. Assuming a minimum of four temperature manipulations and the risk that experimental logistics may fail 1 year in 2, or 50 percent of the time, at least eight years of evaluation will be necessary for this component. Time for this experiment may be increased depending on how the temperature manipulations are carried out in coordination with flow and drawdown experiments under Upper Big Questions 1, 2, 4, and 5. If combinations of temperature, flow, sediment, and drawdown are considered, the number of years of experiments could extend farther in time than indicated.

Decision criteria for application of component

Experimental control imposed in this component will add to the ability to quantify effects of water temperature manipulations on pallid sturgeon recruitment in the Upper Missouri River. However, the experiments will still take place within a system where many sources of variability are not controlled, such as weather systems and tributary inputs. Moreover, the number of true replicates of the experiment will be low or zero. It is therefore unlikely that these experiments will result in statistically rigorous results. Instead, a decision to accept the value of manipulated water temperatures in increasing pallid sturgeon recruitment, or to reject it, will probably be based on judgement of multiple lines of evidence including the risk to other authorized purposes. This may require consideration of the cumulative level 1 and level 2 information.

C.2.3.7 Critical scientific uncertainties and constraints

The overarching critical uncertainty for this Big Question is whether actions to manipulate water temperature on the Upper Missouri River are justified if increased fish passage at Intake Dam results in recruitment to the population on the Yellowstone River side. The next critical uncertainty is whether feasible water temperature infrastructure can increase water temperatures on the Upper Missouri River to a biologically significant point, that is, temperatures that would increase recruitment by increasing development rate or increasing food productivity. Implicit in these uncertainties are the accuracy of advection/dispersal models presently being used to evaluate drift/disperal, and uncertainties in the developemental rates of embryos and free embryos as a function of water temperature and genotype and whether reproductive adults can be attracted sufficiently far upstream on the Upper Missouri River. The staging of science components addresses the implicit uncertainties by staging them early in the process.

C.2.3.8 Utility of study component

This study component will provide critical information to determine if pallid sturgeon recruitment can be increased by temperature manipulation at Fort Peck Dam. Given the high estimated costs of mechanisms to accomplish increased temperatures ($10's–$100's of millions), the information developed in these studies is critical to substantive decisions. In particular, if temperature is an over-riding variable determining recruitment success, and temperature manipulation is not feasible, that knowledge will determine future decisions. If temperature changes are shown to be possible and influential, the study components will provide guidance about temperature management in relation to other management actions.

C.2.3.9 Ancillary information benefit

The results of the assessment will provide ancillary information applicable to the river system productivity and response of other organisms in the river to temperature management.

C.2.3.10 Risks

Manipulating water temperature from the dam imposes little risk but substantial cost. Risk to pallid sturgeon is minimal as temperatures would not be increased to a level harmful to the fish. Impacts on stakeholders would be minimal because temperature increases would be in spring before other temperature constraints would apply.

C.2.3.11 Adaptive actions

Based on the results of these study components, the information would be used to optimize water temperature (and discharge) during the spring to increase recruitment probability. This might mean combinations of increased water temperature, decreased releases (to minimize velocity), and drawdown of Lake Sakakawea.

C.2.3.12 Estimated costs

Estimated costs of components 1–4 are relatively low and would provide a high return on investment, both in relation to management of the Upper Missouri River but also by providing fundamental, highly transferable information to managing the Lower Missouri River. Extension of this Big Question to level 2 would be very costly because of the investment needed to increase water temperature at the river scale.

C.2.4 Upper Big Question 4; can sediment bypass at Fort Peck contribute significantly to increased chance of reproduction and recruitment?

C.2.4.1 Objective of study components

The objective of this study component is to evaluate capability and biological value of sediment augmentation at Fort Peck Dam to increase turbidity and decrease predation on embryos, free embryos, and exogenously feeding larvae. This objective includes a feasibility study to address whether sediment bypass is viable, and field and laboratory studies to determine rates of predation related to turbidity. The relevance of these study components depends on ability of the Fort Peck segment to retain free embryos; if recruitment is demonstrated on the Yellowstone these components may not be a high priority.

C.2.4.2 Description of study components

Two levels of study components are presented. Level 1 includes a feasibility study for mechanisms to bypass sediment around Fort Peck Dam and a biological screening study in the laboratory to document whether turbidity-mitigated predation is likely to be a limiting factor. In contrast to other Big Questions, the biological screening study is pursued in the laboratory because of the challenges of measuring predation under field conditions. If screening studies demonstrate that predation may be a limiting factor, additional mesocosm studies will be designed to develop quantitative relations of predation risk as a function of turbidity. Follow-on level 2 components include an engineering study to pilot test the sediment bypass mechanism and validate with turbidity measures downstream. The manipulated field experiment is intended to validate mesocosm models in the real world. Because validation of mortality of age-0 and age-1 fish due to predation is practically impossible in the field, biological metrics will not be addressed; instead, biological performance will be inferred from physical variables.

C.2.4.3 Relation to Effects Analysis

This Big Question informs the EA hypothesis: installing sediment bypass at Fort Peck will increase and naturalize turbidity levels, resulting in decreased predation on embryos, free embryos, and exogenously feeding larvae.

C.2.4.4 Approaches

Two levels and five total components are presented to address sediment bypass. Level 1 includes an engineering feasibility study to determine practicality of sediment by pass at Fort Peck dam, costs, and effects on other authorized purposes. Level 1 also includes a biological screening study using laboratory mesocosms to establish whether it is likely that predation of embryos, free embryos, or larvae is limiting to the population and whether predation is affected by turbidity. If the previous study indicates a measurable turbidity effect, a follow-on mesocosm study will attempt to develop quantitative relations between survival of predation-susceptible life stages and turbidity. Level 2 components would be pursued if level 1 components provide sufficient support for the hypotheses. Level 2 components would include an engineering test of a constructed sediment bypass (or procedure) and a manipulated field experiment to quantify how much of the river would have significantly increased turbidity.

C.2.4.5 Level 1

C.2.4.5.1 Component 1

Component 1 is a feasibility study of various mechanisms, structures, and procedures that could be used to bypass sediment around Fort Peck Dam. Because the dam was not designed to process annual sediment loads, a mechanism to transport sediment from areas of accumulation in the headwaters to the base of the dam will probably involve extensive engineering. This study will establish alternative engineering approaches to bypass and associated costs, as well as providing predictive models for how much turbidity may be increased as a result.

Sediment augmentation may target various particle-size ranges, and costs will vary depending on the targeted size classes. Although long-term sustainability of the Upper

Missouri River may be enhanced by augmenting to restore natural fluxes and particle sizes, the emphasis here is on turbidity (and washload) as the effective abiotic variable.

Metrics

Metrics for this study will be predicted cost (including environmental, construction, and operations) and predictions of the extent of the Upper Missouri River that will have turbidity raised on average, and by how much.

Timelines and contingencies

We anticipate that the feasibility study would require two years. Relevance of the feasibility study to pallid sturgeon population dynamics would only accrue if free embryo drift conditions are such that free embryos do not disperse into Lake Sakakawea. This component will be pursued simultaneously with the start of mesocosm studies under component 2.

Decision criteria for application of component

The relevant decision after this component would be to accept the information as relevant to decision making, in particular whether the determination of whether sediment bypass was practical or would significantly increase turbidity.

C.2.4.5.2 Component 2

Component 2 is a mesocosm-based experiment to determine whether turbidity is possibly a limiting factor in predation of pallid sturgeon embryos, free embryos, and larvae. The experiment would subject these three life stages to varying levels of turbidity in the presence of different prospective predators. Mesocosm conditions should include variable velocity and bed complexity as co-variates. Survival will be enumerated after set time intervals.

Metrics

The primary metric for this component will be survival by life stage and predator species, as a function of turbidity.

Timelines and contingencies

The study is anticipated to take three years, including mesocosm construction and running experiments over two spawning seasons. Additional replicates of the experiment may be possible using shovelnose sturgeon early life stages are a surrogate.

Decision criteria for application of component

Decisions at this stage are primarily whether to accept the information as useful in decision making. Statistical results for these mesocosm studies should be quite rigorous in establishing whether turbidity has a significant effect on survival.

C.2.4.5.3 Component 3

This component is an extension of component 2. Component 2 will establish whether a relation exists between turbidity and survival whereas component 3 will establish quantitative functional relations. For component 3 it may also be possible to focus on one or two of the life stages and perhaps a limited number of predators, instead of all considered in component 2. The experiments would involve evaluating predation effectiveness for a range of turbidity conditions; those relations would provide a quantitative model (with appropriate covariates) for linking sediment bypass to survival.

Metrics

The primary metric for this component will be survival by life stage and predator species, as a function of turbidity.

Timelines and contingencies

The study is anticipated to take two years to run refined experiments. Additional replicates of the experiment may be possible using shovelnose sturgeon early life stages as a surrogate. This component may be pursued in parallel with components 1 and 2, or sequentially after feasibility and screening have been established in components 1 and 2.

Decision criteria for application of component

The decision at this stage is whether the information is useful in decision making and supports moving to level 2. Statistical results for these mesocosm studies should be quite rigorous in establishing functional relations between turbidity and survival. The decision to move to level 2 may depend more on feasibility determined in component 1 and identification of effect determined in component 2; component 3 results will help define the experiments in component 5.

C.2.4.5.4 Criteria to move to level 2

The decision to move to field experimentation is likely to depend mostly on the feasibility study in component 1 because sediment bypass may be impractical or the costs may be prohibitive. Decisions based on cost are policy decisions, not scientific, and the appropriate decision making steps would be invoked. After feasibility, the next level of criteria would be whether an effect of turbidity could be established. If not, the hypothesis would be abandoned. If an effect is evident and the action feasible, the decision could be made to proceed to level 2 experimentation. In the event that turbidity is shown to be an over-riding variable determining recruitment success, and increasing turbidity is not a viable option, the information would indicate a fundamental constraint on recovering pallid sturgeon in the Upper Missouri River.

C.2.4.6 Level 2

Although level 2 components are included in this compilation, they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.4.6.1 Component 4

Component 4 is a field-scale test of the mechanism or procedure selected to bypass sediment around Fort Peck Dam and to increase turbidity.

Metrics

The primary metrics for this study will be operational costs and extent of downstream increases in turbidity, and compared relative to predictive models. Additional metrics may be related to negative effects on socioeconomic values like public water supply.

Timelines and contingencies

This component would occur after all Level 1 components and before the field experiment, component 5. Depending on the bypass mechanism, testing may require specific hydrologic conditions. Several tests may be practical in a particular year; we anticipate two years of tests after an estimated four years of design and construction.

Decision criteria for application of component

The decision to move forward with component 5 would be based on demonstrable success in raising turbidity with the field test to biologically meaningful levels.

C.2.4.6.2 Component 5

Component 5 is a field-scale experiment of sediment bypass, resulting in downstream increases in turbidity sufficient to decrease predation on embryos, free embryos, and larvae. Because it is impractical and impossible to document survival/mortality of these life stages in the field, the experiment will rely on turbidity levels achieved and results of mesocosm experiments (components 2, 3) to indicate biological effect. It is anticipated that a suite of three experiments with varying magnitude of sediment bypass is needed.

Metrics

In addition to turbidity values and length of river affected, metrics will include implementation costs and effects on other authorized purposes.

Timelines and contingencies

The experiments are anticipated to require three years to provide a suite of three treatments, or magnitudes of sediment bypass. The experiments would follow the field test in component 5.

Decision criteria for application of component

Although the physical metrics (turbidity and length of river) should provide strong statistical evidence for whether the sediment bypass mechanism has a significant effect on the system, the lack of biological endpoints may detract from the value of the experiment. The decision to move to level 3 implementation may require expert judgement based on combined effects of the field experiments, including effects on other authorized purposes and mesocosm lines of evidence.

C.2.4.7 Critical scientific uncertainties and constraints

The central scientific uncertainty addressed in this Big Question is the extent to which predators cause significant mortality of embryos, free embryos, and larvae. Previous laboratory studies have documented that older, age-0 sturgeon are not susceptible to predation (French 2010), whereas one anecdotal study documented predation of age-0 larvae by flathead catfish (Steffensen et al. 2015a). No studies have looked at predation of the early life stages (free embryos and new feeding larvae). A key engineering uncertainty for this Big Question is whether any practical means of sediment bypass exists; to move sediment from headwaters to the Fort Peck Dam or spillway could be a considerable engineering challenge. A technical uncertainty for this Big Question relates to methods to measure predation in turbid mesocosms where behaviors cannot be observed. Overcoming this challenge may require innovative approaches to imaging in turbid water or procedures to drain and count survivors.

C.2.4.8 Utility of study components

The study components are designed to address whether turbidity is limiting to survival of very early life stages, and if so, whether sediment bypass can be used to increase turbidity and decrease predation. Components 1–3 will be of particular utility in documenting whether the significant investment in sediment bypass would be practical or needed.

C.2.4.9 Ancillary information benefit

Information on pallid sturgeon predation and turbidity may be generalizable to other turbid-adapted species. Feasibility studies and engineering designs for sediment bypass (if implemented) may be transferable to other dams.

C.2.4.10 Risks

Risks of components 1–3 are low. Risks implicit in components 4 and 5 would be considered high because of the potential high cost and uncertainty about biological responses. Increased turbidity may present a risk to other authorized purposes like water supply and recreation, or to recreational fish species.

C.2.4.11 Adaptive actions

Adaptive actions are possible in components 1–3, decisions to go ahead with bypass construction or not. The degree of adaptive action available after construction will depend on the mechanism used for bypass and whether it is adjustable. Because it will probably be an active transport procedure, available actions may include abandoning sediment bypass or adjusting for a range of fluxes or sediment sizes.

C.2.4.12 Estimated costs:

Estimated costs of components 1–3 are relatively low. Cost at construction (component 4) may be substantial, and costs of operations (component 5) may also be considerable due to energy demands.

C.2.5 Upper Big Question 5; can combinations of flow manipulation from Fort Peck, drawdown of Lake Sakakawea, and fish passage at Intake Dam on the Yellowstone River increase probability of successful dispersal of free embryos and retention of exogenously feeding larvae?

C.2.5.1 Objective of study components

The objectives of these study components are to improve understanding of the variables affecting drift/dispersal of free embryos, with application to management actions downstream from Fort Peck. The utility of the components will increase to the extent that recruitment does not occur on the Yellowstone River.

C.2.5.2 Description of study components

Multiple study components are included in this Big Question because of the interactions of mechanisms that are hypothesized to affect drift and dispersal. Some of the components have been previously discussed under Big Question 3 and would be identical because they address fundamental science related to drift/dispersal and development. Level 1 components include development of integrated development and drift/dispersal models and an engineering study to evaluate spatial and temporal variation of anoxia in the headwaters of Lake Sakakawea. Biological screening components include the study already proposed in Upper Big Question 3, component 2 to evaluate mortality in Lake Sakakawea and an additional component to evaluate the distribution of suitable spawning habitats upstream of Intake Dam. The latter is considered a screening study as it will document whether spawning potential exists to take advantage of increased passage. Assessment of biological effects relies on opportunistic field experiments of free embryo drift identical to Upper Big Question 3, component 3b. These experiments are intended to validate and refine advection/dispersion models and understand factors that might retard free embryo drift and whether those factors can be managed. Compared to Upper Big Question 3, component 3b, the drift experiments described here would emphasize velocity and available drift distance, but because they are opportunistic the range of conditions sampled may not be large. Complementary mesocosm studies are proposed to provide additional experimental control, in particular to investigate abiotic and biotic factors that affect mechanics of drift and dispersal of free embryos and first-feeding larvae, and reproductive behaviors of adults that determine selection of spawning habitat and hydraulic conditions under which drift begins. Level 2 components include engineering studies to determine experimental effects on authorized purposes, validation of passage hydraulics at Intake Dam, and evaluation of sediment and water-quality effects in the headwaters of Lake Sakakawea. Finally level 2 includes manipulated field experiments to investigate effects of low flows from Fort Peck and drawdowns of Lake Sakakawea, coupled with monitoring of passage and upstream migration of reproductive adults upstream of Intake Dam.

C.2.5.3 Relation to Effects Analysis

These study components address hypotheses 3, 7, and 10 from the effects analysis:

- Reduction of mainstem Missouri flows from Fort Peck Dam during free-embryo dispersal will decrease mainstem velocities and drift distance; thereby, decreasing mortality by decreasing numbers of free embryos transported into headwaters of Lake Sakakawea.

- Fish passage at Intake Diversion Dam on the Yellowstone River will allow access to additional functional spawning sites, increasing spawning success and effective drift distance, and decreasing downstream mortality of free embryos and exogenously feeding larvae.

- Drawdown of Lake Sakakawea will increase effective drift distance, decreasing downstream mortality of free embryos and exogenously feeding larvae.

C.2.5.4 Approaches

The approaches include technology development studies in level 1 to improve ability to integrate advection/dispersion and developmental models, field-based biological screening studies, and mesocosm biological effects studies to quantify relations between abiotic and biotic variables. For level 2 field experiments, engineering studies are proposed to refine experimental designs and document ancillary effects. Finally, manipulative field experiments are proposed to evaluate spawning and drift performance under realistic conditions. Monitoring and assessment of passage, spawning, dispersal, and contribution to recruitment at Intake Dam are included under level 3 in Chapter 4 of the AMP.

C.2.5.5 Level 1

C.2.5.5.1 Component 1

Component 1a develops modeling technology to merge hydrodynamics, water temperature, and developmental rate models, to predict population dynamics. It is identical to Upper Big Question 3, component 1. Component 1b is an engineering study to evaluate temporal and spatial variation of anoxia in the headwaters of Lake Sakakawea. This study would be complementary to ongoing studies of the anoxia zone but would extend results through modeling effects of flows and drawdowns. The following sections apply only to component 1b.

Metrics

Metrics for this engineering study will be number of years and how much free-flowing length of the Upper Missouri will occur with drawdown and flow scenarios. Some of this modeling has already been completed by the effects analysis but it is anticipated that additional runs will be required to explore a greater range of options.

Timelines and contingencies

These studies will be useful to inform what management options may be practical on the Upper Missouri River. Component 1a is contingent on ongoing developmental series studies (also Big Question 3, component 4b) that are expected to provide data 2017. Model integration would require one year. Modeling of the location of the headwaters of Lake Sakakawea has been partially accomplished by the effects analysis and expansion is likely to require one year. These components are not contingent upon one another.

Decision criteria for application of component

Component 2 will proceed regardless of the outcomes from component 1a or 1b. Components 1a and 1b, along with components 2, 3 and 4, will be done in parallel and will together inform a decision to move to level 2. The results of the engineering study will provide information on how the anoxic zone might move over time depending on interaction of flows from Fort Peck and drawdown of Lake Sakakawea. If these results show that biologically sufficient movement of the anoxic zone (extension of free flowing river) is sufficiently rare under management scenarios, a decision may be made to abandon drawdown as a potential management action.

C.2.5.5.2 Component 2

These study components include two screening studies based on abiotic variables. The first of these is to document anoxia related mortality in Lake Sakakawea; this component is already underway by a research group from Montana State University and is included here as Big Question 3, component 2b. The second is to document presence of suitable spawning habitat on Yellowstone upstream from Intake, tributaries, and on the Upper Missouri and tributaries.

Metrics

For component 2a, the metrics are measures of spatial and temporal distribution (extent and variability) of anoxia, much of which may come from the ongoing study. The spatial and temporal scope of this component will be expected to be more fine-grained than models in component 1b. For component 2b, the metrics will be spatial distributions of suitable spawning habitat and ancillary physical variables upstream from Intake Diversion Dam, at least to the Cartersville Diversion Dam, and for some distance up larger tributaries. Determination of suitability will be based on ongoing documentation of spawning habitats that are selected by reproductive pallid sturgeon.

Timelines and contingencies

The ongoing study of anoxia (Upper Big Question 3, component 2b) will be completed in 2017 and it is anticipated that two additional years of fine-scale complementary assessment is needed. Component 2a may occur simultaneous with component 1. Component 2b can be completed in two years, but is highly dependent on reliable definition of spawning habitat. Current studies at spawning habitats on the Yellowstone River will provide useful definitions but these definitions may be updated as additional spawning sites are identified. Component 2b results will have substantial leverage on the prospects of successful recruitment on the Yellowstone River.

Decision criteria for application of component

The decisions at this stage relate to how useful information is to inform decision making and whether to move to level 2 science components. Results from component 2a are fundamental to assumptions about sources of mortality and recruitment failure, and evidence needed from this component supporting level 2 drawdown studies also includes suitable habitat to take advantage of the increased distance. If the results indicate that the anoxia zone is patchy in time and space, or does not develop as intensively as has been assumed, many management options will open up because dispersal into the headwaters of Lake Sakakawea would not necessarily be fatal. If instead, the studies confirm that anoxia is pervasive and fatal, management options are limited and studies are unlikely to proceed to level 2. If the results of component 2b document a lack of spawning habitat upstream of Intake Diversion Dam a major assumption of the Intake project will be challenged. This information would inform expectations of the role of the Yellowstone River in recruitment and would possibly increase the level of interest in Upper Missouri River management actions.

C.2.5.5.3 Component 3

Component 3 is a series of opportunistic field experiments using drifting free embryos and other potential tracers in an attempt to improve understanding of the joint effects of temperature, velocity, drawdowns, and developmental rates in controlling fates of dispersing free embryos. These experiments are intended to refine basic understanding on physical and biological processes governing dispersal, and to validate and refine advection/dispersion models. Because the experiments are not controlled, temperature, velocity, and drawdowns are not controlled, so the experiments in Upper Big Question 3, component 3b, and components 3a and 3b are essentially the same; the substantive differences would be attempts to emphasize opportunities with varying velocity and drawdown for these components. Because of the importance placed on advection/dispersion modeling in the effects analysis process for both the upper and lower river, validation of the model is presented as a high priority; current plans are to begin with an experiment in 2017.

Metrics

Metrics for these components will be space and time distributions of larvae and surrogate tracers developed through Eulerian sampling during the experiment. Free embryos will have known genetics to allow for discrimination from wild-produced sturgeon. Metrics will include Lagrangian evaluation of the flow fields experienced by the tracers to characterize mean velocities, variance, and longitudinal dispersion coefficients; these data will be collected by acoustic Doppler current profile mapping from boats floating with the tracers. Areas identified with increased loss of tracers will be identified for subsequent, high-resolution measurement and modeling of the flow field to determine conditions that retard or retain drifting larvae.

Timelines and contingencies

Component 3 is fundamental to acceptance of information from advection/dispersion modeling in the decision making process, supporting the argument that it should be prioritized among the Upper River Big Questions. Component 3 is anticipated to start in 2017 in parallel with components 1 and 2. A minimum of two experiments is anticipated to establish some confidence in replicability (additional controlled experimentation would occur under level 2). To allow for variability in years and availability of sufficient numbers of free embryos, four years are indicated for the component. It should be noted that prerequisites for these experiments are availability of a large number of free embryos and agreement among the pallid sturgeon recovery team that release of free embryos would not skew desired genetics of stocked fish. In addition, experiments will require coordination with USACE reservoir control to manage releases from Fort Peck during the experiments.

Decision criteria for application of component

Decision criteria at this stage apply to the value of information in decision making and the decision to move to level 2. In particular, the results of drift/dispersal experiments will likely document the probability distribution for free embryos to be retained upstream of the headwaters of Lake Sakakawea, and therefore the probability for successful recruitment. Results could be definitive (for example, a vanishingly small probability of retention in the free-flowing river) or equivocal (for example, 2% probability of retention in the free-flowing river). If equivocal, other science components may be useful in determining how survival could be maximized.

C.2.5.5.4 Component 4

Component 4 is a mesocosm study designed to quantify how and why free embryos velocities depart from passive transport assumptions. The study will take place in racetrack flume mesocosms, or similar facility, to quantify the factors that may operate to alter transport conditions from purely passive assumptions. If component 3 information is definitive, these studies may not be necessary, although the staging (Appendix F) shows them taking place in parallel.

Metrics

Metrics for component 4 will be virtual velocity of the free embryo as a function of time, cumulative temperature units, and developmental stage. These metrics will be evaluated for different levels of channel complexity in constructed in racetrack flumes (e.g., varying substrate and varying bedforms). Qualitative observations will also be important for direct insight into if and how actual dispersal mechanisms depart from purely passive assumptions.

Timelines and contingencies

This study is likely to take three years in order to test useful ranges of velocity, bed configurations, substrate, and perhaps genotype. Quantification of processes responsible for departures from passive transport assumptions will be important to the extent that experiments in component 3 indicate that departures exist. From previous studies we expect biological processes to become an increasing influence on lowering dispersal rates after about 8 days post hatch (Braaten et al. 2012); these components will quantify these processes. This study is anticipated to begin in 2017 simultaneous with components 1, 2, and 3.

Decision criteria for application of component

Results from this study component will contribute to understanding of probabilities of free embryo retention and to the decision to move to level 2 experimentation. The mesocosm experiments are likely to provide robust statistical evaluation of relations among abiotic variables, development stages, and dispersal rates. However, because the mesocosms cannot be expected to capture the range of velocities, hydraulics, and macroturbulence of the real river, substantial uncertainty will exist about whether all factors potentially influencing drift will be captured. The information will contribute useful information, however in design of level 2 experiments.

C.2.5.5.5 Criteria to move to level 2

The decision to move to level 2 field experimentation, component 5, will be based on judgement from multiple lines of evidence. If anoxia is documented to be pervasive and fatal and advection/dispersion models (component 1a) and field experimentation (component 3) indicate that dispersal from likely spawning locations (component 2b) indicate that retention in free-flowing parts of the Upper Missouri and Yellowstone has an extremely low probability, then level 2 experiments would not provide useful information. On the other hand, if the anoxic zone is patchy (component 2a, 1b) and/or retardation mechanisms can be identified and quantified (components 3, 4), then some reasonable probability may exist that slowly dispersing free embryos could be retained and thrive in free-flowing reaches. In this case, field experimentation to quantify survival rates under controlled conditions would be useful.

C.2.5.6 Level 2

C.2.5.6.1 Component 5

Component 5 is in anticipation of field experimentation and consists of experimental determination of effects on authorized purposes of reduced flows and velocities from Fort Peck intended to slow dispersal.

Metrics

Metrics will be velocities, water-surface elevations, and potential dispersal distances for an appropriate range of low-flow releases during dispersal season, compared to potential authorized purposes like public- and irrigation water supply and recreation.

Timelines and contingencies

This study component would be highly contingent on results from components 1–4 indicating reasonable probabilities for survival and recruitment. While it is expected that much of the effect of a low-flow release experiment is already captured in existing 1-d models, it is anticipated that a pilot experiment of one or more releases to evaluate velocities achieved and to assess any negative influences on other authorized purposes. A series of low-flow releases could be completed in one year.

Decision criteria for application of component

Decisions related to this science component will be whether pilot results are sufficiently satisfactory to move onto field experimentation. If low-flow pulses provide anticipated decreases in mean velocities and do not substantially diminish attainment of other authorized purposes, results would support moving to field experimentation in component 6.

C.2.5.6.2 Component 6

The final science components in this Big Question are two inter-related efforts. Component 6a is a series of controlled field experiments in which combinations of flow releases from Fort Peck Dam and drawdown of Lake Sakakawea are tested to determine whether management actions can provide for first feeding within the supportive, free-flowing reach of the Upper Missouri River. These experiments will use day-1 free embryos and other tracers injected into the Upper Missouri River at likely spawning locations near Fort Peck, and downstream transport and survival will be monitored using the same protocols described in component 3. Survival estimates from these studies will be directly applied to population models to assess effects of these management actions on population dynamics. The form of the experiment will be very similar to component 3, only with manipulated releases and drawdowns.

Component 6b is an experiment to address a fundamental uncertainty associated with passage at Intake Dam. The experiment will translocate and release a dozen or more tagged, reproductive male and female pallid sturgeon upstream of the dam during June when temperatures rise above 16C. Upstream migration of the fish will be monitored through active and passive telemetry to determine where they select for spawning habitat. That habitat will then be extensively characterized to quantify the physical environment, and free-embryo collection will be implemented downstream to attempt to confirm successful spawning, fertilization, hatch, and recruitment to the drift. Whether this experiment takes place before or after construction of the passage at Intake, the results will provide a clearer view of spawning habitat selection, without the requirement to first pass by the dam. If spawning occurs, the spawning site will allow for calculation and assessment of adequate drift distance using advection/dispersion models.

Metrics

Metrics for component 6a will be very similar to component 3; space and time distributions of larvae and surrogate tracers developed through Eulerian sampling during the experiment. Free embryos will have known genetics to allow for discrimination from wild-produced sturgeon. Metrics will also include Lagrangian evaluation of the flow fields experienced by the tracers to characterize mean velocities, variance, and longitudinal dispersion coefficients; these data will be collected by acoustic Doppler current profile mapping from boats floating with the tracers. Depending on the location of the headwaters and the presumptive anoxic zone, survival will be calculated as the proportion of free embryos that remains in the free flowing river at first feeding. The advection/dispersion models and sampling will indicate what section of the lower river will likely retain exogenously feeding larvae, and those sections will be targeted for aggressive capture of larvae to establish survival.

Metrics for component 6b will be similar to Big Question 1, components 2 and 5, and will include intensive and passive network telemetry tracking data of reproductive adults (males and females) to determine spawning locations. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes, combined with sampling for free embryos. Spawning sites will be extensively characterized with hydroacoustic instruments to quantify depth, velocity, velocity profiles, basal shear stress, and substrate. Based on spawning location, survival probability of free embryos will be calculated using the refined advection/dispersion models.

Timelines and contingencies

Components 6a and 6b will occur contingent upon results from components 5a and 5b. Component 6a may require a series of low flows combined with a series of drawdown events. Without replication, assuming 4 treatment levels of each, 16 years would be required; however, the experiments could be implemented to minimize the numbers of treatment combinations based on results acquired from some of the extreme combinations. Anticipating the ability to accomplish some optimization, eight years are estimated for these experiments. Larval drift sampling for this component would also be supportive of larval drift sampling from component 6b. The Intake translocation experiment is contingent on deployment of the passive telemetry network and availability of reproductive adults, but is otherwise not contingent on other science components. This experiment could occur as early as spring 2017 (Appendix F). The experiment should be replicated at least four times, during four years, to characterize reproducibility.

Decision criteria for application of component

For component 6a, decision criteria at this stage apply to the decision to move to level 3 on the Upper Missouri, to implement flow changes, or drawdowns, or both. For component 6b, the information will contribute to understanding the potential for the Intake Passage Project to result in successful recruitment. If the translocated fish spawn sufficiently far upstream to allow for settling before hitting Lake Sakakawea, then a significant assumption will be validated and focus can be applied to level 3 monitoring of passage at the project. Conversely, if the fish do not spawn far enough upstream, then management options on the Upper Missouri River may be worthy of reconsideration.

C.2.5.7 Critical scientific uncertainties and constraints

The fundamental scientific uncertainty for component 6a is whether spawning locations on the Upper Missouri, flow management to minimize advection, and drawdown to maximize drift distance can combine to result in recruitment. The fundamental uncertainty for component 6b is whether reproductive adults who find passage around or over Intake Dam will migrate sufficient distance to find suitable spawning habitat, and spawn in sufficient numbers to recruit to the population. Resolution of these uncertainties will have a profound effect on the ability to predict whether recruitment is possible in the upper river. In the event that spawning upstream of Intake is not successful, other uncertainties become more important. One of those relates to biological departures from purely passive transport of free embryos. If free embryos progressively develop the ability to move themselves out of the current or to slow dispersal by interacting with benthic bedforms, then advection/dispersion calculations will overestimate dispersal distance. In such a case, management actions on the Upper Missouri River may have the potential to support recruitment. Components 3, 4, and 6 address this uncertainty and will contribute to refinement of the advection/dispersion model.

C.2.5.8 Utility of study components

These components directly address the foremost decisions on the upper river: whether passage at Intake Diversion Dam is sufficient to support recruitment, or instead whether recruitment can be accomplished through management actions on the Upper Missouri River.

C.2.5.9 Ancillary information benefit

Ancillary information collected during these science components will include detailed characterization of channel morphology, flow fields, transport rates, and ecological complexity, all of which may provide useful insights into ecosystem health. Captures of free embryos of species other than pallid sturgeon will provide insights into how spawning, drift, and dispersal affect recruitment of those species.

C.2.5.10 Risks

Level 1 science components present few risks, except possibly to the population augmentation program because of changes in genetic diversity and increased mortality of very young free embryos in field experiments. Parentage will need to be carefully selected so under-represented genetics are not potentially wasted in the experiments, or if survival is high, that over-represented parents are not used. Level 2 risks may be substantial because low flows and drawdowns on Lake Sakakawea may have implications for a wide range of authorized purposes. Risk involved with the translocation experiment include potentially wasting opportunities to use the fish in the propagation program, or to apply the tagged fish to other science components.

C.2.5.11 Adaptive actions

Results of these science components will establish important decision space for adaptive actions in the upper river. Knowing whether or not the Intake Project is likely to work as planned will indicate whether the Yellowstone River can be relied on for future recruitment, or if instead, an action should be taken to improve recruitment on the Upper Missouri River. The information developed in these science components will show what combination of Fort Peck low releases and Lake Sakakawea drawdowns may produce recruitment.

C.2.5.12 Estimated costs:

Estimated costs for components 1–4 are relatively low. Costs for components 5a and 6a could be substantial depending on how many test flows and drawdowns are needed, and how costs to authorized purposes accrue. The cost for robust monitoring and assessment of the Intake Project to support Missouri River decisions is estimated at about $500,000 per year.

C.2.6 Upper Big Question 6: Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?

C.2.6.1 Objective of study components

The science components for this Big Question are nearly identical to those for the lower river (Lower Big Question 6), with differences limited to geographic location. The objective of these study components is to provide the understanding needed to optimize population augmentation in recovery of the pallid sturgeon. While population augmentation is thought to be necessary for recovery of the pallid sturgeon, by itself it is not sufficient as the Endangered Species Act requires a self-sustaining population objective. Nevertheless, augmentation can help severely depleted populations recover numbers of individuals needed to evaluate what works and what doesn't in recovering the population.

The study components listed here will provide information to improve population augmentation methods and hopefully achieve higher survival at lower cost, while maintaining needed genetic diversity. Population augmentation is already taking place at the level where it has a measurable effect on the population (level 3), and it is assumed that population augmentation is presently following best management practices, to the extent possible, to maintain genetic diversity. The study components described here are not considered necessary steps before implementing level 3. Instead, the level 1 and level 2 components will develop information to improve on the level 3 implementation. The USFWS is preparing an update of the Pallid Sturgeon Rangewide Stocking Plan that, in combination with the collaborative decision making process of the Pallid Sturgeon Recovery Team and basin workgroups, may determine specific population-augmentation policies and information needs. The study components outlined here can be considered indicative of the types of studies that may be needed, rather than definitive.

Study components include an engineering study to investigate facility-design options for the pallid sturgeon hatchery system to determine if it might be possible to increase and maintain consistent production with appropriate, size, health, and genetics; some of this work may be accomplished or preempted by the drafting of a new propagation plan by the USFWS. Field monitoring components are proposed to evaluate how size, health, and genetics have affected survival of previously stocked fish. To develop quantitative relations between propagation decisions and survival probabilities, a modeling study is proposed to evaluate population sensitivity to typical ranges of differential survival that might be affected by size, health, and parentage, and varied stocking rates that might arise from year to year variability in available broodstock or hatchery survival. A similar modeling study is proposed to investigate sensitivity of population genetics to variability in available parents, variable survival of family lots. Finally, a series of field experiments can be envisioned to provide a systematic evaluation of costs and population benefits associated with stocking at a range of sizes (ages).

C.2.6.2 Relation to Effects Analysis

These study components provide information to support EA hypotheses 8 and 9. Since the EA integrative report was written, new information has become available indicating that incidence of disease in hatchery origin fish has substantially constrained stocking levels in recent years. New information has also indicated that fish may have been overstocked in the upper river and that some genetics are over represented among the stocked population. Although disease was not identified as a priority working hypothesis in the EA, the issue is intimately connected to the two issues that were identified, genetic parentage and size. In the case of parentage, population augmentation best-management practices generally do not support culling populations based on genetic makeup, as doing so would apply an unnatural selective pressure. Hence, management actions related to genetics (hypothesis 21) are actually quite limited aside from existing best management practices that seek to manage for diversity. Size at stocking, however, is a variable that can be managed, and doing so has implications for costs, numbers available to stock, and disease exposure. While survival nominally increases with size at stocking, the longer a fish is maintained in the hatchery the greater the cost (including opportunity cost for other fish species that are not propagated) and the greater the opportunity for disease. Consideration of hypothesis 8 therefore, implicitly involves consideration of facilities capacity and disease risk.

C.2.6.3 Approaches

Approaches to these study components at level 1 include an engineering design study, field-based monitoring of differential survival rates, and sensitivity assessments using population and population genetics models. At level 2, a series of field-based experiments can be envisioned for a systematic evaluation of size at stocking effects on differential survival.

C.2.6.4 Level 1

C.2.6.4.1 Component 1

This component would be an engineering feasibility design study to address costs and presumed population benefits for propagation facilities of different designs and capabilities. The selection of design and capability would be based on costs relative to results of component studies 2–4, which would indicate benefits of stocking size, and related disease risk. Much of the work may be accomplished by the USFWS revised propagation plan currently (2016) under development.

Metrics

Metrics for this study would be costs and measures of likely survival for a range of facilities designs, including distribution of risk based on numbers of hatcheries. Measures of survival would be based on existing data for differential survival for stocked age-0, age-1, and juvenile fish, plus an estimate of the relations among designs, operations, size at stocking, and risk of disease.

Timelines and contingencies

Although this study would benefit from new information that evolves from components 2–4, the immediacy of the issue and likely time lag between a study and changes in facilities and operations indicates that the feasibility study should start soon, perhaps as early as October, 2017. The study is estimated to take two years for completion and would be done concurrently with components 2 and 3.

Decision criteria for application of component

The results of the feasibility study would presumably indicate a range of options in facilities and operations, with attendant costs, and benefits to the propagation program in terms of probable increased survival. Indications from this component of benefits from alternative designs, and at a reasonable cost, will provide evidence to move to level 2. The decision of what improvements to implement (a level 3 or 4 action) would be based this information as well as information from components 2, 3, and4.

C.2.6.4.2 Component 2

This study will use monitoring data on growth and survival of hatchery-origin fish to assess how factors such as size at stocking, health history, and parentage may have affected survival. The study assumes that genetic and propagation records for hatchery-origin fish are complete and accurate. Appropriate monitoring could be a stand-alone operation or it could be incorporated within a population-trends monitoring program (see population monitoring project discussion, Appendix D). Monitoring would need to include both the Upper Missouri and the lower Yellowstone Rivers. A Cormack Jolly Seber (CJS) model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

The metrics for this component are estimates of the number and survival rates for stocked pallid sturgeon by stocked size, hatchery of origin, location of release, and health history.

Timelines and contingencies

The timing for this component would be most efficient if coordinated with the population trends monitoring described in Appendix D. It is estimated that 3 years of sampling would be necessary, at a minimum, to provide useful data on differential survival. Sampling could be coordinated and coincident with population trends sampling.

Decision criteria for application of component

Information developed in this component will illustrate the scope of differential survival and whether a need exists for fundamental changes to the propagation facilities and operations. The statistical rigor of the analysis is difficult to anticipate and decisions may need to be made based on judgements informed by multiple lines of evidence, including results from components 1 and 3.

C.2.6.4.3 Component 3

These study components are model simulation studies intended to test sensitivity of population dynamics and population genetic structure to variability in augmentation. The first of these would assess how population dynamics would be affected by typical variation in survival related to size at stocking, results of which would indicate if there is value to the population to develop hatchery capabilities to optimize size, with implications for hatchery capacity and number of hatcheries. The model would also be used to assess effects of variable stocking rates (due to year-to-year variability in broodstock availability), health history, and parentage. The second of these models would investigate sensitivity of population genetics to mating decisions made in the hatchery and other factors like year to year variation in availability of wild broodstock. Results will provide a quantitative basis for assessing risks of genetic swamping and insights into effort needed to collect and keep broodstock.

Metrics

Metrics from these modeling studies will include probability of quasi extinction, instantaneous growth rates, and sensitivity measures under various scenarios and parameterizations of the models.

Timelines and contingencies

Ideally, some of the parameters for the models would be informed with data from the mark/recapture survival data from component 2, although useful assessments of sensitivity do not necessarily need high-precision parameter estimates. The time for completion of the study is estimated to be 3 years and would occur in parallel with components 1 and 2.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities and operations and stocking. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgement informed from multiple lines of evidence.

C.2.6.4.4 Criteria to move to level 2

Level 2 components are field based experiments that will vary size at stocking and release location, and assess differential survival. These level 2 activities may not be necessary to decide among facilities/operations options if the retrospective evidence is sufficiently robust. Moving to level 2 would be indicated if models show a high sensitivity of cost and survival to size at stocking, and more precise parameters for the relationships are needed, and if information from components 1 and 2 also show a need for level 2 studies.

C.2.6.5 Level 2

C.2.6.5.1 Component 4

If results of component 2 are equivocal about relations between size at stocking and differential survival, this component will provide a systematic, field-based experiment to assess the effect. The study would involve stocking fish at variable sizes (representing variable hatchery costs) keeping all other factors as constant as possible. Monitoring over several years would provide information on mortality and provide guidance on tradeoffs between survival and cost. The experiment would require that fish are identifiable from year to year based on tags or genetics, and that genetic and propagation records for the fish are complete and accurate. A CJS model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

Metrics from these experiments will be estimated number of stocked pallid sturgeon and survival rates by stocked age, size and hatchery of origin, fish condition, location of release, and water-year conditions.

Timelines and contingencies

This component would only be pursued if deemed necessary to make decision regarding facilities and operations. The monitoring approach would be a subset of the previously described population trends assessment; we estimate a minimum of five years to provide useful information on survival based on two years of stocking of 4 size ranges and 4 years of monitoring.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities, operations, and stocking. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgement informed from multiple lines of evidence.

C.2.6.6 Critical scientific uncertainties and constraints

One critical uncertainty for these components is the geographic scope that needs to be sampled to assess survival. Another uncertainty is how co-variates – environmental conditions, genetics, and health history – will interact to determine actual survival. A critical constraint in implementing field-based experiments with stocking is the availability of fish with appropriate genetics from the hatchery system.

C.2.6.7 Utility of study components

The study components under this Big Question address information that may be useful in improving effectiveness of the population augmentation program, which is in turn, a critical part of the recovery program. The information developed will be useful in cost: benefit decisions about investments in hatchery facilities and capabilities.

Monitoring proposed as parts of components 2 and 4 will be consistent with monitoring efforts envisioned for drift/dispersal studies and may contribute to population-trends monitoring.

C.2.6.8 Risks

Risks to pallid sturgeon populations presented by these components are low as long as best management practices for conserving appropriate genetics are practiced. Risks to stakeholders appear also to be low.

C.2.6.9 Decision criteria

The information gained in these studies will inform investments in hatchery facilities and capabilities, and perhaps contribute to refinement of some propagation decisions.

C.2.6.10 Adaptive actions

Information provided through these components would be useful in incremental changes to hatchery facilities and procedures.

C.2.6.11 Estimated costs

Costs of development of new facilities or expansion of existing facilities could be high. The intent of this set of components is to provide a cost: benefit basis for understanding the value of that investment.

C.3 Lower River

The lower river refers to the Missouri River mainstem downstream of Gavins Point Dam, the influences (to the extent they are relevant) from upstream reservoirs like Fort Randall and Lewis and Clark Lake, influences of major tributaries, and some distance downstream in the Middle Mississippi River (Figure C2). The level 1 and level 2 adaptive management actions are referred to below by Big Questions.

Although contingencies based on evolving information might dictate a sequential approach to science components and eventual management actions, the staging discussed here assumes all level 1 components are simultaneous, followed by appropriate level 2 field experiments. Appendix F presents more detail on prioritization, staging, and costs.

C.3.1 Lower Big Question 1: Can spring pulsed flows synchronize reproductive fish,

increase chances of reproduction and recruitment?

C.3.1.1 Objective of study components

The objective is to determine if water flow, or changes in flow, from Gavins Point Dam during the spring influences spawning behavior and successful reproduction of pallid sturgeon in the Lower Missouri River.

C.3.1.2 Description of study components

Water discharge is thought to influence pallid sturgeon migration behavior, reproductive readiness, and possibly spawning site selection prior to spawning. By naturalizing the flow regime from the dam during spring, reproductive pallid sturgeon may be cued to migrate in synchrony and lead to increased aggregations at spawning locations. This could increase the chances of successful reproduction.

C.3.1.3 Relation to Effects Analysis

These study components directly support EA hypothesis 11: Naturalization of the flow regime at Gavins Point will improve flow cues in spring for aggregation and spawning of reproductive adults, increased reproductive success.

C.3.1.4 Approaches

Two levels could be implemented to test this hypothesis. Level 1 includes opportunistic field testing in the river and experiments in a constructed mesocosm in order to evaluate behavioral responses under more controlled conditions. Level 2 includes an engineering study to determine the associated effects of flow pulses and implementation of experimental flow releases to test fish reproductive behaviors.

C.3.1.5 Level 1

C.3.1.5.1 Component 1

This component consists of two sub-components, 1a and 1b. Component 1a is a technology-development study to design and implement a passive, fixed-station telemetry receiver network to complement intensive, boat-based tracking. The study is intended to support component 2, but is delineated separately because of the potential challenges in design and implementation in the dynamic Missouri River system. Component 1b is a power analysis of the ability to associate reproductive behaviors with flow pulses. Component 1b will indicate whether existing or future levels of effort will be able to provide statistical rigor to the hypothesis that flow pulses cue spawning and recruitment.

Metrics

Component 1a, telemetry network. Metrics for this technology development study will be performance metrics for detectability of tags and variation of detectability with discharge and sediment load. Cost and reliability will be additional metrics.

Component 1b, power analysis. Power analysis will be used to determine the number of tagged adults required to detect differences in the level of spawning or other reproductive response.

Timelines and contingencies

The technology developed and tested under component 1a would contribute to success and cost effectiveness of subsequent components (components 2 and 5), as well as being a substantive contributor to assessing immigration and emigration for population-level monitoring (see Appendix D). Development and testing could be accomplished in one year, and may begin as early as 2017. Components 1a and 1b would proceed at the same time, and would also be concurrent with the other level 1 studies under components 2 and 3.

Decision criteria for application of component

If testing of a passive telemetry network design proves successful, the decision may be made to deploy passive telemetry receivers in a network that will contribute to sample designs for evaluating sturgeon responses to flow pulses. Success will be determined by the ability to detect fish movements past strategic locations. Power analysis under component 1b will indicate numbers of fish and level of effort that will be necessary to develop statistically significant relations between flow pulses and reproductive responses, either to accept or reject the hypothesis. The results may indicate that statistical rigor is feasible or infeasible.

C.3.1.5.2 Component 2

This study component would involve monitoring of water discharge, pallid sturgeon movement, and pallid sturgeon location data. Flows would need to be measured continuously across numerous locations longitudinally downriver from Gavins Point Dam. A range of opportunistic flows (low to high) would be needed to bracket ecologically ineffective and effective flows. Variation in flow regimes from upstream to downstream provide dynamic range in discharges, without requiring intentional flow releases. Pallid sturgeon in reproductive condition would need to be tracked via telemetry methods to determine movement patterns. Telemetry would include documenting reproductive behavior (aggregation, spawning) and spawning success as measured by production of free embryos and/or age-0 catch rates. Statistical relationships of flow-regime components (mean discharge, change in discharge, e.g.), and covariates (turbidity and temperature) to pallid sturgeon behavior would be evaluated.

Metrics

Metrics for this component will include the degree of association of reproductive migrations and successful spawning with monitored hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, water quality). Intensive telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes. Catch of free embryos and/or age-0 pallid sturgeon can also be used as an indicator of reproductive success as demonstrated in 2014 and may be collected as part of other science activities.

Timelines and contingencies

This component is an extension of existing research efforts in understanding reproductive ecology of the pallid sturgeon. A collaboration among agencies has collected 8 years of reproductive movement data based on telemetry, and those data have not been sufficient to associate reproductive success with hydrologic characteristics. More tagged fish and a longer record will be required to reach a significantly improved understanding if hydrologic links exist and are important to the pallid sturgeon population. We anticipate an additional 8 years of data collection will be necessary. Success of the study will depend in part on development of passive receiver networks (component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program.

Information on spawning habitat selection generated in this science component will also be used in Big Question 5, component 2, related to identifying and quantifying functional spawning habitat.

This component may progress in parallel with mesocosm experiments in component 3, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Decision criteria for application of component

Based on research experience, it is unlikely that this component will result in a statistically rigorous decision. Instead, a decision to use the information in decision making will probably be based on judgement of multiple lines of evidence, probably combined with results of mesocosm experiments in component 3.

C.3.1.5.3 Component 3

Many of the same aspects of component 2 would be measured in component 3, however at a small scale in a controlled environment. Possibilities for mesocosm experiments include very large circulating tanks, circulating ponds, or constructed side channels to the Missouri River. Mesocosm experiments would vary water velocity, temperature, and turbidity (and rates of change) to evaluate behavioral responses of reproductive adults. Acoustic video and 3-d telemetry arrays would allow for detailed characterization of behaviors.

Metrics

Metrics for this component will include the degree of association of reproductive behaviors with manipulated hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, water quality). Intensive, fine-scale telemetry tracking data of reproductive adults (males and females) will be evaluated in trials with varying discharge, temperature, and turbidity. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes, complemented with targeted sampling of free embryos. The ultimate metric will be probability of successful spawning as a function of abiotic variables.

Timelines and contingencies

This component may progress in parallel with field-scale telemetry in component 2, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Implementation of this component will require construction of a mesocosm (large flume facility) that is capable of creating a wide range of hydrologic and water-quality conditions; in addition, the facility will need to be large enough to accommodate multiple full-sized adult fish (see discussion of Lower Big Question 2, component 3). This facility could be semi-controlled side channel of the

Missouri River or a highly controlled experimental flume such as the USACE-ERDC cognitive fish flume (http://el.erdc.usace.army.mil/emrrp/nfs/facilities.html). Mesocosms for this science component would presumably be the same as those used in the upper river for Big Question 1, component 3.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 2 implementation or possibly to decisions about rejecting the hypothesis that flows can be managed to optimize spawning and recruitment. Controlled mesocosm studies may provide statistically rigorous results indicating the presence or absence of hydrologic effects on reproductive success, and the strength of any association that exists. Such information would likely be an incomplete assessment of field-scale conditions, and so would be evaluated in a lines-of-evidence approach along with information from components 1 and 2.

C.3.1.5.4 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is or is not a likely relation between actionable hydrologic characteristics and reproductive success. The judgement should be based on the strength and replicability of relations between flow pulses (and associated water quality characteristics) and reproductive migrations, spawning, and spawning success demonstrated by capture of free embryos. In addition, movement to level 2 should entail development of design parameters for a series of pulsed-flow experiments.

C.3.1.6 Level 2

C.3.1.6.1 Component 4

In anticipation of intentional experimental flow releases in approach 4, an engineering study may be conducted to evaluate effects of experimental flow releases on other authorized purposes such as interior drainage and tern/plover nesting habitat. This study would also be used to design monitoring of ancillary effects during intentional flow releases.

Metrics

Metrics for this component will include measures of the effects of flow pulses on other authorized purposes. Some of the elements of these studies will have been developed in earlier planning efforts, such as human consideration proxies and metrics in the MRRMP. New studies on the specific effects of the experimental releases will provide similar metrics, such as days above flood stage or days above flap-gate elevations, but specific to the planned experiments.

Timelines and contingencies

This component is expected to take 2 years and is contingent on completing all of the level 1 analyses so the results of the experimental design parameters can be evaluated.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 5. That decision will be based on development of functional relations between experimental flow pulses and effects on other authorized purposes. If experimental flow-pulse characteristics thought to be biologically significant (magnitude, duration, frequency, timing, rate of change) reach a threshold wherein impacts to other authorized purposes are a concern and/or are beyond levels previously given NEPA coverage, then additional analysis and approval may be needed to move to level 2. If experimental flow pulse hydrologic characteristics are within previously approved levels, then the decision to be made to move to level 2 field experimentation would be based on anticipated biological results.

C.3.1.6.2 Component 5

This study is similar to Level 1, component 2, but uses experimental flow releases from Gavins Point to exert additional experimental control. Flows from Gavins Point dam would be deliberately manipulated over a range of magnitude, duration, timing, and rate of change to evaluate reproductive behavior of pallid sturgeon. Years with flow pulses should also be tested against control years without flow pulses. Implementation of Component 5 depends on the outcome of Level 1, Component 2, and the decision criteria describe in the evidentiary framework, Table 49 in section 4.2.6.6 of AM Plan).

Metrics

Metrics for this component will be very similar to component 2 and will include the degree of association of reproductive migrations and successful spawning with monitored experimental flow pulses. Intensive telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes. The experiment will be a series of pulsed-flow releases over several years; the series will result in a functional relationship between flow-pulse characteristics and probability of producing viable gametes.

Timelines and contingencies

For the experiment to be successful there will need to be a substantial number (50 or more) of tagged, reproductive adult fish identified and tracked each experimental year in the river segments upstream from the Platte River. The number will be determined by the power analysis in component 1b. Assuming a minimum of 4 pulse levels and the risk that experimental logistics may fail 1 year in 2, at least 8 years will be necessary for this component. Success of the study will depend in part on development of passive receiver networks (component 1a) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 3. Experimental control imposed in this component will add to the ability to detect and quantify reproductive behavioral changes related to flow pulses; however, the experiments will still take place within a system where many sources of variability are not controlled, such as weather systems and tributary inputs. It is therefore unlikely that these experiments will result in a statistically rigorous result. Instead, a decision to accept the value of manipulated flow pulses in increasing pallid sturgeon reproductive success, or to reject it, will probably be based on judgement of multiple lines of evidence.

C.3.1.7 Critical scientific uncertainties and constraints

Several science components require the ability to tag and monitor a large population of pallid sturgeon in the Lower Missouri River so reproductive condition and history of subject fish are known. A tagged population will also aid a population monitoring program by quantifying reproductive home ranges and immigration and emigration. Implementation of mesocosm studies will require a facility that can culture reproductive adult fish for experiments and construction of a mesocosm large enough to accommodate ecologically significant velocity, temperature, and turbidity pulses. Locations of fish in the field and mesocosms must be established with high spatial and temporal frequency during spawning season in order to infer with confidence that behaviors are relatable (or not) to flow pulses. Data on flow-related covariates (water temperature and turbidity) are also necessary to discriminate cause and effect.

Implementation of field experiments will require buy-in from agencies and stakeholders to accept risks from providing flow pulses of a magnitude that are likely to be measurable and effective. Improved evaluation of spawning success will require additional investment in technology to image spawning behaviors, egg release, and fertilization in challenging hydraulic environments.

C.3.1.8 Utility of study components

These study components will provide critical information to determine if pallid sturgeon require flow cues that ultimately lead to successful reproduction. If flow cues are apparent, the study component will provide guidance about flow thresholds, changes in flow, or other aspects of flow influencing spawning behavior.

C.3.1.9 Ancillary information benefit

The results of the assessment will provide ancillary information applicable to habitat use, spawning locations, reproductive ecology, and migration routes of pallid sturgeon.

C.3.1.10 Risks

Manipulating discharge from Gavins Point Dam (component 5) imposes the greatest risk for this Big Question. Impacts on stakeholders could be considered high, depending on the magnitude of flow changes. Manipulated flows that are too low or too high could lead to problems with navigation, water supply, or flooding, for example. Little risk to stakeholders is associated with level 1 components. Risk to pallid sturgeon is minimal as telemetry on the species has been practiced for a decade without issue.

C.3.1.11 Adaptive actions

Results of these study components could provide information to optimize releases from Gavins Point Dam in the spring, or potentially to indicate that flow manipulations are not necessary to elicit a reproductive behavioral response from pallid sturgeon. The hydrologic characteristics of the flow pulses (magnitude, duration, frequency, timing, rate of change) can be adaptively managed to elicit an optimal biological response while minimizing effects on other authorized purposes.

C.3.1.12 Estimated costs

Estimated cost of this study component is medium to high. Maintenance of a telemetry tagged population, construction of a passive telemetry array, intensive telemetry tracking, and construction of a large-scale mesocosm would all require substantive investments on the order of several million dollars per year.

C.3.2 Lower Big Question 2: Can water-temperature manipulations at Fort Randall and/or Gavins Point contribute significantly to increased chance of reproduction and recruitment?

C.3.2.1 Objective of study components

The objective of these study components is to determine if increased water temperature from Ft. Randall and/or Gavins Point dams during the spring influences spawning behavior and successful reproduction of pallid sturgeon in the Lower Missouri River.

C.3.2.2 Description of study components

Water temperature could influence the timing of pallid sturgeon migration behavior and spawning activity. By increasing water temperature in the Lower Missouri River during spring, reproductive pallid sturgeon may be cued to migrate in synchrony, leading to increased aggregations at spawning locations. This could increase the chances of successful reproduction.

C.3.2.3 Relation to Effects Analysis

This study component directly supports EA hypothesis 15: Operation of a temperature management system at Fort Randall and/or Gavins Point dams will increase water temperature downstream of Gavins Point dam, providing improved spawning cues for reproductive adults. The EA presented data indicating that the effects of flows out of Fort Randall on water temperatures downstream of Gavins Point were uncertain, as was the net cooling effect from joint Fort Randall and Gavins Point operations (Jacobson et al., 2016a).

C.3.2.4 Approaches

Two levels with five different components could be implemented to evaluate this hypothesis. Level 1 includes modeling temperature increases as a function of water releases from the dams (component 1), relating temperature differences to fish behavior using surrogates (component 2), and relating water temperature to fish behavior in mesocosms (component 3). Level 2 includes pilot engineering tests to measure temperature increases in the Lower Missouri River as result of temperature manipulation from either of the two dams (component 4) and field experiments of pallid sturgeon reproductive behavior related to temperature increases (component 5).

C.3.2.5 Level 1

C.3.2.5.1 Component 1

This engineering study component would investigate, through modeling, alternate water release geometries or mechanisms at Ft. Randall and/or Gavins Point dams to determine if operations of the dams substantively decrease water temperatures downstream of Gavins Point Dam, and by extension, whether operations could mitigate this effect. Historical water temperature data from the Ft. Randall reach and downstream from Gavins Point Dam could be used in a modeling approach to predict the requirements for an ecologically significant increase in river water temperature downstream from Gavins Point Dam. Modeling should include scenarios where temperatures are increased from Ft. Randall Dam, Gavins Point Dam, and both dams. Modeling should also include the longitudinal extent of increased temperatures and include a seasonal component (early spring to summer).

Metrics

Metrics for this technology development study will include absolute water temperatures and changes relative to existing and unregulated water temperatures, by river mile downstream of Gavins Point Dam for various temperature control implementations. In addition, costs and performance metrics for the temperature control scenarios will be used to evaluate cost effectiveness.

Timelines and contingencies

The models developed in this component will provide 1) quantitative understanding of need and efficacy for water temperature control and 2) an estimate of costs. As such, this component will provide foundational information to determine whether the hypothesized action is necessary and realizable. Components 1, 2, and 3 would start at the same time, possibly as early as 2017. If models indicate a significant lowering of water temperature, additional models will be run to address feasibility of mitigating water temperature effects; results of these models will be used as a foundation for component 4.

Decision criteria for application of component

Results of the modeling will demonstrate whether operations of Ft. Randall and Gavins Point dams create a significant decrease in water temperature relative to historical, and if so, how much of the river is affected. If the change in water temperature is within prediction error, there will be no need to continue with other science components of this management action. However, if results show a significant decrease, then results from additional models will be used to decide on feasible methods to mitigate dam operations on temperatures. Moreover, if water temperature decreases are significant relative to the unregulated river, then there will be support to continue with components 2 and 3 to develop biological significance.

C.3.2.5.2 Component 2

This study would examine how reproductive behaviors of surrogate species (other sturgeon species) respond to water temperature variations in other rivers. This could be accomplished by combining a literature search for existing information with targeted telemetry studies of shovelnose sturgeon behaviors on tributary rivers to the Missouri (Big Sioux, Kansas, and Platte) where seasonal water temperature variation occurs. This component would serve to evaluate the extent of temperature response expected in pallid sturgeon. The impetus to use surrogate species is based on the rarity of the pallid sturgeon and the value of developing larger, more statistically robust datasets.

Metrics

Metrics for this component will include the degree of association of reproductive migrations and successful spawning with monitored water temperatures, discharge, and other ancillary water quality parameters. Intensive telemetry tracking data of reproductive adult sturgeon (males and females, pallid sturgeon and shovelnose sturgeon) on the Missouri River and selected tributaries will be evaluated against time series of water temperatures and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes.

Timelines and contingencies

This component is highly related to Lower Big Question 1, component 2, so there would be some economies of scale in carrying out both components. Working with shovelnose as a surrogate (or comparative) species, a larger number of fish can be tagged than can be accomplished with pallid sturgeon alone. In addition, shovelnose use of tributaries will allow for a wider range of environmental effects (temperature, discharge, turbidity) than would result from working in the mainstem Missouri River. This work is not necessarily contingent on other components, but would provide information that would be mutually supportive with component 3. Component 2 may proceed simultaneously with components 1 and 3.

Decision criteria for application of component

It is unlikely that this component will result in a statistically rigorous result due to interactions with uncontrolled variables, and the dependence on surrogate species. Instead, a decision to use the information in decision making will probably be based on judgement of multiple lines of evidence.

C.3.2.5.3 Component 3

This study would evaluate reproductive behavior of pallid sturgeon in relation to water temperatures in mesocosms. The experiment is intended to evaluate fish activity and indicators of reproductive behavior across a temperature gradient to determine the influence of temperature on pallid sturgeon reproductive ecology. Temperatures would need to replicate those in the current system and simulate hypothesized temperature increases from component 1. Mesocosm studies could make use of the facilities and study design used for Lower Big Question 1 (spawning cues).

Metrics

Metrics for this component will include the degree of association of reproductive behaviors with manipulated water-temperature characteristics (magnitude, duration, timing, rate of change of discharge, water quality). Intensive, fine-scale telemetry tracking data of reproductive adults (males and females) will be evaluated in trials with emphasis on varying water temperature, but also considering covarying discharge, and turbidity. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes. The ultimate metric will be probability of successful spawning as a function of water temperature, with or without other interacting abiotic variables.

Timelines and contingencies

This component is shown in the accompanying schedule (Appendix F) as progressing in parallel with field-scale telemetry in component 2, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Implementation of this component could be coordinated with Lower Big Question 1, component 3 because a mesocosm facility for addressing discharge characteristics could also accommodate temperature and other related variables. The same experimental fish populations could be used for both. The mesocosm (large flume facility) would need to be is capable of a creating a wide range of hydrologic and water-quality conditions, and it would have to be big enough to have multiple adult fish. This facility could be semi-controlled side channel of the Missouri River or a highly controlled experimental flume similar to the USACE-ERDC cognitive fish flume (http://el.erdc.usace.army.mil/emrrp/nfs/facilities.html). Presumably, the same mesocosm facility would be used for the upper river, Big Question 1 component 3 and Big Question 3, component 4a.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 2 implementation or, if results are very convincing, to use the information to reject or embrace the hypothesis. Controlled mesocosm studies may provide statistically rigorous results indicating the presence or absence of water-temperature effects on reproductive success, and the strength of any association that exists. Such information would likely be an incomplete assessment of field-scale conditions, and so would be evaluated in a lines-of-evidence approach along with information from component 2.

C.3.2.5.4 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is or is not a likely relation between feasible temperature mitigation and reproductive success. The judgement should be based on the strength and replicability of relations between temperature variation (and associated abiotic characteristics) and reproductive migrations, spawning, and spawning success demonstrated by capture of free embryos. In addition, movement to level 2 should entail development of design parameters for a series of temperature experiments.

C.3.2.6 Level 2

Although level 2 components are included in this compilation, they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and costs of experimental implementation may be untenable.

C.3.2.6.1 Component 4

This study component would be field tests of water temperature manipulation structures or managed water releases to determine if anticipated river water temperatures are realized downstream. Water temperature could be increased by water heating devices, variable depth release structures, or by releasing/pumping surface water from the reservoir into the river. A controlled release of heated water into the river would be measured and monitored. A longitudinal series of temperature monitors would need to be placed downstream to evaluate the effectiveness of water temperature manipulations.

Metrics

Metrics for this component will be increase of water temperatures above those that would have prevailed without the temperature mitigation. This will necessitate well-calibrated water-temperature models to be able to simulate what temperatures would have been in the absence of the mitigation. Field tests may include a range of implementations that would have a range of temperature effects. Field tests would also check to see that water temperature effects were not adverse for other users of the river, e.g. power-plant cooling.

Timelines and contingencies

This component is expected to take 4 years to address climatic variability. It is contingent primarily on component 1 results that will indicate whether water temperatures have been adversely affected by system operations, and components 2 and 3 which will address whether the temperature effects are biologically significant. If results for components 1-3 are negative, components 4 and 5 would be abandoned.

This component is highly related to Lower Big Question 1, components 2, 4, and 5 as studies of flow pulses would need to be coordinated with studies on water temperature manipulations. Empirical data may emerge that both flow and temperature are significant in reproductive success, which would indicate the need for experimental manipulations combining water temperature and flow pulses. Conversely, it may emerge that one or the other, or neither, is significant in increasing reproductive success.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 5. That decision will be based on lines of evidence from components 1-3 and information developed during component 4 that temperature mitigations can be effective. The decision to proceed with component 5 would be based on the demonstrated ability to raise water temperature by an increment thought to be biologically significant.

C.3.2.6.2 Component 5

This component would be a field-based experiment parallel to that of Lower Big Question 1, component 5 in which behaviors of tagged reproductive pallid sturgeon are used as response variables. Temperatures associated with releases from Gavins Point Dam or Fort Randall Dam, or both, would be deliberately manipulated over a range of magnitude, duration, timing, and rate of change to evaluate reproductive behaviors. The experiment would include discharge and turbidity as covariates.

Metrics

Metrics for this component will be very similar to component 2 and will include the degree of association of reproductive migrations and successful spawning with monitored temperature manipulations. Intensive telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of water temperature characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes, and complemented by capture of free embryos. The experiment will be a series of experimental temperature manipulations, likely interspersed with and combined with flow-pulse releases over several years; the series will result in a functional relationship between water temperature characteristics and probability of producing viable gametes.

Timelines and contingencies

For the experiment to be successful there will need to be a substantial number (12 or more) of tagged, reproductive adult fish identified and tracked each experimental year in the river segments upstream from the Platte River. Assuming a minimum of 4 temperature manipulations and the risk that experimental logistics may fail 1 year in 2, at least 8 years will be necessary for this component. Success of the study will depend in part on development of passive receiver networks (Lower Big Question 1, component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program. Time for this experiment may be increased depending on how the temperature manipulations are carried out with in coordination with flow-pulse experiments. If combinations of temperature and flow pulses are considered, the number of years of experiments could extend farther in time than indicated.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 3. Experimental control imposed in this component will add to the ability to detect and quantify reproductive behavioral changes related to temperature manipulations; however, the experiments will still take place within a system where many sources of variability are not controlled, such as weather systems and tributary inputs. It is therefore unlikely that these experiments will result in a statistically rigorous result. Instead, a decision to accept the value of manipulated water temperatures in increasing pallid sturgeon reproductive success, or to reject it, will probably be based on judgement of multiple lines of evidence.

C.3.2.7 Critical scientific uncertainties and constraints

A critical uncertainty is whether water temperatures downstream from Gavins Point Dam have been significantly decreased due to reservoir operations, and if so, whether engineering designs are feasible to increase temperatures. Intentional field experiments will require that water temperature can be increased in an ecologically meaningful manner, probably several degrees Celsius over several hundred km of the river. In addition, comprehensive movement and location data of pallid sturgeon must be obtained in order to make valid inferences about reproductive behavior. Confounding factors that may also influence reproductive behavior, such as discharge and turbidity, must also be taken into consideration. The potential for channel reconfigurations (e.g., IRCs) to increaase water temperatures is discussed in section C.3.3.5.3.

C.3.2.8 Utility of study components

This study component will provide critical information to determine if pallid sturgeon respond to increased temperature cues that ultimately lead to successful reproduction. If temperature cues are apparent, the study component will provide guidance about temperature management and its influence on spawning behavior.

C.3.2.9 Ancillary information benefit

The results of the assessment will provide ancillary information applicable to the river system productivity and response of other organisms in the river to temperature management.

C.3.2.10 Risks

Manipulating water temperature from the dam imposes little risk except cost. Risk to pallid sturgeon is minimal as temperatures would not be increased to a level harmful to the fish. Impacts on stakeholders would be minimal because temperature increases would be in spring before other temperature constraints would apply.

C.3.2.11 Adaptive actions

Based on the results of this study component, the information would be used to optimize water temperature (and discharge) during the spring to increase reproductive success.

C.3.2.12 Estimated costs

The estimated cost of component 1 is relatively low, requiring perhaps one year of engineering modeling study. Components 2 and 3 would incur moderate costs over 2-4 years. Implementation of a field experiment would be extremely costly because of the infrastructure investment ($10's to $100's of millions) needed to increase water temperature at the river scale.

C.3.3 Lower Big Question 3: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?

C.3.3.1 Objective of study components

This Big Question includes 4 inter-related hypotheses from the EA process. The study components are intended to provide the scientific basis for understanding how flow regime and channel reconfiguration can interact to provide food-producing and foraging habitats supportive of increased growth and survival.

C.3.3.2 Description of study components

The hypothesis states that increases in food and foraging habitats, through a combination of channel reconfiguration and flow management, will increase growth and survival of age-0 pallid sturgeon. In this context, flow naturalization refers to using elements of the natural hydrograph to design a more supportive flow regime, but one that is socially and economically acceptable. Channel reconfiguration refers to reconstruction of some combination of main-channel geometry, channel margin geometry, river-training structures, and construction of off-channel water bodies like backwaters and flow-through side channels (chutes). The underlying assumption is that engineering latitude exists in the present channel and channel reconfigurations can be designed to be compatible with other authorized purposes.

Under these hypotheses, food-producing and foraging habitats would be developed in Interception-Rearing Complexes (IRCs) where channel geometry would create conditions conducive to secondary currents that would contribute to advection of free embryos into the complex. Study components at level 1 will focus on engineering, technology development, and field-gradient/mesocosm studies that would establish whether habitats are limiting and how habitats vary within existing IRCs. Contingent on results of level 1 components, study components at level 2 will involve design and implementation of field-scale experiments to quantify linkages from management actions to habitat availability, growth, and survival.

C.3.3.3 Relation to Effects Analysis

Study components address 4 inter-related hypotheses (12, 13, 17, and 18) of the EA. They are treated together in one Big Question because of recognition that flow regime and channel configuration interact in creating habitat, and because of the assumption that both food-producing and foraging habitats will be needed, either in close proximity or linked by transport vectors, to promote age-0 survival.

C.3.3.4 Approaches

Two levels with 6 different components could be implemented to evaluate the 4 management hypotheses. Level 1 is proposed to include methods development and engineering studies to understand spatial characteristics such as IRC size and location. Level 1 will also include screening studies to determine whether food or foraging habitats are limiting to pallid sturgeon, field-gradient studies to quantify relations between management actions (flow and form) and habitat and food availability, and mesocosm studies to attempt to develop quantitative relations between abiotic variables and growth and survival. If level 1 results are supportive, level 2 components would include design and implementation of controlled, field-scale experiments to validate quantitative relations from actions to growth and survival.

C.3.3.5 Level 1

C.3.3.5.1 Component 1

Component 1 studies are biological screening studies to determine, if possible, whether food production or foraging habitats are likely to be limiting to pallid sturgeon. These studies may be very powerful in determining whether these components of IRC are necessary to survival of the pallid sturgeon. These studies could be based on sampling a gradient of assumed habitat quality or as a randomized design and would involve assessing age-0 sturgeon for indications of starvation or growth. Because of dietary overlap between shovelnose and pallid sturgeon at this life stage, shovelnose sturgeon may be used to some extent as a surrogate to contribute comparative information.

Metrics

The metrics for this study are indicators of starvation or impending death of age-0 sturgeon. Such indicators may be based on stomach contents (percentages of empty/full stomachs) or physiological indicators (lipid content). Because it is extremely rare to catch dead age-0 fish, these metrics are useful to characterize the surviving population but may fail to address actual mortality rates – that is, sampling will be biased toward live fish. This bias can at least be partially overcome base on the fish that are sampled. If, for example, the distribution is skewed toward the food-limited end of the spectrum, then it is likely that results are biased due to mortality of starved fish which couldn't be sampled. If, however, the distribution is skewed toward full stomachs and relatively high lipid contents then there would be no reason to believe that a significant bias exists due to presence of starved fish which could not be sampled. Because these metrics are likely to measure the net bioenergetic effects of a combination of food availability (food-producing habitat) and energy expenditures (foraging habitats), additional studies may be needed to address cause and effect.

Timelines and contingencies

These studies started in 2013 and are likely to provide results by 2017. The question of whether bioenergetic conditions are limiting to age-0 survival is fundamental to decisions to pursue further components, hence subsequent components are largely contingent on these results. Component 1 may occur simultaneously with components 2-4.

Decision criteria for application of component

Decision criteria from this component apply to the decision to move to level 2, in concert with evidence from the other level 1 components under this Big Question. Results from this component may be indicative of bioenergetic constraints, but will likely not be authoritative. Most of the age-0 sturgeon evaluated will be shovelnose, and although there is evidence to support the notion that the pallid and shovelnose diets and bioenergetic demands are very similar at this life stage, there is residual uncertainty about how well the surrogate species represents pallid sturgeon. If results indicate that age-0 sturgeon have full stomachs and healthy lipid content, it indicates that current bioenergetic conditions are unlikely to be limiting. Nevertheless, food could become limiting under future conditions of increased population. Therefore, understanding the processes of food production, transport, and foraging would be valuable. If results indicate that stomachs are not full and/or lipid content is not healthy, it will not necessarily be clear whether this is attributable to food availability or energetic demands. Therefore, information developed in this science component may contribute to decision making, but is unlikely to be sufficient.

C.3.3.5.2 Component 2

Technology development studies will be needed to develop a) sampling technology for relating food production to pallid sturgeon growth and survival and b) modeling strategies to integrate hydrodynamic models with bioenergetics models to inform population models. The first would involve techniques for understanding age-0 diet dependence on other elements of the river's food-web. This may include detailed diet studies or stable isotope approaches to defining food sources. The second would involve developing an integrated modeling approach for calculating survival from hydrodynamic and bioenergetic inputs, including methods to trace food origin to foraging.

Concurrent with studies to quantify biological functioning of IRCs, we envision a need for development of engineering modeling studies to provide predictive understanding of effective channel geometries, river locations, and spatial extent of IRCs and how IRCs may interact with other authorized purposes.

Metrics

Metrics for this group of studies includes measures of density of food items (chironomid larvae) in prospective IRCs, and measurement and model results that indicate pathways for those food items to drift to foraging areas. Models will provide flux of food items that will then be used to parameterize bioenergetics models. Modeling will be coordinated with engineering studies which will produce optimized designs to connect food and foraging habitats in IRCs.

Timelines and contingencies

The measurements and models anticipated in this component would require 3 years for development, although some of this work is already underway. This work could proceed simultaneously with components 1, 3, and 4 to provide mutually supportive information.

Decision criteria for application of component

Results of the measurement and modeling should help in understanding of spatial relations between food and forage habitats within and among IRCs, and whether flux of food to foraging habitats is a significant factor in growth and survival. This information would inform subsequent design of IRCs and to inform sampling efforts in component 3. If measurement and modeling revealed no spatial linkage between local (bend-scale) food production and foraging locations, the concept of IRC would need to be substantially refined.

C.3.3.5.3 Component 3

The information value of this study component depends in part on support from component 1 that food, forage habitat, or both, are presently limiting survival of age-0 pallid sturgeon. The objective will be to develop quantitative links from actions (flow manipulation and channel reconfiguration) to amount and quality of food-producing and foraging habitat. The study will incorporate component 2 information to improve definition of food-producing habitats through understanding of spatial linkages and geometries. It can be pursued on a field-gradient design by evaluating food and forage habitat conditions along existing ranges of habitat conditions (flow variability and channel complexity) along the river. For food, the study would include repeated measures sampling of biota judged to be food items for larval and juvenile pallid sturgeon. For foraging habitat, the study would include habitat selection based on catch rates from trawling for age-0 sturgeon in comparison to well-characterized habitat conditions. Habitat characterization at the scale of age-0 sturgeon will be challenging and may require innovative applications of acoustic Doppler current profilers, acoustic velocity meters, and/or benthic imaging technologies to establish bioenergetic conditions experienced by age-0 fish. Co-variates such as dissolved oxygen (DO) and water temperature will be measured to address how water quality may interact with productivity and the quality of food producing habitats in IRCs. As well, it is possible IRCs will provide conditions that would increase water temperatures (increased top width, shallow depths, low velocities). Thus, IRC development may interact with the temperature hypothesis in Big Question 2.

Metrics

Habitat metrics (potential explanatory variables) will be measures of depths, velocities, and substrate, including means and variances, potentially complemented with metrics of spatial complexity, such as patch sizes and orientations. Metrics for this study would include measures of habitat selection for food items (chironomids) and foraging (age-0 sturgeon), based habitats occupied and unoccupied.

Timelines and contingencies

The measurements and models anticipated in this component would require 4 years for development, although some of this work is already underway. This work could proceed simultaneously with components 1, 2, and 4 to provide mutually supportive information.

Decision criteria for application of component

Results of the measurement and modeling should help develop quantitative statistical associations between habitat characteristics and selection by food sources and age-0 fish. The statistical analysis is unlikely to be robust (i.e., it is likely to have relatively low confidence), and a lines-of-evidence approach may be necessary to decide on next steps. If the data indicate systematic relations, the information can be used to define mesocosm experiments in component 4 that would further refine understanding of functionality of these habitats. If the data do not indicate systematic relationships, the decision could be made, based on cumulative lines of evidence from components 1, 2, and 3, that the hypothesis that channels can be reconfigured to increase growth and survival is not supported. In this case, the concept of IRCs would need to be substantially refined or abandoned.

C.3.3.5.4 Component 4

This study component would attempt to develop quantitative relations between a range of habitat conditions identified in component 3 and quantitative productivity rates and growth and survival of pallid sturgeon, using mesocosms. This component would provide the parameter values for the integrated bioenergetic model described in component 1a.

Metrics

Habitat metrics (potential explanatory variables) will be measures of depths, velocities, and substrate, including central tendency and variance, potentially complemented with metrics of spatial complexity. Metrics for this study would be relative growth rates and survival as a function of habitat characteristics.

Timelines and contingencies

The measurements and models anticipated in this component would require 4 years for development and could be pursued concurrently with components 1, 2, and 3. It would be most effective to wait for completion of part of component 3 so the range of conditions needed in mesocosm experiments would be known and hypotheses would be rigorously formulated. The mesocosms used in this study would presumably be the same as those used in Upper Big Question 2, component 4, Upper Big Question 3, component 4a, and Upper Big Question 5, component 4.

Decision criteria for application of component

Decision criteria from this component apply to the decision to move to level 2, in concert with evidence from components 1-3. Results of the mesocosm experiments will quantify relations between abiotic variables and growth and survival. These are likely to be relations that show a peak of growth and survival at some interval, with decreasing growth/survival at higher and lower values. If growth/survival does not show a systematic relation to abiotic variables, the concept of IRCs would need to be substantially refined or abandoned. If there is a systematic relation, this would provide more support moving to level 2, and the supportive range of abiotic variables would be used to design field experiments in components 5 and 6.

C.3.3.5.5 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement across component 1-4 results that there is or is not a systematic relation between channel reconfigurations to build IRCs and increases in growth and survival of age-0 sturgeon. The judgement should be based on the strength and replicability of relations between abiotic habitat variables describing food and forage habitats, and growth and survival of age-0 sturgeon. In addition, movement to level 2 should be contingent on development of design parameters for IRC experiments in component 6.

C.3.3.6 Level 2

C.3.3.6.1 Component 5

Components 5 and 6 be related to the type and quality of information provided from previous components; however, because existing shallow-water habitat projects can be used for the experimental structure, components 5 and 6 may proceed effectively in parallel with level 1 components. The objective of component 5 will be to use habitat information gleaned from the gradient studies (components 3, 4) and supporting quantitative data from component 5, to design IRC configurations for field experiments. This component would make use of the integrative hydrodynamic-bioenergetic model to test alternative channel designs and flow regimes for the ability to provide effective amounts of both food-producing and foraging habitats. It will be an iterative design process varying channel width and wing-dike characteristics

Metrics

Metrics for this component will be relative performance of designs, measured as areas of functional habitat, using linked hydraulic and biological models.

Timelines and contingencies

We recognize benefits could accrue from starting this component early, especially if some aspects of the field experimentation are expected to have long time lags associated with them and experimental units already exist. The staging scenario (Appendix F) indicates 6 years for this component from recognition that designs for IRC complexes may be developed in the near term under existing shallow water habitat projects, and that the geomorphic form of the complexes may take several years to reach an equilibrium.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to continue with IRC experiments in component 6. That decision will be based on lines of evidence from components 1-4 and success in developing designs in component 6. The decision to proceed with component 6 would be based on the demonstrated ability to increase those habitat components that have been shown to increase growth and survival of age-0 sturgeon, and to do so without unacceptable risk to other authorized purposes.

C.3.3.6.2 Component 6

The objective of component 6 will be to evaluate the functions of food-producing and foraging habitats under controlled, experimental conditions. A control-impact (CI) sample design comparing a channelized reach to one or more levels of experimentally reconfigured IRCs would provide evaluation of the functional response of habitats to reconfiguration. A before-after-control-impact (BACI) design would provide additional confidence because it would establish the spatial variability among treatments; time-variant implementations of IRCs can be evaluated in a staircase design as documented in Appendix E. Responses can be measured in terms of hydraulic conditions, functional habitat area, and food production; response in terms of growth and survival would need to be calculated from mesocosm results. The role of flow manipulations can be evaluated based on measured variation from year to year and/or through hydrodynamic modeling of a flow time series through the IRCs.

Metrics

The study design will incorporate a gradient of IRCs with varying amounts of channel reconfiguration and varying amounts of flow regime naturalization. Because growth and survival cannot be measured reliably under field conditions, the metrics will need to be indirect and may include area of food-producing habitat, area of foraging habitat, catch per unit effort of age-0 sturgeon, stomach contents, and lipid content.

Timelines and contingencies

This component is expected to take 5 years to complete. It is contingent on some progress under component 5. Habitat quality and quantity in experimental IRCs will vary with both channel configuration and hydrologic characteristics. Therefore, the experimental design should include a range of channel reconfigurations as well as a range of flow naturalization; flow naturalization may be provided, in part, through utilization of reaches downstream of the Platte River where unregulated tributary influence increases flow variability. This component has a high degree of interaction with science components or implementations that alter the flow and temperature regimes (e.g., components under Lower Big Questions 1, 2, and 4).

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward to level 3 implementation. Statistical relations are likely to have high uncertainty, and the decision may therefore require a judgement based on lines-of-evidence presented in components 1-6. If experimental results in component 6 fail to support systematic increase in habitat and fish condition, then the hypothesis may need to be refined or abandoned. If the experimental results support the hypothesis that channel reconfigurations can provide increased food-producing and foraging functional habitats, then the decision would be to move toward level 3 implementation.

C.3.3.7 Critical scientific uncertainties and constraints

Critical scientific uncertainties include the food base for age-0 exogenously feeding pallid sturgeon, and relation of that food base to habitat conditions in IRCs. Additional critical uncertainty relates to foraging behaviors of age-0 sturgeon and the extent to which foraging habitat can be measured and modeled at appropriate scale. Finally, the linkage from habitat variables to survival is critical to link management actions to population-level responses; it is unlikely that this linkage will be measurable in the field and so inferences will need to be borrowed from laboratory and mesocosm results.

C.3.3.8 Utility of study components

These study components will provide scientific information bearing on whether flow manipulation, channel reconfiguration, or a combination of the two, will be effective in increasing survival and recruitment of age-0 pallid sturgeon. If successful, the study components will provide functional relations indicating how much habitat and what proportions are needed to increase survival, and the tradeoff between flow management and channel reconfiguration in achieving increased survival.

C.3.3.9 Risks

Level 1 components present little risk to stakeholders, authorized purposes, or pallid sturgeon. At level 2, field experimentation would require flow manipulations and/or channel reconfigurations that could be perceived as risks to flood control, power generation, water supply, navigation, and floodplain farming. An underlying assumption is that channel reconfigurations for IRCs will not interfere with other authorized purposes.

C.3.3.10 Adaptive actions

The results of these will have a bearing on decisions regarding extent of flow-management at Gavins Point Dam and extent and nature of channel reconfiguration on the Lower Missouri River.

C.3.3.11 Estimated costs

Estimated costs of level 1 components are relatively small. Field-gradient studies will rely on existing gradients of flow regime and channel reconfigurations. Mesocosm studies may require some investment in laboratory facilities to provide ecologically meaningful conditions, but much of the culture and laboratory investment already exists and the same mesocosm facilities can be used for multiple science components. Level 2 studies with field experiments will be more costly, and may involve substantial investments in land and construction although the experiments could capitalize to some extent on the significant investments in shallow-water habitat that have already been made.

C.3.4 Lower Big Question 4: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to decreased direct mortality and increased interception of free embryos into supporting habitats?

C.3.4.1 Objective of study components

The objective of these study components are to understand the role of flow regime and channel configuration in mediating drift, dispersal, and survival of pallid sturgeon free embryos. The information developed in these components is intended to help in management decisions that will increase survival of free embryos to exogenously feeding larvae.

C.3.4.2 Description of study components

Early pallid sturgeon life stages are believed to be dependent on downstream transport. Once hatched, free embryos are transported downstream as they derive nutrition from a yolk sac. After 9-15 days of drift and ontogenetic development, free embryos transition to benthic orientation ("settling") and must begin feeding. The ultimate fate of embryos in terms of river location and habitat is dependent on spawning location and instream conditions. For example, embryos fertilized in the upper reaches of the Lower Missouri River can be transported 100's of km downstream. These study components are intended to answer decision-critical questions about how flow regime (and resultant velocities) and channel configuration (and resultant hydraulic complexity) may be manipulated to increase survival of free embryos. Channel reconfiguration refers to reconstruction of some combination of main channel geometry, channel margin geometry, river-training structures, and construction of off-channel water bodies like backwaters and flow-through side channels (chutes). The underlying assumption is that engineering latitude exists in the present channel and channel reconfigurations can be designed to be compatible with other authorized purposes.

C.3.4.3 Relation to Effects Analysis

This Big Question encompasses two related hypotheses from the EA (14, 19). The first states that the flow regime at Gavins Point Dam may be optimized to decrease velocities, decrease effective drift distance, and potentially minimize direct mortality of free embryos. Our present emphasis is on minimizing direct mortality, because there is no evidence to support the idea that increased drift distance (e.g., into the Middle Mississippi River) by itself would lower survival. On the other hand, it has been hypothesized that increased turbulent energy associated with high discharges from dam releases could directly damage fragile free embryos at very early stages. The second hypothesis holds that reconfiguring channel morphology in selected reaches will increase channel complexity that will serve to intercept and retain drifting free embryos in areas with supporting habitats. This so called interception habitat is a critical part of IRCs and will therefore be addressed in part in close coordination with Big Question 3.

C.3.4.4 Approaches

These components are a suite of studies intended to elucidate fundamental controls and biology of drift, dispersal, and retention of free embryos. Level 1 components include technology studies to develop necessary tracking and sampling tools, engineering studies to define designs of interception habitats, and field and laboratory based studies to provide scientific context. Level 2 components include experimental flow releases and channel reconfigurations intended to test the efficacy of those actions in increasing free embryo survival.

C.3.4.5 Level 1

C.3.4.5.1 Component 1

The primary objective of this study is to determine whether surrogate particles can be used for tracking and predicting movement in a large riverine system. The first issue to address is whether virtual, physical, or mechanical surrogates perform similarly to biological counterparts. Large flume studies, replicate streams, and field trials can be used to compare the performance of proposed surrogates to biological counterparts.

The study element will be addressed through technological development and research of virtual, physical, mechanical, and biology surrogates for early pallid sturgeon life stages. Virtual particles can be used within existing hydrological models (2-d, 3-d) to model the transport and fate of virtual particles in riverine systems like the Missouri River. Physical surrogates may be developed as positively, neutrally, or negatively buoyant particles. Mechanical particles may take the form of some sort of developed particle that may be tracked in real time or provide some sensor for retrieval. Biological surrogates may use marked propagated fish. Marking may be chemical, such as oxytetracycline, genetic, or physical, such as coded wire tags such that the origin of recaptured fish can be determined. These 4 approaches provide potential methods to ascertain the transport and fate of particles in a large riverine system.

Metrics

Metrics for this study component will include recovery rate of marked particles used in tracer studies and measures of strength of prediction for particle fate (1-d and 1-2 models compared to field tests), including particle residence time in the main channel and adjacent habitats.

Timelines and contingencies

This component is expected to take 4 years to complete; because part of this work is already underway it could be completed by 2017. Because the component addresses the interception part of the IRC concept, it is highly interdependent with emerging information on IRC habitat (food-producing and foraging), and this component could therefore be tightly coordinated with Lower Big Question 3, component 2, 3, 5, and 6. This component may occur with substantial overlap with components 1-6.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to use the technology in related studies. If methods cannot be developed that provide strong inference on transport pathways, the decision may be made to delay additional components until satisfactory detection technology has been developed.

C.3.4.5.2 Component 2

The objective of this screening component is to characterize how resilient pallid sturgeon free embryos are to hydraulic conditions, particularly turbulent energy. If embryos are fragile, flow modifications, such as increased flow during spawning periods may increase embryo mortality. If embryos are found to be susceptible to mortality due to physical disturbance imparted by velocity or turbulence, flow regimes may be modified to minimize embryo mortality.

The study element may be addressed experimentally in circular or racetrack flumes where a range of flow and substrate, and resulting turbulence and shear conditions can be evaluated. Using this approach, embryos will be introduced into pond or flume systems for a range of flow velocities and substrates (e.g., sand, gravel, organic). Fragility, which is related to survival, will be estimated as the number of embryos introduced to the experiment and the number of living free embryos produced. The effect of flow and substrate can then be compared to the survival or free embryo production from a negative control. This type of experiment can be analyzed using a generalized linear model assuming a binomial response. Effects observed in the laboratory will be interpreted in the context of known velocities and turbulent intensities in the Missouri River.

Metrics

Metrics for this component will be survival of free embryos related to measures of fluid stress, including velocity distributions, turbulent intensity, and shear.

Timelines and contingencies

This component addresses the subhypothesis that free embryos are too fragile to survive the turbulent, fast flow in the Missouri River. It is not contingent on other components in this Big Question, but may have implications for understanding of limiting conditions being addressed by other components. The laboratory studies are expected to require 2 years, assuming availability of free embryos. This component is staged at the same time in parallel with other components. The mesocosms used in this study will be optimized for early stage free embryos (0-4 dph) and therefore will not be the same as mesocosms used for late-stage free embryos and exogenously feeding larvae (Lower Big Question 3 components).

Decision criteria for implementation of component

Information from this component will be used to inform decisions and science components whether actions to naturalize the flow regime from Gavins Point Dam and/or channel reconfigurations would contribute to increased survival. If survival is sensitive to the range of velocities, turbulence, or shear prevailing in the river during dispersal, then this would provide evidence to support pursuing level 2 science components to address how flow and channel form could be manipulated to increase survival. Because we do not believe it will be feasible to actually measure free-embryo survival under Missouri River field conditions, decisions about implementation may need to be made largely from inference from laboratory results in this component.

C.3.4.5.3 Component 3

The objective of this component is to document conditions under which free embryos would fail to exit the thalweg and therefore starve. Testing of this hypothesis with free embryos might be impossible, as it would require tracking free embryos through starvation in the thalweg. However, physical surrogates (beads, dye) or computational particle tracking may provide useful indicators. Assuming that a well-calibrated particle-tracking model can be developed (component 1) that accurately depicts free embryo transport and retention, a computational model could be used to evaluate a wide range of flow and channel morphology conditions under which retention succeeds or fails.

Metrics

Metrics for this component will be proportion of surrogate particles (real or computational) that exit the thalweg and are retained in IRCs under various channel geometries.

Timelines and contingencies

This component addresses the specific hydraulics affecting free embryo exit from the thalweg and is therefore highly interdependent with methods developed in component 1 and with emerging information on IRC habitat (food-producing and foraging). It could occur in parallel with components 1, 2, 4, 5 and 6, and may also be concurrent with level 1 IRC studies under Lower Big Question 3. This component start as early as 2017), overlapping with component 1 for one year) and ending after 3 years of directed study.

Decision criteria for application of component

Information from this component will be used to inform decisions and science components about whether actions to naturalize the flow regime from Gavins Point Dam and/or channel reconfigurations would contribute to increased advection of free embryos into IRCs. If advection of surrogate or digital particles varies substantially with discharge or channel configuration, then results could inform a decision to move ahead with implementation of field experiments at level 2. Results are likely to have substantial statistical uncertainty and application will likely require a judgement based on multiple lines of evidence.

C.3.4.5.4 Component 4

This component is an exploratory, field-gradient based study that will sample age-0 occurrence (e.g., catch per unit effort) from systematic sampling along a gradient of channel complexity. Relative catch of age-0 sturgeon will be compared to indices or measurements of channel complexity that should be related to interception mechanics and flow variation. The results will help narrow the definition of interception habitats and will serve to focus hypotheses regarding channel configurations that are amenable to interception and retention of free embryos.

Metrics

This component is complementary to Lower Big Question 3 component 3 and could make use of the same field-gradient sampling design. The difference is that candidate explanatory variables would focus on measures of channel complexity relevant to interception hydraulics, and sampling would attempt to evaluate the flux of free embryos from the thalweg. The fundamental metric, therefore, will be a catch per unit effort, but established from ichthyoplankton net sampling arranged to evaluate transport into IRCs.

Timelines and contingencies

This component could occur in parallel with components 1, 2, 3, 5 and 6, and could also be concurrent with level 1 IRC studies under Lower Big Question 3. The component would require 4 years of study.

Decision criteria for implementation of component

A field gradient study on free embryo transport paths is likely to lead to results with relatively high statistical uncertainty. The information developed will likely be used in a judgement based on multiple lines-of-evidence about whether to proceed with manipulated field experiments at level 2. The decisions would be informed by the strength of association between advection metrics and channel configuration options.

C.3.4.5.5 Component 5

A fundamental question for pallid sturgeon recovery in the Missouri River is what proportion of free embryos hatched in the Missouri River may disperse and recruit in the Mississippi River. This study component will be addressed through monitoring of young fish in the Lower Missouri River and Middle Mississippi River. Specifically, marked hatchery-origin fish will be stocked into the system and then recaptured over time. Marking of early life stages will be a significant challenge, however oxytetracycline, genetic, coded wire tag, and genetics have all been used to mark small fish. Monitoring efforts to recapture these fish will occur repeatedly over the study period. A Cormack Jolly Seber (CJS) model will then be used to estimate apparent survival using the multiple recapture occasions; this effort would proceed efficiently as part of the population monitoring plan (see Appendix D). Because there are discrete life stages, the CJS model may include a multistate model where the transition of pallid sturgeon from one stage to another (e.g., free embryo to exogenously feeding larvae) can be estimated conditional on the fish surviving to transition. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

The main metrics for this component are estimates of the number and survival rates for pallid sturgeon produced in the hatchery and released into the Missouri River that end up in the Mississippi River, relative to the number that remain and survive in the Missouri River, during the age-0 to juvenile-age interval. Micro-chemistry analysis to assess study fish duration of presence in each river would support study goals for this component.

Timelines and contingencies

This component depends on having sufficient age-0 fish from hatcheries and concurrence from the USFWS that stocking of these fish would align with stocking goals and genetics objectives of the propagation plan. It would occur in parallel with components 1, 2, 3, 4 and 6, and also be concurrent with level 1 IRC studies under Lower Big Question 3. The results would provide important context for both Lower Big Question 3 and 4 as it would indicate the extent to which free embryos and later stages may bypass IRCs constructed on the Missouri River. Moreover, if recruitment is sufficient on the Mississippi River to sustain the population, this science component would provide information fundamental to management decisions on the Missouri River. The technical approach to this question – a mark/recapture – would be most efficient if coordinated with the population trends monitoring described in Appendix D. Understanding of the significance of recruitment in the Mississippi River will require comparison to similar population trends data for the Missouri.

We estimate that 6 years of sampling would be necessary to provide useful data, assuming that stocking of marked age-0 is sustained and genetic and micro-chemistry techniques would allow for discrimination of Missouri River, wild-produced fish.

Decision criteria for application of component

Information developed in this component could be fundamental to multiple decisions. If the population recruiting in the Mississippi River is high enough to sustain the population – by reference to applicable population models –there may be implications for the species recovery strategy, and potentially the understanding of what constitutes jeopardy on the Missouri River. If survival and recruitment in the Mississippi River are zero or insufficient to sustain the population, this information may be used to justify increased effort to intercept free embryos in the Missouri River. Survival and recruitment estimates from the mark/recapture approach are likely to have wide confidence intervals, so that decisions will likely require multiple lines of evidence.

C.3.4.5.6 Component 6

The objective of this component is to validate, in the field, the outputs of 1- and 2-d drift models to determine dispersal and retention of drifting pallid sturgeon. The study will use experimental tracking of free embryos and/or other tracers introduced under existing hydrologic and morphologic conditions. Results and predicted patterns generated from 1- and 2-d drift models will be compared to experimental patterns observed in the Lower Missouri River. This can be done by predicting patterns of distribution and retention for a reach on the Lower Missouri River. Then pallid sturgeon free embryos or surrogates can be introduced there during a period with similar flow conditions as modeled. Once drifting particles are introduced, field crews can sample downstream locations to document a pattern of dispersion and interception. This sampling should occur in areas of high drifting particle abundance identified by simulations, but also areas of low or no particle abundance to verify model predictions. Tracer sampling will be coordinated with detailed hydraulic data collection (by boat-mounted acoustic Doppler current profilers) to provide independent estimates of advection/dispersion model parameters. These field experiments will be conducted for the range of flows that pallid sturgeon free embryos can be expected to experience to ensure the 1- and 2-d drift models adequately predict dispersion and interception for a range of conditions.

This component is very similar to manipulated field experiments envisioned in components 7, 8, and 9, but will rely on opportunistic flows and existing channel configurations rather than instituting specific, more-controlled experiments. These experiments also have elements in common with drift/dispersal experiments in the upper river. Tracer methods and modeling developed for the upper river, in particular, will contribute to efficiencies in the lower river.

Metrics

Key metrics for this component will be the distributions of free embryos or other tracers, over time and space, as the constituents disperse downstream as a function of discharge and interception efficiency. From the distributions, mean constituent velocity, range of velocities, and fate (range of river miles at a specific developmental stage) can be evaluated. In the opportunistic context of this component, these metrics will be compared to prevailing discharges and current velocities, and related to the types of channel configurations that the particles encounter. Longitudinal dispersion coefficients will be calculated from the ADCP measurements and compared to tracer distributions to help in calibration and validation of 1-d advection/dispersion models.

Timelines and contingencies

Success of this component would be improved by methods developed in component 1, and on supporting information developed in components 3 and 4. In a parallel staging, these components could operate with considerable overlap. Experimental design for this study would also benefit from results of free-embryo drift experiments in the upper river (Upper Big Question 5, component 3. Use of free embryos as tracers will require sufficient production from hatcheries and sufficient confidence that these fish could be lost from the population-augmentation process, or would not unbalance genetics of the population.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward with level 2. Results from this component will contribute substantially to decisions to move forward with field experiments, both for the value of experiments and for specific design parameters. The results from this component are likely to have considerable statistical uncertainty but will be useful for decision making when combined with mutually supportive information from components 1-5 and results from Lower Big Question 3, level 1 components. The results will also serve to test validity of 1-dimensional advection/dispersion models for application to understanding dispersal and management options. In the case of the advection/dispersion models, results may well be amenable to statistical tests of how well models represent reality.

C.3.4.5.7 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there are (or are not) systematic relations between flows and channel reconfigurations and increases in retention of free embryos in supportive IRC habitats. The judgement should be based on the strength and replicability of relations between abiotic habitat variables describing drift behaviors/retention, and growth and measured retention of free embryos (or surrogate tracers) in IRCs. Results from component 5 – transport to the Mississippi River --may also have a bearing on moving to field experimentation. If linkages from stocking or wild production on the Missouri

River to recruitment on the Mississippi River are documented, it might be argued that retention in the Missouri River is not needed or useful to the population, and therefore the action hypothesis could be dropped and level 2 experimentation would not be necessary.

C.3.4.6 Level 2

C.3.4.6.1 Component 7

Field experimentation to elucidate drift/retention/survival dynamics will require a preliminary step of engineering studies for site-specific design and test of IRC concepts. Designs will explore range of options available in channel reconfigurations while maintaining other authorized purposes, principally navigation and flood control. The objective of these studies will be to use computational models to explore hydraulic geometries that will contribute to interception of free embryos (through increased secondary currents) while minimizing other effects. The study component will be based on information gathered from previous level 1 components. That is, once optimal flows and channel configuration criteria are established to intercept and retain free embryos, engineers can use that information to develop in-stream designs for habitat and in-channel structure or modification that meet interception and retention habitat objectives. To provide the best foundation for field experimentation, designs would ideally include a range of interception efficiencies.

Metrics

Results from this component will be a range of designs that meet practical hydraulic needs of the Missouri River channel and contribute to interception/retention of drifting free embryos. Metrics would be similar to those listed in Level 1 Components 5 and 6. Relative cost would also be a relevant metric.

Timelines and contingencies

Benefits may be recognized from starting this component early, especially if some aspects of the field experimentation are expected to have long time lags associated with them. The staging scenario (Appendix F) indicates 6 years for this component from recognition that designs for IRC complexes may be developed in the near term with existing shallow water habitat projects; geomorphic form of the complexes may take several years to reach equilibrium.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to manipulative experiments in components 8 and 9. That decision will be based on lines of evidence that the designs will provide information needed to assess the contribution of the IRCs to growth and survival of age-0 pallid sturgeon, and will do so while minimizing effects to other authorized purposes.

C.3.4.6.2 Component 8

The first set of field experiments related to drift will incorporate tracer releases with manipulated flows from Gavins Point Dam to validate modeled relations between discharge and advection/dispersion. Pallid sturgeon free embryos or surrogates will be introduced into the Lower Missouri River at varying flows. Downstream interception habitats will then be monitored for these released pallid sturgeon or surrogates to evaluate whether interception is occurring. This will be done for varying flows out of Gavins Point such that the optimal flow can be identified; assuming flow is related to the likelihood of interception. This study can occur over the year if suitable pallid sturgeon surrogates can be used, or during the period of year that sufficient free embryo life stages are available from conservation hatchery operations. Analysis will focus on relating the proportion of free embryos intercepted as it relates to flow, which can be evaluated using a generalized linear model assuming a binomial distribution. However, imperfect sampling will underestimate the proportion of free embryos intercepted, and therefore hierarchical Bayesian approaches will likely be necessary to estimate capture probability and interception probability. These two probabilities, while confounded can be estimated if replicate sampling in time or space is used. Tracer sampling will be coordinated with detailed hydraulic data collection (by boat-mounted acoustic Doppler current profilers) to provide independent estimates of advection/dispersion model parameters. Because control over flows decreases downstream, most of the assessment will in the Gavins, Big Sioux, and Platte segments of the river. Channel configuration will be a necessary covariate for the experiments.

Metrics

The fundamental metric for this component will be the proportion of free embryos intercepted and retained. Additional metrics will include the distributions of free embryos or other tracers, over time and space, as the constituents disperse downstream. From the distributions, mean constituent velocity, range of velocities, and fate (range of river miles at a specific developmental stage) can be evaluated. In the experimental context of this component, these metrics will be compared to a series of flow releases and resultant current velocities, and related to the types of channel configurations that the tracers encounter. Longitudinal dispersion coefficients will be calculated from the ADCP measurements and compared to tracer distributions to help in calibration and validation of 1-d advection/dispersion models.

Timelines and contingencies

Success of this component will be increased with the information provided in components 1, 3, 4, 6, and 7. It will occur after component 7, and be conducted concurrently with component 9. It is likely that flows explored in this component will interact with flows envisioned for experiments in Lower Big Questions 1 and 2; the experiments may be designed to complement one another in a naturalized flow regime, or may instead need to occur in separate years to avoid confusion. The experiment should clearly occur after the design phase (component 7). The series of experiments is estimated to take 7 years as a minimum, to allow for a range of 4 treatments, some replication, and the logistical challenges of experimentation within a highly dynamic hydrologic system.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward with level 3 implementation, considering results from both components 8 and 9. The results of this component are expected to document sensitivity of drift and retention to manipulated flows. The science will inform decisions about how much retention and survival are likely to be affected by flow releases, with channel configuration as a necessary covariate. For the physical results (tracer distributions) the results may attain statistical rigor, but there will be substantial residual uncertainty about how physical results can be linked to pallid sturgeon survival and growth. Therefore, criteria for implementation of results from these experiments may need to be based on multiple lines of evidence.

C.3.4.6.3 Component 9

This study component will evaluate proposed engineering designs for instream modifications of channel and habitat as a field experiment. Similar to component 8, free embryos or surrogates will be introduced upstream of restoration projects. The number of free embryos intercepted and retained in the new habitat will be quantified and the proportion of fish intercepted and retained will be evaluated using a generalized linear model assuming a binomial distribution. Accurate and precise estimates of the number of free embryos intercepted and retained will be challenging, especially given imperfect capture. Therefore unless numbers are adjusted for imperfect capture, the estimated proportion will be underestimated. Ideally, a range of interception geometries will be used for multiple experiments so varying geometry can be tested. Tracer tests will be most useful if accompanied by computational particle-tracking models that will serve as explicit hypotheses of particle movement and will aid in sample design. This component is interactive with component 8. In order to understand separate and combined effects of flow regime and channel configuration, the experimental design will include a range of configurations in the Platte Segment and a range of configuration sin the Grand Segment. It is anticipated that over the 7 years of experiment, there will be opportunity for both replication and a wide range of hydrologic conditions using this upstream/downstream comparative approach.

Metrics

The fundamental metric for this component will be the proportion of free embryos intercepted and retained. Additional metrics will include the distributions of free embryos or other tracers, over time and space, as the constituents disperse downstream. From the distributions, mean constituent velocity, range of velocities, and fate (range of river miles at a specific developmental stage) can be evaluated. In the experimental context of this component, these metrics will be compared to a series of flow releases and resultant current velocities, and related to the types of channel configurations that the tracers encounter. Longitudinal dispersion coefficients will be calculated from the ADCP measurements and compared to tracer distributions to help in calibration and validation of 1-d advection/dispersion models.

Timelines and contingencies

Success of this component will be increased with the information provided in components 1, 3, 4, 6, and 7. It is likely that flows explored in this component will interact with flows envisioned for experiments in Lower Big Questions 1 and 2; the experiments may be designed to complement one another in a naturalized flow regime, or may instead need to occur in separate years to avoid confusion. These experiments would occur after the design phase (component 7) and concurrent with component 8. The series of experiments is estimated to take 7 years as a minimum, to allow for a range of 4 treatments, some replication, and the logistical challenges of experimentation within a highly dynamic hydrologic system.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward with level 3 implementation, considering results from both components 8 and 9. The results of this component are expected to document sensitivity of drift and retention to manipulated channel configuration. The science will inform decisions about how much retention and survival are likely to be affected by channel configuration, with flow regime as a necessary covariate. For the physical results (tracer distributions) the results may attain statistical rigor, but there will be substantial residual uncertainty about how physical results can be linked to pallid sturgeon survival and growth. Therefore, criteria for implementation of results from these experiments may need to be based on multiple lines of evidence.

C.3.4.7 Critical uncertainties and constraints

Critical uncertainties include the extent to which dispersal of free embryos deviates from the assumption of passive transport. To the extent that free embryos have the facility to move vertically and horizontally in the water column in the highly turbulent Lower Missouri River, fundamental assumptions of advection/dispersion and particle-tracking models may be violated. Additionally, locomotor capacity may not be static, but improving along an age gradient (scaled to days or hours) as embryos develop (whether in dispersion or retention status); calibrating models to account for continually improving locomotor capacity may significantly improve output. Studies proposed here are intended to test model assumptions with biological data when possible. Other authorized purposes and land availability may be constraints for implementation of field experiments.

C.3.4.8 Utility of study components

These study components are essential for developing understanding of controls on free embryo dispersal, how to increase retention in supportive habitats, and how to improve simple advection/dispersion models. Results may relate to mortality – direct through damaging turbulence and indirect through starvation – and will also be applicable to regional planning and design of IRCs.

C.3.4.9 Risks

Level 1 components involve little risk until free embryos are used in experiments. Experimental seeding of free embryos promises to provide the most realistic information on transport and fate, but puts those free embryos at risk because they will be stocked at a very early age (~ day 1). Parentage will need to be well documented so future collections can be used to assess survival and so that genetic diversity is not compromised. Level 2 components include similar risks to free embryos stocks and general risks to other authorized purposes associated with flow manipulations as well as some minimal risks to navigation and floodplain development from construction.

C.3.4.10 Adaptive actions

Quantitative hydraulic information that can be associated with increased retention (and probably survival) of free embryos can be used to design interception components of additional IRCs and can be used to extrapolate retention through other parts of the river system. Understanding of relations between discharge, velocity, and advection of free embryos can be used to tailor flow management and channel geometry to promote retention of free embryos in particular parts of the Lower Missouri River system.

C.3.4.11 Estimated costs

Because field-based particle tracking studies are complex, the costs will be substantive. Costs of field experiments will be high, but costs will be shared with field experimentation for food-producing and foraging habitats.

C.3.5 Lower Big Question 5: Can channel reconfiguration and spawning substrate construction increase probability of survival through fertilization, incubation, and hatch?

C.3.5.1 Objective of study components

While numerous spawning areas have been documented in the Lower Missouri River, the functionality of the spawning locations have been questioned, leading to the action hypothesis that improved spawning habitat will result in increased probability of recruitment. It has been suggested that the distribution and characteristics of existing spawning sites may not provide the properties needed for the successful aggregation of reproductive pallid sturgeon, gamete release, fertilization, egg adhesion, incubation and/or hatch. At present, a comprehensive understanding of the habitat conditions which promote successful spawning on the Lower Missouri River has not been determined. This information is vital to validating or refuting the hypothesis that survival probability through hatch will increase with improved channel reconfiguration and spawning substrate.

Channel reconfiguration or re-engineering is used in the Big Question to mean construction of patches of habitat that meet hydraulic and substrate requirements for successful spawning. The patches are anticipated to be relatively small and we believe they would have minimal effect on channel geometry, although designs have not yet been validated. The underlying assumption is that the designs will minimize conflict with authorized purposes.

The objective of these study components is to determine whether spawning habitat is limiting to pallid sturgeon population growth, and if so, determine ways to improve functioning of the habitat to increase probability of producing viable gametes to the extent that positive population growth results.

C.3.5.2 Description of study components

Three study components are presented at level 1 and two at level 2. Level 1 components seek to understand Lower Missouri River spawning needs through evaluation of successful spawning locations on the Yellowstone River and understanding the biological response and mechanics of spawning under current and potential future habitat conditions. Level 2 elements build upon the knowledge gained during level 1 by implementing pilot spawning habitat restoration and evaluating resulting spawning with detailed microhabitat analyses of river dynamics effects on developing eggs. By understanding habitat and biological factors, these study elements will inform design of the hydraulics, geometry, and substrate which are supportive of spawning on the Lower Missouri River. Such an optimized spawning habitat is expected to provide environments for successful adult aggregation, fertilization of gametes, egg adhesion, embryo incubation and hatch of viable free embryos thereby increasing probability of survival.

A corollary hypothesis that extends beyond specific properties of spawning habitat is that existing habitats selected by pallid sturgeon for spawning are suboptimal and not sufficiently attractive (or rare) to attract aggregations of reproductive fish. This hypothesis recognizes the social aspect of spawning and that functional spawning may require aggregations of multiple prospective mates. If this hypothesis holds, managed spawning habitat may need to satisfy biological functions to support incubation and hatch, but may also need to have characteristics that would attract fish to it in preference over abundant, poorly functioning habitats on outside revetted bends. If constructed spawning habitat is not sufficiently attractive, purposeful degradation of alternative habitats may be necessary.

C.3.5.3 Relation to Effects Analysis

These study components provide information to support EA hypothesis 16: Re-engineering of channel morphology in selected reaches will create optimal spawning conditions -- substrate, hydraulics, and geometry -- to increase probability of successful spawning, fertilization, embryo incubation, and hatch.

C.3.5.4 Approaches

Approaches to these study components at level 1 include engineering studies to evaluate what is possible in the Lower Missouri River navigation channel, field-based screening studies to confirm whether spawning habitat is limiting, field-gradient studies to learn what abiotic factors are most directly associated with successful spawning, and laboratory studies. Laboratory studies are needed to establish fundamental biomechanics of egg release, fertilization, adhesion, hatch, and initial drift behaviors; mesocosm studies may provide for controlled experiments of adult reproductive responses to spawning habitat characteristics. At level 2, components would include site-specific engineering studies of design and construction techniques for spawning habitat, and field-scale experiments that will quantify effectiveness of restored spawning habitats.

C.3.5.5 Level 1

C.3.5.5.1 Component 1

This component will map and evaluate the documented spawning habitat from the natural reference condition on the Lower Yellowstone River. Quantitative assessment of these spawning patches will be used to develop engineering design parameters for construction of optimized spawning patches on the Lower Missouri River.

This study element will build upon previous bathymetric, sidescan sonar mapping and substrate sampling and imaging of the Lower Yellowstone River spawning patches. Radio telemetry and 3-d tracking of acoustic telemetry tags will be utilized to track reproductive pallid sturgeon to persistently used spawning patches at Yellowstone river miles 4.5-7.5 (Fairview reach). Upon initiation of spawning behaviors, previous techniques – complemented with new technologies (dual-scale submersible benthic imaging system) -- be employed allowing for habitat mapping and fine-scale sediment evaluation throughout the spawning event, incubation period, and hatch.

Metrics

The metrics developed in this component will be design parameters for spawning habitat based on assessment of habitat selection in the Fairview reach. The specified metrics will be combinations of depth, velocity, or substrate, and possibly derivatives such as shear velocity or basal shear stress. Habitat stability – measured as bed mobility -- will be evaluated as an additional metric.

Timelines and contingencies

This component is already underway and is expected to require until 2017 to have well-documented design parameters. Completion of this component is contingent on availability of telemetry-tagged, reproductive males and females in the Upper Missouri/Lower Yellowstone segments. The component will be most useful in comparison to conditions documented in component 2, and will proceed concurrently with components 2 and 3.

Decision criteria for application of component

The relevant decision from this component is whether to use results from the reference condition in design of mesocosm experiments, and eventually field-scale experiments, based on the results of this work and comparative information from components 2 and 3. The habitat selection information from the Fairview reach is likely to be indicative, but not statistically rigorous, and may therefore need to be combined with other lines of evidence. The decision will be informed by the strength of spawning habitat selection documented at Fairview, the ability to replicate results within and among years, the degree of contrast with Lower Missouri River results (component 2), and the concordance of results with spawning habitats quantified for other sturgeon species.

C.3.5.5.2 Component 2

This study component is a field-gradient study to document reproductive response of adults and gametes to the range of habitat conditions existing on the Lower Missouri River. Evaluations will help determine which spawning habitat characteristics are lacking and limiting relative to the natural reference condition on the Yellowstone River. Similar imaging and hydroacoustic technologies to that used in component 1 (submersible benthic imaging system, side scan, ADCP, multibeam bathymetry) will be optimized to observe and characterize *in situ* pallid spawning behavior from gamete release to hatch. This scale of measurement presents a significant challenge that may require development of new technology to evaluate spawning mechanics at the scale needed to verify which spawning sites are not functional. The study component will use tracking of telemetry tagged, reproductive fish to increase understanding of where and when spawning occurs under current conditions on the Lower Missouri River.

Metrics

The metrics developed in this component will be similar to the design parameters for spawning habitat based on assessment of habitat selection in the Fairview reach, but will expand to include metrics for reproductive behaviors and spawning success. The specified metrics will be combinations of depth, velocity, or substrate, and possibly derivatives such as shear velocity or basal shear stress. Habitat stability – measured as bed mobility -- will be evaluated as an additional metric.

Timelines and contingencies

Although this component is under way since 2013, we anticipate it will require until 2017 to have well-documented habitat selection on the Lower Missouri River. This due to the need to establish new methods to evaluate substrate at > 6 m depth and at velocities in excess of 2.5 m/s. Components 1, 2, and 3 could be pursued concurrently.

Decision criteria for application of component

The relevant decision from this component is whether to go ahead with mesocosm experiments, and eventually field-scale experiments, based on the results of this work and comparative information from component 1. The habitat selection information from the Lower Missouri River serves to document the degree of difference from that documented on the Yellowstone River at Fairview. The difference may not be statistically significant because of lack of true replication and a relatively small number of events, and may therefore need to be combined with other lines of evidence and submitted to expert judgement.

C.3.5.5.3 Component 3

This study element will build upon previous information obtained and will utilize various controlled laboratory and mesocosm settings to systematically determine the effect of abiotic conditions on spawning behaviors and mechanics. Laboratory studies will evaluate the mechanics of spawning, egg deposition, fertilization, incubation, and hatch under variable conditions including turbidity, temperature, current velocity, light regimes, and substrate types. Controlled experiments will be carried out in raceways /living streams, circulating tanks/ponds, and hatching chambers. An initial, fundamental question to answer is whether free embryos drift immediately after hatch or instead take up residence in substrate for some period of time; understanding of this phenomenon will have a substantive influence on how many days are needed for dispersal, and therefore how much total river distance would be used. Multivariate statistical models predicting probability of successful hatch will be constructed from measured variables and measured success rates.

At a broader scale, reproductive adult behaviors will be documented in mesocosms to develop models for factors that result in aggregations, interactions, and spawning behaviors. Behaviors will be quantified using 3-d telemetry and observations using acoustic cameras. These mesocosm facilities for adult reproductive behavior will presumably be the same as used for Big Question 1, component 3 and Upper River Big Question 1, component 3. The mesocosm facilities for egg biomechanics may be the same as used in other mesocosm studies in which water velocities and substrate can be controlled.

Metrics

The ultimate metric for this component is hatch rate as a function of different combinations of depth, velocity, substrate, and derivative hydraulic variables, with covariates relating to water quality and fish behaviors. Intermediate metrics will be fundamental measures of fish aggregation and spawning behaviors (e.g., optimum male: female ratios in spawning aggregations), degree of attraction/specificity of adults to different spawning substrates, and biomechanics of egg adhesion and dispersal.

Timelines and contingencies

The mesocosm experiments can be carried out concurrently with components 1 and 2 to maximize development of supportive information.; under parallel staging the component (which already has some pilot information) would extend to 2019. The component is highly contingent on having the ability to construct mesocosm, pond, or side channel facilities with sufficient range of depth, velocity, and substrate to support controlled experiments under a range of conditions applicable to the Missouri River. It is also contingent on availability of a captive research population of pallid sturgeon sufficient in size to have reproductive individuals available each year over the 4 years of the component. The success of the component will depend as well on implementation of technology that can be used to evaluate reproductive movements and success; work is currently underway on validating combinations of acoustic video platforms, 3-d telemetry, and data storage tags for these purposes.

Decision criteria for application of component

The relevant decision at this component is whether and how to move ahead to level 2. Component 3 results are intended to contribute to this decision by providing quantitative criteria for abiotic (and biotic) variables influencing spawning, from aggregation of adults to hatch of embryos. Although some mesocosm results may be statistically robust, it is inevitable that mesocosm conditions will not perfectly replicate field conditions, and therefore residual uncertainty will remain about the quantitative dependencies of successful hatch on design variables.

C.3.5.5.4 Criteria to move to level 2

The decision to move to active field experimentation will necessarily be based on multiple lines of evidence because no single source of information is likely to provide statistically robust results. Information from components 1, 2, and 3 is intended to provide the best attainable information to underlie this decision.

C.3.5.6 Level 2

C.3.5.6.1 Component 4

In preparation for field-scale experimentation, we anticipate the need for site-specific engineering design studies for spawning habitats, especially to understand how to sustain habitats in the dynamic sediment-transport environment of the Missouri River. Designs will also need to minimize effects on navigation and other authorized purposes; spawning patches will likely directly underlie the navigation channel. Detailed velocity surveys, hydrodynamic modeling, and bathymetric mapping will be used to evaluate habitat characteristics and stability.

Metrics

The metrics for this component will be design performances, measured in terms of how well they create the hydraulic and substrate conditions developed in components 1-3. Additional relevant metrics will be how well designs support other authorized purposes (principally degree of interference with the navigation channel), and cost, including sustainability in a dynamic channel.

Timelines and contingencies

Component 4 is dependent on components 1-3. Evaluation of alternative designs is expected to take at least 2 years assuming useful design criteria are provided from level 1.

Decision criteria for application of component

The applicable decision at this component is whether and how to move forward to active field experimentation. This will be based on a combination of information that defines functional spawning habitat and the feasibility of designs to achieve that habitat as documented in this component. The decision to move forward would be based on the judgement that designs will provide useful information while minimizing adverse effects to other authorized purposes.

C.3.5.6.2 Component 5

Study component 5 will be field-scale implementation and testing of prototype spawning habitat on the Lower Missouri River. Location of the test spawning patches will be determined through analysis of previous spawning locations. Evaluations will include:

- Evaluating interactions of migrating, telemetry-tagged, reproductive pallid sturgeon to determine whether these fish are attracted to habitat. Both male and female reproductive, tagged fish will be used because of previous information indicating that habitats may be selected by males who subsequently attract reproductive females. 3-dimensional telemetry receiver networks will provide high-frequency, high-precision tracking of spawning behaviors near spawning sites.

- Evaluating hydraulics (velocity and turbulence) of as-built spawning patches compared to biomechanical properties of eggs, in particular specific gravity, fall velocity, and rate of development of adhesion.

- Evaluating disposition of spawned, fertilized eggs during incubation, particularly where they are deposited relative to release location and whether they are subject to burial or abrasion by transporting sand.

- Quantifying hatch rate *in situ*. As indicated in component 2, new technologies may need to be developed to visualize and document hatch rates at depths, velocities, and turbidities common in the Missouri River. The objective of these studies will be to quantify hatch success as a function of habitat design variables.

Metrics

The ultimate metric for this component is hatch rate, which can be equated to the probability for that stage transition in the population model, but it will be challenging to determine this from field conditions. From ichthyoplankton sampling downstream from known spawning events, catch per unit effort may be compared among habitat treatments to evaluate relative hatch performance.

Sampling biases in these nets are unknown, however, and the inherent error is likely to be large. This process would also need to assume spawning of parents with known genotypes and the ability to identify their progeny genetically.

Short of hatch rates, several other metrics will provide information on relative performance of different designs. Repeat high-resolution multibeam maps of the spawning patches during incubation will indicate whether the substrate is subject to burial or erosion, either of which is likely to result in zero hatches. Measured hydraulic variables can be compared to fall velocities of unfertilized eggs to evaluate whether eggs are likely to be deposited in the manipulated habitats; innovative imaging techniques from remote cameras may be able to validate exactly where eggs are deposited. Single receiver and multi-receiver, 3D telemetry and acoustic video can be used to evaluate behaviors of reproductive adults on the spawning patches to identify spawning aggregations and egg-release events.

Timelines and contingencies

This component is logically contingent on completion of engineering studies in component 4, and construction of spawning habitat treatments. The experiments are expected to take at least 4 years to allow for natural variability in hydroclimatic events and to attempt to achieve some replication. Success will depend on having a sufficiently large population of telemetry tagged adults so there will be 6-12 available for intensive tracking each year of the experiment. It may be possible to seed the prevailing population of adults with captive adults that have been treated with hormones to assure they are reproductively ready. High-resolution imaging of spawning substrate in the fast, turbid Missouri River remains a challenge and will require additional technical development. This component interacts with experimental flow pulses in Lower Big Questions 1 and 2: flow and temperature pulses may or may not serve as additional stimuli to draw fish upstream to spawning habitats. Successful design of the experiment will also require additional identification of spawning sites so locations of experimental patches can be placed where fish are likely to encounter them.

Data collected on reproductive migrations of adults may also shed light on a complementary hypothesis, that existing bank revetment serves as an attractive nuisance with low probability of successful hatch. Under this hypothesis, restored spawning patches would have to be sufficiently attractive that adults would not select the more abundant, easy to find revetment habitat.

Decision criteria for application of component

The relevant decision would be whether to move forward into level 3 implementation, change the experimental patch design, or abandon the action hypothesis. Robust statistical results cannot be expected for the ultimate metric – hatch rate – because of the difficulties in enumerating this under field conditions. However, the results of other metrics described above should contribute to a lines-of-evidence decision of whether the spawning patches are functioning as intended.

C.3.5.7 Critical scientific uncertainties and constraints

Present (2017) fertilization and hatching success is unknown. Although it is hypothesized that spawning success is low, little effort has been directed at evaluating until recently. In 2014, 4 pallid sturgeon drifting free embryos and 3 age-0 pallid sturgeon were sampled despite the extreme difficulty in sampling. These collections may indicate that successful spawning, fertilization, incubation, and hatch occur, but there continues to be uncertainty whether the numbers of fish participating in spawning and numbers of fish that hatch successfully are sufficient to maintain the population.

Critical uncertainties relate as well to understanding and measuring processes at the scale of deposited, incubating eggs. Success of incubation and hatch may depend on hydraulic or water quality effects at a very fine scale that will be challenging to measure in real-world conditions. Laboratory and mesocosm studies can provide greater observability at these scales with the trade-off of diminished reality.

Optimal locations of spawning habitats for implementation of field experiments are unknown, although previously documented spawning locations provide some guidance and tracking associated with components 2 and 5 will provide additional information.

Implementation of field experiments under component 5 may be constrained by achieving designs that do not interfere with navigation.

C.3.5.8 Utility of study components

The study components under this Big Question address a hypothesis thought to be important in explaining recruitment failure of pallid sturgeon. Understanding gained through these studies will provide information to validate or invalidate the notion that spawning habitat is limiting, and if validated, the studies will provide design specifications that can lead to habitat restoration, successful spawning, and population growth.

Deployment of sensors to observe processes associated with spawning success will likely also shed light on a reserve hypothesis: that predation of pallid sturgeon eggs may be a significant source of mortality.

C.3.5.9 Risks

Risks to pallid sturgeon populations presented by these science components are low. Telemetry has been shown to have low risk and laboratory/mesocosm studies can be carried out with research broodstock propagation.

Risks to stakeholders appear to be low with the possible exception of navigation interests. Constructed spawning habitats will be located in areas of high velocity and unit discharge, either directly in the navigation channel or adjacent. Design and construction will minimize risk to navigation.

C.3.5.10 Adaptive actions

Information provided through field experimentation will indicate whether channel geometries and/or substrate should be altered to improve performance, and whether additional locations would contribute to spawning success and population growth.

C.3.5.11 Estimated costs

Costs of development of sensors to image fine-scale processes in spawning patches may be substantive, although the technology can probably be adapted from existing marine technology. Costs of implementing field experiments would include design and construction, but because the spatial scope of spawning patches is much less than IRCs, the relative cost will be low.

C.3.6 Lower Big Question 6: Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?

C.3.6.1 Objective of study components

The science components for this Big Question are nearly identical to those for the upper river (Upper Big Question 6) with differences limited to geographic location. The objective of these study components is to provide the understanding needed to optimize population augmentation in recovery of the pallid sturgeon. While population augmentation is thought to be *necessary* for recovery of the pallid sturgeon, by itself it is not *sufficient* as the Endangered Species Act requires a self-sustaining population objective. Nevertheless, augmentation can help severely depleted populations recover numbers of individuals needed to evaluate what works and what doesn't in recovering the population. Moreover, if a depensation effect applies, very low numbers of fish may have low rates of reproduction because mates cannot find one another.

The study components listed here will provide information to improve population augmentation methods and hopefully achieve higher survival at lower cost, while maintaining needed genetic diversity. Because population augmentation is already taking place at the level where it has a measurable effect on the population (level 3), the study components described here are not considered necessary steps before implementing level 3. Instead, the level 1 and level 2 components will develop information to backfill and improve on the level 3 implementation. In addition, it is assumed that population augmentation is presently following best management practices to maintain genetic diversity, as determined and implemented by the Pallid Sturgeon Recovery Team. We recognize that the USFWS is preparing an update of the Pallid Sturgeon Rangewide Stocking Plan that, in combination with the collaborative decision making process of the Pallid Sturgeon Recovery Team and basin workgroups, may determine specific population-augmentation policies and information needs. The study components outlined here may be considered indicative of the types of studies that may be needed.

C.3.6.2 Description of study components

Study components include an engineering study to investigate facility-design options for the pallid sturgeon hatchery system to determine size and type of facilities, and hatchery operations that might be possible to increase and maintain consistent production with appropriate, size, health, and genetics; some of this assessment may be accomplished by the drafting of a new propagation plan by the USFWS. Field monitoring components are proposed to evaluate how size, health, and genetics have affected survival of previously stocked fish. To develop quantitative relations between propagation decisions and survival probabilities, a modeling study is proposed to evaluate population sensitivity to typical ranges of differential survival that might be affected by size, health, and parentage, and varied stocking rates that might arise from year to year variability in available broodstock or hatchery survival. A similar modeling study is proposed to investigate sensitivity of population genetics to variability in available parents, variable survival of family lots. Finally, a series of field experiments can be envisioned to provide a systematic evaluation of costs and population benefits associated with stocking at a range of ages (sizes).

C.3.6.3 Relation to Effects Analysis

These study components provide information to support EA hypotheses 20 and 21. Since the EA integrative report was written, new information has become available indicating that incidence of disease in hatchery origin fish has substantially constrained stocking levels in recent years. Although disease was not identified as a priority working hypothesis in the EA, the issue is intimately connected to the two issues that were identified, genetic parentage and size. In the case of parentage, population augmentation best-management practices generally do not support culling populations based on genetic makeup, as doing so would apply an unnatural selective pressure. Hence, management actions related to genetics (hypothesis 21) are actually quite limited aside from existing best management practices that seek to manage for diversity. Size at stocking, however, is a variable that can be managed, and doing so has implications for costs, numbers available to stock, and disease. While survival nominally increases with size at stocking, the longer a fish is maintained in the hatchery the greater the cost (including opportunity cost for other fish species that are not propagated) and the greater the opportunity for disease. Consideration of hypothesis 20, therefore, implicitly involves consideration of facilities capacity and disease risk.

Additional information that has emerged since the EA relates to reports of poor fish condition in the Lower Missouri River. Hypotheses to explain poor condition include several that assert that the carrying capacity of the river to support pallid sturgeon has diminished in recent years. If so, assumptions that more fish should be stocked may need to be re-evaluated.

C.3.6.4 Approaches

Approaches to these study components at level 1 include an engineering design study, field-based monitoring of differential survival rates, and sensitivity assessments using population and population genetics models. At level 2 a series of field-based experiments is proposed for systematic evaluation of size at stocking effects on differential survival.

C.3.6.5 Level 1

C.3.6.5.1 Component 1

This component would be an engineering feasibility design study to address costs and presumed population benefits for propagation facilities of different designs and capabilities. The selection of design and capability would be based on costs relative to results of component studies 2-4, which would indicate benefits of stocking size, and related disease risk. Much of the work may be accomplished by the USFWS revised propagation plan currently (2017) under development.

Metrics

Metrics for this study would be costs and measures of likely survival for a range of facilities designs. Measures of survival would be based on existing data for differential survival for stocked age-0, age-1, and juvenile fish, plus an estimate of the relations among designs, operations, size at stocking, and risk of disease.

Timelines and contingencies

The immediacy of the propagation issue, and likely time lag between a study and changes in facilities and operations, indicates that the feasibility study should start soon, perhaps as early as 2017. The study is estimated to take two years for completion and could be pursued concurrently with components 2 and 3.

Decision criteria for application of component

The results of the feasibility study would indicate a range of options in facilities and operations, with attendant costs and benefits to the propagation program in terms of probable increased survival and stocking rates. The decision of what improvements to implement (a level 3 or 4 action) would be based on costs and information developed in components 2-4 that would quantify benefits.

C.3.6.5.2 Component 2

This study will use monitoring data on growth and survival of hatchery-origin fish to assess how factors such as size at stocking, health history, and parentage may have affected survival. The study assumes that genetic and propagation records for hatchery-origin fish are complete and accurate. Appropriate monitoring could be a stand-alone operation or it could be incorporated within a population-trends monitoring program (see population monitoring Appendix D). Monitoring would need to extend to the Middle Mississippi River to include fish that may have migrated out of the Lower Missouri. A Cormack Jolly Seber (CJS) model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

The main metrics for this component are estimates of the number and survival rates for stocked pallid sturgeon by stocked size, hatchery of origin, and health history.

Timelines and contingencies

This component can be done concurrently with components 1 and 3. The technical approach to this question – a mark/recapture model– would be most efficient if coordinated with the population trends monitoring described in Appendix D and with Lower Big Question 4, component 5. We estimate that 3 years of sampling would be necessary to provide useful data on differential survival.

Decision criteria for application of component

Information developed in this component will illustrate the scope of differential survival and whether a need exists for fundamental changes to the propagation facilities and operations. The statistical rigor of the analysis is difficult to anticipate and decisions may need to be made based on judgments informed by multiple lines of evidence.

C.3.6.5.3 Component 3

These study components are model simulation studies intended to test sensitivity of population dynamics and population genetic structure to variability in augmentation. The first of these would assess how population dynamics would be affected by typical variation in survival related to size at stocking – results of which would indicate if there is value to the population to develop hatchery capabilities to optimize size. The model would also be used to assess effects of variable stocking rates (due to year-to-year variability in broodstock availability), health history and parentage. The second of these models would investigate sensitivity of population genetics to mating decisions made in the hatchery and other factors like year to year variation in availability of wild broodstock. Results will provide a quantitative basis for assessing risks of genetic swamping and insights into effort needed to collect and keep broodstock.

Metrics

Metrics from these modeling studies will include probability of quasi extinction, instantaneous growth rates, and sensitivity measures under various scenarios and parameterizations of the models.

Timelines and contingencies

Some of the parameters for the models will be informed with data from the mark/recapture survival data developed in component 2. This component will be done concurrently with components 1 and 2, and the time for completion of the study is estimated to be 3 years.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities, operations, and propagation plans, the decision to move to level 2 experimentation. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgment informed from multiple lines of evidence.

C.3.6.5.4 Criteria to move to level 2

Level 2 components are envisioned to be field based experiments that will vary size at stocking and assess differential survival. These level 2 activities may not be necessary to decide among facilities/operations options if the retrospective evidence is sufficiently robust. Moving to level 2 would be indicated if models indicate a high sensitivity of cost and survival to size at stocking, and more precise parameters for the relationships are needed.

C.3.6.6 Level 2

C.3.6.6.1 Component 4

If results of component 2 are equivocal about relations between size at stocking and differential survival, this component will provide a systematic, field-based experiment to assess the effect. The study would involve stocking fish at variable sizes (representing variable hatchery costs) keeping all other factors as constant as possible. Monitoring over several years would provide information on mortality and provide guidance on tradeoffs between survival and cost. The experiment would require that fish are identifiable from year to year based on tags or genetics, and that genetic and propagation records for the fish are complete and accurate. A CJS model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

Metrics from these experiments will be differential survival as a function of size or age at stocking as well as ancillary variables including health history, hatchery of origin, stocking location, and parentage.

Timelines and contingencies

This component would only be pursued if deemed necessary to make decision regarding facilities and operations. The monitoring approach would be a subset of the previously described population trends assessment (Appendix D); we estimate a minimum of five years to provide useful information on survival based on two years of stocking of 4 size ranges and 4 years of monitoring.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities and operations and stocking. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgement informed from multiple lines of evidence.

C.3.6.7 Critical scientific uncertainties and constraints

One critical uncertainty for these components is the geographic scope that needs to be sampled to assess survival, in particular how fish disperse among tributaries and the Middle Mississippi River. Another uncertainty is how covariates – environmental conditions, genetics, and health history – will interact to determine actual survival. A critical constraint in implementing field-based experiments with stocking is the availability of fish, with appropriate genetics, from the hatchery system.

C.3.6.8 Utility of study components

The study components under this Big Question address information that may be useful in improving effectiveness of the population augmentation program, which is in turn, a critical part of the recovery program. The information developed will be useful in cost: benefit decisions about investments in hatchery facilities and capabilities.

Monitoring proposed as parts of components 2 and 4 will be consistent with monitoring efforts envisioned for drift/dispersal studies and may contribute to population-trends monitoring.

C.3.6.9 Risks

Risks to pallid sturgeon populations presented by these components are low as long as best-management practices for maintaining genetic diversity are followed. Risks to stakeholders appear also to be low.

C.3.6.10 Decision criteria

The information gained in these studies will inform investments in hatchery facilities and capabilities, and perhaps contribute to refinement of some propagation decisions.

C.3.6.11 Adaptive actions

Information provided through these components would be useful in incremental changes to hatchery facilities and procedures.

C.3.6.12 Estimated costs

Costs of development of new facilities could be high. The intent of this set of components is to provide a cost: benefit basis for understanding the value of that investment.

C.4 Technical Development Components

Two areas of technical development have been identified as priority science components because of their applicability to the science and monitoring at all levels. These science components are a) development, refinement, and maintenance of a collaborative pallid sturgeon population model and b) optimization of a population monitoring effort.

C.4.1 Collaborative population model

Although much of the structure and parameterization of the pallid sturgeon population dynamics model has been developed through the EA process, we recognize that this model will be the central, integrating process for assimilating data on management actions and population responses. As such, it will be continuously updated as new information becomes available from science components, monitoring of process effectiveness, and from monitoring of population status and trends. This will require a standing level 1 science effort over the lifetime of the adaptive management program to maintain and update the model.

A critical feature of the population model is the presence of explicit links from management actions to key model parameters, chiefly survival from life stage to life stage. The explicit linkages allow for exploration and forecasting of how management actions will affect population growth.

The model is described as a collaborative population model (Appendix D) to emphasize that agencies, universities, and other institutions involved in pallid sturgeon science will have access to the model and ability to alter parameters and algorithms. The collaborative and flexible structure of the model will promote growth to keep pace with technical advances. The archival version of the model would be maintained within the AM program Technical Team. More information on the population model is available in Appendix D.

C.4.2 Optimization of population monitoring

We have identified the need to undertake a specific investigation of how population monitoring might be optimized to support management decision making as a level 1 science effort. Appendix D presents options for population monitoring and some limited results of simulations that address characteristics of a program that will provide useful estimates of numbers and survival of fish. Design of the optimal monitoring program will require an additional level 1 science effort. An optimal design will maximize information on the size and quality of the population, will support and be supported by the population model, and will perform with high cost effectiveness.

This technical component proposes two years of intensive sampling and simulation modeling to help in that design process. Intensive sampling will provide improved estimates of the capture/recapture probabilities that are fundamental to designing the scope and intensity of a mark/recapture monitoring effort. Simulations will be used to assess monitoring performance as assumptions are relaxed or violated, thereby indicating worst case scenarios for monitoring efficiency. The result of this effort will be a redesign of the pallid sturgeon population assessment program that will provide the data needed to link pallid sturgeon populations to management actions of the MRRP.

Simulation modeling will be conducted through an iterative process that will use targeted sampling to update model parameters. In addition, the modeling team will elicit feedback from fisheries biologists with experience in pallid sturgeon sampling to address practicalities and logistics of sampling design.

C.5 References

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Appendix D. Population Monitoring and Modeling for Pallid Sturgeon

DRAFT/Pre-Decisional/For Discussion Purposes

Prepared: September 30, 2016

By: Timothy L. Welker, Michael E. Colvin and Daniel James

D.1 Introduction

The Missouri River Recovery Management Plan (MRRMP) consists of a series of management actions intended to avoid jeopardy to interior least terns, piping plovers, and pallid sturgeon, while achieving acceptable trade-offs with authorized purposes and socio-economic considerations. Management of all three species exists within the context of hydro-climatic uncertainty imposed by the Missouri River basin, and also must accommodate imperfect knowledge of linkages from independent drivers, to habitat conditions, to ecological consequence, and finally to population dynamics. Implementing an appropriate suite of timely management actions to avoid jeopardy of the species in the face of this uncertainty dictates an adaptive management (AM) approach.

D.1.1 Background on Effects Analysis and Adaptive Management

The MRRMP has been influenced by the Missouri River Effects Analysis (EA), an effort to compile what is known and unknown about the three species. The results of the pallid sturgeon have been documented in four reports (Jacobson et al. 2015b, Jacobson et al. 2016a, Jacobson et al. 2016b). While the EA documents the wealth of information that has been developed about pallid sturgeon reproductive ecology and the Missouri River over the last 2 decades, it also demonstrates the fundamental uncertainties linking habitats to population processes and rates (Jacobson et al. 2016a). As a result, the AM plan for the pallid sturgeon emphasizes a systematic and strategic science effort to address these uncertainties. The EA compiled and assessed working management hypotheses believed to be relevant to pallid sturgeon population dynamics, resulting in 21 key hypotheses, 10 in the Upper River and 11 in the Lower River. In turn, these hypotheses were organized and grouped according to common physical context and scientific approaches into 12 Big Questions (6 Upper River, 6 Lower River) to focus high priority management decision needs and facilitate effective communication.

The AM plan recognizes the need for long-term population trend assessment to complement the detailed science components that address specific management hypotheses. The AM plan is organized around 4 levels of implementation that progress from an emphasis on learning to full implementation:

1. Foundational, enabling science.
2. Field-scale experiments.
3. Initial implementation of actions at a level intended to elicit a population response.
4. Full implementation of actions.

Level 1 and 2 science components are presented in Appendix C. It should be noted that the population monitoring and the collaborative population modeling described in this appendix also are level 1 science components where additional technical development is needed and ongoing. Therefore, Section D.4 of this appendix will receive significant scrutiny as part of level 1 science to optimize monitoring design, evaluate the consequences of violated assumptions, and how to appropriately estimate population trend and abundance. As information is developed through the science components, we anticipate that hypotheses, management options, and information needs will change, and therefore plans for acquiring that information will change. Information needs for understanding population trends, however, are expected to be fairly stable.

D.1.2 Management Objectives

Adaptive management of the pallid sturgeon (*Scaphirhynchus albus*) in the Missouri River is intended to fulfill the fundamental species objective developed by the U.S. Fish and Wildlife Service (USFWS): "Avoid jeopardizing the continued existence of the pallid sturgeon from US Army Corps of Engineers (USACE) actions on the Missouri River." (USFWS, Draft Species Objectives, 9/12/2013). The USFWS notes that this objective is consistent with species recovery goals (U.S. Fish and Wildlife Service 2014) but is specific to Missouri River management actions. The fundamental species objectives are accompanied by sub-objectives that are measurable and relevant (Table D1).

Table D1. Fundamental and sub-objectives for pallid sturgeon provided by the U.S. Fish and Wildlife Service during development of the Missouri River Recovery Management Plan.

Fundamental Objective	Avoid jeopardizing the continued existence of the pallid sturgeon from the US Army Corps of Engineers actions on the Missouri River.			
Sub-objectives		**Metric**	**Target**	**Time Frame**
Sub-objective 1	Increase pallid sturgeon recruitment to age 1	Catch rates of age 2 and 3 year-old pallid sturgeon	Short-term: recruitment; long-term: projection from population models of an annual egg to age-1 survival rate > 0.03.	10 years
Sub-objective 2	Maintain or increase numbers of pallid sturgeon until sufficient and sustained natural recruitment occurs	Catch rate of all size classes	Viable population size necessary to successfully overcome recruitment bottleneck. Target: Minimum of 5000 adults in each management unit*	20 years

*From U.S. Fish and Wildlife Service (2014).

The emphasis on recruitment reflects the fact that in the Missouri River, no genetically determined, successful recruitment of pallid sturgeon to age-1 has been recorded over the last 20 years (that is, no wild-spawned, naturally produced fish have been collected) (U.S. Fish and Wildlife Service 2014).

The MRRMP is the umbrella planning effort of the USACE under which AM takes place. The geographic scope of the MRRMP is the Upper Missouri River mainstem from Fort Peck Dam to the headwaters of Lake Sakakawea, the Yellowstone River upstream of the confluence with the Upper Missouri River for an unspecified distance, the Lower Missouri River mainstem from Gavins Point Dam to confluence with the Mississippi River at St. Louis, tributaries used by pallid sturgeon, and an unspecified distance downstream in the Mississippi River (Figure D1). The geographic scope is constrained in part by decision-making authority of the USACE and in part by present understanding of the geographic distribution of pallid sturgeon. The reservoirs and inter-reservoir reaches (from Lake Sakakawea to Lewis and Clark Lake) are excluded from the analysis based on the assumption that these habitats are unlikely to sustain reproductive populations of pallid sturgeon. The distance in the Mississippi River is unspecified because presently available information (2015) is ambiguous about the extent to which Missouri and Mississippi river populations mix through migrations and dispersal.

D.1.3 Monitoring and Assessment

Adaptive management of the pallid sturgeon in the Missouri River will require multiple sources of information. In addition to the level 1 and level 2 science components (Appendix C), we recognize three types of monitoring and assessment that will accompany implementation of management actions:

1. **Implementation monitoring/assessment** – was the management action implemented as intended. For example, did construction of an interception-rearing complex (IRC) follow and achieve specifications related to size, elevation distribution, and hydroperiod?
2. **Process monitoring/assessment** – did the management action achieve desired changes to ecological processes thought to lead to increased growth and survival? For example, did an IRC achieve an increase in functional food-producing and foraging habitats? Did food abundance actually increase? Were more free embryos advected into and retained in the IRC? Can increases in population growth-rate parameters be inferred confidently from performance of the IRC?
3. **Population monitoring/assessment** – did the effect of the management action propagate to recruitment and population growth? For example, can IRC development be associated or linked by cause and effect with increases in population size or growth rate?

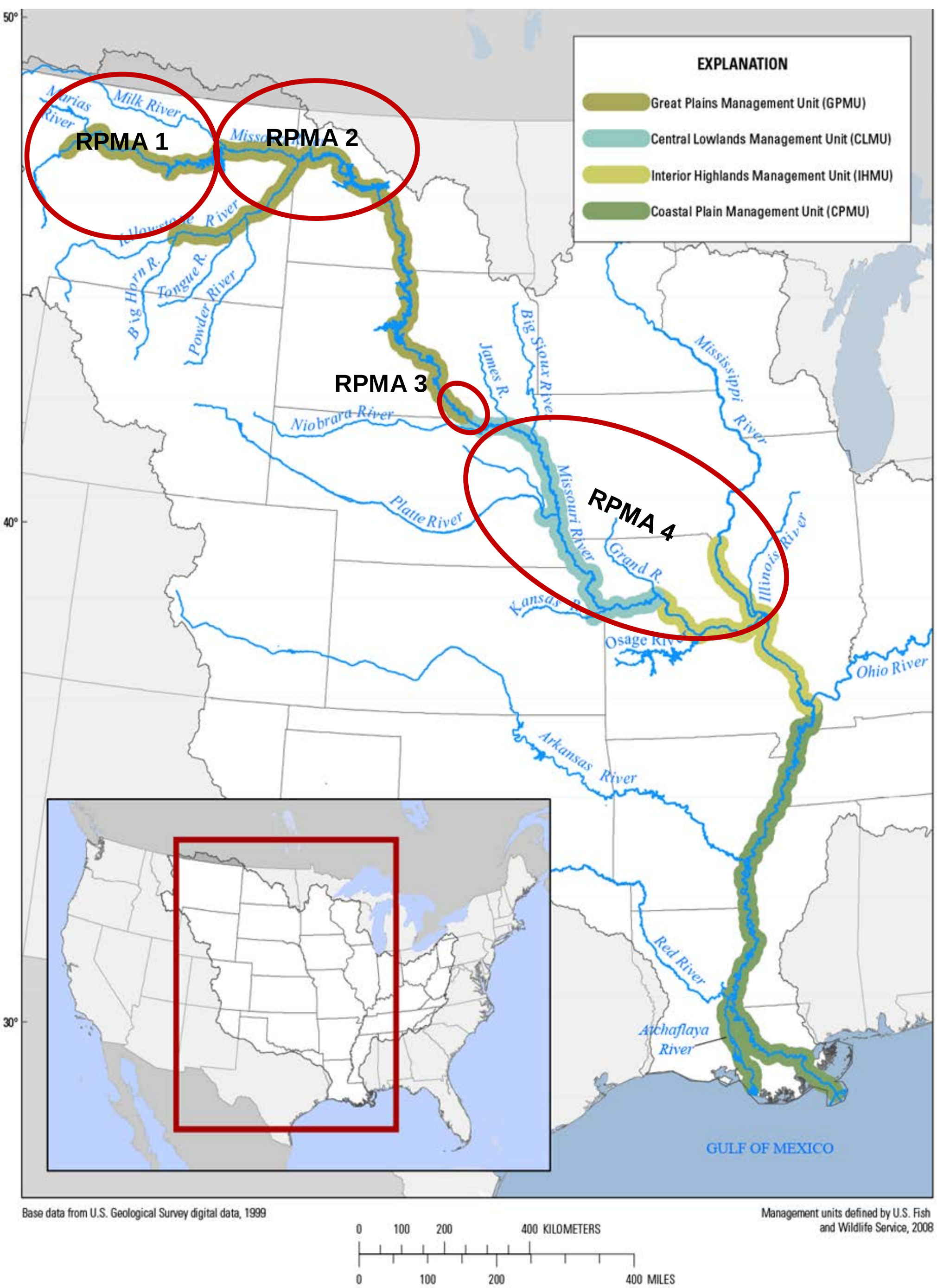

Figure D1, Pallid sturgeon recovery management units, showing previous recovery priority management areas (RPMA) and contemporary management units (U.S. Fish and Wildlife Service, 2014).

All three of these types of monitoring and assessment may provide important information for decision making and AM. There is debate, however, about the distribution of resources among the three types and the resulting utility of information to support decisions. Whereas the contributions of implementation and hypothesis-driven process monitoring are fairly clear, the value of population monitoring is less clear. In particular, there are differences of opinion (for pallid sturgeon and many other rare species) about the relative value of enumerating numbers of organisms to document status and trends, compared to modeling population changes based on measured or inferred changes to population growth parameters.

Arguments against investment in population-level monitoring center around high costs (or low information:cost ratio) and the difficulty in testing management hypotheses with population-level data. For example, we would anticipate difficulty assigning cause and effect to changes in estimated pallid sturgeon population as a result of management actions like increased flow naturalization or IRC area. Arguments to include some level of effort in population-level monitoring include:

- Value of population estimates as a reality check on inferences from process monitoring/assessment and (or) population models. Without a population-level assessment, indicators of general population health – positive and negative – may be missed resulting in risk to the species or spending resources where they are not needed.
- Value of population estimates as a metric of success for achieving population targets.
- Value of population estimates to track and predict need for continued investment in population augmentation.
- Value of population estimates and associated survival estimates to continuously update critical parameters in population models, thereby increasing reliability.
- Value of population estimates as a metric for understanding trend compared to performance and cost effectiveness of other metrics such as catch per unit effort (CPUE).
- Value of population estimates in understanding density-dependent processes in population dynamics including potential carrying-capacity limitations or depensation effects.
- Some process-level hypotheses are effectively tested, or testing will be enhanced, by population-level monitoring. This is particularly true about hypotheses related to population augmentation.

The present pallid sturgeon Population Assessment Program (PSPAP) is based on a catch per unit effort that is applied consistently throughout the geographic scope of the Missouri River Recovery Program (MRRP). The PSPAP was developed to support information needs articulated in the USFWS 2003 Amended Biological Opinion (BiOp) (U.S. Fish and Wildlife Service 2000, 2003). It is reasonable to expect that information needs and priorities would shift in 15 years since implementation of the BiOp and that the new management plan would have new information needs.

D.1.4 Objective of This Report

The objective of this report is to explore options for refining a population trends monitoring approach so it is effective and efficient in meeting the needs of the adaptive-management program. Effectiveness will be judged based on ability to discern long-term trends and the degree to which the monitoring complements and enhances assessments of specific management actions. Because there are many unknowns about future performance of a population monitoring effort, we do not make specific recommendations about the details of the effort. Instead, we present an assessment of existing efforts and current information needs (Section D.2), design guidance from previous studies (Section D.3), and a general concept for redesign (Section D.4). We provide detail on existing efforts, including sampling protocols and gears, because that information is the foundation from which more effective and efficient methods can be designed. The greatest unknown is level of effort and cost, and the degree to which population-level monitoring can coordinate and leverage resources (staffing, equipment) with process-level monitoring. We therefore recommend investment in a detailed planning and simulation process to refine a population-monitoring effort as a level 1 science effort (included in science components, Appendix C and described in section D4.2.1).

D.2 Past and Current Monitoring Projects

Several long-term monitoring projects have been implemented on the Missouri River and its tributaries during the last 10 years. Most were specifically designed to meet reasonable and prudent alternatives (RPA) elements in the BiOp for the Missouri River, each with different objectives. The PSPAP was developed to provide an assessment of long-term trends in pallid sturgeon abundance, population structure, and habitat use. Catch-per-unit effort (CPUE) was selected as the metric to evaluate trends in abundance due to the low numbers of sturgeon in the river and the perceived amount of effort that would be required to provide reliable abundance estimates through a mark-recapture effort. A description of the PSPAP and other, past projects is below.

D.1.5 Pallid Sturgeon Population Assessment Project

The PSPAP is the primary fish monitoring element for the BiOp (U.S. Fish and Wildlife Service 2000, 2003) and the MRRP. Data collected through the PSPAP are used to evaluate the pallid sturgeon propagation and population-augmentation management action (RPA element IV) and provide long-term assessments of fish metrics (RPA element V; population trends, survival, movement, distribution, and habitat use by pallid sturgeon and other target fishes). The PSPAP also collects pallid sturgeon broodstock each spring for meeting BiOp stocking requirements (RPA element IV) and the stocking levels identified by management biologists for Recovery Priority

Management Areas 1-4 (RPMAs, Figure D1).

D.1.1.2 Objectives

The Project objectives, sample design, and protocols were developed by an inter-agency team of Missouri River basin experts and continue to be guided by the Project Delivery Team (PDT) that is comprised of 8 agency offices from the USFWS, Montana Fish, Wildlife, and Parks (MTFWP), South Dakota Game, Fish, and Parks (SDGFP), Nebraska Game and Parks Commission (NGPC), Missouri Department of Conservation (MDC), and USACE. In addition to pallid sturgeon, a representative group of native Missouri River fishes is also monitored to detect improvements in the system as reflected by changes in the warm water benthic fish community. Project monitoring targets the following species: pallid sturgeon (*Scaphirhynchus albus*), sand shiner (*Notropis stramineus*), sicklefin chub (*Macrhybopsis meeki*), sauger (*Sander canadensis*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), plains minnow (*Hybognathus placitus*), western silvery minnow (*Hybognathus argyritis*), shoal chub (*Macrhybopsis hyostoma*; formerly speckled chub, *Macrhybopsis aestivalis*), sturgeon chub (*Macrhybopsis gelida)* and blue sucker (*Cycleptus elongatus*).

Objectives for PSPAP were developed to meet the 2003 BiOp RPA elements IV and V and are as follows:

- Evaluate trends in pallid sturgeon population abundance, distribution and habitat use throughout the Missouri River system.
- Evaluate survival, growth and habitat use of stocked pallid sturgeon in the Missouri River system.
- Document and evaluate pallid sturgeon reproduction and recruitment in the Missouri River system.
- Evaluate current and long-term trends in native Missouri River fish species abundance, distribution and habitat usage, with emphasis on warm water benthic fish community.

D.1.1.3 Geographic Scope

The PSPAP area encompasses the Missouri River from Fort Peck Dam, Montana at rivermile (RM) 1771.5 downstream to the confluence of the Missouri and Mississippi rivers near St. Louis, Missouri (RM 0) and the lower reach of the Kansas River (Figure D1). The BiOp divides the PSPAP area into river and reservoir segments and assigns high, moderate, or low priority management action to these segments for the pallid sturgeon. The focus of the PSPAP is the high-priority management-action segments (Figure D1). The segments identified as moderate or low priority for pallid sturgeon are categorized as reservoirs or transitional zones between rivers and reservoirs (USFWS 2000).

D.1.1.4 Sample Design

Fish and habitat data collections within 13 river segments (Figure D2) began in 2003 with full implementation of standardized sampling in all high-priority segments in 2006. The PSPAP uses a three-tiered hierarchical habitat classification system (macrohabitat, mesohabitat and microhabitat; see Welker and Drobish (2012) for a detailed description of habitat types) that allows for both general and specific categorization for sampling to serve the needs for biological and physical data collection efforts. PSPAP recognizes 14 river segments based on hydrologic criteria. Within each segment, macrohabitats are arranged by bends, which serve as the basic sampling unit (replicate) within each river segment. A bend comprises three continuous macrohabitats, an outside bend (main channel; OSB), an inside bend (main channel; ISB) and a channel crossover (main channel; CHXO). Within a segment, a minimum of 25.2% of all bends are sampled in a sample year. Within a bend, 12 potential discrete macrohabitats could occur beyond the three continuous macrohabitats [that is, large (TRML) and small (TRMS) tributary mouths, confluences (CONF), large (SCCL) and small (SCCS) secondary connected channels, non-connected secondary channels (SCN), deranged (DRNG), braided (BRAD), dendritic (DEND), and island tips (ITIP)]. All available macrohabitats are subsampled within a randomly-selected bend.

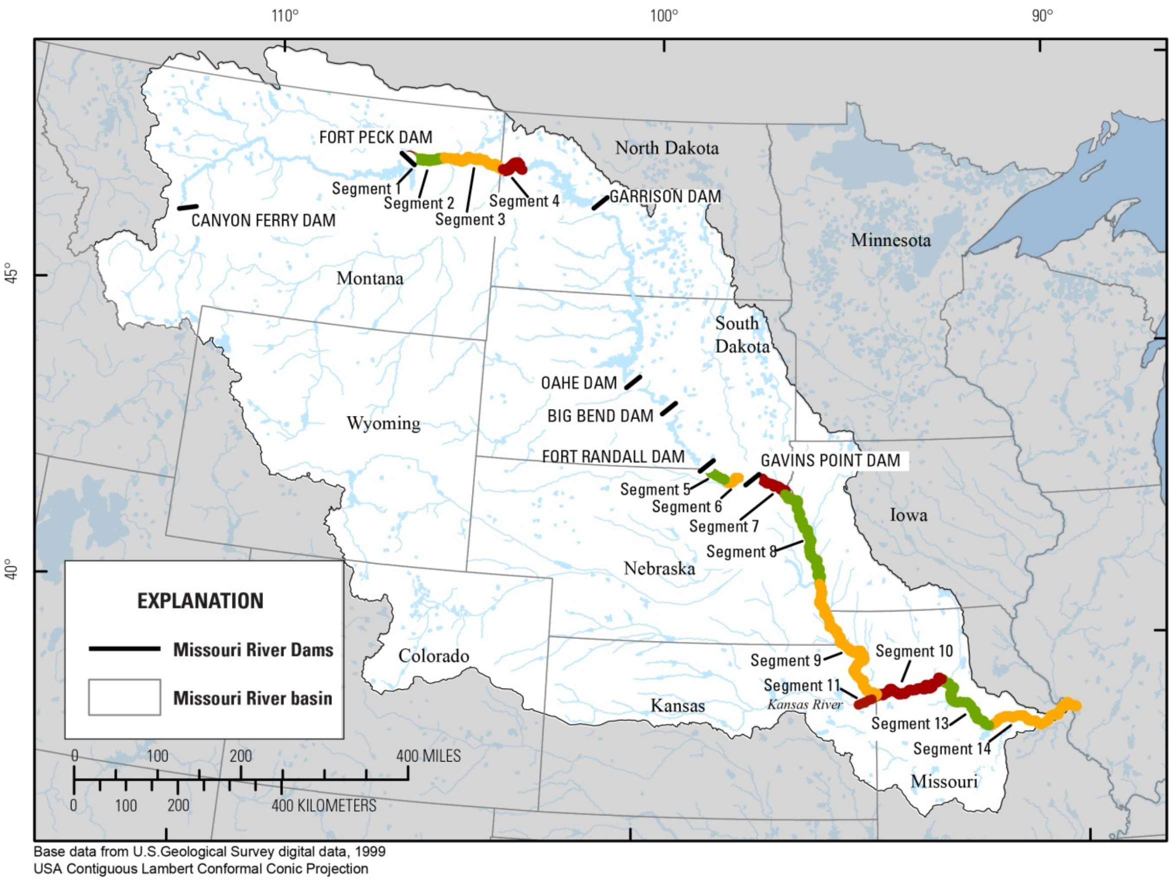

Figure D2. Segments used by the Pallid Sturgeon Population Assessment Program.

Sampling occurs from October 31 (or when water temps fall below 12.8 C (55 °F)) of the preceding calendar year to October 30 of the current calendar year. Each year includes two sampling seasons: sturgeon-focused (Sturgeon Season; ST) and native fish community-focused (Fish Community Season; FC) season. Sturgeon season runs from fall when water temperatures are first below the maximum (12.8 °C) set for gill nets to June 30 in attempts to minimize pallid sturgeon stress during collection. Fish community season runs from July 1 to October 31, overlapping ST for water temperatures below 12.8 °C (55 °F) prior to October 31.

A variety of fish and habitat metrics are measured through the PSPAP. For each pallid sturgeon capture, length and weight, morphological (meristics), genetic, marking (PIT tags, elastomer tags, or scute removal), habitat at capture location (depth, velocity, turbidity, and temperature), and location data are collected; some of these data are also collected for the other target fish species. Additional information on PSPAP data is available in Jacobson et al. (2015a).

D.1.1.5 PSPAP General Sampling Approach

Fish-sampling gears and methods were developed by the PSPAP team and are described in detail in Welker and Drobish (2012). A list of the standard-gear types analyzed in this report and the methods used by the PSPAP to deploy the gears are listed below.

D.1.1.5.1 Sampling Seasons

Two sampling seasons were established to accomplish sampling objectives for the PSPAP. These sampling seasons are determined by dates and water temperatures to provide flexibility in sampling across the geographic range of the Missouri River Basin. The sturgeon season begins in the fall when the water temperature is < 12.8°C (55°F) and continues through June 30th. The water temperature criteria addresses the issue of the water temperature variations between the upper and lower portions of the Missouri River and the amount of time in the field season to accomplish restrictive sampling (that is, gill netting) prior to ice up. On July 1st, sampling efforts remain the same with an additional emphasis on the associated fish community. The fish community season runs from July 1st through October 31st. The two seasons may overlap in portions of the river when temperatures fall below 12.8°C prior to the conclusion of the fish community season. A variety of fish-sampling gears were used during the sample seasons in both the Upper and Lower Missouri River.

D.1.1.5.2 Trammel Net

Trammel nets were used during both sampling seasons within the Upper and Lower Missouri River; however, trammel net sampling was dropped from the sturgeon season in the Lower Missouri River in 2010. The standard trammel net was 125 feet (38.1 m) long by 8 feet (2.4 m) high and had 1-inch (2.5-cm) inner panel bar mesh and 8-inch (20.3-cm) outer panel bar mesh. The top of each trammel net was supported by foam float line; a lead line ran along the bottom. Targeted drift distances for trammel nets were between 75 m and 300 m.

D.1.1.5.3 Otter Trawl

Otter trawls were used during both sampling seasons within the Upper and Lower Missouri River. The standard otter trawl was 16 feet (4.9 m) wide at the mouth, 3 feet (0.9 m) high, and 25 feet (7.6 m) long. Otter trawls had ¼-inch (6-mm) inner bar mesh, ¾-inch (19-mm) outer bar mesh, and a cod-end opening of 16 inches (40.6 cm). Trawl doors were 30 inches (76.2 cm) by 15 inches (38.1 cm) and were used to keep the trawl deployed while on the bottom of the river. Otter trawls were fished in a downstream direction with the distance of the tow depending on the size of the macrohabitat and mesohabitat being sampled and presence of snags. Targeted tow distances for otter trawls were between 75 m and 300 m (minimum of 75 m required).

D.1.1.5.4 Gill Net

Gill nets were used only during the sturgeon season within the Lower Missouri River. The standard gill net was a 100-foot (30.5-m) long by 8-foot (2.4-m) high experimental gill net that consisted of four 25-foot (7.6-m) long panels. Each net had one panel each of 1.5-inch (3.8-cm), 2-inch (5.1-cm), 3-inch (7.6-cm), and 4-inch (10.2-cm) multifilament square/bar mesh. A 200-foot (61.0-m) experimental gill net was also used and consisted of two 100-foot nets attached together. The first panel deployed from the boat during each set was randomly selected. Gill nets were set over night with a targeted maximum set time of 24 hours.

D.1.1.5.5 Trotline

Trotlines were used during both sampling seasons within the Upper and Lower Missouri River. The standard trotline consisted of a 105-foot (32-m) main line with hooks spaced 5 feet (1.5-m) on 18-inch (0.5-m) leaders (20 hooks per 105-foot main line). The level of effort (hooks and lines) could be doubled per deployment (205 ft. main line length with 40 hooks). Hooks were baited with night crawlers. Trotlines were set over night with a targeted maximum deployment of 24 hours.

D.1.1.6 Evaluation

PSPAP data provide useful information for several reasons in addition to trend detection:

1) It allows an evaluation of gear effectiveness and comparison with other fish collecting gears.
2) It provides a way to evaluate the cost of monitoring with a particular gear and to compare that cost to other gears.
3) It can be used to optimize the sampling strategies needed to meet objectives.

Pallid sturgeon objectives for the MRRP include reproduction (<1 year-old pallid sturgeon), recruitment (1-3 year-old pallid sturgeon), and quantifying demographic parameters. It is somewhat difficult to determine ages of pallid sturgeon based on body length; however, it is generally accepted that those <109 mm (Ridenour et al., 2011) are < 1 year old (that is, age-0, young-of-year; hereafter referred to as YOY). For this assessment, we quantified CPUE separately for fish <=109 mm (YOY) and >109 mm (juvenile + adult). Few pallid sturgeon <=109 mm have been captured through MRRP monitoring; therefore, we used shovelnose sturgeon as a surrogate for YOY pallid sturgeon.

The PSPAP uses a variety of standard gears to sample the different ages and sizes of pallid sturgeon. For fish <109 mm, the otter trawl was the gear used to quantify catch (Table D2). The trammel net, gill net, trotline, and otter trawl were used to quantify catch for fish > 109 mm (Table D2). Gear subsamples were averaged across years and segments within a basin to obtain a single CPUE value for each gear type. Catch was reported as number of fish/100 m^2 for the trammel net and the otter trawl. Gill net catch was quantified as number of fish/net night and trotline catch as number of fish/20 hooks. The number of sturgeon/gear deployment (subsample) was also reported for all gears (Table D3). For a description of standard gear dimensions, consult Welker and Drobish (2012).

Table D2. Sturgeon catch for gears used during standard, random sampling in the Pallid Sturgeon Population Assessment Project (PSPAP; 2006-2015)*, targeted broodstock collection (2006-2015)**, the Habitat Assessment and Monitoring Project (HAMP; 2013-2014), and the Platte River Assessment (Platte River; 2009-2012).
[Standard Error (when available) has been identified in parenthesis below catch data]

		Gears					
Monitoring Effort	**Size/Age**	**Trawl* (#/100 m^2)**	**Trammel Net* (#/100 m^2)**	**Trotline*/** (#/20 hooks)**	**Gill Net* (#/net night)**	**Trammel Net 48** (#/100 m^2)**	**Trammel Net 610** (#/100 m^2)**
		Upper Basin					
PSPAP	<109 mm	0.030 (0.004)					
	>=109 mm	0.002 (0.0001)	0.001 (0.0001)	0.55 (0.030)			
Broodstock	>=109 mm					0.001 (0.0002)	0.001 (0.0001)
		Lower Basin					
PSPAP	<109 mm	0.004 (0.003)					
	>=109 mm	0.004 (0.0002)	0.0005 (0.00003)	0.108 (0.005)	0.035 (0.001)		
HAMP	<109 mm	0.330 (0.027)					
Broodstock	>=109 mm			0.180 (0.006)			
Platte River	>=109 mm			0.058			

Table D3. Sturgeon catch (number of fish per deployment) for gears used during standard, random sampling in the Pallid Sturgeon Population Assessment Project (PSPAP; 2006-2015)*, targeted broodstock collection (2006-2015)**, the Habitat Assessment and Monitoring Project (HAMP; 2013-2014), and the Platte River Assessment (Platte River; 2009-2012).

[Standard Error (when available) has been identified in parenthesis below catch data]

Monitoring Effort	Size/Age	Gears					
		Trawl*	Trammel Net*	Trotline*/**	Gill Net*	Trammel Net 48**	Trammel Net 610**
Upper Basin							
PSPAP	<109 mm	0.080 (0.0095)					
	>=109 mm	0.087 (0.0041)	0.106 (0.0053)	0.55 (0.030)			
Broodstock	>=109 mm					0.062 (0.025)	0.065 (0.013)
Lower Basin							
PSPAP	<109 mm	0.129 (0.0073)					
	>=109 mm	0.011 (0.0010)	0.019 (0.0014)	0.180 (0.0071)	0.0035 (0.001)		
HAMP	<109 mm	0.472					
Broodstock	>=109 mm			0.336 (0.010)			

For pallid sturgeon >109 mm, trotlines had the highest CPUE in both the Upper (0.55/20 hooks, 0.55/deployment) and Lower (0.180/20 hooks, 0.180/deployment) basins (Table D2). The gill net had the lowest CPUE for all gears (0.035/net night, 0.0035/deployment). Catch for the trawl and trammel net were similar within their respective basins across the two size classes (Table D2). Catch as quantified by number of fish/deployment followed similar trends across the gears (Table D3).

In addition to the data presented here, several analyses of the PSPAP add understanding of what the project has provided (Sustainable Ecosystems Institute 2004, Wildhaber et al. 2011b, Wildhaber et al. 2015).

D.1.6 Habitat Assessment and Monitoring Project

The Habitat Assessment and Monitoring Project (HAMP) was developed in 2004 by an interagency collaboration of representatives from the Iowa Department of Natural Resources, Missouri Department of Conservation (MDC), Nebraska Game and Parks Commission (NGPC), South Dakota Game, Fish and Parks (SDGFP), University of Missouri, USACE, USFWS, and U.S. Geological Survey (USGS). The HAMP was initiated to evaluate habitat modifications designed to increase shallow, slow water habitat within the main channel of the Missouri River. The concept of shallow water habitat (SWH) has been defined operationally as 0-5 ft (0-1.5 m) depth and 0-2 ft/s (0-

0.6 m/s) current velocity (U.S. Fish and Wildlife Service 2000a); a recent clarification emphasized dynamics and variability of SWH elaborated on its hypothesized functions: “Shallow water habitat provides locations for increased primary productivity, invertebrate production, and larval/young-of-year nursery habitat” (Olson 2009).

From 2004-2009, pallid sturgeon and other target species were monitored to evaluate changes in relative abundance between habitat-modified and unmodified river bends. A before-after-control-impact (BACI) study design was used to evaluate the potential effects of habitat alteration (dominantly dike notching) on fish communities. The assessment (Schapaugh et al. 2010) cited the HAMP as an excellent design to achieve active AM, yet noted that the assumptions of the underlying BACI designs were not being met under real-world conditions and therefore ability to detect effects of SWH was limited. In particular the authors reported that the actions of dike notching did not result in detectable changes in the fish community. The authors suggested that specific hypotheses addressing mechanisms of change associated with changes in habitat and fish production need to be addressed. . However, Ridenour et al. (2009) used HAMP collected Macryhbopsis spp. chubs to demonstrate ontogenetic shifts in habitat use from age-0 to adulthood, and discussed the role of SWH and the potential for strategic dike notching, in support of pallid sturgeon recovery.

Recently, HAMP efforts have been modified to de-emphasize the previous BACI design and to focus on specific hypotheses relating SWH and life-stage processes of larval and young-of-year pallid sturgeon (Todd Gemeinhardt, USACE, pers. comm.). The purpose of the current HAMP study is to evaluate the efficacy of existing SWH to support early life stages of age-0 *Scaphirhynchus spp*. (undifferentiated age-0 pallid sturgeon and shovelnose sturgeon) to facilitate adaptive decision making for future habitat construction actions.

D.1.1.7 Objectives

The recent, primary objectives of HAMP are to: 1) compare density (numbers per unit area) of age-0 sturgeon between reaches with high acreages of SWH (existing or restored) against reaches with no or minimal SWH; and 2) identify and prioritize the types, or suite of types, of habitats that best promote use by age-0 sturgeon to guide management decisions on future SWH restoration.

D.1.1.8 Geographic Scope

The current HAMP study includes 5 river reaches that are approximately 20 miles in length. The study area begins at RM 327 (approximately 30 miles downriver from Kansas City, MO) and extends to RM 33 near St. Louis, MO.

D.1.1.9 Sample Design

To maximize efficiency and value of the HAMP's limited sampling resources, a stratified random approach was used in 2014-2015 to guide sampling efforts through the habitat classification hierarchy to avoid oversampling in habitats where age-0 sturgeon (≤109 mm) are not likely to occur (based on PSPAP capture data collected from 2003 to 2013 in segments 10, 13, and 14 and existing HAMP data). Sampling units are limited to short (approximately 20 mile) reaches of Missouri River from Kansas City to St. Louis and is implemented to meet the two objectives listed above. Subsampling was distributed with a goal of achieving representativeness (prevent clustering of sampling in any part of reach) and rapid progression through each reach to minimize effects of changing environmental conditions on data interpretation within and among reaches. Additional information related to the sample design can be found in Gosch et al. (2015). Habitats in the 5 reaches are sampled from May through October. Habitats >1.5 m in depth are sampled with an otter trawl similar to that used by the PSPAP (see Welker and Drobish 2012 for description); however, the HAMP trawl has a smaller mesh size (4 mm vs. 6.35 mm for PSPAP). In habitats <1.5 m deep, the HAMP samples with a 4-mm mesh push trawl (Gosch et al. 2015).

D.1.1.10 Evaluation

The catch information reported here is for the 2014 sample season. Catch for age-0 (<109 mm) *Scaphirhynchus* sturgeon through the HAMP project was approximately 5 times greater than the catch rate obtained for PSPAP (Tables D2 and D3). This is likely due to differences in sample design and gear types, in particular the emphasis on targeted, habitat-based sampling rather than completely non-stratified randomizaton.

D.1.7 Broodstock Sampling

The pallid sturgeon Propagation and Population Augmentation element (RPA IV) is a direct effort to supplement year-class structure to the pallid sturgeon population due to the lack of spawning and/or recruitment in the Missouri River. It also attempts to provide for survival of the species, retention of the remaining population genetics and structure, provides adults to test management actions and recruitment hypotheses, and provides a reliable source of progeny for addressing uncertainty related to age-0 pallid sturgeon survival.

D.1.1.11 Objective

The objective of broodstock sampling is to provide reproductive adults for the augmentation program. Wild pallid sturgeon are collected each spring and brought into hatcheries for spawning and the eventual stocking of their progeny into the Missouri River; this occurs in the Upper (Fort Peck Reservoir to Lake Sakakawea and the Lower Yellowstone River) and Lower (Lewis and Clark Lake to the Missouri River mouth) Missouri River basins (Figure D1). Currently, pallid sturgeon broodstock collection activities in the upper river are conducted by Montana Fish, Wildlife, and Parks (MTFWP), U.S. Geological Survey (USGS), and the U.S. Fish and Wildlife Service (USFWS), and generally occur in May and June. In the Lower River, broodstock collection occurs primarily in April and is conducted by the USFWS and the states of South Dakota, Missouri, and Nebraska.

The largest broodstock collection effort occurs in the Lower River. For example, in 2015 over a two-week sample period, Nebraska Game and Parks Commission (NGPC) utilized 175 personnel, mostly volunteers, in an intensive effort. A similar, but smaller effort was conducted in the Lower Missouri River by the Missouri Department of Conservation (MDC) where they used a combination of 78 agency and volunteer personnel to collect pallid sturgeon broodstock. In the Upper and Lower rivers, most of the agency personnel that are involved with broodstock collection also conduct fish monitoring through USACE funded projects (e.g., PSPAP, HAMP, and Comprehensive Sturgeon Research Project [CSRP]).

D.1.1.12 Geographic Scope

Pallid sturgeon broodstock collection occurs in the four Recovery Priority Management Areas (RPMA; 1-4) for pallid sturgeon in the Missouri River. RPMA 1 is outside of the geographic scope of the MRRP (that is, upriver of Fort Peck Reservoir); however, the MRRP does include those portions of the Missouri River encompassed by RPMA’s 2-4. The USACE has jeopardy responsibilities for pallid sturgeon under the Endangered Species Act in these three RPMA’s.

D.1.1.13 Sample Design

Broodstock sampling throughout the Missouri River basin is a targeted effort rather than randomized, and is therefore subject to considerable bias in estimating fish density. Sampling is concentrated during spring in areas where adult-sized pallid sturgeon have been found in high concentration in the past (e.g., reaches, bends, habitats, river confluences). A variety of fish sampling gears are used throughout the basin; trammel nets (TN48, 38.1 m long x 2.4 m deep with 4 in and 8 in panel mesh; TN610, 38.1 m long x 2.4 m deep with 6 in and 10 in panel mesh) serve as the primary gear in the upper river with PSPAP standard trotlines the primary gear used in the Lower River (for a description of gear dimensions, consult Welker and Drobish (2012)). Sampling by the various resource agencies is concentrated into a two- to three-week period.

D.1.1.14 Evaluation

For this report, broodstock CPUE was quantified for two types of trammel nets in the Upper Basin and for the standard PSPAP trotline. Gear subsamples were averaged across years and segments within a basin to obtain a single CPUE value for each gear type. Catch was reported as number of fish/100 m^2 for the trammel nets and the number of fish/20 hooks for the trotline. The number of sturgeon per gear deployment (subsample) was also reported for all gears (Table D3).

In the Lower River, targeted broodstock sampling with the trotline provided the highest catch per deployment (0.336; Table D3) when compared to the gears used for PSPAP standard, random sampling (Table D2). Targeted broodstock sampling in the upper river provides lower catch rates (Table D3) compared to trotline and trammel net sampling through PSPAP (Table D2). However, the broodstock trammel nets (TN48 and TN610) were selected and are deployed to capture the large and rare upper river legacy broodfish. This likely results in a lower catch rate than if the entire population of pallid sturgeon were also targeted for capture.

D.1.8 Platte River Assessment

Sampling for pallid sturgeon began in 2009 as part of a research effort designed to determine the distribution and abundance of pallid sturgeon in the Lower Platte River. Pallid sturgeon were collected annually from 2009-2012 with the research effort renewed in 2014.

D.1.1.15 Geographic Scope

The research area extends up the Platte River from river kilometer (rkm) 0 at the confluence with the Missouri River to rkm 159 near the Loup River Power Canal confluence.

D.1.1.16 Sample Design

Data collection occurred in randomly selected 1-km reaches within two study segments. A stratified-random sampling approach was used to select 20 sample reaches within each segment. Fish were collected with drifting trammel nets (depth=1.8 m; length=38.1 m; outside mesh panel=15.0 cm; inside mesh panels=2.5 cm) and trotlines (30.5 m main line; 20 3/0 O'Shaughnessy hooks). Data provided as a personal communication from M. Hamel (2015).

D.1.1.17 Evaluation

Trammel net catch for pallid sturgeon >=109 mm was 0.058 fish/100 m drifted which is higher than the 0.017/100 m found for the PSPAP in the Lower Missouri River. Trotline CPUE in the Lower Platte River was 0.015/20 hooks which is lower than the 0.108/20 hooks obtained for pallid sturgeon in the Lower Missouri River through the PSPAP. Targeted broodstock sampling with the trotline for the PSPAP yielded 0.180/20 hooks. It should be noted that the Platte River is substantially shallower and has more complex habitats on average than the Missouri River, so gear efficiencies would be expected to vary.

D.1.9 Comprehensive Sturgeon Research Project

The CSRP is an interagency collaboration of the USGS, NGPC, MTFWP, USFWS, and the USACE Missouri River Recovery—Integrated Science Program. The goal of CSRP is to improve the fundamental understanding of the reproductive ecology of the pallid sturgeon (*Scaphirhynchus albus*) to better inform river and species management decisions. The CSRP is not intended to be a monitoring project, but it has had aspects of monitoring in its long-term datasets.

D.1.1.18 Objectives

Specific objectives pursued 2005-2014 include:

- Determine movement, habitat use, and reproductive behavior of pallid sturgeon;
- Understand reproductive physiology of pallid sturgeon and relations to environmental conditions;
- Determine origin, transport, and fate of drifting pallid sturgeon larvae and evaluate bottlenecks for recruitment of early life stages;
- Quantify availability and dynamics of aquatic habitats needed by pallid sturgeon for all life stages; and
- Manage databases, integrate understanding, and publish relevant information into the public domain.

CSRP has emphasized understanding of reproductive ecology of adult and early-life-stage sturgeon. For understanding reproductive behaviors of adults, the CSRP approach has been to capture adult shovelnose and pallid sturgeon, evaluate the reproductive status of each individual (Korschgen 2007), and instrument each with a uniquely coded acoustic or acoustic/radio combined telemetry transmitter and archival data storage tag (DST) to record temperature and depth (as pressure) at 15 to 30 minute interval. Telemetry has been used to locate individual sturgeon over long periods to collect information on movement, habitat use, behavior, and response to environmental cues or habitat manipulations.

D.1.1.19 Geographic Scope

CSRP activities range from the Upper Missouri and Yellowstone rivers to the Middle Mississippi River. Some telemetry and supporting abiotic datasets have collected in tributaries like the Osage, Kansas, Platte, and Big Sioux rivers. The inter-reservoir reaches from Lake Sakakawea to Lewis and Clark Lake have not been included.

D.1.1.20 Sample Design

The CSRP telemetry dataset is focused on hypotheses relating to the reproductive ecology of pallid sturgeon adults. The sample design includes comparative studies of migration, aggregation, and spawning in the Upper Missouri-Yellowstone and the Lower Missouri River. In the Lower Missouri River, reproductive behaviors upstream of the Platte River are compared to reproductive behaviors downstream of Kansas City in an attempt to isolate effects of flow management.

Since the CSRP was initiated, 175 pallid sturgeon and 376 shovelnose have been implanted with telemetry tags and telemetry tags in combination with DST devices in the Lower Missouri River. Of these, 172 (98.3%) pallid sturgeon 352 (94.6%) Shovelnose Sturgeon were located at least once after release. More than 80 pallid sturgeon have been in the CSRP study for multiple years and had multiple telemetry and DST devices during that time. From pallid sturgeon implanted with DST devices, CSRP has archived more than 3.3 million depth and temperature records. All locations on the Lower Missouri River are determined through boat-mounted acoustic receivers. On the Upper Missouri and Yellowstone Rivers, most tags have been radio frequency.

CSRP has also carried out some free-embryo sampling to address specific questions about where and when sturgeon spawn. Systematic sampling for free embryo sturgeon and paddlefish was initiated through CSRP in 2012 and is conducted along transects perpendicular to the flow of the river at intervals throughout the spawning and dispersal periods. Systematic sampling was performed in 2012 in the Lower Missouri River near St. Charles, MO from mid-April into October to detect timing, and extent of spawning by sturgeon and paddlefish, and species composition and abundance of Acipensiform free embryos drifting in the Lower Missouri River. Systematic sampling efforts during 2012 and 2013 resulted in a total of 2043 gear deployments at two locations, collecting a total of 665 sturgeon and 412 paddlefish free embryos.

D.1.1.21 Evaluation

CSRP studies have established telemetry methods for implantation, tracking, and data analysis for pallid sturgeon. The experience indicates that boat-based acoustic telemetry tracking is viable on the Lower Missouri River and combined acoustic and radio tags are useful on the Upper Missouri River. The results show the long distances some fish will travel in their reproductive migrations (100's of km) and, in some case, some spatial fidelity to their reproductive home ranges. This experience with telemetry techniques and data processing is likely to be useful in design and implementation of future population trends monitoring, including the use of telemetry in evaluating emigration and immigration.

D.1.10 Summary of Past and Current Projects

Of the projects described above, only the PSPAP was developed and implemented to capture trends in pallid sturgeon population metrics. PSPAP catch information, evaluated within the context of the other projects, documents which gears, habitats, and sampling designs appear to be most efficient and therefore likely to be useful in future population monitoring. In addition to the data presented here, several analyses of the PSPAP add understanding of what the project provides and the reliability of the quantified trends. Early in the development of PSPAP, an independent science review was conducted by Sustainable Ecosystems Institute (2004). A number of recommendations was provided and later implemented to better integrate the project components and meet objectives. Statistical power analyses were performed periodically (Peery 2004, Bryan et al. 2010, Schapaugh and Tyre 2011) to identify investments and trade-offs in the project design and to evaluate the ability to detect changes in abundance. Population trends were quantified through a number of assessments (Oldenburg et al. 2010, Wildhaber et al. 2011, Wildhaber et al. 2015) following standardization of the project design in 2006. Recent work by Wildhaber et al. (2015) provided new models that incorporated covariates (e.g., water temperature, velocity, gear, habitat) that improved the detection of abundance and habitat-use changes over time. Their assessment determined that "....a large-scale, large-river, PSPAP-type monitoring program can be an effective tool for assessing population trends and habitat usage of large-river fish species. Using multiple gears, PSPAP was effective in monitoring shovelnose and pallid sturgeons, sicklefin, shoal and sturgeon chubs, sand shiner, blue sucker and sauger." However, the question to be answered through this report is: will implementing the current PSPAP monitoring design, or an alternative design, best meet the future needs and objectives identified in the MRRP AM Plan?

D.1.11 Design Guidance from Current Monitoring Information

Current and past monitoring projects on the Missouri River can provide valuable insight into important design criteria such as when, where, and at what level of effort to sample; choosing the appropriate level of each criterion will optimize the sample design for meeting MRRP objectives. Review of these projects will lead to development of the most efficient design that provides high quality data, the least-biased estimates, and high precision or certainty. Detailed analysis (e.g., simulations that examine trade-offs) as part of a level 1 science effort will be required to identify the most appropriate design based on the type of information needed, the level of detail, the metrics, and the cost of collecting the data; however, at this preliminary stage, numerous design considerations can be identified. The design considerations are provided below for sub-objectives 1 and 2. Considerations identified for sub-objective 2 would also apply to quantifying or updating population demographics (that is, catch rates for all size classes of pallid sturgeon).

D.1.1.22 Temporal Sampling Distribution

Temporal sampling considerations will depend on the objectives and the metrics selected to assess the Fundamental and Species objectives. The current temporal sampling units vary depending on the project (e.g., PSPAP or HAMP). The PSPAP sampling is separated into two temporal units per year, a sturgeon season (ST) and a fish community season (FC); these generally run from early winter through spring (ST) and summer to late fall (FC). Sampling in the PSPAP has occurred sporadically, representing every month of the year and usually summarized by season or year. Other projects have more specific time periods for sampling such as during the spring/early summer to track reproductive adults or during the late summer to sample for larval sturgeon in the drift, for example.

Temporal sampling units can widely vary (e.g., day, month, season, or year). Depending on the specific objectives of a study, timing of sampling is important especially when directed at certain life stages. Thus, identifying time frames to conduct sampling for specific life stages of interest throughout the year at specific locations will result in the collection of data that can address the objectives of a study. Pallid sturgeon use many locations in the Missouri River and can move extensively throughout the year, thus timing of sampling and location must match to address study objectives.

D.1.1.23 Upper River

Most effort for age 2-3 pallid sturgeon from 2006-2014 was in May (n=3,679 subsamples) and June (n=3,132 subsamples) followed by August and September (n=2,894 and 2,904 subsamples, respectively) (Figure B3). Although the number of subsamples averaged 506 fewer in August/September than in May/June, catch rate (#/subsample) was highest in August/September (mean = 0.04) compared to May/June (mean = 0.025). However, the month of April also had a catch rate of 0.04 when the number of subsamples was only 1,105. The highest catch rate was 0.05 in October where the number of subsamples was 2,081.

The majority of pallid sturgeon < 109 mm were caught in August (Figure B3). Sub-adult pallid sturgeon catch rates were low in the spring/summer and higher from August through October. Few (n=40) large pallid sturgeon (> 1,000 mm) have been caught, however, 31 of those were caught from August through October (Table D5).

The largest amount of subsampling from 2006-2014 has been in May and June, although these two months have generally resulted in a fewer number of pallid sturgeon caught per subsample relative to the other months. The month of April has the largest catch rate relative to number of subsamples for age 2-3 fish and August generally appears to have the greatest catch rates for all sizes of pallid sturgeon.

Table D5. PSPAP catch for pallid sturgeon (>=109-1,000 mm; >1,000 mm; age 2-3) and *Scaphirhynchus* species (< 109 mm FL) for each month (March-October) in the upper Missouri River basin for the years 2006-2014. *

[FL: fork length; mm: millimeter.]

Size	Month	Area	Number sturgeon caught	Number per subsample
<109 mm	Apr	Segment 4	6	0.02
	May		15	0.03
	Jun		3	0.01
	Jul		12	0.05
	Aug		77	0.27
	Sep		28	0.07
	Oct		6	0.02
>=109 mm – 1,000 mm	Mar	Segments 2-4	0	0
	Apr		188	0.17
	May		515	0.14
	Jun		345	0.11
	Jul		248	0.12
	Aug		695	0.24
	Sep		842	0.29
	Oct		728	0.35

Only otter trawl subsamples are reported for *Scaphirhynchus* spp. sturgeon <109 mm; otter trawl, trammel net, and trotline subsamples are reported for the other length/age groups.

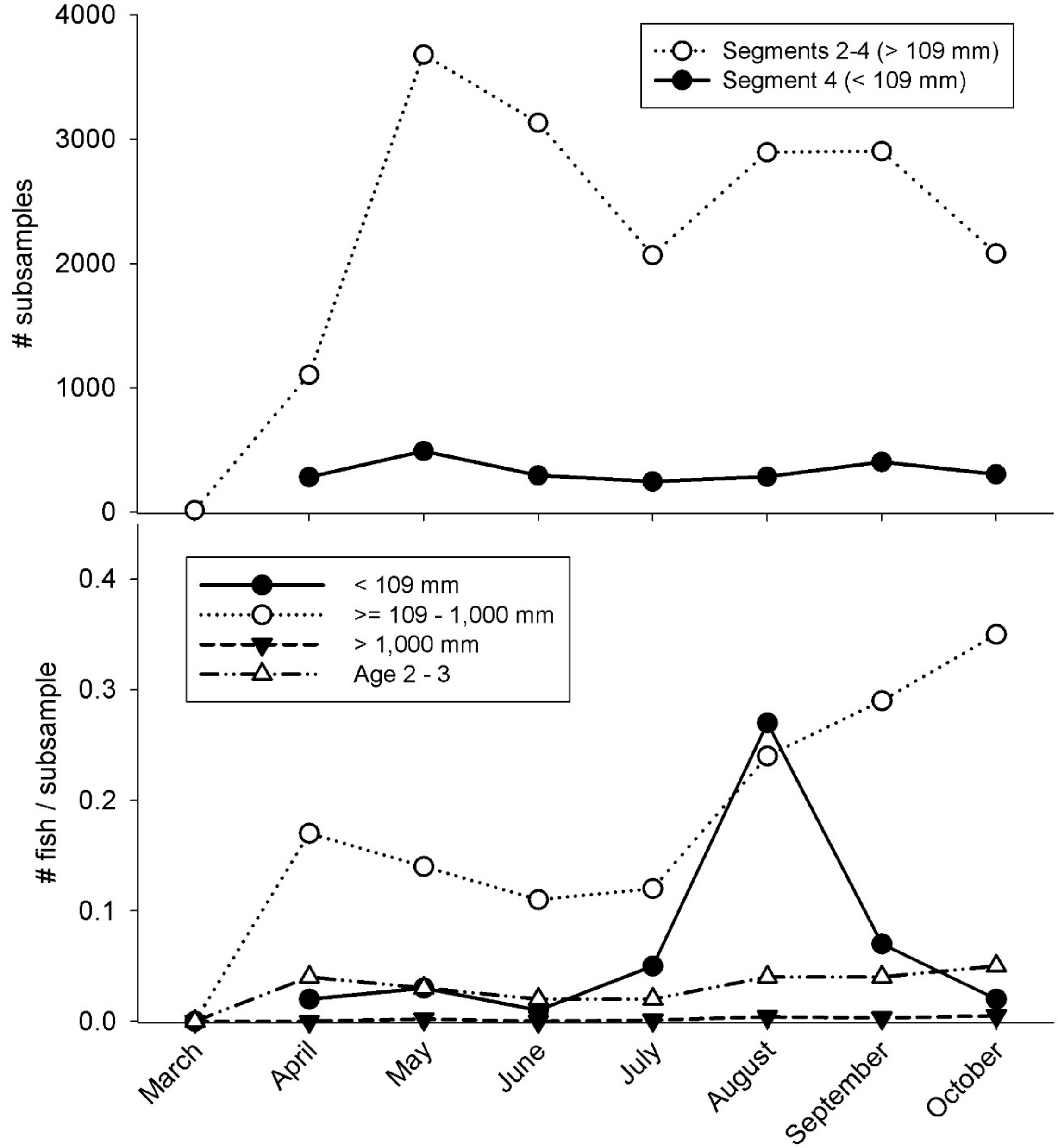

Figure D3. PSPAP effort (top panel) and catch (bottom panel) for pallid sturgeon (>=109-1,000 mm; >1,000 mm; age 2-3) and *Scaphirhynchus spp.* (< 109 mm FL) for each month (March-October) in the upper Missouri River basin for the years 2006-2014. Only otter trawl subsamples are reported for *Scaphirhynchus spp.* sturgeon <109 mm; otter trawl, trammel net, and trotline subsamples are reported for the other length/age groups.

D.1.1.24 Lower River

Most effort for age 2-3 pallid sturgeon from 2006-2014 was from May through August (range: 3,946-5,072 subsamples) (Figure B3). The lowest effort was from December through February. Catch rate (#/subsample) was either 0.0 or 0.01. Age 2-3 pallid sturgeon have only been caught from March-May and October-November (Table D6).

Pallid sturgeon < 109 mm were catch rate increased from May to August and peaked in September (Figure D3). Sub-adult pallid sturgeon catch rates were highest in the spring and late fall while low from June through September (Figure D3). The month for the highest catch rate of large pallid sturgeon (> 800 mm) was October.

D.1.1.25 Summary

The largest amount of subsampling from 2006-2014 has been from May through August, although these months have generally resulted in a fewer number of pallid sturgeon caught per subsample relative to the other months. Both spring and fall months have similar catch rates age 2-3 fish, but the months of September and October generally appear to have the greatest catch rates for all sizes of pallid sturgeon. Furthermore, catch rates in September and October are higher with less effort than that observed for the month of May through August.

Table D6. PSPAP catch for pallid sturgeon (>=109-1,000 mm; >1,000 mm; age 2-3) and *Scaphirhynchus* species (< 109 mm FL) for each month (March-October) in the lower Missouri River basin for the years 2006-2014. *

[FL: fork length; mm: millimeter.]

Size	Month	Area	# sturgeon caught	#/Subsample
<109 mm	May	Segments 10, 13, 14	19	0.02
	Jun		65	0.08
	Jul		74	0.13
	Aug		143	0.18
	Sep		201	0.31
	Oct		60	0.13
>=109 mm – 800 mm	Jan	Segments 7-14	15	0.03
	Feb		44	0.05
	Mar		198	0.06
	Apr		147	0.06
	May		190	0.04
	Jun		39	0.01
	Jul		101	0.02
	Aug		84	0.02
	Sep		71	0.02
	Oct		281	0.08
	Nov		251	0.09
	Dec		48	0.06
>800 mm	Jan	Segments 7-14	5	0.01
	Feb		26	0.03
	Mar		66	0.02
	Apr		25	0.01
	May		0	0
	Jun		0	0
	Jul		0	0

	Aug		0	0
	Sep		0	0
	Oct		140	0.04
	Nov		56	0.02
	Dec		16	0.02
Age 2-3	Jan	Segments 7-14	0	0
	Feb		0	0
	Mar		33	0.01
	Apr		25	0.01
	May		48	0.01
	Jun		0	0
	Jul		0	0
	Aug		0	0
	Sep		0	0
	Oct		35	0.01
	Nov		28	0.01
	Dec		0	0

Only otter trawl subsamples are reported for *Scaphirhynchus* spp. sturgeon <109 mm; otter trawl, trammel net, gill net, and trotline subsamples are reported for the other length/age groups.

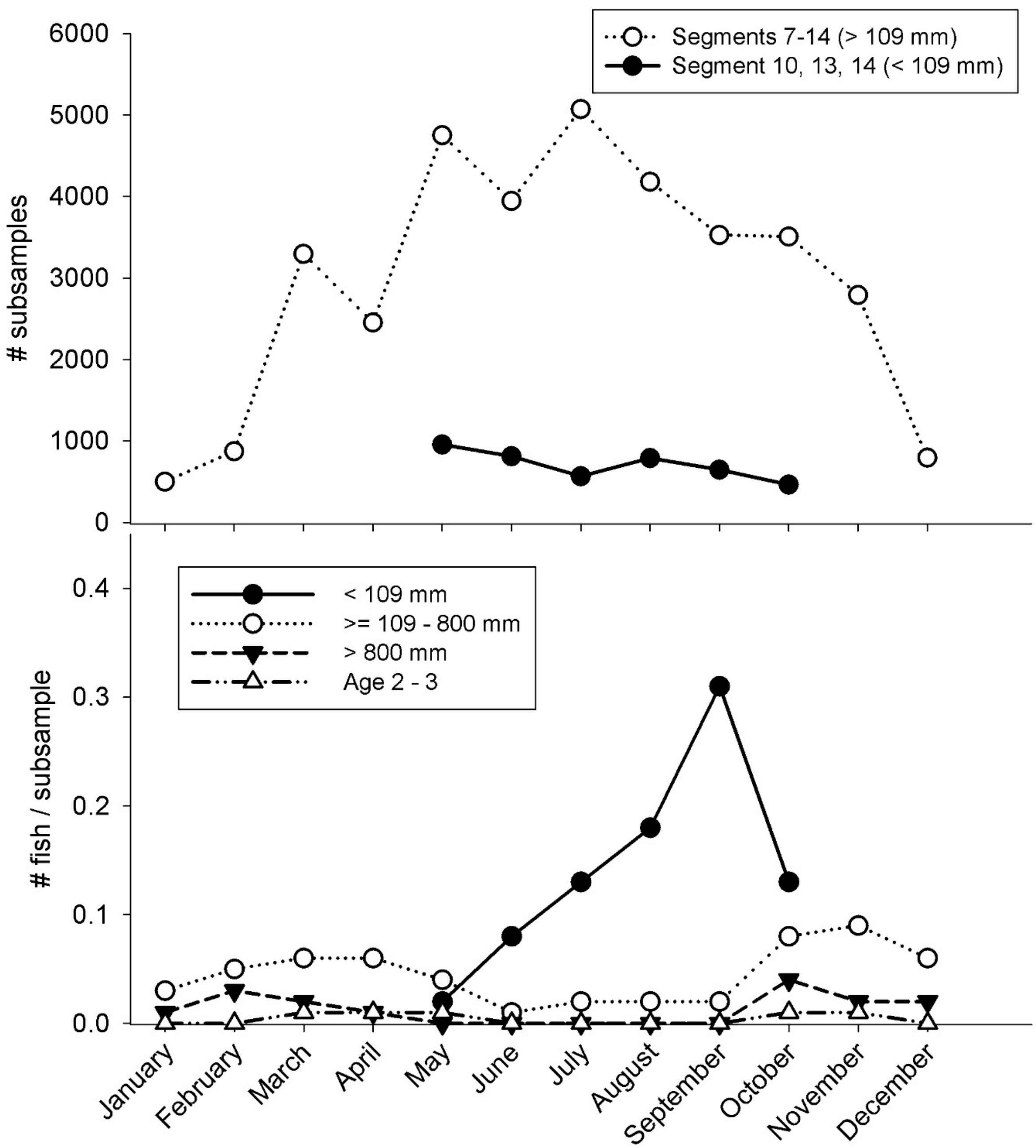

Figure D4. PSPAP effort (top panel) and catch (bottom panel) for pallid sturgeon (>=109-800 mm; >800 mm; age 2-3) and *Scaphirhynchus spp.* (< 109 mm FL) for each month in the lower Missouri River basin for the years 2006-2014. Only otter trawl subsamples are reported for *Scaphirhynchus spp.* sturgeon <109 mm; otter trawl, trammel net, gill net, and trotline subsamples are reported for the other length/age groups.

D.1.1.26 Spatial Sampling Distribution

Spatial sampling considerations depend upon the objectives under consideration and the metrics selected to assess how actions are meeting these objectives. The largest spatial units of interest for pallid sturgeon monitoring are identified in the EA and MRRMP and are as follows: 1) the Upper Missouri River mainstem from Fort Peck Dam to the headwaters of Lake Sakakawea and 2) the Lower Missouri River mainstem from Gavins Point Dam to confluence with the Mississippi River at St. Louis. These are the largest spatial units that may be considered when developing a monitoring plan for pallid sturgeon through the MRRP for a variety of reasons: 1) these two spatial units reflect biologically significant opportunities for achieving benefit to pallid sturgeon, 2) management actions may be implemented in these areas, 3) the results of management actions may be detected in these spatial units (e.g., successful recruitment), 4) these are the areas where the USACE impacts to pallid sturgeon have been previously identified (e.g., 2003 BiOp), and 5) they encompass the decision-making authority of the USACE. Other spatial units to consider (see reasons 1 and 2 above) are the Yellowstone River upstream of the confluence with the Upper Missouri River for an unspecified distance, an unspecified distance downstream in the Mississippi River, and tributaries used by pallid sturgeon.

The fundamental spatial sampling consideration for any design will be the gear (e.g., trammel net, or gill net) subsample location. Subsample locations can be organized and selected in a variety ways; the most objective approach would be to randomly select points within a larger spatial construct (e.g., river reach). However, such an approach would seem haphazard as much has been learned regarding habitat use by pallid sturgeon in the Missouri River for a variety of life stages. Identifying the habitat types most likely to contain the life stage(s) of interest and incorporating this information into the sample design will likely provide the most efficient path to decision-influencing results. Further, the habitat types that are utilized by pallid sturgeon may also vary longitudinally in the Missouri River. The PSPAP employs a hierarchical sample design that progresses from largest to smallest spatial units as follows: Basin (Upper, Middle, Lower MR), Segment, River Bend, Habitat (Macro, Meso, Micro), and gear subsample. The current HAMP project selected and then targeted those habitat types from PSPAP that provided the highest catch rates for very young (that is, age-0) *Scaphirhynchus* sturgeons. The HAMP project provides an example of what a targeted habitat-sampling effort can provide with regard to detecting a size/age of interest. Tables D5 and D6 provide the number of *Scaphirhynchus spp.* (surrogate for age-0 pallid sturgeon), juvenile/sub-adult pallid sturgeon, and adult pallid sturgeon captured in each habitat type from 2006-2014 within Upper and Lower Missouri River segments. HAMP capture information for the 2014 sample year is provided in Table D7. Body length was used to partition the captures into age-0 (<109 mm; Ridenour et al. 2011), juvenile/sub-adult (>= 109 mm – 800 mm in the LB and 1,000 mm in the UB), and adult (>800 mm LB, >1,000 mm UB) for sub-objective 2. Tables D5 and D6 provide the same information for pallid sturgeon 2-3 years of age (hereafter referred to as 2-3 yr old). The length range for 2-3 yr-old pallid sturgeon was derived from the growth models of known-age hatchery-produced pallid sturgeon in Shuman et al. (2011); the length range between the predicted length for the 2 and the 3-year old age groups was used to select the catch information for this category (that is, 275-400, Upper River; 325-425, Lower River).

Table D7. Catch [number/subsample] for *Scaphirhynchus spp.* (less than 109 millimeters fork length) for each Macrohabitat-Mesohabitat combination in the Lower Missouri River below Kansas City, Mo. sampled through the HAMP from 2013-2014.
[See Welker and Drobish 2012 for a description of gears and habitat types.]

Macro/Meso	Gear	Gear Subsample Count	Individuals Captured/Subsample
River miles 327-307; 237-215			
CHXO-BARS	Micro-mesh Otter Trawl	12	0.25
CHXO-CHNB	Micro-mesh Otter Trawl	41	0.46
ISB-BARS	Micro-mesh Otter Trawl	142	0.27
ISB-CHNB	Micro-mesh Otter Trawl	451	0.73
OSB-CHNB	Micro-mesh Otter Trawl	1	1.00
OSB-BARS	Micro-mesh Otter Trawl	9	0.22
SCCL-BARS	Micro-mesh Otter Trawl	136	0.11
SCCL-CHNB	Micro-mesh Otter Trawl	530	0.44
SCCL-ITIP	Micro-mesh Otter Trawl	1	0.00
River miles 180-157; 110-94; 54-33			
CHXO-BARS	Micro-mesh Otter Trawl	59	0.05
CHXO-CHNB	Micro-mesh Otter Trawl	436	0.38
CHXO-POOL	Micro-mesh Otter Trawl	12	0.5
ISB-BARS	Micro-mesh Otter Trawl	257	0.20
ISB-CHNB	Micro-mesh Otter Trawl	2040	0.51
ISB-ITIP	Micro-mesh Otter Trawl	2	4.50
ISB-POOL	Micro-mesh Otter Trawl	7	3.14
SCCL-BARS	Micro-mesh Otter Trawl	21	0.05
SCCL-CHNB	Micro-mesh Otter Trawl	26	0.15
SCCL-ITIP	Micro-mesh Otter Trawl	16	0.19
SCCL-TLWG	Micro-mesh Otter Trawl	6	0.00
SCCS-CHNB	Micro-mesh Otter Trawl	2	0.50

While Tables D5-D7 provide an average of the annual catch rates for sampling through the PSPAP and HAMP, Tables D8-D11 of pallid sturgeon (or *Scaphirhynchus* spp.) throughout the sample year (by month). Tables D12-D15 (Upper River) and Tables D16-D19 (Lower River) provide the gear-habitat distributions of catch rates over the same monthly time frame for the combined segments in each basin (Upper River and Lower River).

Table D8. Heat map of sturgeon catch rates for Scaphirhynchus sturgeon less than 109 millimeters in fork length captured with the otter trawl within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The UpperRiver includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Mar.												0.000	0.000	
Apr.		0.000	0.000	0.021				0.000	0.000	0.000	0.000	0.043	0.000	
May.		0.000	0.005	0.029				0.000	0.000	0.000	0.016	0.014	0.038	
Jun.		0.000	0.000	0.007				0.000	0.003	0.054	0.015	0.109	0.115	
Jul.		0.000	0.000	0.035				0.000	0.045	0.118	0.086	0.130	0.043	
Aug.		0.000	0.004	0.338				0.000	0.000	0.056	0.222	0.211	0.088	
Sep.		0.000	0.002	0.059				0.000	0.008	0.034	0.261	0.375	0.160	
Oct.		0.000	0.000	0.019				0.000	0.000	0.054	0.367	0.216	0.162	
Nov.									0.000		0.038			

Catch rate key (number/subsample)

(yellow)	Low Value
(orange)	Mid-point (50th percentile)
(red)	High Value

Table D9. Heat map of sturgeon catch rates for pallid sturgeon greater than or equal to 109 millimeters but less than 800 millimeters (Lower River) or less than 1000 millimeters (Upper River) in fork length captured with the otter trawl, trotline, trammel net, and gill net (Lower River only) within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The Upper River includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Jan.								0.079		0.023	0.059	0.007	0.025	
Feb.								0.010	0.150	0.060	0.016	0.057	0.052	
Mar.		0.000						0.047	0.074	0.066	0.051	0.082	0.035	
Apr.		0.116	0.298	0.153				0.034	0.090	0.074	0.073	0.061	0.022	
May		0.132	0.165	0.103				0.037	0.051	0.033	0.014	0.023	0.012	
June		0.095	0.129	0.062				0.021	0.031	0.007	0.000	0.010	0.004	
July		0.048	0.096	0.249				0.027	0.031	0.013	0.004	0.016	0.004	
Aug.		0.096	0.115	0.413				0.034	0.031	0.010	0.004	0.014	0.004	
Sept.		0.169	0.195	0.388				0.039	0.013	0.005	0.018	0.005	0.009	
Oct.		0.211	0.238	0.527				0.027	0.144	0.143	0.068	0.008	0.011	
Nov.								0.089	0.142	0.103	0.055	0.077	0.051	
Dec.								0.118		0.045	0.000	0.036	0.025	

Catch rate key (number/subsample)

(yellow)	Low Value
(orange)	Mid-point (50th percentile)
(red)	High Value

Table D10. Heat map of sturgeon catch rates for pallid sturgeon 2-3 years of age captured with the otter trawl, trotline, trammel net, and gill net (Lower River only) within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The Upper River includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Jan.								0.000		0.008	0.000	0.007	0.000	
Feb.								0.000	0.050	0.000	0.000	0.008	0.000	
Mar.		0.000						0.015	0.013	0.012	0.000	0.010	0.002	
Apr.		0.101	0.188	0.094				0.007	0.006	0.009	0.008	0.016	0.000	
May		0.085	0.089	0.057				0.014	0.012	0.006	0.000	0.002	0.000	
June		0.055	0.068	0.044				0.010	0.014	0.002	0.000	0.004	0.000	
July		0.029	0.061	0.121				0.011	0.011	0.003	0.002	0.000	0.000	
Aug.		0.059	0.074	0.192				0.018	0.010	0.002	0.000	0.002	0.000	
Sept.		0.114	0.117	0.144				0.016	0.006	0.000	0.004	0.000	0.002	
Oct.		0.114	0.143	0.199				0.005	0.012	0.006	0.023	0.000	0.000	
Nov.									0.039	0.024	0.011	0.012	0.004	
Dec.										0.000	0.000	0.006	0.000	

Catch rate key (number/subsample)

- Low Value
- Mid-point (50th percentile)
- High Value

Table D11. Heat map of sturgeon catch rates for pallid sturgeon greater than 800 millimeters (Lower River) or greater than 1000 millimeters (Upper River) in fork length captured with the otter trawl, trotline, trammel net, and gill net (Lower River only) within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The Upper River includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Jan.								0.032		0.008	0.000	0.007	0.012	
Feb.								0.000	0.000	0.006	0.032	0.041	0.026	
Mar.		0.000						0.006	0.026	0.021	0.019	0.014	0.005	
Apr.		0.000	0.000	0.000				0.004	0.045	0.021	0.000	0.002	0.012	
May		0.001	0.000	0.004				0.001	0.003	0.003	0.000	0.000	0.004	
June		0.000	0.000	0.000				0.000	0.001	0.000	0.000	0.000	0.000	
July		0.001	0.000	0.004				0.000	0.000	0.001	0.002	0.000	0.000	
Aug.		0.000	0.002	0.007				0.001	0.002	0.002	0.000	0.000	0.000	
Sept.		0.000	0.000	0.006				0.000	0.006	0.001	0.004	0.003	0.002	
Oct.		0.003	0.001	0.010				0.014	0.052	0.068	0.028	0.021	0.002	
Nov.								0.010	0.017	0.027	0.028	0.014	0.024	
Dec.								0.008		0.000	0.068	0.006	0.022	
Catch rate key (number/subsample)														
		Low Value												
		Mid-point (50th percentile)												
		High Value												

Table D12. Heat maps of catch rates for *Scaphirhynchus* sturgeon less than 109 millimeters in fork length captured with the otter trawl in Segments 2-4 (minimum of 200 subsamples) within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations code, OT indicates fish were caught with otter trawls.]

	Gear_Macrohabitat-Mesohabitat Combination			
Month	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.				
Apr.	0.000	0.029	0.008	0.000
May	0.002	0.030	0.000	0.000
June	0.000	0.004	0.000	0.000
July	0.009	0.006	0.015	0.000
Aug.	0.101	0.078	0.169	0.000
Sept.	0.022	0.022	0.039	0.000
Oct.	0.012	0.000	0.014	0.000
Catch rate key (number/subsample)				
	Low Value			
	Mid-point (50th percentile)			
	High Value			

Table D13. Heat maps of catch rates for pallid sturgeon greater than or equal to 109 millimeters to 1,000 millimeters in fork length captured with the trammel net, trotline, and otter trawl captured in Segments 2-4 (minimum of 200 subsamples) within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination										
Month	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	TN_SCCL-CHNB	TL_CHXO-CHNB	TL_ISB-CHNB	TL_OSB-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.	0.000	0.000	0.000								
Apr.	0.234	0.134	0.266	0.010	0.400	0.759	0.105	0.136	0.080	0.090	0.227
May	0.085	0.124	0.102	0.145	0.567	0.496	0.269	0.105	0.109	0.075	0.071
June	0.097	0.037	0.060	0.090	0.734	0.560	0.447	0.076	0.118	0.048	0.088
July	0.173	0.142	0.167	0.068	0.211	0.292	0.105	0.090	0.107	0.073	0.104
Aug.	0.195	0.229	0.527	0.349	0.360	0.351	0.125	0.147	0.097	0.110	0.059
Sept.	0.284	0.275	0.471	0.440	0.382	0.345	0.257	0.171	0.205	0.179	0.068
Oct.	0.127	0.103	0.280	0.488	0.734	0.715	0.832	0.180	0.103	0.146	0.133
Catch rate key (number/subsample)											
Low Value											
Mid-point (50th percentile)											
High Value											

1

Table D14. Heat maps of catch rates for pallid sturgeon 2-3 years old captured with the trammel net, trotline, and otter trawl in Segments 2-4 (minimum of 200 subsamples) within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination										
Month	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	TN_SCCL-CHNB	TL_CHXO-CHNB	TL_ISB-CHNB	TL_OSB-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.	0.000	0.000	0.000	0.033							
Apr.	0.122	0.070	0.050	0.084	0.275	0.571	0.100	0.120	0.043	0.053	0.091
May	0.043	0.067	0.065	0.087	0.383	0.289	0.063	0.051	0.061	0.043	0.060
June	0.041	0.023	0.037	0.045	0.461	0.284	0.184	0.055	0.061	0.030	0.031
July	0.092	0.059	0.095	0.291	0.053	0.083	0.105	0.059	0.060	0.037	0.074
Aug.	0.105	0.120	0.221	0.213	0.220	0.228	0.000	0.076	0.062	0.050	0.036
Sept.	0.149	0.099	0.161	0.220	0.236	0.155	0.143	0.111	0.138	0.091	0.067
Oct.	0.085	0.071	0.099	0.488	0.337	0.312	0.248	0.117	0.078	0.085	0.100
Catch rate key (number/subsample)											
Low Value											
Mid-point (50th percentile)											
High Value											

2

Table D15. Heat maps of catch rates for pallid sturgeon greater than 1000 millimeters captured with the trammel net, trotline, and otter trawl in Segments 2-4 and 22 (Lower Yellowstone River); minimum of 200 subsamples within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination										
Month	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	TN_SCCL-CHNB	TL_CHXO-CHNB	TL_ISB-CHNB	TL_OSB-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.	0.000	0.000	0.000								
Apr.	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
May	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
June	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	0.003	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug.	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sept.	0.002	0.005	0.005	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
Oct.	0.005	0.005	0.005	0.000	0.000	0.007	0.020	0.000	0.000	0.005	0.000
Catch rate key (number/subsample)											
Low Value											
Mid-point (50th percentile)											
High Value											

3

Table D16. Heat maps of catch rates for Scaphirhynchus sturgeon less than 109 millimeters in fork length captured with the otter trawl in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations code, OT indicates fish were caught with otter trawls.]

	Gear_Macrohabitat-Mesohabitat Combination				
Month	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.		0.000	0.000	0.000	
Apr.	0.000	0.000	0.024	0.000	0.000
May	0.000	0.007	0.012	0.010	0.000
June	0.000	0.059	0.059	0.000	0.034
July	0.000	0.017	0.122	0.000	0.037
Aug.	0.000	0.050	0.121	0.026	0.078
Sept.	0.000	0.048	0.179	0.010	0.000
Oct.	0.034	0.105	0.108	0.000	0.000
Nov.		0.000	0.000		

Catch rate key (number/subsample)

Low Value

Mid-point (50th percentile)

High Value

Table D17. Heat maps of catch rates for pallid sturgeon greater than or equal to 109 millimeters to 800 millimeters in fork length captured with the trammel net, trotline, gill net, and otter trawl in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, GN indicates fish were caught with gill nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination											
Month	TN_BRAD-CHNB	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	GN_BRAD-CHNB	GN_CHXO-CHNB	GN_CHXO-POOL	GN_ISB-CHNB	GN_ISB-POOL	GN_OSB-CHNB	GN_OSB-POOL	TL_BRAD-CHNB
Jan.						0.021	0.018	0.006	0.036	0.038	0.028	0.000
Feb.					0.000	0.048	0.060	0.024	0.091	0.059	0.019	
Mar.	0.000	0.000	0.023	0.000	0.018	0.039	0.079	0.029	0.071	0.008	0.028	0.147
Apr.	0.043	0.000	0.010	0.100	0.000	0.031	0.100	0.011	0.076	0.000	0.000	0.100
May	0.059	0.020	0.020	0.000			0.000					0.039
June	0.047	0.017	0.002	0.022								0.000
July	0.055	0.013	0.021	0.027								
Aug.	0.028	0.006	0.026	0.019								0.000
Sept.	0.032	0.000	0.018	0.142								0.000
Oct.	0.017	0.000	0.005	0.022	0.000	0.040	0.092	0.073	0.139	0.041	0.038	0.053
Nov.					0.020	0.042	0.069	0.052	0.091	0.017	0.013	0.127
Dec.						0.015	0.012	0.025	0.014	0.000	0.000	0.096

Table D17. Heat maps of catch rates for pallid sturgeon greater than or equal to 109 millimeters to 800 millimeters in Segments 7-14 - Continued

Month	TL_CHXO-CHNB	TL_ISB-CHNB	TL_ISB-POOL	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Jan.	0.000	0.059	0.000					
Feb.	0.053	0.087	0.036					
Mar.	0.164	0.171	0.099		0.000	0.019	0.000	
Apr.	0.123	0.165	0.097	0.000	0.000	0.008	0.000	0.000
May	0.214	0.202	0.018	0.019	0.012	0.010	0.030	0.016
June		0.000		0.012	0.009	0.017	0.014	0.034
July				0.019	0.004	0.011	0.023	0.019
Aug.	0.000	0.000		0.000	0.009	0.006	0.013	0.000
Sept.	0.000	0.059	0.000	0.000	0.005	0.008	0.000	0.053
Oct.	0.282	0.251	0.108		0.026	0.020	0.000	0.000
Nov.	0.224	0.229	0.109		0.000	0.000		
Dec.	0.229	0.153	0.095					

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

Table D18. Heat maps of catch rates for pallid sturgeon 2-3 years old captured with the trammel net, trotline, gill net, and otter trawl in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, GN indicates fish were caught with gill nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination											
Month	TN_BRAD-CHNB	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	GN_BRAD-CHNB	GN_CHXO-CHNB	GN_CHXO-POOL	GN_ISB-CHNB	GN_ISB-POOL	GN_OSB-CHNB	GN_OSB-POOL	TL_BRAD-CHNB
Jan.						0.021	0.018	0.000	0.000	0.000	0.000	0.000
Feb.					0.000	0.000	0.000	0.004	0.006	0.020	0.000	
Mar.	0.000	0.000	0.000	0.000	0.000	0.013	0.018	0.002	0.012	0.000	0.009	0.059
Apr.	0.043	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000
May	0.029	0.005	0.005	0.000			0.000					0.000
June	0.009	0.006	0.002	0.000								0.000
July	0.021	0.002	0.005	0.009								
Aug.	0.009	0.004	0.008	0.010								0.000
Sept.	0.006	0.000	0.006	0.071								0.000
Oct.	0.017	0.000	0.003	0.000	0.000	0.000	0.031	0.006	0.014	0.000	0.000	0.026
Nov.					0.000	0.008	0.017	0.010	0.027	0.000	0.000	0.016
Dec.						0.000	0.000	0.000	0.000	0.000	0.000	0.027

Table D18. Heat maps of catch rates for pallid sturgeon 2-3 years old captured in Segments 7-14 - Continued

Month	TL_CHXO-CHNB	TL_ISB-CHNB	TL_ISB-POOL	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Jan.	0.000	0.000	0.000					
Feb.	0.000	0.000	0.000					
Mar.	0.014	0.005	0.000		0.000	0.000	0.000	0.000
Apr.	0.014	0.018	0.010	0.000	0.000	0.005	0.000	0.016
May	0.031	0.028	0.000	0.013	0.005	0.002	0.020	0.022
June		0.000		0.008	0.003	0.007	0.007	0.000
July				0.009	0.000	0.004	0.023	0.000
Aug.	0.000	0.000		0.000	0.000	0.002	0.000	0.026
Sept.	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000
Oct.	0.007	0.010	0.015		0.010	0.004	0.000	
Nov.	0.047	0.034	0.016		0.000	0.000		
Dec.	0.029	0.000	0.000					

Catch rate key (number/subsample)

- Low Value
- Mid-point (50th percentile)
- High Value

Table D19. Heat maps of catch rates for pallid sturgeon greater than 800 millimeters in fork length captured with the trammel net, trotline, gill net, and otter trawl captured in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, GN indicates fish were caught with gill nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination											
Month	TN_BRAD-CHNB	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	GN_BRAD-CHNB	GN_CHXO-CHNB	GN_CHXO-POOL	GN_ISB-CHNB	GN_ISB-POOL	GN_OSB-CHNB	GN_OSB-POOL	TL_BRAD-CHNB
Jan.						0.000	0.000	0.000	0.036	0.000	0.000	0.000
Feb.					0.000	0.012	0.012	0.020	0.057	0.039	0.019	
Mar.	0.000	0.000	0.000	0.000	0.000	0.007	0.025	0.008	0.025	0.023	0.009	0.000
Apr.	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.011	0.023	0.000	0.000	0.017
May	0.000	0.000	0.002	0.000			0.000					0.000
June	0.000	0.000	0.000	0.000								0.000
July	0.000	0.000	0.001	0.000								
Aug.	0.005	0.000	0.002	0.000								0.000
Sept.	0.000	0.000	0.003	0.000								0.000
Oct.	0.000	0.000	0.000	0.022	0.000	0.035	0.041	0.030	0.060	0.041	0.000	0.026
Nov.					0.000	0.013	0.026	0.006	0.030	0.000	0.000	0.000
Dec.						0.029	0.037	0.015	0.007	0.000	0.000	0.014

Table D19. Heat maps of catch rates for pallid sturgeon greater than 800 millimeters in fork length captured in Segments 7-14 - Continued

Month	TL_CHXO-CHNB	TL_ISB-CHNB	TL_ISB-POOL	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Jan.	0.000	0.000	0.000					
Feb.	0.053	0.000	0.036					
Mar.	0.000	0.059	0.022		0.000	0.000	0.000	
Apr.	0.043	0.047	0.019	0.000	0.000	0.000	0.000	0.000
May	0.010	0.008	0.000	0.000	0.000	0.002	0.000	0.000
June		0.000		0.000	0.000	0.001	0.000	0.000
July				0.000	0.000	0.001	0.000	0.000
Aug.	0.000	0.000		0.000	0.000	0.001	0.000	0.000
Sept.	0.000	0.029	0.000	0.000	0.000	0.004	0.000	0.000
Oct.	0.074	0.116	0.046		0.000	0.002	0.000	0.000
Nov.	0.037	0.031	0.047		0.000	0.000		
Dec.	0.029	0.014	0.000					

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

D.1.1.27 Upper River

Scaphirhynchus sturgeon <109 mm (that is, age-0) and sub-adult (>=109 mm-1,000 mm) pallid sturgeon were most often captured in three habitat types: ISB-CHNB, OSB-CHNB, and CHXO-CHNB (Tables D12 and D13).

In addition, data indicate that segment 4 (downstream from the Yellowstone River-Missouri River confluence) provides the best opportunity to capture pallid sturgeon < 109 mm (few *Scaphirhynchus spp*. <109 mm are captured upstream from the confluence).

D.1.1.28 Lower River

The highest catch rates for *Scaphirhynchus* sturgeon <109 mm occurred in CHXO-BARS and ISB-BARS habitats (Tables D16 and D17); however, only 39 subsamples were taken from these habitat types. Of the remaining habitat types, the ISB-CHNB provided the highest catch rate (Tables D16 and D17). Sub-adult (>=109 mm-800 mm) and adult (>800 mm) pallid sturgeon were captured in a variety of habitat types, but most frequently in the CHNB mesohabitat (CHXO-CHNB, ISB-CHNB, OSB-CHNB, SCCL-CHNB) and macrohabitats associated with tributaries (CONF-CHNB, CONF-POOL) (Tables D16 and D17).

Additional insights can be gained from HAMP samples. The current HAMP implements a design that focuses sampling in habitats where age-0 *Scaphirhynchus* sturgeon were most commonly found through the PSPAP. This approach allows the HAMP to avoid over sampling in habitats that are unlikely to contain young sturgeon. From RM 327-215, ISB-CHNB and SCCL-CHNB provided the highest catch rates for sturgeon <109 mm for habitat types with >100 subsamples (Table D7). CHXO-CHNB and ISB-CHNB exhibited the highest catch rates between RM 180 and RM 33 (Table D7). Catch rates of sturgeon <109 mm for the HAMP were at least 6 times greater than those found for the PSPAP (Tables D16 and D17).

D.1.1.29 Summary

Reviewing capture information for macrohabitat types provides insight into fine-scale spatial elements of a sample design, however, it does not provide insight into larger-scale elements. Murray et al. (2014) conducted a basin-wide analysis of PSPAP capture data to elucidate geographical patterns in pallid sturgeon abundance and found that several small- and large-scale factors were associated with higher probability of pallid sturgeon capture in both the Upper and Lower Missouri River:

1) in the Lower Missouri River, gears used in the pool mesohabitat had significantly higher probability of capturing a pallid sturgeon than any other habitat type;
2) macrohabitats associated with a large tributary mouth or a tributary confluence had a greater probability of catching a pallid sturgeon, as well as having greater abundance in the Upper Missouri River;
3) wider valley floor widths were associated with greater probabilities of pallid sturgeon capture or high pallid sturgeon relative abundances in the Upper and Lower Missouri River;
4) in the Upper Missouri River, the probability of pallid sturgeon capture and the relative abundance increased with increasing distance downstream from Fort Peck Dam;
5) in the Lower Missouri River, the abundance of pallid sturgeon decreased from upstream to downstream.

Murray et al. (2014) did not evaluate spatial distribution patterns according to size or age structure. The possibility of examining differences between juvenile/sub-adult and adult habitat preferences was evaluated early in their study; however, only a small proportion (~6.4%) exceeded the adult-length cutoff used to identify adult pallid sturgeon (>800 mm in the Lower MR and >1,000 mm in the Upper MR). Therefore, both size classes of pallid sturgeon were combined for the analysis (which was comprised mainly of juvenile/subadult-sized pallid sturgeon). The longitudinal distribution of catch summarized in this report indicates that age-0 (<109 mm) *Scaphirhynchus* sturgeon are most likely to be found in the lower segments of the Upper and Lower rivers (Table D8); however, older and larger pallid sturgeon tend to be distributed throughout the segments (Tables D9-D11; it should be noted that stocking location likely influences the distribution of age 2-3 year-old pallid sturgeon catch in Table D10).

D.1.1.30 Effective Gears

To evaluate specific fisheries objectives requires the selection of gears that most effectively sample the species or life history of interest. Researchers must consider the selectivity of the sampling gear during field-study design. Capture efficiency is a complex dynamic that includes the sampling gear, technique, and the availability/vulnerability of the target species. Capture efficiency and size selectivity bias is problematic for researchers because it can lead to under or over estimating a population and it can also affect estimates of various population factors, such as recruitment, size structure, and mortality (Levesque 2013). Thus, selecting the most appropriate fish collecting gears should be at the core of any sample design.

In the Upper Missouri River basin, four gears are used by PSPAP crews to sample the fish community: trotline, trammel net, otter trawl, and mini fyke. PSPAP crews in the

Lower Missouri River sample pallid sturgeon with the mini fyke, gill net, trotline, trammel net, and otter trawl. The mini fyke net does not effectively sample pallid sturgeon, so it was not considered during this assessment. The HAMP uses an otter trawl similar to that employed by the PSPAP (see Welker and Drobish 2012 for description) in habitats >1.5 m in depth; however, the HAMP trawl has a smaller mesh size (4 mm vs. 6.35 mm for PSPAP). In habitats <1.5 m deep, the HAMP samples with a 4-mm mesh push trawl (see Gosch et al. (2015) for a description of HAMP gears).

D.1.1.31 Upper River

Pallid sturgeon similar in length to 2-3 year old known-age fish were most effectively captured with the trotline in a variety of habitat types (Table D14). The trammel net was also an effective gear, while capture rates for the otter trawl were similar to, but lower than, the trammel net (Table D14).

For PSPAP, only the otter trawl was effective at sampling pallid sturgeon <109 mm (that is, age-0) (Table D12). Sub-adult (>=109 mm – 1,000 mm) pallid sturgeon were most effectively sampled with the trotline (Table D13); nearly 30% of the subsamples in CHXO-CHNB, ISB-CHNB, OSB-CHNB, and SCCL-CHNB contained sub-adult pallid sturgeon. Capture rates for pallid sturgeon greater than 1,000 mm were low for the trotline and trammel net (Table D15). This is likely due to the low numbers of these larger, older fish and the potential poor capture efficiency for these gears. Larger mesh trammel nets are used to capture these larger, adult fish during broodstock collection, although catch rates are still low (Table D15).

D.1.1.32 Lower River

Catch rates were similar and low for pallid sturgeon in the 2-3 year-old length category for all gear types (Table D18). Better catchability information can likely be obtained by reviewing the catch information for sub-adult pallid sturgeon (Table D17) as the sample size is much higher.

Similar to the Upper River, the otter trawl was the only gear effective at sampling age-0 sturgeon (Table D16). As described previously, the combined catch of <109 mm *Scaphirhynchus* sturgeon for the HAMP trawls exceeded those found for PSPAP, likely due to the smaller mesh size, the use of the push trawl in shallow habitat replicates, and the focus on habitats most likely to contain young sturgeon.

The highest catch rates for sub-adult (>=109 mm – 800 mm) pallid sturgeon were obtained using the trotline (Table D17); 11.8% of the trotline subsamples contained at least 1 pallid sturgeon from this category. Pallid sturgeon >800 mm in length were also most effectively captured with the trotline (Table D19).

D.1.1.33 Summary

Analysis of PSPAP catch data by Murray et al. (2014) identified gear-related patterns for pallid sturgeon that can be considered in developing a monitoring approach that meets the two sub-objectives and provides the demographic data needed to update population models. Their gear-related findings are as follows: 1) the trotline was found to be the most efficient gear for catching pallid sturgeon when sampling in both the Upper and Lower Missouri River; it had a significantly lower proportion of deployments with zero catch than the other trawl, trammel net, and gill net, 2) expanding the trotline sampling effort at the cost of reduced sampling effort among other standard gear types may be beneficial, and 3) the otter trawl and trammel net deployments did not provide much useful information about the abundance and distribution of pallid sturgeon. It should be noted that pallid sturgeon less than 109 mm were not evaluated by Murray et al. (2014) as none were collected through PSPAP; however, shovelnose sturgeon <109 mm are frequently captured with the otter trawl (Tables D12, D16).

D.1.12 Summary Guidance

The purpose of this section is to summarize the foregoing analysis of temporal, spatial, and gear influences on catch rates to provide guidance for future sampling. This sampling could be a continuation of a CPUE-centered sampling strategy for documenting trends, or as discussed in Section D.4, the sampling could be integrated into a mark/recapture-centered strategy that promises to provide estimates of population size and survival, as well as trends. The guidance is organized by subobjectives.

D.1.1.34 Sub-objective 1 – Increase Pallid Sturgeon Recruitment to Age 1

D.1.1.34.1 Upper River

Longitudinal Sampling Distribution

Past sampling through PSPAP indicates that the majority of age-0 *Scaphirhynchus* sturgeon has been captured downstream from the confluence of the Yellowstone and Missouri rivers in Segment 4 (FigureD2, Table D8). Further, predictive flow models developed through the Effects Analysis indicate that the majority of the drifting free-embryo pallid sturgeon would settle into this segment, if they do not drift through it into Lake Sakakawea. Therefore, the most effective and efficient trawling to capture age-0 and age-1 pallid sturgeon and to detect recruitment to age-1 would be in Segment 4.

Macrohabitats

Age-0 pallid sturgeon have been captured in a variety of macro-mesohabitats through the PSPAP; however, the highest catch rates were obtained in the CHXO-CHNB, ISB-CHNB, and the OSB-CHNB macro-mesohabitat combinations (Table D12). The highest CPUE in these habitats has been found in the months of July through September (Table D12). In the Upper River, pallid sturgeon (and shovelnose sturgeon) typically spawn in late-April through May. Therefore, age-0 *Scaphirhynchus* should be available for capture in June, July, and August. The lack of catch in the month of June and a low CPUE in July for age-0 *Scaphirhynchus* sturgeon (Figure D4) may be an artifact of the sampling gear used by the PSPAP. The HAMP has recently used a smaller mesh size to collect very young and small sturgeon (that is, < 50 mm total length) in the Lower River. For maximum efficiency, sampling for age-0 pallid sturgeon would begin in June and focus on the three habitat types identified above.

Gears

The only gear utilized by PSPAP and HAMP for sampling age-0 sturgeon is the trawl. PSPAP uses an otter trawl (OT16) with an opening 16 ft. (4.9 m) wide by 3 ft. (0.9 m) high and 6-mm inner bar mesh. HAMP uses a trawl (OT04) of similar dimensions; however, the inner bar mesh is 4-mm. The HAMP has implemented a targeted sampling protocol that primarily uses the OT04 trawl in the habitats with the highest CPUE values found during 10 years of sampling through the PSPAP. This resulted in the HAMP sampling over 1,300 *Scaphirhynchus* sturgeon < 50 mm in length in the Lower River during a single season (2014). Comparatively, the PSPAP has sampled less than 200 of these small sturgeon in 10 seasons (2005-2014). It is recommended that age-0 and age-1 sturgeon sampling be conducted with either the OT04 or the OT16 fitted with 4-mm inner bar mesh instead of the standard 6-mm mesh size.

Summary

For maximum efficiency in addressing the recruitment objective, sampling for age-0 would begin in June, following the pallid sturgeon spawning period. Sampling with the trawl (OT04 or OT16) for these small sturgeon could continue through the summer and into the fall; however, it is anticipated that much of the effort in the fall will need to be focused on mark-recapture sampling. Therefore, it is recommended that trawling to sample age-0 and age-1 pallid sturgeon occur in the months of June and July. The spatial focus of the sampling should be restricted to Segment 4 in the CHXO-CHNB, ISB-CHNB, and OSB-CHNB habitat types. A complete summary of the information can be found in Table D20.

D.1.1.34.2 Lower River

Longitudinal Sampling Distribution

Past sampling through PSPAP (Table D6) and HAMP (Table D7) indicates that the majority of age-0 *Scaphirhynchus* sturgeon occur downstream from Kansas City, MO in Segments 10, 13, and 14; the only larval (non-drifting) pallid sturgeon found in the Lower River were captured downstream from Kansas City, although drifting free embryos have been captured upstream of the Platte River (DeLonay et al., 2016). Similar to the Upper River, predictive flow models developed through the Effects Analysis show that the majority of the drifting free-embryo pallid sturgeon would settle into this portion of the Missouri River or downriver in the Mississippi River. These models still need to be calibrated and validated, but to maximize efficiency age-0 and age-1 pallid sturgeon trawling would be restricted to Segments 10, 13, and 14 (Figure D2); this restriction could be removed as more is learned about dispersal of age-0 pallid sturgeon.

Macrohabitats

Age-0 pallid sturgeon have been captured in a variety of macro-mesohabitats through the PSPAP; however, the highest catch rates were obtained in the CHXO-CHNB and ISB-CHNB macro-mesohabitat combinations (Table D16). The highest CPUE in these two habitats has been found in the months of June through October (Table D16). Similarly, 95% of the age-0 *Scaphirhynchus* sturgeon sampled through HAMP were collected in these two habitat types in the same time frame. In order to maximize efficiency for the recruitment objective, sampling for age-0 pallid sturgeon would begin in June and focus on the two habitat types identified above.

Gears

The only gear utilized by PSPAP and HAMP for sampling age-0 sturgeon is the trawl. As described above, PSPAP uses the OT16 otter trawl with 6-mm inner bar mesh and the HAMP uses the OT04 that possesses a much smaller (4 mm) mesh. The smaller mesh size used through HAMP results in a much higher catch rate for sturgeon < 50 mm (total length). Therefore, it is recommended that age-0 and age-1 sturgeon sampling be conducted with either the OT04 or the OT16 fitted with 4-mm inner bar mesh instead of the standard 6-mm mesh size.

Summary

For maximum efficiency of sampling applied to the recruitment objective, sampling for age-0 pallid sturgeon would begin in June, following the spawning period. Sampling with the trawl (OT04 or OT16) for these small sturgeon could continue through the summer and into the fall; however, it is anticipated that much of the effort in the late fall will need to be focused on mark-recapture sampling. Therefore, it is recommended that trawling to sample age-0 and age-1 pallid sturgeon occur in the months of June, July, and August. The spatial focus of the sampling should be restricted to Segments 10, 13, and 14 in the CHXO-CHNB and ISB-CHNB habitat types. A complete summary of the information can be found in Table D20.

D.1.1.35 Sub-objective 2 – Population Growth, Abundance, and Stability

D.1.1.35.1 Upper River

Longitudinal Sampling Distribution

Past sampling through PSPAP and other monitoring projects indicates that pallid sturgeon juvenile and adult (>109 mm in length) have been captured in all Segments (2, 3, 4) on the Missouri River (Tables D9-D11, D13-D15). Therefore, it is recommended that mark-recapture monitoring occur in all Segments (2, 3, 4) of the Missouri River.

Macrohabitats

Juvenile and adult pallid sturgeon have been captured in a variety of macro-mesohabitats through the PSPAP; however, catch rates are closely linked to gear-habitat combinations and time of year. Overall, the highest catch rates have been found for the same three habitat types (that is, CHXO-CHNB, OSB-CHNB, ISB-CHNB) as YOY Scaphirhynchus sturgeon (Tables D13-D15) with high catch rates also found for the SCCL-CHNB. Tributary mouths have also provided high catch rates for juvenile and adult pallid sturgeon in the Upper River and could also be included in the sample design. Catch rates are highest in April-May and August-October.

Gears

The trammel net and the trotline have been used to effectively sample juvenile and adult pallid sturgeon in the Upper River (Tables D13-D16). Trotline CPUE is generally higher than that of the trammel net. Sampling with the trotline is generally ineffective in the spring due to high debris loads in the river that bury the gear and in the summer/early fall due to loss of bait to non-target fish species. The trammel net is most effective in August-October when river stage and discharge begins to decline.

Summary

For maximum efficiency in addressing the population growth, abundance, and stability objective, sampling for juvenile and adult pallid sturgeon would begin in August with the trammel net and continue through October. Trotline sampling can occur in October when this gear is effective at sampling pallid sturgeon (Ryan Wilson, USFWS, pers. comm.). The spatial focus of the sampling should be Segments 2, 3, 4 (Table D14) in the CHXO-CHNB, ISB-CHNB, OSB-CHNB, and SCCL-CHNB habitat types. Tributary mouths (TRML), such as the mouth of the Yellowstone River, may also be incorporated into the sample design. A complete summary of the information can be found in Table D20.

D.1.1.35.2 Lower River

Longitudinal Sampling Distribution

Past sampling through PSPAP indicates that pallid sturgeon juvenile and adult (>109 mm in length) have been captured in all Segments (7, 8, 9, 10, 13, 14) of the Lower River (Tables D9-D11). Therefore, it is recommended that monitoring for pallid sturgeon >/= 109 mm occur in all segments of the Lower River.

Macrohabitats

Past PSPAP sampling indicates catch rates for juvenile and adult pallid sturgeon are closely linked to gear-habitat combinations and time of year. Overall, the highest catch rates have been found for the four habitat types: BRAD-CHNB, CHXO-CHNB, ISB-CHNB, and ISB-POOL (Tables D17-D19). Tributary mouths have also provided high catch rates for juvenile and adult pallid sturgeon in the Lower River and could also be included in the sample design. Catch rates are highest in March-May and October-December (Tables D17-D19).

Gears

In the Lower River, the trotline has been the most effective gear for sampling juvenile and adult pallid sturgeon (Tables D17-D19). Sampling with the trotline is generally effective in the spring and late fall. The gear is much less effective during May-September when small, non-target fishes remove much of the bait from hooks (Kirk Steffensen, NGPC, pers. comm.). The other gears exhibit very low catch rates for pallid sturgeon and would require large amounts of effort in a mark-recapture approach (Tables D7, D17-D19); however, fall sampling with the gill net may be considered as catch rates are comparable to the trotline.

Summary

For maximum efficiency in addressing the population growth, abundance, and stability objective, sampling for juvenile and adult pallid sturgeon would occur with the trotline during two time periods: 1) in spring beginning in March and continuing through mid-May and 2) in fall beginning in mid-September and continuing through December. The beginning and end of each sample period in a particular segment is closely tied to water temperature. Water temperature greatly influences the capture efficiency of the trotline as the activity of bait-stealing fish increases as water temperature increases. Ice-up can also prevent crews from accessing sample sites in the late fall. The spatial focus of the sampling should be all Lower River segments in the BRAD-CHNB, CHXO-CHNB, ISB-CHNB, and ISB-POOL habitat types. Tributary mouths (TRML), such as the Platte River, have provided high catch rates for the trotline and therefore may also be incorporated into the sample design. A complete summary of the information can be found in Table D20.

Table D20. Summary of sampling information from previous pallid sturgeon monitoring projects that identifies the most effective gears, habitats, segments, and sample periods for capturing pallid sturgeon.

Targeted Size	Gear	Habitats	Segments	Effective Periods
Upper Missouri River				
<109 mm (age-0)	OT04/OT16	CHXO-CHNB, ISB-CHNB, OSB-CHNB	4	June-October
>=109 mm	Trammel Net	CHXO-CHNB, ISB-CHNB, OSB-CHNB	2, 3, 4, lower 48 km of the Yellowstone River	August-October
	Trotline	CHXO-CHNB, ISB-CHNB, OSB-CHNB, SCCL-CHNB	2, 3, 4, lower 48 km of the Yellowstone River	October
Lower Missouri River				
<109 mm (age-0)	OT04/OT16	CHXO-CHNB, ISB-CHNB	10, 13, 14	June-October
>=109 mm	Trotline	BRAD-CHNB, CHXO-CHNB, ISB-CHNB, ISB-POOL	7, 8, 9, 10, 13, 14	March-May; October-December

D.3 An Integrated Approach to Population-level Monitoring, Assessment, and Modeling

In this section we discuss a potential approach to optimize population-level monitoring, assessment, and modeling to support AM of the pallid sturgeon in the Missouri River. Additional future analysis will be required to develop details of this approach as a level 1 science effort. Our objective in this section is to provide a broad outline of this potential approach.

Our approach has been highly influenced by concerns that many species monitoring programs have been poorly structured to address specific management hypotheses and fit into the category of unfocused and inefficient surveillance monitoring (Nichols and Williams 2006). This same concern was articulated by the Missouri River Independent Science Advisory Panel (ISAP) in its recommendation that "monitoring programs along the Lower Missouri River should be re-designed so as to determine if expected outcomes are attributable to specific management actions" (Doyle et al. 2011). While the approach implemented by the PSPAP has met BiOp RPA requirements, the ISAP described it as surveillance monitoring that has "unfocused monitoring targets, unrelated to specific hypotheses or management actions" that "produce results that are problematic to interpret" (Doyle et al. 2011).

The three types of monitoring and assessment described in the introduction are designed to address these concerns, although optimal distribution of effort among the three hasn't been determined. According to the draft AM plan, the population trends monitoring and assessment process will track metrics for the fundamental objectives, whereas science components and process-level monitoring/assessment will develop the understanding of how management actions affect population processes. Each of the science components is aimed at understanding relationships between management actions and changes to growth or survival. Inferences for how management actions propagate to the population level will be strengthened through integration in the population model (discussed in Section D4.2).

Based on the assumption that some level of population-level monitoring/assessment will be beneficial to management of the river and the species, we present a broadly defined framework for what a new, more effective population-level assessment would look like. A new approach to assessing population trends in pallid sturgeon in the Missouri River will optimally address multiple objectives, including:

- Provide accurate assessments of population status and trends to evaluate fundamental species management objectives;
- Make maximum use of historical population assessment data;

- Benefit from information developed through science components that focus on specific management hypotheses as well as providing information to those science components;
- Support population modeling and decision making;
- Include relevant ancillary variables that would be useful to explain occupancy, such as physical and chemical habitat;
- Achieve results that are efficient and cost effective.

While the previous population assessment effort provided a means for tracking indicators of population status through CPUE, it was not amenable to providing population or survival estimates needed for population-dynamics models and decision making. The approach described here is a hybrid of methods intended to track population metrics relevant to the fundamental species objectives while also providing mechanisms to estimate population size and survival rates for updating population models. The approach is intended to increase efficiency, cost effectiveness, and utility of monitoring to support AM.

Because the approach is focused narrowly on information needed to understand pallid sturgeon population dynamics related to management actions, the approach sacrifices collection of a broad suite of surveillance data. Using the analysis presented in Section D.3 of this appendix, the gears, habitats, and timing of fish sampling can be optimized for the specific sub-objectives. By neglecting other native fish species (in contrast to the PSPAP), however, the approach would exclude opportunities to use CPUE of multiple species to infer inter-species interactions or multi-species responses to stressors. While efficiencies will be gained in the new approach some additional risk will result from loss of ancillary information that could provide context and explanation. An alternative to a broad monitoring program to establish comparable time series of pallid sturgeon and native or non-native species, would be to address specific hypotheses about interactions with specific, short-term science projects. While the data and analyses presented here are not meant to be a comprehensive evaluation of PSPAP and HAMP data, they are intended to provide context and understanding that has a bearing on potential, future designs for population monitoring.

D.1.13 Mark-Recapture Based Alternatives

There are several possible approaches to undertaking a monitoring program for pallid sturgeon in the Missouri River. The current program, PSPAP, uses a CPUE based approach, which is designed to yield trend information, but not demographic parameters. A CPUE sampling design may be thought of as a place-based approach, rather than an individual-based approach. CPUE sampling programs yield valuable life history information in showing spatial and temporal use of varying habitats by life stages of an organism. However, they tend to be extensive in scope, and therefore relatively expensive. Once there is an understanding of an organism's use of available habitats through its life stages, if the focus of the study is to be the organism itself, it is usually more efficient to switch to an individual based mark-recapture methodology. Mark-recapture analysis tends not to yield extensive habitat information, but instead yields demographic information about the population, in particular, population size, survival, and capture probability.

CPUE programs have some inherent flaws. There are inevitable problems with observer bias, for example. From the analysis standpoint, all equipment sets are treated equally, yet those sets are made by people, who differ greatly in both their experience and fishing ability. The problem of individual variation in fishing "power" (that is, the "skipper effect") has been acknowledged as a real, if understudied and little acknowledged, effect (Hilborn 1985, Abrahams and Healey 1990). A CPUE approach also tends to treat fish as inert particles, disregarding the ability of fish to learn (that is, trap-happy or trap-shy). CPUE approaches, because of rigid sampling schemes, normally are zero heavy; that is, the sampling design, unless an AM scheme is built in, will continue to sample areas and utilize gears found to have lower probabilities of capture, and thus have high numbers of zero catches.

There are few other approaches toward population estimation of fishes, such as transect sampling or multiple removal methods. Most of these have their intellectual roots in a CPUE framework, and all would be inapplicable to pallid sturgeon, a rare fish in a large, turbid, low-visibility system.

In comparison, mark-recapture programs work by repeatedly sampling a population over a series of defined time periods. The metric of interest is not the gear set, but rather the capture or recapture of individuals. Individuals are marked with unique and lasting identifying marks, and released back into the population. By assessing the proportion of recaptures of these marked individuals to the capture of unmarked individuals over multiple recapture periods, population demographics including survival, recapture probability, and population size are estimated.

D.1.1.36 Assumptions of Mark-Recapture

There are several assumptions that have to be met for a mark-recapture program to generate valid data. They include:

- Marked and unmarked animals have equal probabilities of capture;

- marked animals mix evenly in the population of interest between capture sessions;
- marks are unique, distinguishable over the time of the study, do not adversely affect the survival or behavior of the animals, and are not lost;
- effort is proportional to the size of the study area and the size of the study population (the rate of recapture has to be reasonably high); and
- emigration and immigration can be measured or estimated reliably.

Many violations of these assumptions can be compensated for through model selection, if the effects aren't severe. If, for example, the act of marking an animal causes it to be trap-shy, or avoid recapture for a time period, the effect can be accommodated for in the population model if the study length exceeds the period of trap-shyness. If, however, the act of capture and marking causes the animal to permanently avoid recapture, then assumptions 1 & 3 are violated, and a mark recapture program may not generate reliable estimates.

The sampling universe has to be well defined, such that marked animals have the ability to mix through the population of interest. If the interval between the marking period and the resampling period is too short for marked animals to have physically spread throughout the defined sampling universe, then assumption 2 may be violated, and the population of interest may have to be redefined in terms of where marked animals may have been able to spread to.

Marks must be unique, and last. If the animal loses its mark, then when it is recaptured it will be mistakenly treated as a new, never-before-seen animal. This has the effect of inflating the population estimate, by creating an invalid capture history. If an animal is recognized as a recapture but has no identifying information (that is, has tag scars, but no readable tag), it creates a limbo state for that animal in terms of the population estimation.

The effort and catch must be proportional to the study area and the estimated size of the population. There are no hard rules for the proportion of the population under study that must be observed in each sampling period. However, there must be recaptures in order for the method to work. Rule of thumb and simulation studies suggest that a study should attempt to observe approximately 10% of the expected population per period if the study is to be short-term (between 2-10 sampling periods), or 5% per period if the study is to be long term (>10 sampling periods, where a sampling period is biologically relevant to the population of interest). The initial population estimate can be an order-of-magnitude estimate, if no prior information is available, and should be revised as information is gathered during sampling. If, for example, the original estimate was that there were 1,000 animals in the population, but the first sampling event captures 200, then the estimate should be revised upwards; if the second sampling event captures another 200, with no recaptures, then the estimate, and the expected sampling intensity, should be revised upwards again. If, on the other hand, 100 of the animals in the second sample are recaptures, then the estimate would be revised downwards, and the estimate of capture efficiency would be revised upwards. Sampling should be distributed across the study universe in order to ensure that all animals have an equal opportunity to be sampled, but should be highly weighted towards the gears, habitats, and seasons with the highest efficiency.

Mark-recapture studies report apparent survival, as emigration and immigration from or into the study population create confounding effects. Over short time frames, the study population can be treated as a closed population, but over long time frames, births, deaths, immigration, and emigration must be accounted for in the modelling. Within a mark-recapture framework, there are multiple model designs available, ranging from the simple to the complex. The choice of models depends on the complexity of the sampling situation and biology of the population under study. Pallid sturgeon populations in the Missouri River are a situation of high complexity. Factors adding complexity include: a long lifespan, stocking of juveniles of different ages, and the inherent complexity of environmental changes along the long latitudinal range of the species.

Telemetry can be merged with mark recapture in several ways. First, telemetry returns can be used as a proxy for actual captures of the telemetered fish; if they were alive and moving during the sampling period, then they can be included as a virtual recapture. Secondly, telemetered fish can serve as an indicator for where sampling should occur (that is, “Judas animals”). Last, if enough animals are telemetered, and the tag life is long enough, then demographic estimates of survival, emigration, and immigration can be derived directly from telemetered animals, and applied to the rest of the population of interest.

D.1.1.37 Comparisons: CPUE, Mark-Recapture, Telemetry

Telemetry, mark-recapture, and CPUE trend analysis each have unique strengths, but also certain weaknesses. Telemetry is limited in that only a small portion of fish can be instrumented, tags have limited life, and it is difficult to maintain continual observation of marked animals. However, telemetry reveals details of fish movements and distributions in a way that no other observation system can. The entry costs for telemetry continue to decline as technology improves, and adoption of the latest technology (e.g., autonomous receivers) can decrease observation costs to entirely reasonable levels. A specific science component in Appendix C addresses a feasibility study of autonomous receivers on the Missouri River. Mark-recapture programs can generate capture histories for individuals that reveal information about population demographic values such as survival, recruitment, population size and composition. However, mark-recapture programs yield very limited information of movements, or the characteristics of other fish stocks. CPUE trend analysis gives an imprecise view of population demographic values, and almost no knowledge of fish movements, but does yield local-level use information, and a larger picture of local fish stock assemblages.

D.1.1.38 Benefits and Limits of Mark-Recapture

The current population of pallid sturgeon in the Missouri River can be best thought of as being several disjunct populations. In the upper river, RPMA 1, (RM 2052-1867) above the headwaters of the Fort Peck reservoir, has a very small (~40) population of old wild fish, which recruited over 60 years ago, and approximately 8,000 surviving hatchery reared fish (2013 estimate; Rotella et al.., 2015), released since 1998. RPMA 2, from the Fort Peck dam to Lake Sakakawea (RM 1764.1 to 1537; PSPAP Segments 1-3), including 147 RM of the Lower Yellowstone River, has a small (~100-200) population of old wild fish, and a hatchery released population of approximately 43,000 fish (2013 estimate; Rotella et al., 2015), released since 1998.

In the Lower River, RPMA 3, between Fort Randall Dam and Lewis and Clark Lake (RM 863-843; PSPAP Segments 5-6), is not thought to have any wild fish, and only approximately 1900 hatchery released fish (2013 estimate; Rotella et al., 2015). RPMA 4, from Gavins Point Dam to the Mississippi River confluence (RM 811-RM 0; PSPAP Segments 7-10, 13-14), has an unknown (but probably in the high hundreds to low thousands) number of wild fish, and approximately 29,000 surviving hatchery released fish (2015 estimate, of 155,316 hatchery fish released through 2014, based on Steffensen et al., 2010). Steffensen et al. (2013) estimated a wild population between 715 and 437, and a hatchery population between 2,304 and 2,600 for a 80.5 km stretch of this RPMA between 2008 and 2010. Extrapolating this to the entire reach yields estimates of a wild population between 7,000 and 11,500 wild fish, and 37,000 and 41,800 hatchery fish. However, this would assume an even distribution along the entire reach, a tenuous assumption; the 80.5 km section sampled by Steffensen is one of the higher quality areas, and probably has a higher population density than other reaches. Limited natural recruitment may occur in this RPMA; however, there is also probably emigration of larvae from this RPMA into the Mississippi River, with only limited return of adults. RPMAs 1 and 3 are outside the scope of the MRRMP; however, downstream emigration (through Gavins Point Dam) has been documented for RPMA 3 and likely occurs for RPMA 1 (through Fort Peck Dam) as well. The Mississippi and Atchafalaya Rivers (RPMA 5 &6) are also outside the scope of the MRRMP, but are known to have adult populations which may migrate into the Missouri, but with an unknown extent.

If the criteria for selection of a sampling approach is that the sampling tests the effectiveness of the system changes proposed to avoid extirpation of pallid sturgeon, then a combination of a long term mark-recapture program and a modest telemetry effort may be an effective prescription. The number of animals in the system (approximately 82,000 hatchery released fish, and a few thousand wild fish), as well as the quantity of information derived from the years of sampling conducted by the PSPAP, HAMP, and CSRP, provides sufficient information for designing a sampling program.

There are several objectives that a mark-recapture/ telemetry program will not address that the current sampling does address. A sampling regime aimed at providing robust mark-recapture data would not sample newly recruiting fish. Thus, there would be a lag of two to three years after a recruitment event before the juveniles would be vulnerable to the sampling gear and be detected. Therefore, fundamental sub-objective 1 – increase recruitment of age-1 fish – may need to be addressed through a separate sampling design. Also, a targeted sampling design would not furnish ecological information on the other fish species present in the system. However, there is an argument to be made that a sampling regime to which fish are vulnerable two to three years after recruitment is valid, as long as there is a commitment for the sampling to extend a sufficient length of time.

D.1.1.39 Mark-Recapture Level of Effort

The level of effort needed to derive high quality estimates of population and demographic rates can be estimated broadly based on the estimated population in each RPMA and the expected catch rates from the current sampling. From the PSPAP, HAMP, and broodstock sampling, catch rates on trotlines in the upper river are expected to be 0.55 fish/ 20 hooks, while the Lower River catch rate is expected to be 0.25 fish/ 40 hooks. If the objective is to capture 5% of the expected population in each segment, and if a field crew can run 10 40-hook lines in a day, then a rough estimate of the required effort would be 218 crew-days in RPMA 2and 344 crew-days in RPMA 4 (Table D21).

Table D21. Recovery priority management area, population estimate, sample size and estimated effort required for robust population estimation assuming trotline deployment (*RPMA 2 = PSPAP Segments 1-3; RPMA 4 = Segments 7-10, 13-14).

Recovery priority management area*	Length, kilometers	Number of wild pallid sturgeon	Number of hatchery pallid sturgeon	Number of wild fish per kilometer	Number of hatchery fish per kilometers	Number to sample each year at 5% target	Number of trotline sets at 40 hooks/set at 5% capture	Crew days at 10 sets per day
2	598.4	150	43000	0.25	71.86	2158	1961	218

4	1297.6	2000	29000	1.54	22.35	1550	6200	344

D.1.1.40 Robust Design Overview

A variant on the mark-recapture design is what is referred to as a robust design (Pollock 1982, Kendall 1997). As originally described by Pollock (1982), a robust design consists of primary sampling occasions with secondary sampling occasions nested within the primary sampling occasion. Primary occasions are spaced temporally to capture processes such as survival and growth. Secondary occasions occur over a short timeframe, short enough that closure of the population from demographic processes (that is, recruitment, mortality, immigration, emigration) can be assumed. The secondary sampling occasions also provide multiple opportunities for individuals to be captured, allowing for the estimation of capture probability providing an estimate of the population rather than an index of relative abundance. True abundance estimates are important to ongoing AM and recovery because species recovery objectives and sub objectives are specified as abundance and population growth rate (λ) is estimated as $\lambda = N_{t+1} / N_t$ where N is population abundance.

The robust sampling design has been applied across a wide range of taxa to estimate demographic rates and population abundance. The robust design was originally conceived to provide a robust population estimates derived from open capture-recapture models, the Jolly Seber model in particular. Its use has been extended to studies of species occurrence (i.e., occupancy models; MacKenzie et al. 2002 Tyre et al. 2003) and abundance (N-mixture models; Royle 2004b, Royle 2004a) of unmarked individuals. Therefore it provides a rigorous framework that allows for the estimation of relevant demographic rates and abundance, using marked or unmarked individuals. It should be recognized that monitoring pallid sturgeon in a system as large as the Missouri River is inherently challenging and it is likely that any approached used will violate one or more assumptions required to estimate demographic rates or population abundance. Additional modeling calculations will be needed to evaluate whether violations of assumptions would lead to unreliable results as part of a level 1 science effort. The following sections provide a preliminary overview of the robust design as a potential monitoring design for pallid sturgeon populations of the Upper and Lower Missouri River.

D.4 A Hybrid Population Assessment Approach

The hybrid approach presented here is intended to achieve pallid sturgeon population-level monitoring and assessment objectives. It involves a core of mark-recapture effort based on a robust design, sampling to identify recent recruitment (age-0 and age-1), an integrative population model to serve as the population inventory framework, collection of ancillary data needed to estimate parameters for the population model and to provide explanation, and a CPUE effort to provide a check on population-estimate trends. The population-level monitoring is intended to complement level 1 and 2 science components, and effectiveness and process monitoring of level 3 and 4 implementations of management actions.

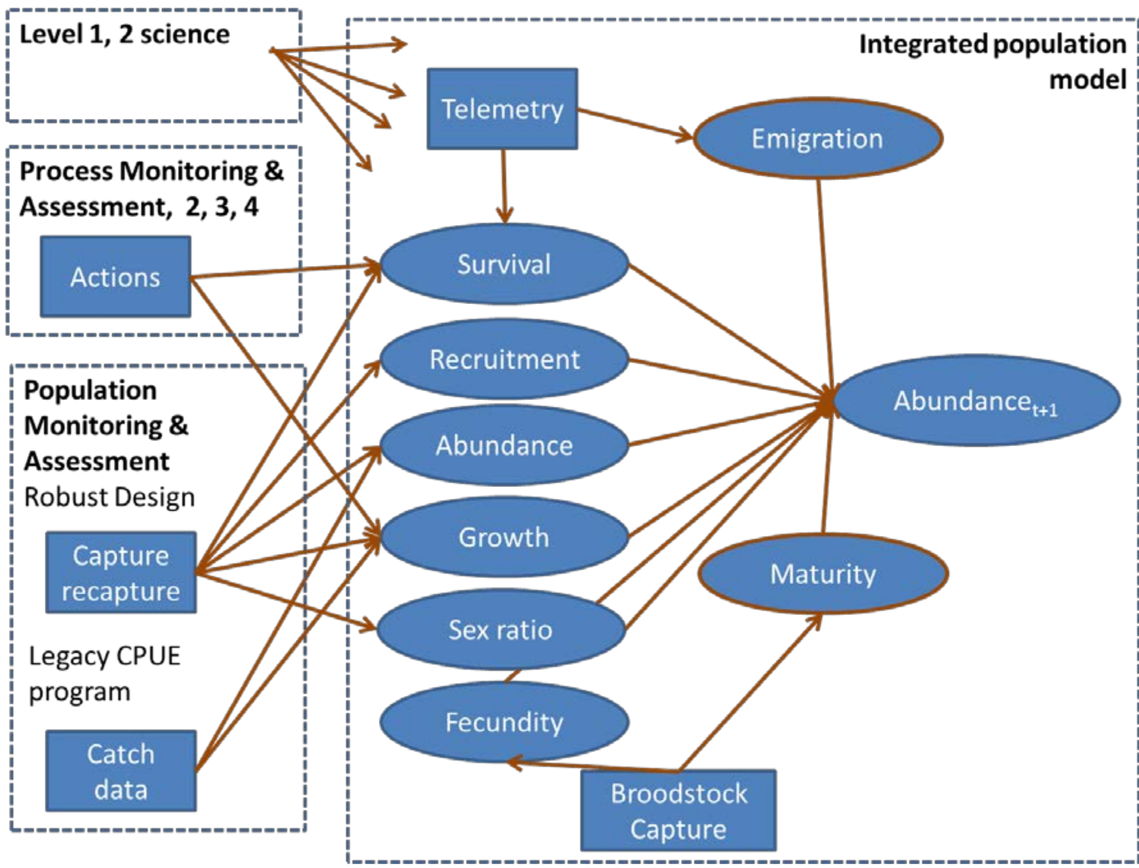

Figure D5. Concept of interrelations among level 1, 2 science, process monitoring and assessment, population-level monitoring and assessment, and the integrative population model.

D.1.14 Population Monitoring

Population monitoring for the MRRP will be designed to provide the data to meet the USFWS's species objectives (that is, Fundamental Objective; Sub-objectives 1 and 2) and the demographic data needed to develop the pallid sturgeon population model (e.g., survival, population size). The approach detailed below is a recommended starting point and should be evaluated as part of a level 1 science effort and adjusted periodically to improve the design so that it more effectively meets the monitoring and species objectives. The recommended population monitoring will consist of two components: 1) age-0/age-1 trawling to detect reproduction and recruitment to age 1 (Objective 1) and 2) mark-recapture sampling to evaluate Objective 2 and provide the demographic data needed for predictive population modeling. Both components will be implemented in the Upper and Lower Missouri rivers; however, the sample designs may differ depending on factors like relative gear efficiencies and seasonality. The general design elements (e.g., river bend, macrohabitat, segment) will follow that of USACE's PSPAP (Welker and Drobish 2012) which includes the river bend functioning as the sample unit. Much has been learned regarding pallid sturgeon distribution, sample gears, and sampling effort through the monitoring programs implemented by the USACE since 2005 (Section D.3). This information along with input from PSPAP and HAMP biologists was used to form the monitoring and sampling recommendations below, including the target levels of effort provided in Tables D22-D24.

D.1.14.1 Sampling to Identify Recent Recruitment (age-0 and age-1)

Monitoring recent reproduction and recruitment can be used to track the effects of management actions. Increases in the occurrence of young pallid sturgeon through time can be used to identify the positive incremental effects on this portion of the population, the portion that is hypothesized as the recruitment bottleneck. Additionally, annual fluxes in the occurrence of these fishes may be used to directly evaluate the effects of individual management actions (e.g., IRC). Trawl sampling will be used to monitor the occurrence of age-0 and age-1 pallid sturgeon in the Upper and Lower Missouri rivers to detect reproduction and recent recruitment of pallid sturgeon. Yearly changes in abundance of young sturgeon will be measured using CPUE or changes in occupancy rates.

D.1.1.40.1 Upper River

Under this proposed design, sampling for age-0 and age-1 pallid sturgeon would be restricted to Segment 4 (below the confluence of the Missouri and Yellowstone rivers). Past sampling and Effects Analysis drift models (Fischenich, in review) indicate that the majority of young pallid sturgeon will reside in this portion of the Upper River. At the local scale, sampling will be confined to the CHXO-CHNB, ISB-CHNB, and OSB-CHNB habitat types during the months of June and July. These habitats have provided the highest CPUE values for young *Scaphirhynchus* sturgeon during the previous 10 years of PSPAP sampling. Although these small sturgeon will recruit to the sampling gear from June through September, sampling will be restricted from June (near the time of spawning) through July to accommodate the start of mark-recapture sampling.

Gears

To maximize efficiency, only two types of trawls should be considered for sampling age-0 and age-1 pallid sturgeon as they have been used extensively and effectively by USACE monitoring projects: OT16 otter trawl (PSPAP; consult Welker and Drobish 2012 for a detailed description) and the OT04 trawl used by the HAMP (Gosch et al. 2015). Using the OT16 would provide continuity between the monitoring through the AM plan and the historic PSPAP monitoring. However, pallid sturgeon < 50 mm would not be effectively sampled with the OT16. Therefore, we recommend that sampling be conducted with the OT04 or the OT16 fitted with an inner bag made of 4 mm bar mesh.

Effort

The level of effort needed to monitor age-0 and age-1 pallid sturgeon is difficult to determine as few have been captured in either the Upper or Lower Missouri rivers through USACE monitoring. The HAMP has been very successful at sampling YOY *Scaphirhynchus* sturgeon and the targeted monitoring approach described here follows that of the HAMP. The HAMP samples at an effort of 4 trawls per mile (approximately 3/km) with repeated sampling at sites where young sturgeon are captured. The average river-bend size in the Upper Missouri River is 2.3 km which would result in an average of 7 trawls per bend (based on the 3 trawls/km sample through the HAMP; Table D22). Twenty-five percent of bends in Segment 4 will be sampled each month (June and July), resulting in 50% of the bends (that is, 24) sampled per year; this was a realistic level of effort (25%) for this type of sampling in the PSPAP (Table D22). Additional trawl subsamples will be taken at sites where young sturgeon are captured and may result in more than 7 trawls per bend and 84 trawls per month (Table D22). Additional bends may be added per sample period as time allows. Sampling designs and levels of effort may be evaluated via simulation to identify tradeoffs in efficiency and precision.

Table D22. Target sampling effort for Objective 1 (Identify recruitment to age 1) in Recovery Priority Management Area 2 and 4 with trawls (OT04 and/or OT16).

Recovery Priority Management Area	Pallid Sturgeon Population Assessment Program Segment	Length, in kilometers	Average Bend Length (km)	Number of Trawls per Kilometer	Average Number of Trawls per Bend[1]	Number of Bends	Number of Bends to Sample per Month	Estimated Total Trawls per Segment per Month[2]
2			2.3	3	7			
	4	84				47	12	84
4			4	3	12			
	10	191				39	10	120
	13	193				45	9	108
	14	210				56	14	168

[1] Based on HAMP sampling experience

[2] Additional trawls will be sampled at sites where age-0 Scaphirhynchus sturgeon are captured

D.1.1.40.2 Lower River

Sampling for age-0 and age-1 pallid sturgeon will be restricted to Segments 10, 13, and 14 (below Kansas City, MO to the Missouri River mouth). The HAMP has recently sampled larval pallid sturgeon in habitats below Kansas City which represent the only larval (settled) pallid sturgeon captured in the Lower River. Effects Analysis drift models also indicate that the majority of young pallid sturgeon will reside in this portion of the Lower River (and the Middle Mississippi River). At the local scale, sampling will be confined to the CHXO-CHNB and ISB-CHNB habitat types in the months of June, July, and August. These habitats have provided the highest CPUE values for young *Scaphirhynchus* sturgeon during the previous 10 years of PSPAP sampling and recently through the HAMP. Although these small sturgeon will recruit to the sampling gear from June through October, sampling will be restricted from June through August to accommodate the start of mark-recapture sampling.

Gears

As with the Upper River, the most effective sampling gears for age-0 and age-1 *Scaphirhynchus* sturgeon are the OT16 and the OT04 trawls. Therefore, the recommendation for sample gears follows that made for the Upper River with either the OT04 or the OT16 (fitted with an inner bag made of 4-mm bar mesh) used to sample age-0 and age-1 pallid sturgeon.

Effort

Monitoring in the Lower River will follow that of the HAMP. The average river-bend size in the Lower River is 4 km which would result in an average of 12 trawls per bend (based on the 3 trawls/km sample through the HAMP; Table D22). A target of 25% of the bends in Segments 10, 13, and 14 will be sampled each month (June, July, August), resulting in 75% of the bends (that is, 24) sampled per year (Table D24). Additional trawl subsamples will be taken at sites where young sturgeon are captured and may result in more than 12 trawls per bend and the estimated trawls per month (Table D22). Additional bends may be added per sample period as time allows. Tradeoffs (that is, cost, precision, bias) amongst candidate sample designs may be evaluated through simulation.

D.1.14.2 Sampling for Population Characteristics: Mark-Recapture Robust Design

D.1.1.40.3 Description

Changes in population size through time are a function of births, deaths, immigration, emigration, and recruitment. Open capture-mark-recapture (CMR) models assume that the population is influenced by natality, mortality, emigration, and immigration and is therefore considered open between sample periods. Closed population models assume that the size of the population remains unchanged between sampling events and require that multiple samples are taken over a short period of time to assume closure. The advantages and disadvantages of each type of model are well documented (Pollock et al. 1990, Nichols 1992) with CMR models used to estimate survival, emigration, and immigration and the closed CMR models used to estimate population size and capture probability. The Robust Design integrates the advantages of both types of models which allows considerable flexibility in estimating a very large number of important demographic parameters, including abundance, survival, and recruitment. The concept behind the Robust Design is to break the mark-recapture sessions into shorter sampling occasions so that capture probabilities can be estimated among encounter occasions within these sessions. The capture sessions are brief enough that we can assume the population is closed (that is, no births, deaths, immigration, or emigration). Therefore, closed models can be used for the estimation of population size and then integrated with open models to estimate true survival, emigration, and immigration over the longer, open primary sampling periods. The basic design is to sample over two temporal scales.

The pallid sturgeon populations in the Upper and Lower Missouri Rivers are unique in many respects (e.g., size and age at maturity, growth rates, life span). The habitats in which they live are also very different. The Lower River is characterized by a narrow, self-scouring channel with higher water velocities, especially in the main channel. In contrast, the Yellowstone and Upper Missouri Rivers are characterized by lower velocities, shallower depths, and a more natural channel form. The nature of the differences between these two portions of the Missouri River has shown that the most effective sampling methodologies and potential strategies also differ significantly and therefore necessitate that the mark-recapture sample designs be tailored to each population.

The accurate estimation of population parameters represents a critical component of assessing the system state for pallid sturgeon in the Missouri River and providing key demographic values for evaluating management actions through predictive population modeling. The estimation of these metrics depends on the quality and quantity of data collected from a well-developed sampling design. The optimal design must be cost-efficient, and provide reliable, accurate data. Implementing an untested design on a large system like the Missouri River could prove costly from the expenditure of time and effort if the selected design performs poorly. For the initial stage of development, we recommend that candidate sampling designs be evaluated by simulation modeling to identify the optimal design (that is, tradeoffs between precision, bias, and cost) and provide proof of concept prior to testing or implementing in the field. This effort is included as a level 1 science component in Appendix C under Technical Development. Once the sample design has been optimized through implementation and adjustment over a number of sample years, only periodic monitoring may be required (e.g., every few years) to estimate and update demographic values.

D.1.1.40.4 Design Understanding from Simulations

A preliminary simulation was performed as a proof of concept to evaluate whether a capture-recapture study of individual fish using a robust design would be feasible on a river the size of the Missouri River. First a geographic template was used based on the current PSPAP river bend sampling units, where a river bends are defined as a three continuous habitats (channel cross-over, inside bend, outside bend) and vary in number and size from for the lower and upper basin (Lower: N=317, mean=4 rkm, min=0.2, max=19; Upper: N=157, mean=2.3, min=0.6, max=8). Simulations were performed using the lower basin sampling units as templates. Population dynamics were simulated given known recruitment, survival, and abundance. Given the population dynamics, capture histories were simulated for two levels of capture probability 0.1 and 0.4. These values were selected based on capture probability estimates (Rotella and Hadley 2010, Steffensen et al. 2015b). These simulated capture histories were then used to estimate population abundance, survival, and recruitment. The robust design estimator used was the simplest case, assuming homogenous capture probabilities among secondary sampling units and that capture probability was homogenous among bends. The simulation used 5 primary sampling periods and varying secondary sampling occasions (2 through 10) to evaluate estimator performance, reliability, and effort levels.

Within a primary sampling occasion at least 2 secondary capture occasions are required to estimate the population using capture-recapture of marked individuals and more are likely needed if heterogeneous capture probabilities are present. Over a spatial extent, sampling at least 20% of the river bends was necessary in preliminary simulations. While this preliminary simulation does not address specific gears, selecting gears and sampling occasions that maximize catch will likely result in reduced effort (Section D.3). Based on preliminary analyses, the population abundance could be estimated (Figure D6). With the exception of a capture probability of 0.1 reasonable abundance estimates were achieve by sampling 20% of the bends if capture probability was 0.4 (Figure D6). If capture probability was 0.1 either more bends needed to be sampled or 6 or greater sampling occasions. There was no appreciable effect of increased secondary occasions to estimate population abundance if capture probability was 0.4. It should be recognized these simulations were conducted under the best case scenario (that is, homogenous survival and capture probability) and therefore may not reflect the challenges to sampling a large turbid river like the Missouri River and additional study is required to evaluate 'worst case' scenarios.

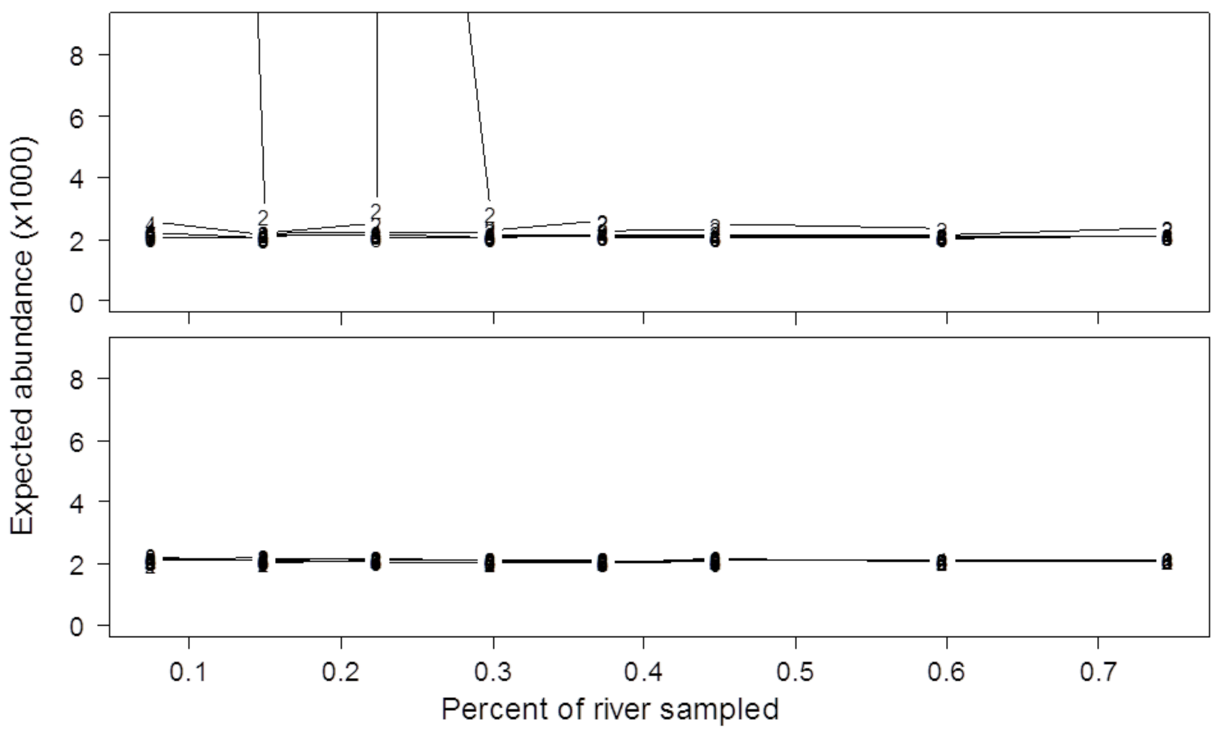

Figure D6. Effect of number of secondary samples and amount of river bends sampled on population abundance estimates. The upper graph assumes a capture probability of 0.1; the lower graph assumes a capture probability of 0.4. The number in the graphs represent the number of secondary sampling occasions.

D.1.1.40.5 Additional Information to Complete Design

This simulation study is preliminary and suggests that a robust design mark-recapture approach may be a useful monitoring approach. To fully complete the robust design, a level 1 study should be implemented to evaluate spatial and temporal configurations required to achieve acceptable population and demographic rate estimates (Appendix C). Additionally, if the monitoring program will be used to detect the effect of management actions, a power analysis must be completed. The amount of effort required to provide reasonable estimates should be considered. Lastly, including auxiliary information such as data from telemetry tracking in an integrated population model is intended to provide a unifying framework incorporating system level monitoring and providing estimates and feedback necessary to parameterize and calibrate the population model.

D.1.1.40.6 Caveats and considerations

There are many assumptions required to estimate population abundance and demographic rates. For example, in this preliminary analysis, survival and detection probability were constant among primary and secondary occasions, which is likely a poor assumption. Additionally, factors affecting pallid sturgeon survival, such as age, growth, condition were not evaluated and should be accounted for to improve estimates and also capture the effect of these variables on survival such that they can then be potentially linked to management actions. Additional research will be required to evaluate the tradeoffs of efforts with estimate bias and precision as part of a level 1 science effort. Also, evaluation of how sensitive estimates are to violation of assumption will be necessary prior to implementation of monitoring programs. Lastly, the monitoring design will have to be optimized within the constraints of the finite resources available to monitor pallid sturgeon on an annual basis, which is not a trivial task in a large turbid system like the Missouri River.

D.1.1.40.7 Upper River

If mark-recapture is to be implemented as part of the population-level monitoring, we would recommend that sampling occur in Segments 2, 3, 4, and the lower 48 km of the Yellowstone River. Past sampling (2000 to present) indicates that the majority of the pallid sturgeon reside in these areas during fall. Gear subsample deployments should occur primarily in the four habitat types that have provided the highest catch rates for pallid sturgeon >/= 109 mm in length: CHXO-CHNB, OSB-CHNB, ISB-CHNB, and SCCL-CHNB. As identified previously, tributary mouths have also provided high catch rates of pallid sturgeon and may be included as a focus habitat. Sampling should occur in August through October dependent upon flows and water temperature.

Gears

The trotline and the trammel net have been effective gears for sampling pallid sturgeon in the Upper River (Tables D13, D14, and D15). However, the trotline is only (generally) effective at sampling pallid sturgeon during October when the water temperatures are low enough to reduce the level of bait stealing by small-bodied fishes (Ryan Wilson, USFWS, pers. comm.). In contrast, the trammel net can be fished effectively from August through October and provides the flexibility to repeatedly sample areas (that is, bends, habitats) within the same day that contain high concentrations of pallid sturgeon. Therefore, we recommend using the trammel net for mark-recapture sampling in the Upper River. The trotline could serve as a replacement gear when low river flows reduce the capture efficiency of the trammel net.

Effort

The proposed sample season for the Upper River would occur in the months of August, September, and October. Approximately 2,150 pallid sturgeon juveniles and adults need to be sampled per year (August, September, October) to achieve a 5% capture rate for the population (Table D21). A capture rate of 0.6 pallids/subsample would require 3,596 trammel net subsamples (1,200 drifts/month) to reach the target of 2,158 pallid sturgeon (Table D23). Closed population estimates of abundance will be obtained at the bend level through repeated sampling of an individual bend over a 3-day period. Simulation will be used to identify the sample design that optimizes the level of effort and precision and that minimizes bias. The estimated number of drifts, bends, and effort needed per segment is included in Table D23.

Table D23. Target sampling effort for targeted Mark-Recapture of pallid sturgeon in Recovery Priority Management Area 2 with the trammel net.

Recovery Priority Management Area	Pallid Sturgeon Population Assessment Program Segment	Length, kilometers	Number of Bends	Number of Bends to Sample Each Year (at 5%)	Number of Net Drifts, 5% of Pallid Sturgeon Population	Number of Drifts per Sample Month	Total Bends per Segment per Year, [number to sample per sample period]	Crew Days
2			145	2158**	3596**			40
	2	59	40		1007	336	12 [4]	12
	3	178	61		1510	503	18 [6]	18
	4	84	24		611	204	9 [3]	9
	Yellowstone River	48	20*		503	168	6 [2]	6

*represents lower 48 km (30 miles) of the Yellowstone River

** targeted sampling capture rate of 0.60/drift (2015 field season, Ryan Wilson, USFWS, pers. comm.)

D.1.1.40.8 Lower River

If mark-recapture is to be implemented as part of the population-level monitoring, we would recommend that mark-recapture monitoring occur throughout the Lower River (Gavins Point Dam to the Missouri River mouth) as past PSPAP monitoring has collected numerous pallid sturgeon in all Segments (7, 8, 9, 10, 13, and 14). Gear subsample deployments should occur primarily in the four habitat types that have provided the highest catch rates for pallid sturgeon >= 109 mm in length: BRAD-CHNB, CHXO-CHNB, ISB-CHNB, and ISB-POOL. Tributary mouths have also provided high catch rates of pallid sturgeon and may be included as a focus habitat. Sampling should occur in March-May and October-December with the timing of sampling dependent upon water temperature.

Gears

The trotline has been the most effective sampling gear for pallid sturgeon >/= 109 mm; therefore, it is recommended that the trotline be used for mark-recapture sampling in the Lower River. The effectiveness of this gear is restricted to spring and late fall due to the activity of bait-stealing fishes.

Effort

The proposed split-sample season for the Lower River contains approximately two sample months in the spring and two months in the fall. Approximately 1,550 pallid sturgeon juveniles and adults need to be sampled per year to achieve a 5% capture rate for the population (Table D21). A capture rate of 0.25 pallids/subsample would require 6,200 trotline (40 hooks/set) subsamples (1,550 sets/month or 3,100 per season) to reach the target of 1,550 pallid sturgeon (Table D24). Selected bends will be sampled for 3 consecutive days to obtain the closed population estimate. Table D24 provides the estimated number of sets, bends, and effort needed per segment. As with the Upper River, simulation will be used to compare designs and optimize the level of sampling effort.

Table D24. Target sampling effort for Mark-Recapture of pallid sturgeon in Recovery Priority Management Area 4 with the trotline.

Recovery Priority Management Area	Pallid Sturgeon Population Assessment Program Segment	Length, kilometers	Number of Bends	Number of Bends to Sample Each Year	Number of Troline Sets, 40 Hooks/Set, 5% of Pallid Sturgeon Population	Number of Sets per Segment, per Sample Period	Total Bends per Segment per Year, [number to sample per sample period]	Crew Days
4		1297.6	316	1550	6200*			
	7		34		682	171	14 [4]	14
	8		61		1178	295	25 [6]	25
	9		81		1612	403	34 [9]	34
	10		39		744	186	16 [4]	16
	13		45		868	217	18 [5]	18
	14		56		1116	279	23 [6]	23

*capture rate of 0.25 pallid sturgeon/set

D.1.14.3 Integrative Pallid Sturgeon Population Model

D.1.1.40.9 Model overview and spatial organization

The collaborative population model structure was developed to meet three objectives:

1) provide a quantitative framework to forecast pallid sturgeon population dynamics given inputs from the CEMs;
2) provide a flexible model structure template that can be used to model upper and lower basin populations, and;
3) account for whether a pallid sturgeon was produced in the Missouri River System or the hatchery system.

A secondary consideration in the development of the integrative model structure was the availability of biological data commonly collected during population assessments (e.g., size, weight, age, sex, origin), which will be necessary to parameterize the model and allow the model to provide decision support and inform monitoring efforts. We provide a brief overview of the model structure as it has documented in detail in the EA integrative report (Jacobson et al. 2016a). Current versions have expanded the temporal and spatial resolution of the model which does not change to stage and age structure in previous versions.

Stages were used to organize pallid sturgeon life history and as a framework to model population dynamics. Seven stages were used in the model to capture biologically important pallid sturgeon stage transitions similar to those identified in Wildhaber et al. (2011a) and correspond to life stage-specific CEMs. Pallid sturgeon life history in the Missouri River System was organized into the following stages:

1) **Embryo** (5-8 days): period from fertilization to hatching.
2) **Free embryo** (8-12 days post hatch (dph)): period from hatching until the larval fish initiates feeding.
3) **Exogenously feeding larvae** and age-0 (8-12 dph - June 1): period from full development of fin rays over the winter period until June 1 of the following year.
4) **Juvenile** (age-1 to age-9): period of pallid sturgeon sexual immaturity, a fish can remain in this stage until age-9.
5) **Spawning adult** (age-7 to age-41): this stage includes juvenile fish that have become sexually mature and are read to spawn and adult fish that have already spawned and are ready to spawn again.
6) **Post-spawn adult**: a pallid sturgeon that has released its gametes, model assumes fish remain in this state until June the following year.
7) **Recrudescent adult**: a post-spawn pallid sturgeon, replenishing gametes, may remain in this state for up to 4 years post-spawn.

Each stage represents an important portion of pallid sturgeon life history in the Missouri River System that varies in duration from days to years. The effect of hatchery operations on the population was accounted for with the addition of stages specific to the hatchery system, including:

1) **Broodstock**: sexually mature fish ready to spawn that are removed from the Missouri River System and used as a source of gametes to fertilize and produce offspring in a controlled hatchery environment.
2) **Fingerlings**: pallid sturgeon hatched in a hatchery setting and reared for 3–4 months and released back into the Missouri River System.
3) **Yearlings**: pallid sturgeon hatched in a hatchery setting and reared for 10–12 months and released back into the Missouri River System.

The current implementation of the model has a geographic extent limited to the Lower and Upper Missouri River segments, denoted as RPMA 2 and 4 (Figure D1). These two river segments are subdivided into bends representing the spatial grain of the population model. River bends are defined as a three continuous habitats (channel cross-over, inside bend, outside bend) and vary in number and size from for the lower and upper basins (lower: N=317, mean=4 rkm, min=0.2, max=19; upper: N=157, mean=2.3, min=0.6, max=8). As currently implemented, fish move among bends. We use bends as a spatial organization because they are the sampling units for the PSPAP and are likely to be retained as the spatial organization for future monitoring. Current temporal extent is user defined and can be up to 50 years with a monthly time step.

D.1.1.40.10 Integrating the population model with monitoring and research

The integrated population model (IPM) can be used to evaluate scenarios of interest, but to be a useful as a decision support or scenario planning tool it needs be able to accept information from ongoing monitoring and research. These monitoring and research efforts can be thought of as ‘plugins' into the model. A preliminary view of this is illustrated in figure B5. Specifically, various monitoring programs and research efforts will provide data for demographic rates and abundances. This approach assimilates monitoring and science programs to inform population simulations. Within this framework we have identified 3 major programs (Level 1 and 2 Science, Process monitoring and assessment, and Population monitoring and assessment) that can inform demographic rates and 2 ancillary programs (Telemetry, Broodstock capture) that can further inform demographic rates.

How specific science and monitoring programs will plug in to the IPM will vary among the programs. Level 1 and 2 science should provide at least baseline or best-case estimates of what parameters might be that cannot be estimated in the system (e.g., embryo survival). Process monitoring and assessment should be able to inform the effect of management actions on demographic rates. For example, IRC habitat is hypothesized to increase survival, so monitoring data from in-river experiments may be assimilated into the model. Lastly the population-level monitoring and assessment can potentially inform survival, recruitment, abundance, growth, and sex ratio of the population. The robust design capture-recapture program proposed can also potentially be used to calibrate CPUE data using a Bayesian framework.

Ancillary programs like telemetry and broodstock capture can further be used to refine relationships and demographic rates. For example, within the broodstock program, information on fish size and fecundity can be used to refine fecundity maturity relationships, which will likely be important to link growth. Telemetry can inform survival and emigration. Periodic detections, if designed correctly, provide information regarding whether a fish is in the system and alive. The use of strategically located autonomous telemetry receiver arrays may be useful inform migration rates (Appendix C).

D.1.1.40.11 Caveats and considerations

The IPM described here is a work in progress and specific methodological and analytical details will be presented as they are developed. Some additional effort is needed to be made to develop the framework and evaluate whether or not it will work given system constraints. The additional effort is planned as a level 1 science effort. However these efforts primarily require computer simulation and therefore could be evaluated early in the process. Another caveat to consider is that with the addition of information streams, computation time may become a limiting factor, however once parameters are estimated population simulation should go relatively quickly. Lastly, in order for science and monitoring programs to plug in to the integrated population model, studies and data need to be conducted in a manner that allows for integration. For example, if all studies estimating survival use a logit-linear model these results can be integrated, however if a study is set up differently, the study may need to be reanalyzed to be integrated. The refinement and maintenance of the IPM is considered to be an ongoing Technical Development in Appendix C.

D.1.14.4 Ancillary Data for Population Assessment

D.1.1.40.12 Data for Parameter Estimation

A population monitoring and modeling intended to provide useful estimates of population size and growth will require several types of information in addition to population size and survival estimates from the mark-recapture robust design. These include:

- Tag loss estimates
- Sex ratios
- Reproductive ratios
- Fish condition, health
- Fecundity estimates
- Age at first reproduction
- Age at senescence
- Growth rates
- Emigration and immigration

Estimates of these parameters values will require additional effort in the monitoring program but required data can be gathered with minimal extra effort.

D.1.1.40.13 Links from Action Hypotheses to Population Assessment

The level 1 and 2 science components outlined in Appendix C are structured to determine whether each hypothesized action will be effective in increasing the population of pallid sturgeon, and if so, how survival at specific life stages will be affected by the action. Changes in survival estimated from laboratory, mesocosm, or field experiments will provide new estimates to update the population model and thereby indicate whether the population is likely to increase. The likelihoods projected from implemented actions will be compared to population sizes estimated from the robust design, documented survival, and CPUE.

In this framework, the level 1 and 2 science components and population assessment are mutually supportive. The population assessment and IPM will serve as the over-arching accounting process to document population trends whereas the science components provide the causal linkages from management actions to changes in survival. Importantly, survival from age-0 to age-1 or age-2 will probably not be measurable in the field or in mark-recapture because of gear limitations in capturing/recapturing small fish. Therefore, science component estimates may be the only information available to address survival at these important life stages.

In addition, we recommend that some ancillary abiotic data be collected during the robust design. These data are not intended to provide habitat selection or resource-use data; instead, they are intended to provide indicators that may be related to survival, or to catchability. We recommend that water temperature, conductivity, and turbidity should be collected with each gear deployment.

D.1.14.5 Catch per Unit Effort Continuity and Check

A limited CPUE effort would serve to provide continuity with previous population trend data developed through the PSPAP and to serve as a check on population estimates obtained from the robust design. The original goal from the PSPAP was to provide information to detect changes in pallid sturgeon populations and the first objective of the PSPAP was to evaluate annual and long-term trends in pallid sturgeon population abundance and geographic distribution throughout the Missouri River System (Welker and Drobish 2012). Although CPUE does not estimate true abundance of the population, it does theoretically detect changes (increases or decreases) in relative population abundance (Hubert and Chamberlain 1996). Because the PSPAP has collected CPUE data for 10+ years and because the pallid sturgeon is a long-lived species, continuing to collect such data would be useful to track relative changes in population abundance in the future.

As previously mentioned, CPUE is not capable of estimating population abundance, but it is assumed to be proportional to estimates of abundance, which will be derived from the robust design. The two measures of abundance (CPUE and population estimates) should serve as abundance measure checks to one another. For example, if population estimates show an increase, it follows that CPUE values should increase as well. In this situation, the combination of both abundance measures would suggest that the population increased. This level of confirmation may provide confidence in a system characterized by great variability.

Measures of CPUE are sometimes prone to large measures of error due to variation in fish behavior and other factors. One way to reduce variability in CPUE is to standardize sampling methods, which the PSPAP has done with their sampling regime and use of gears (Drobish 2008) to a certain degree. The PSPAP currently has large sampling time periods for each of its sampling seasons (sturgeon season = ~8 months, less when constrained by ice in northern segments; fish community season = ~4 months). A further reduction in variability might be obtained by decreasing the length of sampling time periods to narrower time frames, such as spring or fall (2-3 month time periods). Optimizing gear use for each river location (Upper and Lower) might also reduce variability of CPUE estimates. Gears in the Lower River are not necessarily as effective when used in the Upper River. Based on evaluations of the effectiveness of gears (see Section D.3), it seems using trammel nets and otter trawls in the Upper River and trotlines and the otter trawl in the Lower River would most effectively estimate CPUE of pallid sturgeon. The use of trotlines, otter trawls, and trammel nets to estimate CPUE would provide continuity to the 10+ previous years of sampling during the PSPAP.

D.5 Assimilation and Interpretation of Data: Application to Decision Making

D.1.15 Assimilation of Data in Population Model

Adaptive management of the pallid sturgeon in the Missouri River will require multiple sources of information, at varying spatial and implementation scales. Hypothesis driven monitoring and research also will be required to assess specific management actions. Population-level monitoring data provide three inputs to the decision making process and AM. First, monitoring data provides information which in turn reduces uncertainty of the current state of the system (that is, abundance of pallid sturgeon). This is important as management decisions likely depend on the current state of the system. For example, the annual to multiple-year level of population augmentation (that is, stocking) required to meet sub-objectives will likely depend on knowing population abundance and trend with some confidence. Second, population-level monitoring data provide feedback necessary to evaluate implemented system-level management decisions (level 3) as part of the AM process, albeit it may take many years to realize a system level effect in monitoring data. In this case, the effect a management action on the population is predicted and monitoring data provide the necessary feedback to evaluate whether the predicted population response was realized. Population-level monitoring needs to be coordinated with process monitoring in order to evaluate management actions that may not be detectable at the system level (e.g., effect of IRC on free embryo and exogenously feeding larval pallid sturgeon survival). Lastly population-level monitoring is necessary to determine whether population objectives and sub-objectives have been met.

Challenges exist to using monitoring data that provide a relative index of the population for AM and decision making. Specifically, previous PSPAP monitoring indexed population abundance by CPUE, which assumes that CPUE is proportional to abundance and catchability is constant over time and space (Harley et al. 2001). Catch effort data can exhibit patterns of hyper-stability where catch suggests population abundance is higher than it actually is or hyper-depletion where catch suggests population abundance is lower than it actually is. The use of CPUE data is also in apparent conflict with population objectives stated in the present pallid sturgeon recovery plan of 5,000 individual pallid sturgeon in each management unit (U.S. Fish and Wildlife Service 2014). Calibration of CPUE to pallid sturgeon abundance would be necessary to determine whether this population objective has been met. The value of uncalibrated CPUE data can be of limited value in a decision making context if fundamental objectives focus on population abundance rather than relative abundance, especially if relative indexes are biases. The use of varying sources of information (Level 1 and 2 science, process and implementation monitoring, and system level monitoring) in a decision making context presents a final challenge to the AM process.

The model developed to simulate population dynamics and evaluate management actions provides a flexible framework to evaluate the consequences of management actions on population dynamics and growth (λ; defined as N_{t+1}/N_t). The effects of management actions are propagated to the population through effects to demographic rates, survival in this case. In many cases baseline survival is unknown with a high degree of uncertainty and the effect of a management action on survival is an additional unknown. These unknowns may be parameterized by expert elicitation, existing values, new science, or by model calibration. As the adaptive-management process moves forward additional information will become available that will refine and ideally improve the survival rates and associated uncertainties. These values may become available as a result of controlled experiments or field studies and this information should be assimilated and incorporated in a manner that results in a useable input such that the population model can be used as a decision support tool.

D.1.16 Assimilation and Integrating Monitoring, Research, and Management

Integrating monitoring with the AM plan will pose challenges in a decision making context. In particular, the AM plan utilizes multiple sources of information at varying scales of implementation (Level 1 and 2, Process and implementation). Level 1 study consists of small scale experiments and information learned from these studies may not adequately scale to the population level. For example, scientific studies conducted in ponds, flumes, or under controlled laboratory conditions may not generalize to the population level. However this information is important to synthesize and incorporate into decision making and AM as these values may be the only source of that can inform demographic rates used in the population model. A formal framework to integrate information acquired from studies at the varying levels has not been developed and represents a challenge to integrate information across study levels.

The exact nature of a framework to integrate what is learned from levels of studies in the AM plan is uncertain. One approach that has been used to combine sources of information is Bayes Theorem, which can assimilate prior and current information into a posterior distribution of values. This approach is potentially useful because it can be used in either a scenario planning approach (that is, evaluating scenarios through a model) or in a decision model such as a Bayesian Decision Network (BDN) (Nyberg et al. 2006). This section provides an example of how Bayes Theorem may be used to update a distribution of survivals for embryos and some potentially useful applications of BDNs to assimilate and incorporate information learned from studies at varying levels in a decision making context. It should be recognized that this is one approach that shows promise and is commonly used in a decision making context, but there may be other approaches that are more suitable, albeit not yet unidentified.

D.1.17 Example: assimilating and incorporating information on embryo survival

Suppose that prior to any level of study, survival of embryos to free embryos (ϕ_{embryo}) was believed to be some value with some measure of uncertainty. This value and associated uncertainty can be derived by literature review or expert elicitation. In this hypothetical example, suppose the initial value and associated uncertainty for embryo survival (ϕ_{embryo}) was determined by expert elicitation. An approach to perform the elicitation would be to have experts adjust the parameters of the equation $\text{logit}(\phi_{embryo}) = \beta_0 + \varepsilon$, where β_0 is the expected survival on logit scale and ε is a normally distributed error term controlling the uncertainty around ϕ_{embryo}. If the results of this hypothetical elicitation were $\beta_0 = -12.1$ and $\varepsilon = 0.2$, the resulting distribution of ϕ_{embryo} is illustrated in figure B7. This distribution of ϕ_{embryo} values can then be used in stochastic population simulations to evaluate population dynamics and viability over the long term.

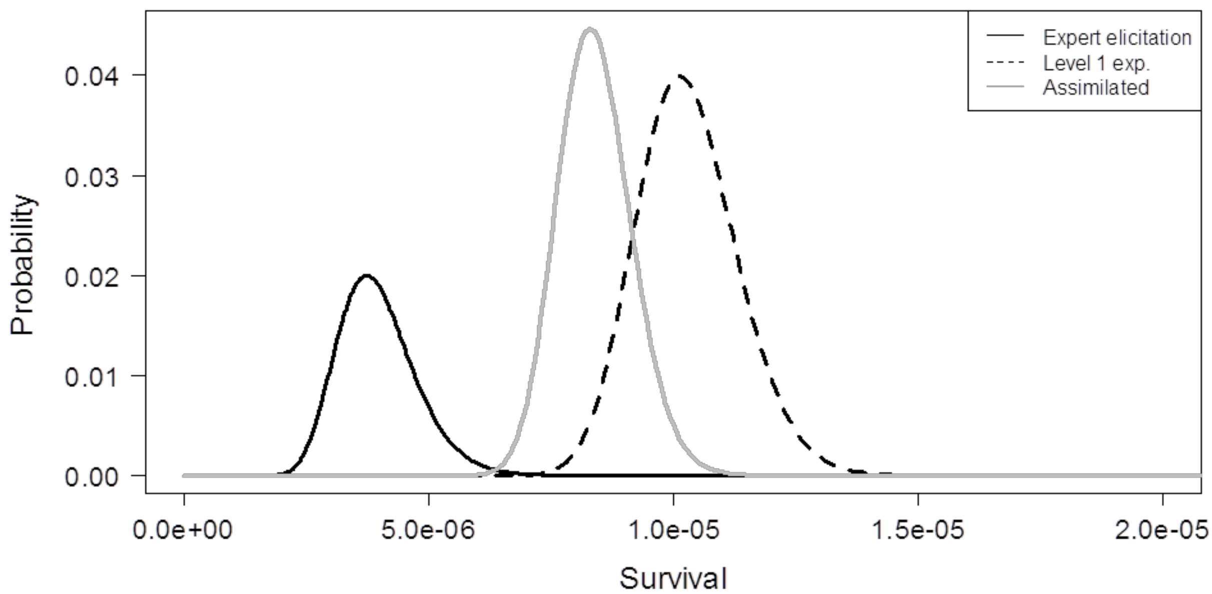

Figure D7. Hypothetical Pallid Sturgeon embryo survival based on expert elicitation (black line), level 1 study (dotted line), and the assimilation of the two using Bayesian updating (grey line).

Model parameterization by expert elicitation provides a rapid framework to evaluate the effect of management actions on an objective that otherwise may take months to years or may be impossible to estimate. Sensitivity analysis provides a method to evaluate how dependent model outcomes are on these inputs and potentially guide research and monitoring. As the AM plan moves forward, studies at varying levels will further inform demographic parameters like ϕ_{embryo}. For example, suppose a study is implemented that provides estimates of embryo survival based on a flume study and survival was estimated from the same logit linear model where $\beta_0 = -11.5$ and $\varepsilon = 0.1$ (Figure B7). This study, while not at the scale of the entire system, provides additional information on embryo survival and can be incorporated and assimilated using Bayes theorem to update the distribution of survival values resulting from expert elicitation (Hilborn and Mangel 1997, Clemen and Reilly 2001, Conroy and Peterson 2013). Incorporating and assimilation the information results in a posterior distribution representing the assimilation of the two information sources (gray line in Figure B7). Population model simulations can then be conducted using the new distribution of survivals assimilating expert elicitation and monitoring results.

D.1.18 Power of Population-Level Monitoring Data to Detect Management Effect

If population-level changes are to be related to management actions, the population-level monitoring program should be designed to provide sufficient power to detect the effect of the action. In most research studies, power is typically set such that the sampling program detects an *a priori* effect size 80% of the time. In the case of pallid sturgeon, management actions are believed to effect population demographic rates, which are illustrated in the CEMs. Many of these responses are on survival which is bound by 0 and 1. Given the bounds on survivals, effects are likely asymmetrical which can complicate simple power analyses. For example, a 10% increase or decrease in an adult survival (ϕ_{adult}) of 0.92 is 1.012 and 0.828 respectively. The 10% increase results in survival exceeding 100%, highlighting the challenge of power analysis to reliably detect biologically meaningful effects due to constrained parameter space. Lastly, suitable effect size should be determined *a priori*, however the practical realities of finite sampling resources will likely limit the reliable detection of an effect, unless the effect is large (that is, it is easier to detect large effects with less effort). Simulation studies as part of ongoing application of the IPM promise to provide information to evaluate whether detecting effects of varying magnitudes is feasible.

D.1.19 Value of Monitoring Data

A challenge facing monitoring programs is how much data is sufficient to make a decision and in the context of finite sampling resources. The value of information can be meaningful in decision contexts where multiple sources of information are assembled to reduce uncertainty around current system state or functional relationships (Conroy and Peterson 2013, Canessa et al. 2015). If a BDN is developed, the network contains a utility that corresponds to an objective, the value of various sources of information, perfect or imperfect (that is, population-level monitoring data), can be calculated (Moore and Runge 2012, Conroy and Peterson 2013, Canessa et al. 2015). Additionally, in cases where there are multiple metrics that require monitoring but resources preclude monitoring all desired metrics, a value-of-information analysis can facilitate prioritization of monitoring efforts in the context of making a decision. For example, the number of pallid sturgeon 50 years in the future depends on the current number of pallid sturgeon. However, there is uncertainty in current pallid sturgeon abundance estimates that could be reduced by monitoring. Similarly, there also is uncertainty in survival rates that could be reduced by monitoring or additional research. How finite monitoring and research resources are allocated (e.g., does an agency target abundance or survival) to reduce uncertainty can be informed by a value of information analysis. This type of analysis when performed in conjunction with a sensitivity analysis can provide a framework to determine how valuable information acquired from monitoring and research is, but it requires BDN which in turn requires a set of decision alternatives and a utility.

D.1.20 Caveats and Considerations

The approach illustrated in the two hypothetical examples is one approach that may be used to assimilate and incorporate information from varying monitoring designs and levels of study in the AM process. This approach is easily used in a BDN framework as well as in scenario modeling, providing support to using the population model for scenario planning or decision support. As demonstrated in the example, attention needs to be applied to studies such that analyses can be assimilated. Specifically one needs to be able to combine information based off a distribution or predictive model. Additional consideration should be given to how much belief or weight is given each information source, if this approach is applied. For example, should data from mesocosm experiments receive similar or twice the weight of expert elicitations? What about in relation to field level studies and implementations? Assimilating and incorporating varying information sources that will arise from the AM plan will be a challenge requiring careful consideration as to how results will fit together with the population model to support for decision analysis and scenario planning.

D.6 Summary and Conclusions

This report explored options for refining a population trends monitoring approach so it is effective and efficient in meeting the needs of the adaptive-management program. Analysis of previously collected data indicates how age-0 through adult age pallid sturgeon can be sampled with increased efficiency and initial exploration of robust design mark-recapture indicates that reliable monitoring of the pallid sturgeon population may be cost effective. Population-level monitoring promises to provide an important complement to level 1 and 2 science, and monitoring for implementation and process, to contribute to information for decision making. We develop an approach that would combine CPUE trawling for age-0 and age-1 (to address the objective of assessing recruitment) with a robust design mark-recapture effort (to address the objective of assessing increases to population size).

The results of level 1 and 2 science components, level 3 monitoring and assessment, and population-level monitoring can be effectively integrated in a population-dynamics modeling framework, the integrated population model (IPM). Under the approach developed in this report, the IPM becomes the central mechanism to assimilate data from diverse sources and provide information for decision making. Importantly, confidence in the IPM will be highly dependent on data from population-level monitoring which will provide key parameter estimates and validation.

In the context of limited resources, simulation modeling of robust design sampling can provide increased detail in how to optimize the contribution of population-level monitoring at least cost. We also discuss how a Bayesian Decision Network may be used to assimilate new information into the integrative population model and to evaluate the value of investments in various forms of monitoring.

Appendix E. Listing and Description of Protocols for Sturgeon-Based Process Monitoring and Assessment

Monitoring and assessment will be components of many level 1 and level 2 science components as well as level 3 and level 4 implementations. Multiple agencies and projects have contributed to more than a decade of experience on the Missouri sampling for pallid sturgeon and characterizing their habitats. This collective experience will be the foundation for design of monitoring and assessment protocols that are optimized for projects. Notwithstanding this broad experience, we also anticipate that some field projects may require development of new measurement and sampling protocols, and sample designs. The purpose of this appendix is to describe an approach to developing specific protocols and to document existing protocols.

For many, if not most, level 1-4 actions, monitoring and assessment protocols will need to be refined from existing protocols, or in rare cases, developed anew. Therefore, we anticipate that at the beginning of each component or implementation, there would be a step in which the experimental design, and sampling, measurement, and assessment protocols are developed and documented. This step would include a power analysis to determine whether the experimental design will be able to discriminate among alternative hypotheses. It may also require pilot studies in the laboratory or field to refine existing techniques or to develop new ones. Some adaptation of designs and protocols may occur also during the course of the project, but care will need to be applied to assure that adaptation does not impart bias. An example of the piloting approach is documented in Appendix A in the Technical Development section wherein a specific level 1 science effort is proposed to optimize population-level monitoring.

A large number of existing protocols exists. The following is not intended to be an exhaustive list; rather it is intended to illustrate the depth and breadth of existing sampling and measurement protocols. Some protocols have been documented in published reports specifically about the protocol, some have been documented in other reports or published articles, and some are documented in unpublished agency documents. The quality and detail of information varies considerably among these formats. The protocols are listed by major project.

- All handling of the endangered pallid sturgeon must conform to U.S. Fish and Wildlife handling protocols (U.S. Fish and Wildlife Service, 2012).

- Pallid Sturgeon Population Assessment Project (PSPAP) protocols are documented in multiple reports, notably (Welker and Drobish, 2012a, b, 2016).
- Habitat Assessment and Monitoring Project (HAMP). Early HAMP projects used PSPAP protocols whereas protocols for later HAMP projects are documented in (Dzialowski and others, 2013; Morris and others, 2013; Gosch and others, 2014; Gemeinhardt and others, 2015; Gosch and others, 2015).
- Comprehensive Sturgeon Research Project (CSRP). This US Geological Survey research project includes integrated abiotic and biotic studies of the reproductive ecology of pallid sturgeon, including extensive research using telemetry, laboratory studies, and physical habitat assessments. The USGS maintains unpublished, very detailed standard operating practices (SOPs) for all aspects of the research. In addition, methods are documented in a variety of documents including (Jacobson and others, 2004; Wildhaber and others, 2005; Bryan and others, 2007; Papoulias and others, 2007; Wildhaber and others, 2007; Reuter and others, 2008; DeLonay and others, 2009; Elliott and others, 2009; Papoulias and others, 2009; Reuter and others, 2009; Papoulias and others, 2011; McElroy and others, 2012; Albers and others, 2013; DeLonay and others, 2016).
- In addition, CSRP scientists have contributed assessments of existing monitoring data and power analyses (Bryan and others, 2010; Wildhaber and others, 2011b)

The following section is an example of a draft monitoring plan for a major MRRP action, creation of interception-rearing complexes (IRCs) for age-0 pallid sturgeon. Attachment 2 presents a monitoring plan for adjustments to existing shallow water habitat projects with an emphasis on chutes. Similar monitoring plans and protocols will be developed for other management actions as the adaptive management process proceeds.

Attachment E.1 IRC Construction and Monitoring

DRAFT/Pre-Decisional/For Discussion Purposes Prepared: April 15, 2016

By: Todd Gemeinhardt, Nathan J. Gosch, Brian O. Ma, Carl Schwarz

E.1.1 Introduction

An Effects Analysis proposed functional definitions of Age-0 sturgeon habitat as interception, food producing, and foraging habitat types (Jacobson and others, 2016a). Collectively these habitat types are referred to as Interception and Rearing Complexes (IRCs) when they are co-located within geographic proximity to benefit age-0 pallid sturgeon. The physical components of these habitat types are defined as follows: 1) food-producing habitat occurs where velocity is less than 0.08 m/s, 2) foraging habitat are areas with 0.5 – 0.7 m/s velocity and 1-3 m depth, and 3) interception habitat is qualitatively described as zones of the river where hydraulic conditions allow free embryos to exit the channel thalweg.

For interception habitat, the hypothesis posed by Jacobson and others (2016a) is that recruitment failure occurs because newly hatched free embryos are not able to exit the thalweg (navigation channel) before they starve because the river lacks hydraulic conditions that would transport them into supportive channel-margin habitats with food and protection. Therefore, construction of IRC restoration sites is planned to enhance interception of age-0 sturgeon as they transition from the drift stage to benthic feeding and provide increased amounts of foraging and food producing habitats.

E.1.2 Management Hypotheses

The IRC Monitoring Plan was developed to monitor the success of the construction of IRC restoration sites on increasing age-0 pallid sturgeon recruitment. To measure the success of restoration activities, monitoring will focus on exogenously feeding age-0 sturgeon with the primary response metric being catch per unit effort (CPUE) of age-0 *Scaphirhynchus sp*. sturgeon given the low numbers of age-0 pallid sturgeon present in the lower Missouri River. This monitoring plan focuses on interception, while the rearing portion of the EA hypothesis (food and protection) is currently being addressed in an ongoing HAMP study. Specifically, this study will test the following hypothesis for the biological response of sturgeon to IRC restoration sites:

$H_{0,1}$: Catches of age-0 sturgeon within river bends that include IRC habitat restoration sites are similar to control sites before and after habitat restoration actions.

$H_{A,1}$: Catches of age-0 sturgeon within river bends that include IRC habitat restoration sites increase relative to control sites after habitat restoration actions.

Coupled with the measurement of the biological response (CPUE of age-0 sturgeon), physical monitoring will characterize the hydrodynamics of interception habitat treatment and control bends. The measure of hydrodynamics will include depth and velocity magnitude and direction. Specifically, this study will test the following hypothesis on the physical response to the construction of IRC restoration sites:

$H_{0,2}$: The hydrodynamics of the river bends that include IRC habitat restoration sites are similar to control sites before and after habitat restoration actions.

$H_{A,2}$: The hydrodynamics of the river bends that include IRC habitat restoration sites are different than control sites before and after habitat restoration actions and allow free embryos to exit the channel thalweg.

E.1.3 Approach

E.1.3.1 Sampling Design

Key uncertainties in the IRC Monitoring Plan were (1) the selection of IRC habitat restoration sites (bends) and corresponding control sites, and (2) the timing of construction of IRC habitat restoration sites. To assist the development of a sampling design, analyses were conducted on existing baseline data from the Habitat Assessment and Monitoring Program (HAMP) on age-0 sturgeon catch data (Sub-Attachment 1A). Only the HAMP data (2005-2009, 2014-2015) were used to estimate the various components of variance in CPUE and conduct the analysis. Data from the MDC program (2014-2015) were also considered but were not used because the CPUE from this program was significantly higher than what is regarded as normal CPUE (~10× the typical CPUE for the Missouri River).

A hierarchical staircase study design was proposed to evaluate the response of age-0 sturgeon catch to IRC habitat restoration activities. A staircase design is a series of staggered before-after-control-impact (BACI) designs (Walters et al. 1988), and therefore requires paired control and treatment bends for the duration of the study. Each IRC habitat restoration site (i.e., treatment site) should also have a corresponding control site. Each IRC and control site should be sampled annually and at least one year prior to initiation of construction.

The decision to use this design was because of (1) logistical constraints, and (2) statistical considerations. Logistical constraints included the speed at which IRC habitat restoration sites could be constructed. It was estimated that up to two sites could be constructed per year. Statistical considerations consisted of power analyses conducted on several candidate configurations to determine a sampling design that would have the most power to detect a significant difference when such a difference actually exists (Brown and Guy 2007) given the existing logistical constraints (see Sub-Attachment 1A).

Generally, power increases with the number of IRC sites implemented, the magnitude of change in CPUE and the total number of years of monitoring. After some exploration of alternative sampling designs, the AM team, Management Team, and Oversight Team converged on a sampling design with 12 IRC-control site pairs implemented over 7 years (i.e., baseline monitoring for the first IRC-control site pair, followed by six years of building and monitoring 2 IRC-control site pairs per year; Figure E4; Table E 1). This sampling led to approximately 80% power to detect an 80% increase in CPUE within 7 years, at an alpha=0.05 and beta=0.2 at the river bend scale based on estimates of variance.

The benefit of a faster rate of construction of IRCs is in providing accelerated learning about action effectiveness. If 10 or more years of monitoring were intended, there was little increase in power for constructing IRC habitats at a rate faster than one per year; however, the rate of two IRC-control sites per year yielded a relatively large increase in power when planning for less than 10 years of monitoring (Figure E 5). To obtain adequate statistical power within the first half of the 15-year time frame of the MRRP, the 12 IRC sites built over 7 years need to create an average increase in CPUE of at least 75% (Figure E 5). The construction of habitat can be delayed (e.g., every second year) without affecting the analysis, but delaying the implementation of an IRC will result in some reduction in power. The power analysis does not consider cost of construction or monitoring, which may add further constraints to the sampling design.

Table E 1:: Biological data collections at IRC and control bends. 'X' represents site-years where monitoring occurs. Shaded boxes indicate the year in which construction will be initiated; CT refers to the control site.

Site/Year	1	2	3	4	5	6	7	8
01	X	X	X	X	X	X	X	X
01 CT	X	X	X	X	X	X	X	X
02	X	X	X	X	X	X	X	X
02 CT	X	X	X	X	X	X	X	X
03		X	X	X	X	X	X	X
03 CT		X	X	X	X	X	X	X
04		X	X	X	X	X	X	X
04 CT		X	X	X	X	X	X	X
05			X	X	X	X	X	X
05 CT			X	X	X	X	X	X
06			X	X	X	X	X	X
06 CT			X	X	X	X	X	X
07				X	X	X	X	X
07 CT				X	X	X	X	X
08				X	X	X	X	X
08 CT				X	X	X	X	X
09					X	X	X	X
09 CT					X	X	X	X
10					X	X	X	X
10 CT					X	X	X	X
11						X	X	X
11 CT						X	X	X
12						X	X	X
12 CT						X	X	X

E.1.3.2 Site Selection

E.1.3.2.1 Treatment Bends

The selection of sites for treatment of IRC habitat designs is based on understanding of typical drift rates of pallid sturgeon free embryos, likely maximum upstream spawning locations, the limitations associated with habitat restoration actions on the river, judgment about the engineering feasibility of constructing an IRC habitat at a specific site, and relevancy of the location of the specific purpose of the IRC characteristic being designed and tested. Sites for IRC habitat implementation are limited to areas adjacent to or owned by public entities. Although not a requirement, chosen sites are generally not in the vicinity of major or federal levee projects or near known navigation channel trouble areas. Once sites are screened out due to common restrictions or limitations, engineering judgment and experience are used to determine which sites are the most amenable to geomorphic or physical habitat change within areas that are most relevant for the specific habitat characteristic being tested. Site history is taken into consideration to determine what kind, if any, habitat restoration work was previously completed and if the site has undergone any previous biological monitoring. The culmination in the above factors will result in the reduction in the pool of potential sites to draw from based on preferential characteristics such as location, size, and accessibility.

E.1.3.2.2 Control Bends

Multiple factors may contribute to the selection of treatment bends (see above); however, increased flexibility in selection of control bends is available because modifications will not be made to those locations for the purposes of creating IRC habitat. In the analysis (Sub-Attachment 1A), we assume that control bends are randomly selected; however, power could be increased if control bends were selected to be as similar as possible to treatment bends, a form of blockingThe Lower Missouri River has been classified into six distinct geomorphic categories (robert Jacobson, unpublished data). For this study, control bends should be selected from the same geomorphic classification as paired treatment bends to minimize geomorphic variability between paired control and treatment bends. Ideally, control bends should be selected upstream of the paired treatment bends to avoid treatment actions from influencing control bends. If this cannot be achieved, the control bends should be selected from a sufficient distance downstream of the treatment bends to reduce treatment effects.

E.1.3.3 Data Collection Tasks

E.1.3.3.1 Biological Monitoring

The sampling protocol at each site (trawl location, site selection, frequency, etc.) of this study follows the sampling standard operating procedures (SOP) for 2014-2015 HAMP efforts, except when noted here. The SOP relied heavily on the SOP developed for monitoring and sampling Missouri River fishes between 2003 and 2013 by Welker and Drobish (2016), and includes protocol with collecting information on length, frequency, distribution, and catch per unit effort (CPUE) for all sturgeon species (Appendix I, Attachment 1). To address the unique sampling objectives of this study, highlights and modifications to the Welker and Drobish (2016) SOP are detailed below. Therefore, if not specified below, refer to Welker and Drobish (2016).

Field Measurements and Data Collection Procedures

To maximize efficiency of limited sampling resources, a stratified random approach will be used to guide sampling efforts through the habitat classification hierarchy (Welker and Drobish 2012) to avoid oversampling in habitats where age-0 sturgeon (<110 mm) are not likely to occur (based on Pallid Sturgeon Population Assessment Program [PSPAP] capture data collected from 2003 to 2013 in segments 10, 13, and 14 and existing HAMP data). Sampling will occur at the following Macro, Meso, and Micro habitats (during situations of extreme low or high water stages additional habitats may be sampled but only after agreement with all sampling crews and project manager to ensure sampling consistency):

Macro Habitats: ISB and CHXO
Meso Habitats: CHNB, ITIP, and BARS
Micro Habitats: Based on known age-0 sturgeon captures and available habitat types within each bend, sampling will focus on the first digit of the of the six-digit micro code. Proportional sampling of each microhabitat if available (first digit), will follow the percent of habitat type counts within each bend. The second and third digit will be recorded based on site specifics, and the last three digits of the micro code will be randomly selected in the field based on the available habitat.

First Digit: (micro habitats selected based on previous age-0 sturgeon capture data)

1 L-Dike
2 Wing Dike
4 Rootless Dike
6 Channel Sand Bar (1 Sampling Unit = 0.25 miles of bar length)

Example:

Bend 1: 4 miles * Sampling effort, 4 trawls/gear/mile. = 32 minimum total trawls each sampling period.

Habitat (Sampling Unit)	Counts	% of total	# trawls
L-Dike	3	17.6%	6
Wing Dike	12	70.6%	23
Rootless Dike	1	5.8%	2
Sand Bar	1	5.8%	2

Fishing gears will follow the original HAMP schedule with two variations on a small-mesh trawl; one to sample in deeper water habitats (OT04) and one in shallow water habitats (PT02/OT02). Based on results from Ridenour and Hill (2010), a target sampling intensity of 4 sites per mile should be completed for each bend per sampling period. A minimum of 4 trawls per mile for each bend will be deployed in depths ranging from 1.5 to 4 meters. Trawl depths should not exceed 6m, if depths exceed this, an alternate site should be selected by the crew leader. An additional 4 trawls per mile for each bend will be deployed at 0.5 to 1.5 m of average depth. If depths do not meet these requirements, it will be considered unavailable and a sample will not be taken at the site. When bow trawling depths less than 1.5m, a bridal rope length of 12.2 to 15.2m may be used to maximize trawl effectiveness. Each control and treatment bend will be sampled during a period with similar environmental conditions (e.g., non-flood) (each bend will be sampled in its entirety within two weeks). Re-sampling of bends will occur monthly from May through September. Crew leader judgment will be important to determine if more sampling is required to adequately represent the fishes in any single bend during any sampling period.

Data collection and handling procedures will follow in accordance with the Missouri River Standard Operating Procedures for Fish Sampling and Data Collection (Welker and Drobish 2012) unless otherwise stated.

Age-0 sturgeon > 50mm will be measured and recorded by fork length to the nearest millimeter when a defined fork is present. Total length to the nearest millimeter, minus the filament, will be measured and recorded for all age-0 sturgeon < 50mm.

Each age-0 sturgeon genetics sample will include a completed genetics card which must contain the following information: Genetics vial #, Datasheet #, Fish ID #, Study Bend, River Mile, Date of Capture, and Length (denoting total length or fork length). Each age-0 sturgeon genetics sample should be in its own individual packaging (zip top bag), which includes the completed genetics card and 2ml genetics vial.

Physical monitoring will also occur, and some physical measures are noted here because they pertain to the modified trawl protocol (for more details, see Section E.3.3.2.1). Water depth, in meters will be measured at the beginning, middle, and end of each trawl run with a depth finder. Water current velocity will be measured near bed (also commonly called bottom velocity) at the middle of trawl run during the following situations:

- on at least 25% of trawl runs, distributed among trawl runs to be representative of and reflect habitat types (1st digit of micro code) sampled.
- on all deployments when age-0 sturgeon are collected

Water turbidity (NTU) measurements and substrate composition estimates are not required.

E.1.3.3.2 Physical Monitoring

Characterizing the geomorphic and hydraulic changes resulting from design features and understanding how changes relate to the capture of young-of-year sturgeon is crucial to the assessment of IRC habitats. Use of hydroacoustic tools to develop high-precision models of depth and velocity magnitude and direction will allow quantification of habitat conditions within both treatment and control bends with the intent of relating those conditions to the biological sampling.

The objective of the physical habitat data collections is to adequately characterize the hydrodynamics of interception habitat treatment and control bends through field surveys of depth and velocity to allow incorporation into 2D hydrodynamic models. This physical habitat data will then be compared with biological sampling data to increase our understanding of where and why age-0 sturgeon are captured and thought to successfully transition from the free-drifting embryo stage to the benthic exogenously feeding stage.

Data Collection Procedures

Hydroacoustic instruments will be used to measure and characterize the hydraulic conditions at IRC treatment bends, both pre- and post-construction, and Missouri River mainstem control bends. Instruments to be used will consist of survey-grade single beam echosounders (single-beam) and acoustic Doppler current profilers (ADCP) georeferenced using real-time kinematic global positioning systems (RTK GPS) or differential global positioning systems (DGPS). The most recently approved USACE digital survey maps will be used to plan transects at survey locations. Sampling transects will be generated between a 20-40-m spacing and oriented perpendicular to the recommended navigation sailing line of the Missouri River. Transect spacing will depend upon the particular site and should provide sufficient spatial coverage for creating continuous surface maps of depth, elevation, and velocity given the expected amount of spatial variation due to site specific features as well as variation expected under variable discharges. Repeat surveys will be conducted at each site utilizing the same transect design for subsequent surveys. Figure E 1 illustrates an example reach with transects spaced at 20-m intervals perpendicular along the recommended sailing line. Additional longitudinal survey lines along the banks and in the thalweg may be used to improve accuracy of continuous surface maps.

The frequency and timing of surveys will largely depend upon flow and water levels. At a minimum, one survey per site per year will take place between May-August, as close to assumed or known times of larval drift as possible. However, since it is likely that at “ideal” flow conditions, or flow conditions at which larval drift is believed to be occurring, areas of shallow depth will occur and hinder the ability of a survey vessel to measure depth and velocity, it would be advantageous to conduct multiple surveys per year per site. At least one survey should take place at flow high enough to adequately capture the elevations of areas too shallow to measure during typical larval drift flows. Additional surveys during assumed or known times of larval drift should focus on ADCP collection to characterize the hydrodynamics that occur during these critical time periods.

The data collected at multiple flows will be beneficial during the construction and development of hydrodynamic models of the surveyed reaches. Surveys during high flow will promote the development of accurate terrain models which serve as the basis for the hydrodynamic model, while measured water surface profiles and velocities at more relevant flows will allow for meaningful calibration and validation of the models. A shift in the timing and frequency of surveys may occur as lessons are learned about the time it takes for sites to develop. Data collection will proceed at least one year in advance of design implementation for IRC sites to allow for development and analysis of the pre-construction site model. This timing is consistent with the biological monitoring effort associated with the staircase design (Table E 1).

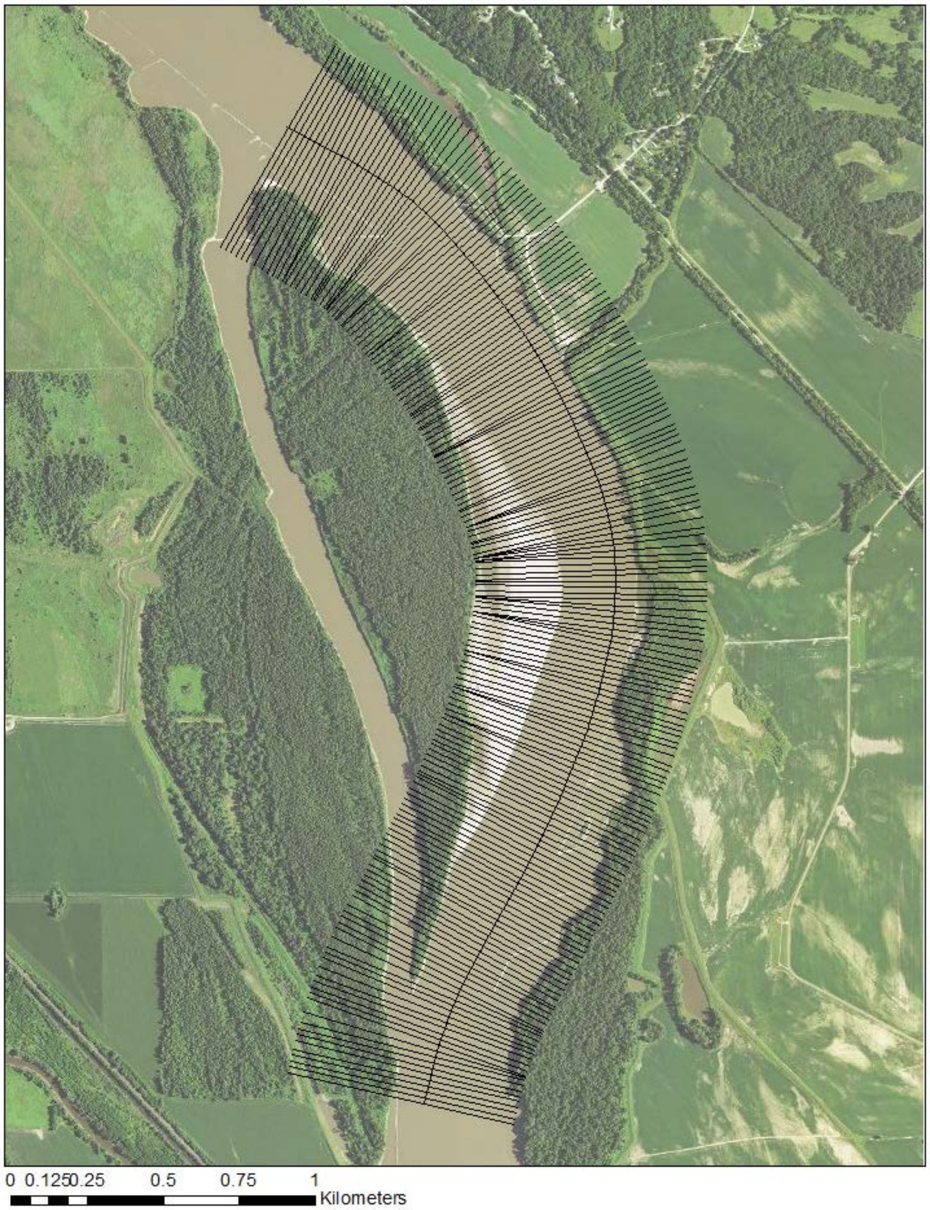

Figure E 1: Example survey reach showing 20-m spaced transects perpendicular to the recommended sailing line.

E.1.3.4 Data Analysis Tasks

E.1.3.4.1 Biological Data Analysis

The analysis of the IRC experiments starts with a data summary to obtain the CPUE at the site level each year because the site is the unit of analysis. The CPUE at the site level was computed as

$$CPUE_{ij} = \frac{\sum_{trawls} Fish_{ij}}{\sum_{trawls} Area_{ij}}$$

where (i, j) refer to site i in year j.

The statistical model for the staircase design (also known as the stepped-wedge design in clinical trials) is discussed in Walter (2008) and Hussey et al (2007). A general linear model can be fit:

$$CPUE_{ij} = \mu + s_i + t_j + (st)_{ij} + I(ij)T + \varepsilon_{ij} \qquad (1)$$

where $CPUE_{ij}$ is the catch per unit area in site i in year j; μ is the overall grand mean; s_i is the effect of site i; t_j is the common year effect; $(st)_{ij}$ is the interaction term; $I(ij)T$ represents the treatment effect – the $I()$ term is 1/0 if the treatment is active/not active in site i in year j, the estimate of T represents the treatment effect; and ε_{ij} represents measurement error and other sources of random noise. This model can be fit with most statistical packages (such as R) and sample code is available in Sub-Attachment 1A.

This analysis can be performed each year after the first IRC restoration habitat is constructed and monitored.

E.1.3.4.2 Physical Data Analysis

Physical Model Development

Data collection will support the development of 2-dimensional hydrodynamic models which will serve as the primary mode for processing, quantifying, and analyzing the physical habitat data at treatment and control sites. The benefits of analyzing physical habitat data through the development of computational hydrodynamic models versus observation of the collected data with a static terrain model using a geographical information system (GIS) is the flexibility afforded by the computational model in predicting and observing the fluctuations of depth and velocity at environmental conditions beyond those during the time of the survey. Analyses are not limited to the flows at which the surveys took place. However, a considerable more amount of time is spent in model development.

Models will be developed using the Surface-Water Modeling System (SMS; Aquaveo, LLC) or comparable graphical interface. A numerical model such as Adaptive Hydraulics (AdH), or comparably advanced model (e.g. SRH-2D, TUFLOW, etc.), will be used to run simulations of 2-dimensional flow through the bends to quantify depth and velocity at flows most relevant to larval drift.

Analysis - Pre-Construction Assessment and Design

Pre-construction surveys will be used to develop models of the sites at "existing conditions". The existing conditions model will serve as the baseline for each site against which the change in habitat is measured and serve as the foundation for the interception habitat design to be built from. A calibrated model can then use specific metrics, under certain assumptions, to approximate how effective interception currently is at a site and evaluate the amount of beneficial habitat that exists. Various engineering design alternatives should be incorporated into the existing conditions model by adjusting the model geometry and/or model input controls to represent the geomorphic or hydraulic transformations expected to occur as a result of the design features. These design alternatives can then be evaluated using the previously defined interception and habitat metrics and compared to the existing conditions model in an attempt to identify designs that improve those metrics.

The particle tracking model (PTM), a module within SMS, is a tool that should be used to provide a metric for conceptualizing and estimating larval interception within a model. PTM can be used to simulate the transport of drifting larval fish by using particles with simplified characteristics in conjunction with the hydrodynamic outputs from AdH or other hydrodynamic model code. Interception can be estimated by quantifying the number of particles entering into the area of interest and comparing to the total number of particles in the simulation to obtain a proportion of particles intercepted. This metric is useful for comparing various design alternatives under the same environmental conditions to evaluate which designs will potentially increase the portion of particles intercepted into the desired area. Additionally, design alternatives can be compared through the amount of beneficial habitat that is created based on specific depth and velocity criteria.

Analysis - Post-Construction Assessment and Design

Monitoring will be conducted following habitat construction and continue through the end of the study. The time required for full development of an IRC habitat will vary between habitats and designs and will be estimated during the design phase of the project. The timing of the post-construction evaluation will depend upon the time it takes the IRC habitat to develop to the desired state. Terrain models developed from survey data of depth and velocity using GIS are useful tools for tracking the progress of site development and should be used as an initial measure when assessing the state of the IRC habitat.

Once it is identified that the IRC habitat has substantially developed to either the design state, or a state of geomorphic quasi-equilibrium, the monitoring data should be re-incorporated back into the existing conditions models to develop post-construction models of depth and velocity. The post-construction model will be useful for direct comparisons to the existing conditions model and will provide a detailed representation of changes in depth and velocity direction and magnitude that occur at critical flows. Metrics used during the design phase can be re-evaluated using the post-construction models to assess the effectiveness of the design to function as intended and evaluate whether assumptions used in the design should be adjusted for ensuing habitats.

E.1.3.4.3 Predictive models of CPUE using physical data

Physical metrics of interception habitat should be compared with biological sampling data (e.g. CPUE) to evaluate any physical metrics are factors that can be used to predict larval interception on the Missouri River. General linear models comparing CPUE of age-0 sturgeon to physical metrics could be compared using an information theoretic approach to model selection like Akaike Information Criterion (AIC) to determine which physical metrics, if any, are useful predictors of larval interception on the Missouri River.

E.1.4 Schedule

The schedule is expected to follow the coarse schedule shown in Table E 2. Noteworthy is the ramping level of effort associated with the staircase design. When considering construction and monitoring activities, the highest levels of effort are in years 6 and 7 of the monitoring plan.

Table E 2: Schedule for IRC Restoration Habitat Construction and Monitoring

	Year							
	1	2	3	4	5	6	7	8
Construction of IRC Habitat		2	2	2	2	2	2	
Biological Monitoring (Bend)	4	8	12	16	20	24	24	24
Physical Monitoring (Bend)	4	8	12	16	20	24	24	24

E.1.5 Literature Cited

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Ridenour, C.J. and T.D. Hill. 2010. Dalbey Bottoms Pallid Sturgeon habitat rehabilitation monitoring project 2009 field season: pre-construction phase annual report. U.S. Fish and Wildlife Service, Columbia Fish and Wildlife Conservation Office, Columbia, MO. 12p.

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E.1.6 Sub-Attachment 1A – IRC Power Analysis Technical Memorandum

April 15, 2016

Authors: Carl Schwarz and Brian O. Ma

E.1.6.1 Introduction

The Before-After-Control-Impact (BACI) design is the standard design for investigating the effect of a treatment but controlling for temporal effects and site effects. In BACI designs, treatment sites are measured before and after the actual treatment occurs and control sites are also measured in each year. The control sites provide information on temporal trends, so that changes in the treatment site between pre- and post-treatment can be distinguished from the temporal trends.

BACI designs are quite flexible because the number of years measured pre- and post-treatment do not have to be the same, and it is also possible to have multiple sites in both the treatment and control groups. However, BACI designs usually assume that the treatment is applied to all the sites in the treatment group at the same time.

In some cases, it is not logistically possible to apply the treatment simultaneously to multiple sites, and often it is not feasible to do many years of pre-treatment monitoring. Walter et al. (1998) and Hussey et al. (2007) discuss a variant called the staircase (or stepped treatment) design. The staircase design relies on a series of staggered BACI designs where each new treatment (typically) starts one year later. The staircase design implicitly assumes that treatment effects are permanent and persist once the treatment has been applied to a site. Control sites serve as control for all of the treatment sites.

For example, Figure E 2 presents a schematic of one such design involving 6 IRC and their associated control sites. For the construction of IRC habitats, logistical constraints make it difficult to construct more than 1 or 2 habitats in a single year. While there is only one year of pre-treatment monitoring for the first treatment site, successive treatment sites have more than one-year of control monitoring.

The staircase design shown in Figure E 2 can be modified in various ways. For example, it is possible to implement the treatment at more than one site in a year; the number of years monitored before any treatment applied can be increased; control sites can be "paired" with particular treatment sites; treatments can be implemented on a more irregular schedule rather than in successive years.

The statistical model for the analysis of data from a staircase design is discussed in Walter (2008) and Hussey et al (2007) and is shown in model 1:

$$Y_{ij} = \mu + s_i + t_j + (st)_{ij} + I(ij)T + \varepsilon_{ij} \qquad \text{(model 1)}$$

where Y_{ij} is the response in site *i* in year *j;* μ is the overall grand mean; s_i is the effect of site *i*; t_j is the common year effect; $(st)_{ij}$ is the interaction term; $I(ij)T$ represents the treatment effect; the *I*() term is 1/0 if the treatment is active/not active in site *i* in year *j*; and ε_{ij} represents measurement error and other source of random noise. This model is easily fit using most linear model routines in common statistical packages (Annex 1). No modification is needed to deal with the different variants of the staircase design discussed earlier except if control sites are explicitly paired with treatment sites. In this case, an additional term corresponding to the pairing (a blocking term) needs to be introduced as is commonly done for blocked designs.

The staircase design can be considered as a combination of small BACI designs, with each BACI components starting in a new year. Consider the mini BACI design consisting of sites 1 and 2 in years 1 and 2 in Figure E 2. The BACI contrast (which is used to see if there is evidence of a treatment effect) would be computed as $(Y_{11}\text{-}Y_{12})$ - $(Y_{21}\text{-}Y_{22})$, i.e., the differential response from year 1 to year 2 between the treatment and control sites. If we expand each of the *Y*'s in that expression by the model in (1), you see that the s_i terms cancel (the same site is measured in multiple years so a within-site contrast is free of site effects); the t_j terms disappear (the difference between the impact and control site in each year is free of time effects), but the $(st)_{ij}$ and ε_{ij} terms do not cancel. If you are willing to assume that the $(st)_{ij}$ and ε_{ij} terms have mean = 0 then the expected value of the BACI contrast is simply the effect of treatment. The actual computations using all of the cells in the design are more complex but the same analogies hold. Notice that the $(st)_{ij}$ and ε_{ij} are completely confounded with each other and represent the noise that reduces the ability to detect the treatment effect.

The power of the staircase design to detect the treatment effect depends on a number of factors:

- the size of the effect – Larger effects are easier to detect than smaller effects
- the noise in the response – Higher amounts of noise make it harder (reduce the power) to detect effects,
- the alpha level – usually set to 0.05; and beta level – usually set to 0.2
- the sample size – larger sample sizes lead to higher power to detect effects.

More specifically in the case of the IRC experiments, the power is a function of the number of IRCs proposed; how quickly the IRCs come on line; the number of control sites; and the length of time these sites are monitored.

The noise in a staircase design consists of three sub-components, some of which have no impact on the power.

First is the year-to-year variation in the response that acts in common on all sites. For example, a particular year may experience river conditions for successful spawning and so the number of young fish seen in the sampling trawls tends to be higher in all bends. Because both treatment and control sites are measured on all years, the year-to-year variation has no impact on the power because in the analysis this term “cancels” as shown earlier.

Second is the site-to-site variation. A particular bend may have some local characteristics that cause it to have higher catches than other bends in a consistent fashion over time. Because both treatment and control sites are repeatedly measured over time, pre- vs. post-treatment-year comparisons will again be “free” of site-effects, and again the site-to-site variation has no impact on the power.

Third is the site-year interaction variation, which represents the non-parallelism of response over time among the sites. For example, we assume that temporal effects have the same effect on all sites (parallel responses), but there may be some site-specific factors that inhibit or amplify temporal trends and so a non-parallel response is observed. The site-year interaction (the residual error in model 1) is the determining factor for the power of a staircase design.

A power analysis will require information on these noise components – in particular the site-year interaction variation.

E.1.6.2 Estimation of Variance Components

In order to estimate the power of a proposed IRC design we need estimates of the site-year interaction term. A site in the IRC experiments is the bend, which then becomes the unit of analysis; i.e., trawl data must be summarized to the bend-level. In order to estimate this term, we need a sample of bends that have been measured in multiple years. It is not necessary for all bends to be measured in all years.

We received data on trawls conducted as part of the HAMP and MDC programs from 2005 to 2009 and 2014 to 2015. Each trawl has information on the bend in which it was measured, the area of the trawl and the number of fish captured in the trawl (Table E 3), and macro/meso habitat of the trawl. Because the bend will be the unit of analysis, the data was summarized to the bend level and the CPUE at the bend level was computed as

$$CPUE_{ij} = \frac{\sum_{trawls} Fish_{ij}}{\sum_{trawls} Area_{ij}}$$

This gives one number per bend in each year that it was measured.

We begin by pooling all trawls over all habitat types.

Some bends were measured in both the HAMP and MDC program and a summary of their results are shown in Table E 4. The CPUE from the MDC program is much higher than that from the HAMP. Based on discussions with the working group, it was decided that the MDC data does not represent realistic values for CPUE going forward. Consequently, it was decided to only use the HAMP data to estimate the variance components.

Many environmental effects operate multiplicatively rather than additively. For example, a year effect may double the CPUE in all sites raising a CPUE from .001 to .002 fish/m^2 and from .004 to .008 fish/m^2. Consequently, a log-transformation will convert the multiplicative year effect to additive effects on the log-scale (e.g., a doubling will simply add log(2)[1]=.7 to all values). A timeplot of the log(CPUE) from the HAMP data is shown in Figure E 3. Following the standard convention, all CPUE values were adjusted by ½ of the smallest non-zero CPUE value to prevent taking log(0). Both site and time effects are evident but there is a large amount of non-parallelism in the response.

A linear mixed model was used to estimate the associated variance components. In a short hand (*R* type) syntax, the model was

$$\log(CPUE) = Site + Time + (SiteTime)$$

Estimated variance components are shown in Table E5. . We see that the Site-Year interaction variance component is quite large relative to the effects of site or that of year. This can be seen in Figure E 3 in the generally weak parallel effects of site or year.

[1] log(x) implies natural logarithms unless otherwise indicated.

E.1.6.3 Power Analysis

These variance components were used to estimate power based on the results of Hussey et al (2007) but using the methods of Stroup (1999)[1]. The basic idea of Stroup (1999) is that the expected values (i.e., incorporating the treatment effects but no random noise) are analyzed as data using the variance components estimated from a pilot study. The resulting F-statistic in the ANOVA table provides information to estimate the power.

We computed the power for the IRC experiments under a number of scenarios involving:

- between 5 and 15 years of monitoring;
- between 6 and 12 IRC sites (plus the same number of control sites)
- between 1 or 2 IRC sites constructed per year
- effect sizes from a 10% to a 100% increase in mean CPUE in IRC sites.

Because the analysis took place on the log-scale, treatment effects can be easily specified using the relationship that a 10% increase in response corresponds very closely to a 0.1 increase on the log-scale.

The specific results for one such power analysis are shown in Table E 6. We see that this proposed design has an approximate 80% power to detect an 80% increase in CPUE at alpha=0.05. Figure E 4 illustrates the relationship between the number of IRC sites, the number of years monitoring, and the power for various effect sizes. Generally, effect sizes less than a 50% increase cannot be detected even with 15 years of monitoring and 12 IRC sites. However, acceptable power (around 80% power) is generally achievable for an effect size of 75% and at least 10 years of monitoring at a construction rate of one IRC site per year.

Over longer periods of monitoring, there is a negligible benefit of implementing 2 IRC-control pairs/year rather than 1 IRC-control pair/year (while keeping the total length of monitoring and total number of sites the same), as shown in Figure E 5. However, the benefit of doubling the rate of IRC construction increases in sampling designs where the number of monitoring years is small. If only one IRC-control pair is implemented per year, it may not be possible to implement all of the proposed IRC sites. For example, it is not possible to fully implement 6 IRC-control pairs with only 5 years of monitoring unless 2 IRC/year are implemented. However, once there are 10 or more years of

[1] The method of Stroup (1999) gave identical results to that of Hussey et al (2007) after correcting an error in Hussey et al (2007) power formula.

monitoring planned, there is no particular advantage to implementing the IRC at a faster rate.

The limiting factor to the power of the design is often the Site-Year interaction variance component. One potential reason why the responses are not-parallel over time is perhaps that the different habitat types respond differently over time and so the overall response at the bend level has extra noise. We investigated this by fitting the linear mixed model to only the trawls at BARS or CHNB meso habitat types (these two meso habitat types account for the majority of the habitat). The variance components from these separate habitat types are shown in Table E 7, but there is no evidence that partitioning by habitat type will lead to improvements as the Site-Year variance components are larger than when pooled together! A power analysis (not shown) indeed shows a reduced power.

Because we summarized CPUE to the bend level, we could not separate the (Site-Year) interaction variance component from measurement error. We can fit a more complex linear mixed effects model to separate out the two components (Table E 8). The two sets of variance components are not directly comparable because the logarithm of the CPUE computed by summing the number of fish and area does not separate into the individual CPUEs in the same fashion as would a regular mean, but this does seem to suggest that trawl-to-trawl variation is large. However, because the average number of trawls per bend is around 42, computing the average CPUE at the bend level reduces the impact of the trawl-to-trawl standard deviation by a factor of around $\sqrt{42}$ [1]. Consequently, the total variation at the bend-year level is mainly due to the Site-Year interaction. Additional sampling (i.e., more trawls) would only lead to minor reductions in the Site-Year variance component and negligible impact on power.

This power analysis assumes that control bends are selected at random from all possible bends. However, power could be increased if control bends were selected to be more similar to treatment bends. This should result in more parallel responses. Unfortunately, we currently lack any information to investigate this alternative.

E.1.6.4 Summary

This report estimated the variance components from the HAMP trawl data and used it to estimate the power of a potential IRC design. This is only an estimate of the power

[1] This is analogous to the fact that the variance of the sample mean is found as $sd(\bar{Y}) = \frac{sd(Y)}{\sqrt{n}}$

and the uncertainty in the variance components has not been incorporated. Consequently, the actual power may be different than forecasted.

Discussions of the analysis with biologists and managers suggested two options, both of which generate 80% statistical power with an effect size of 80% increase in CPUE:

A. 12 IRC-control site pairs implemented over 7 years at the rate of 2 sites / year, with 7 years of total monitoring;
B. 6 IRC-control site pairs implemented over 7 years at the rate of 1 site / year, with 12 years of total monitoring

Generally, power increases with the number of IRC sites and the number of years of monitoring. The benefit of option A is that it provides both a more rapid rate of learning (7 years vs 12 years), and potentially greater cumulative biological benefits (if the IRC sites are indeed effective). The tradeoff between the number of IRC sites and the number of years of monitoring will depend on the relative costs of both activities and was not pursued here. Adding more trawls to the bends is unlikely to lead to useful improvements in power because there is already substantial effort in each bend (mean of ~42 trawls per bend) so that the trawl-to-trawl variation has been "reduced" averaging over all trawls.

E.1.6.5 Literature Cited

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Table E 3: Summary of trawls by bend and year. HAMP and MDC data pooled.

Bend_ID	2005	2006	2007	2008	2009	2014	2015
375	0	0	40	30	40	0	0
379	0	0	0	0	0	801	514
381	0	1	37	33	38	0	0
390	0	0	44	35	39	0	0
391	0	0	0	0	0	8	3
392	0	0	0	0	0	57	37
393	0	0	0	0	0	43	38
394	0	0	0	0	0	170	101
395	0	0	0	0	0	35	19
396	0	4	57	34	28	45	34
397	0	0	0	0	0	70	36
398	0	2	95	74	82	88	48
399	0	0	0	0	0	14	0
403	0	0	0	0	0	1	0
423	0	0	0	0	0	60	62
424	4	9	43	26	45	94	98
425	0	0	0	0	6	107	610
426	0	0	0	0	8	131	128
427	0	0	0	0	0	66	76
428	0	0	0	0	0	32	35
429	0	0	0	2	1	92	88
430	5	20	43	28	46	76	59
432	0	17	48	28	31	0	0
433	0	0	0	0	1	0	0
434	0	0	0	0	2	0	0
442	0	14	42	22	31	0	0
443	0	0	0	0	3	0	0
444	0	11	40	21	40	0	0
445	0	0	0	0	3	0	0
446	0	0	0	2	10	0	0
447	0	0	0	9	24	71	42
448	0	0	0	0	7	77	60
449	0	0	0	0	0	65	37
450	0	0	0	0	0	138	83
451	0	0	0	0	0	97	74
452	0	12	52	24	33	46	42
453	0	0	0	0	0	76	63
454	0	0	0	0	0	4	0
461	0	0	0	0	1	0	0
465	0	0	0	0	0	180	340
466	0	0	41	20	28	0	0
467	0	0	0	0	0	379	525
468	0	0	0	0	0	110	62
469	0	0	0	0	0	39	27

470	0	0	0	0	0	63	32
471	0	0	0	0	0	116	73
472	0	0	0	0	0	60	40
473	0	0	38	14	20	57	50
474	0	0	0	0	0	45	24
475	0	0	0	0	0	61	26
476	0	0	0	0	0	120	73
482	0	0	39	20	25	0	0
489	0	0	43	18	33	0	0
494	0	0	0	0	0	4	0
495	0	0	0	0	0	38	24
496	0	0	0	0	0	40	25
497	0	0	0	0	0	43	28
498	0	0	0	0	0	44	28
499	0	0	0	0	0	70	38
500	0	0	0	0	0	55	47
501	0	0	0	0	0	23	15
502	0	0	0	0	0	29	16
503	0	0	0	0	0	48	34
506	0	0	48	15	25	0	0
510	0	0	44	17	43	0	0

Table E 4: Comparison of CPUE from bends simultaneously measured from HAMP and from the MDC programs.

	Bend_ID	Year	Source	total.Effort	total.numfish	CPUE
48	425	2009	2005-2009 HAMP	8277.0	0	0.0000000000
49	425	2014	2014 HAMP	41792.2	32	0.0007656931
50	425	2015	2015 HAMP	40336.1	40	0.0009916675
51	425	2015	2015 MDC	34507.8	139	0.0040280748
116	467	2014	2014 HAMP	14348.6	5	0.0003484661
117	467	2014	2014 MDC	21232.8	175	0.0082419653
118	467	2015	2015 HAMP	7070.2	0	0.0000000000
119	467	2015	2015 MDC	35330.4	191	0.0054061092

Table E 5: Estimated variance components from fitting a linear mixed model to log(CPUE)

Component	Std.Dev.
Site	0.373
Year	0.508
Site-Year	1.311

Table E 6: Estimated power from two sampling designs: A) 12 IRC-control pairs implemented over 7 years (i.e., two new IRC-control site pairs per year) and 7 years of total monitoring and B) 6 IRC-control site pairs implemented over 7 years (i.e., one new IRC site per year) and 12 years of total monitoring. See Figure E 1. Variance components from Table 3 were used to estimate the power using the method of Stroup (1999). An increase of .1 on the log-scale corresponds to a 10% increase in CPUE as the result of treatment. The power was found for one-sided tests (i.e., to look for an increase in CPUE) at alpha=0.05. If there is no treatment effect (i.e., effect 0.0) the experiment will still detect an effect 5% of the time – these are false positives.

Effect Size (Δ CPUE)	Power with Sampling Design A	Power with Sampling Design B
0.0	0.050	0.050
0.1	0.094	0.091
0.2	0.162	0.154
0.3	0.256	0.239
0.4	0.372	0.346
0.5	0.502	0.467
0.6	0.631	0.590
0.7	0.747	0.705
0.8	0.840	0.803
0.9	0.907	0.878
1.0	0.950	0.930

Table E 7: Estimated variance components when a separate analysis is done on each habitat type.

BARS habitats

Component	Std.Dev.
Site	0.58
Year	0.65
Site-Year	1.54

CHNB habitat

Component	Std.Dev.
Bend_ID	0.64

Year	0.72
Site-Year	1.42

Table E 8: Estimated variance components when trawl measurements are used directly in the linear mixed model (eq. 1). The average number of trawls/bend-year combination is around 42. This implies that the total variation when summarized at the bend-year level would be computed as: $\sqrt{.24^2 + \frac{1.06^2}{42}} = .2904$ which is not much larger than the Site-Year interaction term. Sampling more trawls/site will result in negligible improvements in the power.

Component	**Std.Dev.**
Site-Year	0.242
Site	0.115
Year	0.129
Trawl	1.061

Sampling Design A

	Year						
Site	01	02	03	04	05	06	07
01	C	T	T	T	T	T	T
02	C	C	C	C	C	C	C
03	C	T	T	T	T	T	T
04	C	C	C	C	C	C	C
05	C	C	T	T	T	T	T
06	C	C	C	C	C	C	C
07	C	C	T	T	T	T	T
08	C	C	C	C	C	C	C
09	C	C	C	T	T	T	T
10	C	C	C	C	C	C	C
11	C	C	C	T	T	T	T
12	C	C	C	C	C	C	C
13	C	C	C	C	T	T	T
14	C	C	C	C	C	C	C
15	C	C	C	C	T	T	T
16	C	C	C	C	C	C	C
17	C	C	C	C	C	T	T
18	C	C	C	C	C	C	C
19	C	C	C	C	C	T	T
20	C	C	C	C	C	C	C
21	C	C	C	C	C	C	T
22	C	C	C	C	C	C	C
23	C	C	C	C	C	C	T
24	C	C	C	C	C	C	C

Sampling Design B

	Year											
Site	01	02	03	04	05	06	07	08	09	10	11	12
01	C	T	T	T	T	T	T	T	T	T	T	T
02	C	C	C	C	C	C	C	C	C	C	C	C
03	C	C	T	T	T	T	T	T	T	T	T	T
04	C	C	C	C	C	C	C	C	C	C	C	C
05	C	C	C	T	T	T	T	T	T	T	T	T
06	C	C	C	C	C	C	C	C	C	C	C	C
07	C	C	C	C	T	T	T	T	T	T	T	T
08	C	C	C	C	C	C	C	C	C	C	C	C
09	C	C	C	C	C	T	T	T	T	T	T	T
10	C	C	C	C	C	C	C	C	C	C	C	C
11	C	C	C	C	C	C	T	T	T	T	T	T
12	C	C	C	C	C	C	C	C	C	C	C	C

Figure E 2: Staircase designs A and B. Staircase design A has 12 treatment sites and 12 control sites all measured for 7 years. The treatment (T) is applied to sites 1&3, 5&7, 9&11, 13&15, 17&19, 21&23 starting in years 2, 3, 4, 5, 6, and 7 respectively. Measurement continues in all sites until year 7. Control sites (even numbered sites) are left untreated (C) and measured in all years. Staircase design B has 6 treatment sites, 6 control sites all measured for 12 years. The treatment (T) is applied to sites 1, 3, 5, 7, 9 and 11 starting in years 2, 3, 4, 5, 6, and 7 respectively. Measurement continues in all sites until year 12. Control sites (even numbered sites) are left untreated (C) and measured in all years.

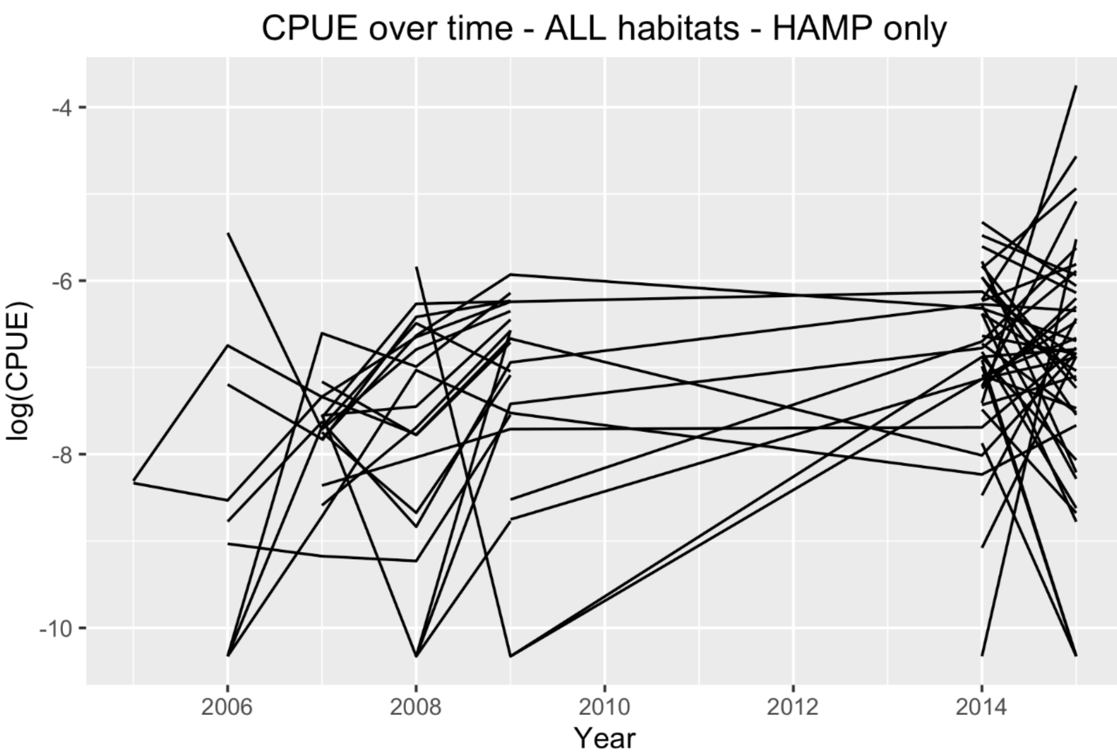
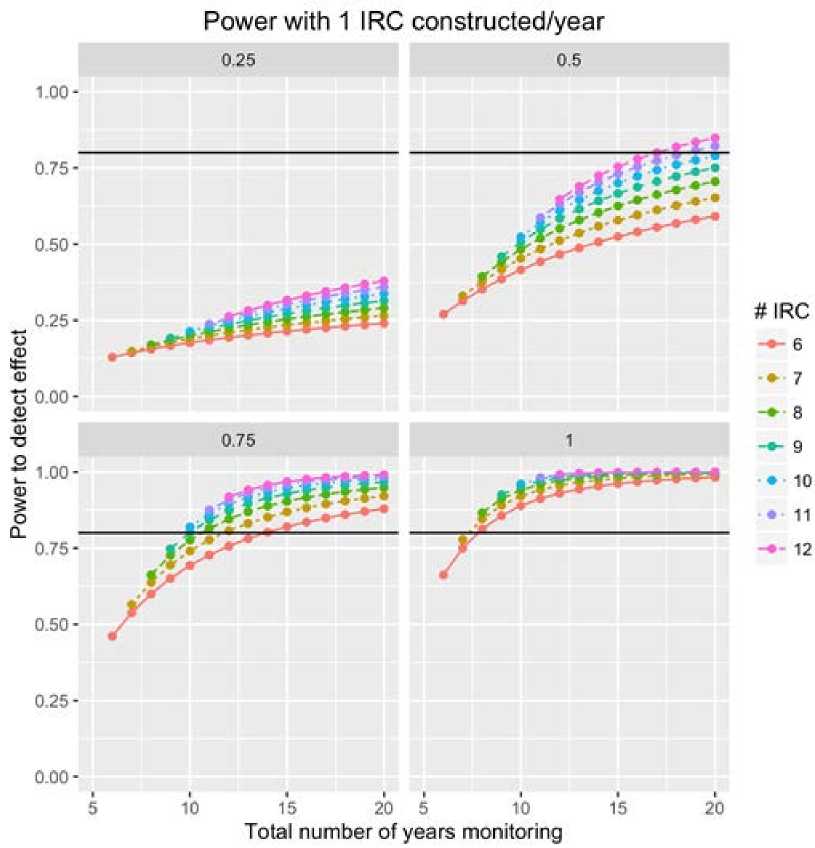


Figure E 3: Time plot of log(CPUE) for each bend from the HAMP data only. ½ of the smallest non-zero CPUE was added to all points to prevent taking log(0).

1 
Power with 1 IRC constructed/year
0.25
0.5
0.75
1
1.00
0.75
0.50
0.25
0.00
Power to detect effect
5
10
15
20
Total number of years monitoring
IRC
6
7
8
9
10
11
12

2

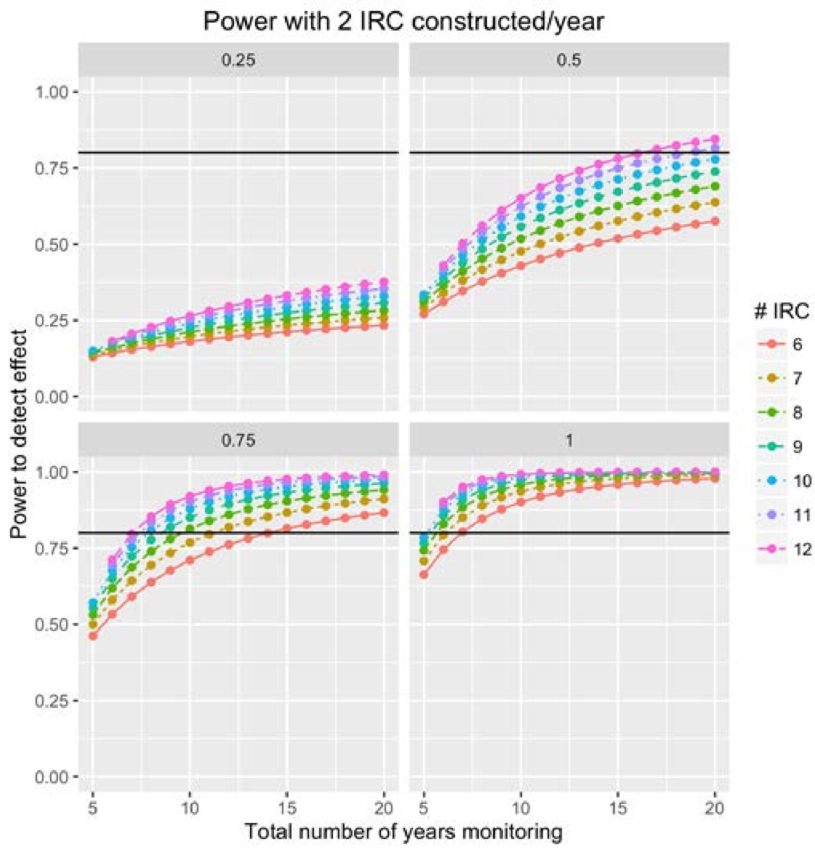


Figure E 4: Comparisons of power for different sampling designs. Top panel of four graphs shows statistical power when the number of IRC sites is varied from 6 to 12 with 5 to 20 years of monitoring and one IRC added per year. The four panels correspond to a 25%, 50%, 75%, or 100% increase in mean CPUE in the IRC sites. Lower panel of four graphs shows the same information with two IRC sites constructed per year.

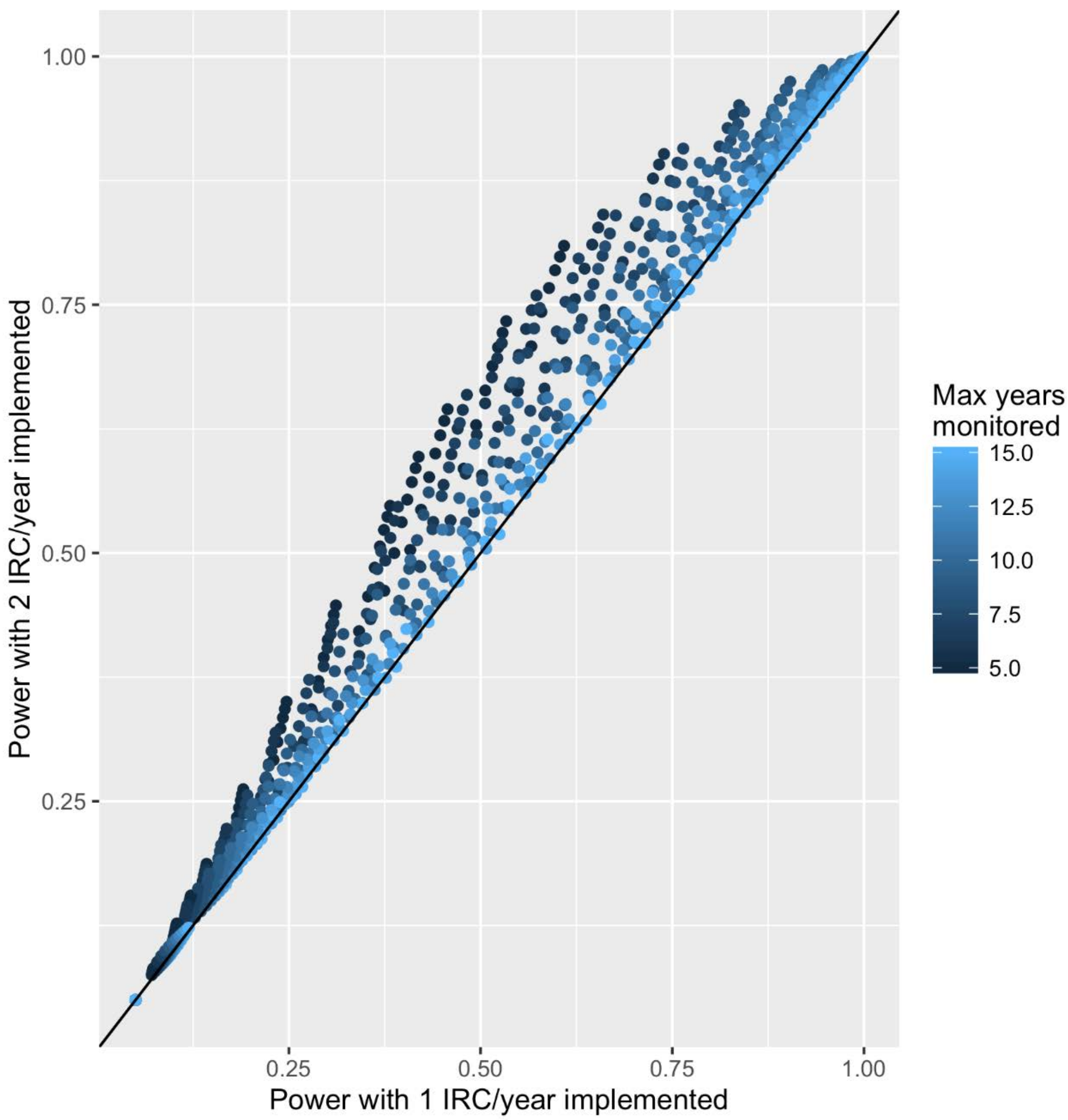


Figure E 5: Impact on power of increasing the number of IRC implemented per year from 1 to 2. Generally speaking the power impact is negligible except in cases where the number of monitoring years is small, and if only one IRC is implemented per year, it is not possible to implement all of the proposed IRC sites. For example, it is not possible to fully implement 6 IRC sites with only 5 years of monitoring unless 2 IRC/year are implemented.

Sample Data:

```
Site      Year      Treatment      Response
1    A     1        C          0.2543600359
2    A    2         C          0.5254238276
3    A    3         C          -3.4408767115
4    A    4         C          -5.0149562110
5    A    5         C          -8.6226452115
6    A    6         C          -1.3488555218
7    A    7         C          -0.0004504614
8    A    8         C          0.5050409681
9    B    1         C          0.5761786426
10   B    2         T          21.5507582294
11   B    3         T          18.6493742449
12   B    4         T          12.3983730044
13   B    5         T          18.0991001401
14   B    6         T          4.6648869696
etc
```

E.1.6.6 Annex 1 – R code for stair case design

Sample data and sample R code to analyze a staircase design. The data need 4 columns corresponding to the site (declared as a factor), the year (declared as a factor), a treatment indicator (declared as a factor), and the numeric response variable. In the portion of the raw data shown, the design is monitored for 8 years. Site A is a control site for all 8 years. Site B is control for year 1, and then has the treatment applied starting in year 2. Additional sites are added as needed.

The *R* code loads the required packages; declares the appropriate factors; and then fits a general linear model with *Site* declared as a random factor. The *lm()* function could also be used with site declared as a fixed factor with identical results in the case of a complete design, but will give different results if the design has missing data. The *lsmeans* package is then used to estimate the treatment effect.

```
library(lmerTest)
ibrary(lsmeans)

sample$Site <- factor(sample$Site)
sample$Year <- factor(sample$Year)
sample$Treatment <- factor(sample$Treatment)
sample.fit <- lmer(Response ~ Treatment+Year +(1|Site), data=sample)
anova(sample.fit)
sample.fit.lsmo <- lsmeans::lsmeans(sample.fit, ~Treatment)
sample.fit.pairs <- pairs(sample.fit.lsmo, infer=TRUE)
cld(sample.fit.lsmo)
vc <- as.data.frame(VarCorr(sample.fit))
vc
```

Attachment E.2 – Monitoring Plan for Existing SWH Projects

DRAFT/Pre-Decisional/For Discussion Purposes Prepared: May 25, 2016
By: Todd Gemeinhardt, , Dave Marmorek and Craig Fischenich

E.2.1 Introduction

E.2.2 Hypotheses

E.2.3 Approach

E.2.3.1 Sampling Design

E.2.3.2 Site Selection

E.2.3.3 Data Collection Tasks

E.2.3.4 Data Analysis Tasks

E.2.4 Schedule

E.2.5 References

Appendix F. Cost Estimates and Prioritization of Level 1 and Level 2 Science Components

This appendix compiles cost estimates for level 1 and level 2 science components for adaptive management of pallid sturgeon in the Missouri River. The objective is to provide general guidance of the order of magnitude of investment in science likely to accompany the Missouri River Science and Adaptive Management Plan (MRSAM) plan and to indicate how the investment would likely be distributed over time. It should be noted that as adaptive management and learning progress, some of these science components will no longer be necessary because the associated hypotheses are shown to be invalid. Similarly, new hypotheses may be introduced to explain documented changes in pallid sturgeon demographic rates or population, thereby requiring new science components with specific costs and timeframes. Hence, the cost estimates provided here should be viewed as general guidelines that will inevitably change over time.

F.1 Approach

Sequence, timing, and duration of each level 1 and level 2 science component were originally estimated assuming that all Level 1 activities occurred essentially in parallel. Subsequently the start dates of some Level 1 activities were shifted into the future, through a prioritization approach that is described below in section F.4 of this Appendix. The start and stop dates for each component were exported from the charting software to a spreadsheet and were used to calculate annual cost for the duration of each component. Annual cost for each component was estimated based on 2016 net costs to agencies. The cost estimates are based on experience with actual research and monitoring costs, and assumptions about whether each component might be pursued by the USACE, or contracted to Federal or State agencies, or universities.

Several important assumptions and caveats apply to these estimates:

- Science components are aggregated by “big questions”; big questions may include several hypotheses that have related science questions, and are therefore effectively pursued as a group. Some science components within a group have been prioritized to occur within the first five years, while others are assumed to occur later.
- Cost estimates begin in 2014 to reflect the fact that some science components are already under way.
- The science component costs do not include construction. Some laboratory/mesocosm studies may be more efficiently pursued if carried out in new facilities, however these estimates assume existing agency and university facilities

will be used. Similarly, estimates for level 2 field-experiment implementations are limited to the science components and do not include construction (of spawning habitat or interception-rearing complexes, for example) that will be accounted elsewhere in the Missouri River Recovery Management Plan (MRRMP).

- Science component costs do include estimates of engineering design and feasibility studies for many big questions because those studies are foundational to design and logistics level 2 science components.
- The annual costs are estimated as of 2016 and have not been adjusted for inflation over the time period of the science components.
- The annual costs are estimated as net to the agency that performs the task. Therefore, these estimates underestimate actual costs that will need to take into account complex agency overhead assessment rates. Accounting for increased costs based on overhead rates will be provided elsewhere in the MRRMP.
- The level 1 and level 2 science components outlined here incorporate existing science efforts under the USACE Integrated Science Program (ISP), including the Pallid Sturgeon Population Assessment Program (PSPAP), Habitat Assessment and Monitoring Program (HAMP), Comprehensive Sturgeon Research Project (CSRP), and various other associated USACE-funded research projects.
- Summary estimates include costs for the next generation of pallid sturgeon population monitoring. As indicated in Appendix D, the details of an efficient monitoring program need to be worked out through focused efforts in simulation modeling which will take one or two years to complete, depending on resources available. For the purposes of this appendix we have used the cost of the present PSPAP as an estimate.
- Some level 2 science components have been described in Appendix C but due to high costs and uncertainties are not planned for implementation during the first 15 years and costs are therefore not included in the estimates. These components are indicated as “Not currently planned” in the estimate tables.
- Some level 1 science components involve laboratory or mesocosm experimentation that applies to both the upper river and the lower river big questions. These costs are enumerated in the upper river table but apply to both upper and lower science components.
- Two technical development level 1 components are included at the end of the lower river table. As described in Appendix C, these are 1) development of an optimal population monitoring program and 2) the ongoing synthesis and assimilation of pallid sturgeon data through maintenance of the population dynamics model and database.
- Planning for science needs over a 15 year time frame is inherently uncertain, as new information will inevitably indicate new directions and science needs. The estimates provided here are all linked to specific hypotheses that emerged from the Effects

Analysis process and do not include components that might address fundamental conditions of the river system (for example, discharge and water quality) or research that could anticipate other stressors to pallid sturgeon populations (for example, hybridization, contaminants, or competition).

- The cost estimates provided here do not include level 3 monitoring and assessment. Some management actions are already at level 3 (population augmentation, for example), and others may proceed to level 3 during the 15-year planning interval. Level 3 monitoring and assessment activities are described in Chapter 4; details and associated costs of level 3 monitoring and assessment activities will depend to a large extent on information developed during level 1 and level 2 activities. Cost estimates for level 3 monitoring and assessment activities will be provided elsewhere.

F.2 Results

Table F 1 and Table F 2 show detailed cost estimates by big question, level, and component by year. The estimates extend to 2025 on the upper river (Table F1), reflecting management actions and science components that are anticipated to be completed by that date. Estimates on the lower river (Table F2) extend to 2032 because of the longer time frame associated with level 2 science on interception-rearing complexes and experimental flow releases). Table F 3 summarizes upper and lower river costs by year and adds in estimates of PSPAP costs. Figure F 1 shows a graph of costs by year. Table F 4 and

Table F 5 show the expected timing of each activity during the first 15 years, based on the prioritization efforts described below in section F.4.

Two additional components to the Gantt charts and cost synthesis (tables F2 and F5). These components are intended to address a) the need for scientific contingency funding to address new information and b) the continuing need for concerted efforts in outreach, reporting, and data management.

Table F 1: Cost estimates for level 1 and level 2 pallid sturgeon science components by year, upper river, reflecting prioritization described in section F.4. Shaded rows indicate components that are not currently planned.

Task Name	Begin	End	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Big Question 1: Spawning Cues	2015	2031																		
Level 1	2015	2031																		
Component 1 Design complementary telemetry network	2017	2019	$ -	$ -	$ 340,000	$ 340,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Opportunistic tracking of reproductive behaviors	2015	2025	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm experiments, reproductive behaviors	2022	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Engineering study effects on other authorized purposes	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Experimental flow releases, Fort Peck	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 2: Flow Naturalization and Productivity	2022	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2021	2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Engineering models, interactions authorized purposes	2022	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Screening: limitations of food or forage habitats	2021	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Field studies along gradients, food and forage habitats	2023	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Mesocosm studies: habitat – survival relations	2023	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Design flow experiments	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Experimental naturalization of flows, Fort Peck	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 3: Temperature manipulations at Fort Peck	2015	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Screening: Feasibility, modeling of effects	2022	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 150,000	$ 150,000	$ 150,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2a Screening: Is food limiting to age-0 survival?	2021	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2b Lake Sakakawea conditions limiting, age-0 survival?	2015	2019	$ 80,000	$ 80,000	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3a Field gradient, temperature and food production	2021	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component3b Field experiment dift model validation	2016	2021	$ -	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4a Mesocosm studies: temperature, food, survival	2015	2019	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4b Development rates of embryos, free embryos, larvae	2015	2019	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Construct, test water temperature mechanisms	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Manipulative field experiments with water temperature	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 4: Sediment bypass	2021	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2021	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Feasibility study sediment bypass and turbidity	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Mesocosm study of turbidity-limited survival	2021	2023	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm study of turbidity-limited survival rates	2023	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Pilot test of sediment bypass	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Field experiment sediment bypass and turbidity	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 5: Passage, drift, and recruitment	2016	2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2016	2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1a Model integration, drift and development	2017	2019	$ -	$ -	$ 100,000	$ 100,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1b Modeling location and rate of change of headwaters	2018	2019	$ -	$ -	$ -	$ 100,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2a Patchiness of anoxic zone	2018	2020	$ -	$ -	$ -	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2b Spawning habitat distribution on Yellowstone	2017	2019	$ -	$ -	$ 92,600	$ 92,600	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Experiment drift model validation	2016	2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Mesocosm studies to quantify transport	2018	2021	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2018	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Engineering studies for effects of low flows	2022	2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 100,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6a Drift experiments, Fort Peck flows and drawdowns	2022	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ -	$ -	$ -	$ -	$ -	$ -
Component 6b Adult translocation experiment, Yellowstone	2018	2022	$ -	$ -	$ -	$ 144,592	$ 144,592	$ 144,592	$ 144,592	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 6: Population Augmentation	2016	2044	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2016	2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Feasibility hatchery facilities, operations*	2016	2018	$ -	$ 50,000	$ 50,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Retrospective: survival and hatchery operations	2017	2019	$ -	$ -	$ 96,750	$ 96,750	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Model population sensitivity - size, health, genetics*	2017	2020	$ -	$ -	$ 65,000	$ 65,000	$ 65,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 - Not currently planned	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Experiment with varying size, location of stocking	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
			$ 727,500	$ 962,920	$ 1,657,270	$ 2,197,862	$ 1,042,512	$ 804,512	$ 965,092	$ 1,508,920	$ 1,754,920	$ 1,501,920	$ 704,420	$ 704,420	$ -	$ -	$ -	$ -	$ -	$ -

Table F 2: Cost estimates for level 1 and level 2 pallid sturgeon science components by year, lower river. Shaded rows indicate components that are not currently planned, , reflecting prioritization described in section F.4..

Task Name	Begin	End	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Big Question 1: Spawning Cues	2015	2033																		
Level 1	2015	2038																		
Component 1 Design complementary passive telemetry network	2017	2019	$ -	$ -	$ 345,000	$ 345,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Opportunistic tracking of reproductive behaviors	2015	2026	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm experiments, reproductive behaviors	2025	2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2017	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Engineerng effects, other authorized purposes - Done	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Experimental flow releases, Gavins Point	2024	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000
Big Question 2: Temperature Control	2017	2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2018	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Model water temperature management options, Ft. Randall	2018	2020	$ -	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Field studies temperature and reproductive behaviors,	2022	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 92,500	$ 92,500	$ 92,500	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm studies temperature and reproductive behaviors	2023	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 164,600	$ 164,600	$ 164,600	$ 164,600	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Field tests of water temperature management, Gavins Point	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Experimental warm water releases, Gavins Point	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 3: Food and Forage	2015	2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Screening: limitations of food or forage habitats	2015	2019	$ 125,000	$ 125,000	$ 125,000	$ 125,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Technology development for IRC sampling, modeling, measurer	2015	2021	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Field studies along gradients, food and forage habitats	2015	2025	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Mesocosm studies: quantitative habitat – survival relations	2022	2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2016	2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Design studies for IRC experiments*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Manipulative field experiments with IRCs @ level 3*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 4: Drift Dynamics	2015	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Technology development surrogate particles, particle tracking	2015	2019	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Resilience, stamina in turbulent flows (lab or mesocosm study)	2017	2019	$ -	$ -	$ 172,400	$ 172,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Field studies on free embryo exit paths	2018	2021	$ -	$ -	$ -	$ 297,400	$ 297,400	$ 297,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Field gradient study, age-0 survival and complexity	2015	2020	$ 223,250	$ 223,250	$ 223,250	$ 223,250	$ 223,250	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Free embryo transport to Mississippi River	2015	2021	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Field experiments with particle tracking, embryos, models	2018	2023	$ -	$ -	$ -	$ 243,330	$ 243,330	$ 243,330	$ 243,330	$ 243,330	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2016	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 7 Engineering designs for interception experiments*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 8 Field experiment: discharge and dispersion – Not currently plan	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 9 Field experiment: IRC complexes*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 5: Spawning Habitat	2015	2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Study of functional spawning habitat, Yellowstone River	2015	2019	$ 85,000	$ 85,000	$ 85,000	$ 85,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Field gradient study, habitat conditions LMOR	2015	2019	$ 85,000	$ 85,000	$ 85,000	$ 85,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm studies on spawn conditions, behaviors	2017	2020	$ -	$ -	$ 172,400	$ 172,400	$ 172,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2018	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Engineering studies for sustainable design	2018	2022	$ -	$ -	$ -	$ 125,000	$ 125,000	$ 125,000	$ 125,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Manipulative field experiment for spawning habitat**	2020	2024	$ -	$ -	$ -	$ -	$ -	$ 271,000	$ 271,000	$ 271,000	$ 271,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 6: Population Augmentation	2017	2044	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2017	2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Engineering feasibility hatchery needs, facilities, operations	2017	2019	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Retrospective study survival linked to hatchery operations	2018	2020	$ -	$ -	$ -	$ 96,750	$ 96,750	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Simulation models, population sensitivity to size, health, geneti	2017	2020	$ -	$ -	$ 56,000	$ 56,000	$ 56,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Field experimentation with varying size, location of stocking	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Technical Development: Modeling and Monitoring Needs	2015	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Adaptive design and optimization of population monitoring	2017	2019	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Continued integration, refinement, and maintenance, collaborative populatio	2015	2033	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000
Research: contingency, outreach, reporting																				
Research contingency for basic science, surprises	2017	2033	$ -	$ -	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000
Reporting and outreach	2015	2033	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500
			$ 2,135,350	$ 2,135,350	$ 3,291,150	$ 4,133,630	$ 3,036,430	$ 2,679,030	$ 2,076,830	$ 2,044,330	$ 1,965,600	$ 2,369,600	$ 2,095,100	$ 1,420,100	$ 1,255,500	$ 1,255,500	$ 1,255,500	$ 1,255,500	$ 1,255,500	$ 1,255,500

Table F 3. Estimate net (to agency) combined level 1 and level 2 costs, Pallid Sturgeon Population Assessment Program costs, and combined costs, 2014 – 2032. The "-R" suffix in the column headings stands for "Revised following prioritization" (see section F.4).

Year	Upper River	Lower River	PSPAP	Combined
2015	$ 727,500	$ 2,135,350	$ 3,450,000	$ 6,312,850
2016	$ 962,920	$ 2,135,350	$ 3,450,000	$ 6,548,270
2017	$ 1,657,270	$ 3,291,150	$ 3,450,000	$ 8,398,420
2018	$ 2,197,862	$ 4,133,630	$ 3,450,000	$ 9,781,492
2019	$ 1,042,512	$ 3,036,430	$ 3,450,000	$ 7,528,942
2020	$ 804,512	$ 2,679,030	$ 3,450,000	$ 6,933,542
2021	$ 965,092	$ 2,076,830	$ 3,450,000	$ 6,491,922
2022	$ 1,508,920	$ 2,044,330	$ 3,450,000	$ 7,003,250
2023	$ 1,754,920	$ 1,965,600	$ 3,450,000	$ 7,170,520
2024	$ 1,501,920	$ 2,369,600	$ 3,450,000	$ 7,321,520
2025	$ 704,420	$ 2,095,100	$ 3,450,000	$ 6,249,520
2026	$ 704,420	$ 1,420,100	$ 3,450,000	$ 5,574,520
2027	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2028	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2029	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2030	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2031	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2032	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500

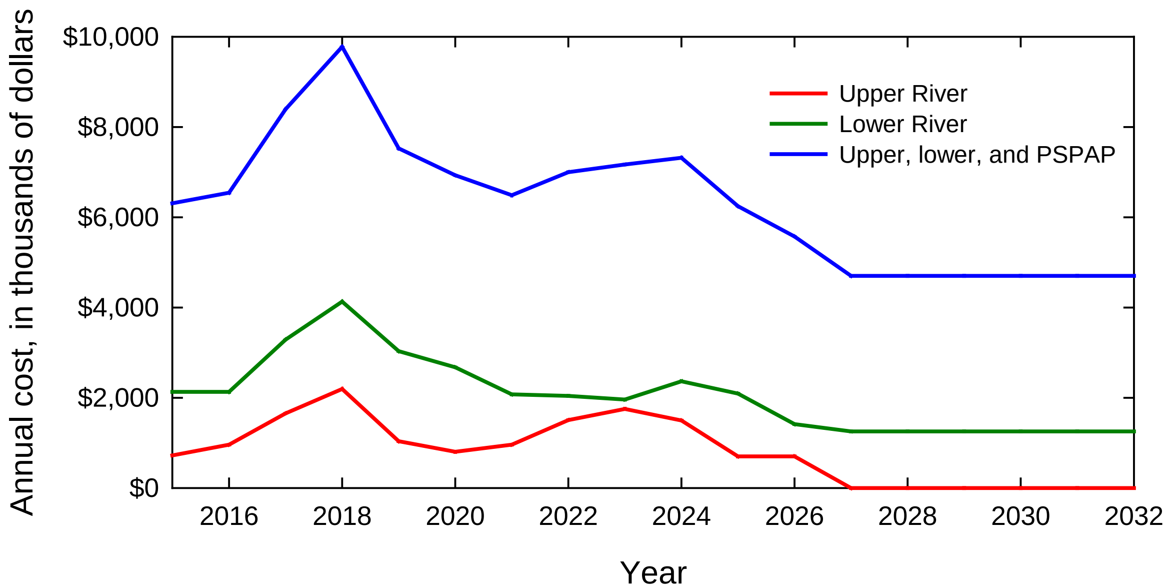


Figure F 1 Graph of level 1 and level 2 science components costs by year. The costs provided are estimates of net to projects; that is, they do not include agency overhead assessments. The blue line combines the upper river and lower river and adds $3.45 million/year for the Pallid Sturgeon Population Assessment Program.

ID	Task Name	Start	Finish
1	**Big Question 1: Spawning Cues**	**10/1/2014**	**10/3/2025**
2	**Level 1**	**10/1/2014**	**10/3/2025**
3	Component 1 Design complementary passive/active telemetry network	10/3/2016	10/3/2018
4	Component 2 Opportunistic tracking of reproductive behaviors	10/1/2014	10/2/2024
5	Component 3 Mesocosm experiments, reproductive behaviors	10/5/2020	10/3/2025
6	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
7	Component 4 Engineerng study effects on other authorized purposes	10/4/2035	10/4/2035
8	Component 5 Experimental flow releases, Gavins Point	10/4/2035	10/4/2035
9	**Big Question 2: Flow Naturalization and Productivity**	**10/5/2020**	**10/2/2026**
10	**Level 1**	**10/5/2020**	**10/2/2026**
11	Component 1 Engineering models, interactions with authorized purposes	10/5/2020	10/6/2023
12	Component 2 Screening: limitations of food or forage habitats	10/5/2020	10/5/2023
13	Component 3 Field studies along gradients, food and forage habitats	10/3/2022	10/1/2026
14	Component 4 Mesocosm studies: quantitative habitat – survival relations	10/3/2022	10/2/2026
15	**Level 2 – Not currenlty planned**	**10/3/2035**	**10/4/2035**
16	Component 5 Design flow experiments	10/3/2035	10/3/2035
17	Component 6 Experimental naturalization of flows, Fort Peck	10/4/2035	10/4/2035
18	**Big Question 3: Temperature manipulations at Fort Peck**	**10/1/2014**	**10/4/2035**
19	**Level 1**	**10/1/2014**	**10/4/2024**
20	Component 1 Screening: Feasibility, modeling of effects	10/6/2014	10/6/2014
21	Component 2a Screening: is food limiting to age-0 survival?	10/5/2020	10/5/2023
22	Component 2b Are Lake Sakakawea conditions limiting to age-0 survival?	10/7/2014	10/5/2018
23	Component 3a Field gradient, temperature and food production	10/5/2020	10/4/2024
24	Component3b Field experiment dift/dispersal advection/dispersion validation	10/5/2015	10/2/2020
25	Component 4a Mesocosm studies: temperature, food, survival relations	10/1/2014	10/5/2018
26	Component 4b Development rates of embryos, free embryos, larvae	10/1/2014	10/5/2018
27	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
28	Component 5 Construct, test water temperature mechanisms	10/4/2035	10/4/2035
29	Component 6 Manipulative field experiments with water temperature	10/4/2035	10/4/2035
30	**Big Question 4: Sediment bypass**	**10/1/2014**	**10/5/2035**
31	**Level 1**	**10/1/2014**	**10/2/2024**
32	Component 1 Feasibility study sediment bypass and turbidity	10/1/2014	10/1/2014
33	Component 2 Mesocosm study of turbidity-limited survival	10/5/2020	10/6/2022
34	Component 3 Mesocosm study of turbidity-limited survival rates	10/3/2022	10/2/2024
35	**Level 2 – Not currently planned**	**10/3/2035**	**10/5/2035**
36	Component 4 Pilot test of sediment bypass	10/3/2035	10/3/2035
37	Component 5 Field experiment sediment bypass and turbidity	10/4/2035	10/5/2035
38	**Big Question 5: Passage, drift, and recruitment**	**10/5/2015**	**9/29/2026**
39	**Level 1**	**10/5/2015**	**10/2/2020**
40	Component 1a Model integration, drift and development	10/3/2016	10/1/2018
41	Component 1b Modeling location and rate of change of headwaters	10/3/2017	10/5/2018
42	Component 2a Patchiness of anoxic zone	10/3/2017	10/2/2019
43	Component 2b Spawning habitat distribution on the Yellowstone River	10/3/2016	10/3/2018
44	Component 3 Field experiment drift/dispersal, advection/dispersion validation	10/5/2015	10/2/2019
45	Component 4 Mesocosm studies to quantify transport	10/3/2017	10/2/2020
46	**Level 2**	**10/3/2016**	**9/29/2026**
47	Component 5 Engineering studies for effects of low flows	10/5/2021	10/5/2022
48	Component 6a Drift experiments, Fort Peck flows and drawdowns	10/1/2021	9/29/2026
49	Component 6b Adult translocation experiment, Yellowstone	10/3/2016	10/1/2020
50	**Big Question 6: Population Augmentation**	**10/5/2015**	**10/4/2035**
51	**Level 1**	**10/5/2015**	**10/3/2019**
52	Component 1 Engineering feasibility hatchery needs, facilities, operations	10/5/2015	10/4/2017
53	Component 2 Retrospective study survival linked to hatchery operations	10/3/2016	10/3/2018
54	Component 3 Simulation models, population sensitivity to size, health, genetics	10/3/2016	10/3/2019
55	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
56	Component 4 Field experimentation with varying size, location of stocking	10/4/2035	10/4/2035

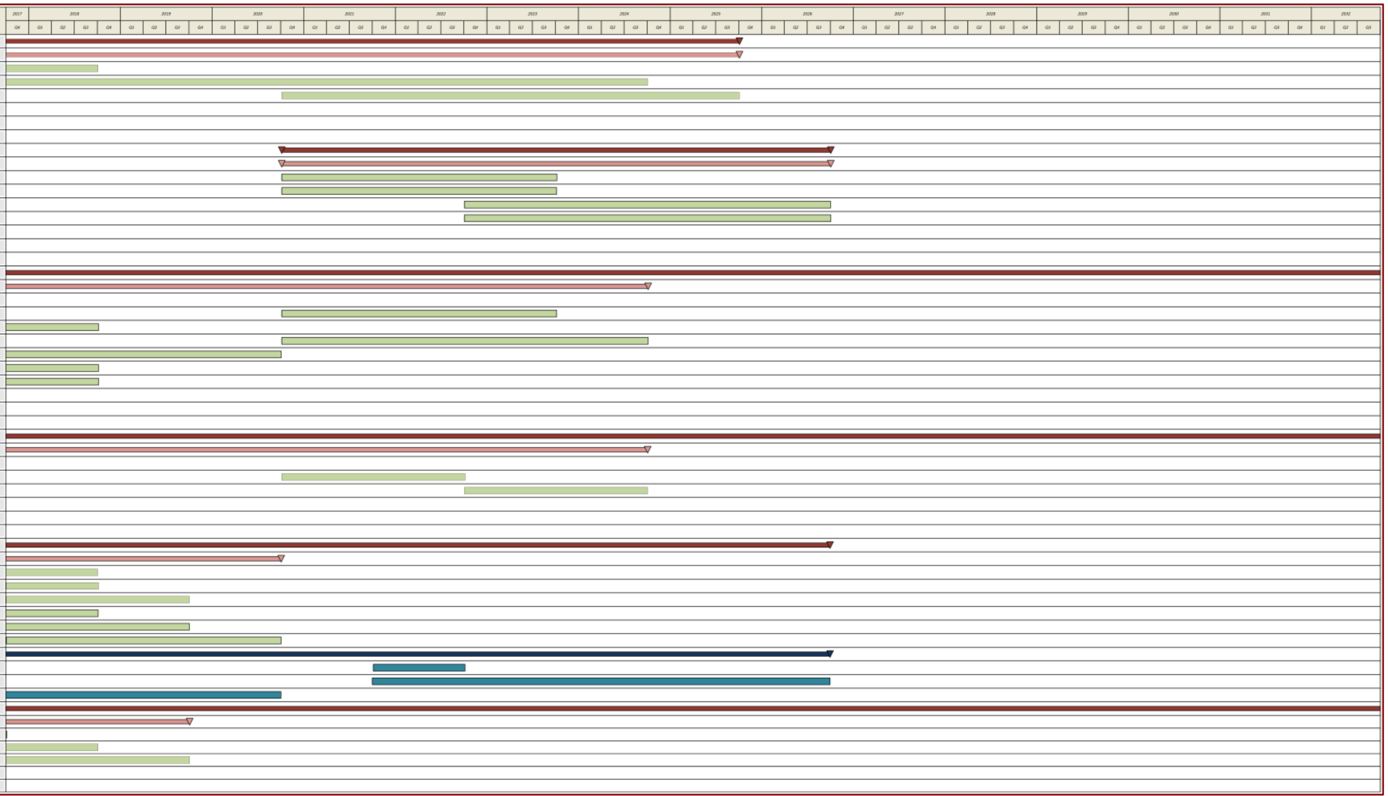


Table F 4:. Planned timing of Level 1 and Level 2 activities for the Upper Missouri River during the first 15 years, based on the prioritization process described in section F.4.

ID	Task Name	Start	Finish
1	**Big Question 1: Spawning Cues**	**10/3/2014**	**10/4/2032**
2	**Level 1**	**10/3/2014**	**9/25/2030**
3	Component 1 Design complementary passive telemetry network	10/3/2016	10/3/2018
4	Component 2 Opportunistic tracking of reproductive behaviors	10/3/2014	10/6/2025
5	Component 3 Mesocosm experiments, reproductive behaviors	10/3/2024	9/25/2030
6	**Level 2**	**10/3/2016**	**10/4/2032**
7	Component 4 Engineerng study effects on other authorized purposes	10/3/2016	10/3/2016
8	Component 5 Experimental flow releases, Gavins Point	10/3/2023	10/4/2032
9	**Big Question 2: Temperature Control**	**10/3/2017**	**10/1/2026**
10	**Level 1**	**10/3/2017**	**10/1/2026**
11	Component 1 Model water temperature management options, Gavins Point	10/3/2017	10/2/2019
12	Component 2 Field studies temperature and reproductive behaviors, surrogates	10/4/2021	10/3/2024
13	Component 3 Mesocosm studies temperature and reproductive behaviors	10/3/2022	10/1/2026
14	**Level 2 – Not currently planned**	**10/4/2032**	**10/2/2040**
15	Component 4 Field tests of water temperature management, Gavins Point	10/4/2032	10/3/2036
16	Component 5 Experimental warm water releases, Gavins Point	10/4/2032	10/2/2040
17	**Big Question 3: Food and Forage**	**10/1/2014**	**10/6/2027**
18	**Level 1**	**10/1/2014**	**10/3/2025**
19	Component 1 Screening: limitations of food or forage habitats	10/1/2014	10/3/2018
20	Component 2 Technology development for IRC sampling, modeling, measurement	10/1/2014	10/1/2020
21	Component 3 Field studies along gradients, food and forage habitats	10/1/2014	9/30/2024
22	Component 4 Mesocosm studies: quantitative habitat – survival relations	10/4/2021	10/3/2025
23	**Level 2**	**10/5/2015**	**10/6/2027**
24	Component 5 Design studies for IRC experiments	10/5/2015	10/1/2021
25	Component 6 Manipulative field experiments with IRCs	10/5/2015	10/6/2027
26	**Big Question 4: Drift Dynamics**	**10/1/2014**	**10/6/2032**
27	**Level 1**	**10/1/2014**	**10/3/2022**
28	Component 1 Technology development surrogate particles, particle tracking	10/1/2014	10/1/2018
29	Component 2 Resilience, stamina in turbulent flows	10/5/2016	10/5/2018
30	Component 3 Field studies on free embryo exit paths	10/3/2017	10/2/2020
31	Component 4 Field gradient study, age-0 survival and complexity	10/3/2014	10/3/2019
32	Component 5 Free embryo transport to Mississippi River	10/3/2014	10/2/2020
33	Component 6 Field experiments with particle tracking, embryos, models	10/3/2017	10/3/2022
34	**Level 2**	**10/5/2015**	**10/6/2032**
35	Component 7 Engineering designs for interception experiments	10/5/2015	10/1/2021
36	Component 8 Field experiment: discharge and dispersion – Not currently planned	10/3/2022	10/3/2028
37	Component 9 Field experiment: IRC complexes	10/5/2017	10/6/2032
38	**Big Question 5: Spawning Habitat**	**10/1/2014**	**10/3/2023**
39	**Level 1**	**10/1/2014**	**10/5/2020**
40	Component 1 Study of functional spawning habitat, Yellowstone River	10/1/2014	10/1/2018
41	Component 2 Field gradient study, habitat conditions LMOR	10/1/2014	10/3/2018
42	Component 3 Mesocosm studies on spawn conditions, behaviors	10/3/2017	10/5/2020
43	**Level 2**	**10/9/2017**	**10/3/2023**
44	Component 4 Engineering studies for sustainable design	10/9/2017	10/7/2021
45	Component 5 Manipulative field experiment for spawning habitat	10/3/2019	10/3/2023
46	**Big Question 6: Population Augmentation**	**10/3/2016**	**10/4/2035**
47	**Level 1**	**10/5/2016**	**10/5/2018**
48	Component 1 Engineering feasibility hatchery needs, facilities, operations	10/5/2016	10/5/2018
49	Component 2 Retrospective study survival linked to hatchery operations	10/3/2017	10/3/2019
50	Component 3 Simulation models, population sensitivity to size, health, genetics	10/3/2016	10/3/2019
51	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
52	Component 4 Field experimentation with varying size, location of stocking	10/4/2035	10/4/2035
53	**Technical Development: Modeling and Monitoring Needs**	**10/1/2014**	**10/1/2032**
54	Adaptive design and optimization of population monitoring	10/3/2016	10/3/2018
55	Continued integration, refinement, and maintenance, collaborative population model	10/1/2014	10/1/2032
56	**Research: contingency, outreach, reporting**	**10/1/2014**	**10/3/2033**
57	Research contingency for basic science, surprises	10/3/2017	10/3/2033
58	Reporting and outreach	10/1/2014	10/1/2032

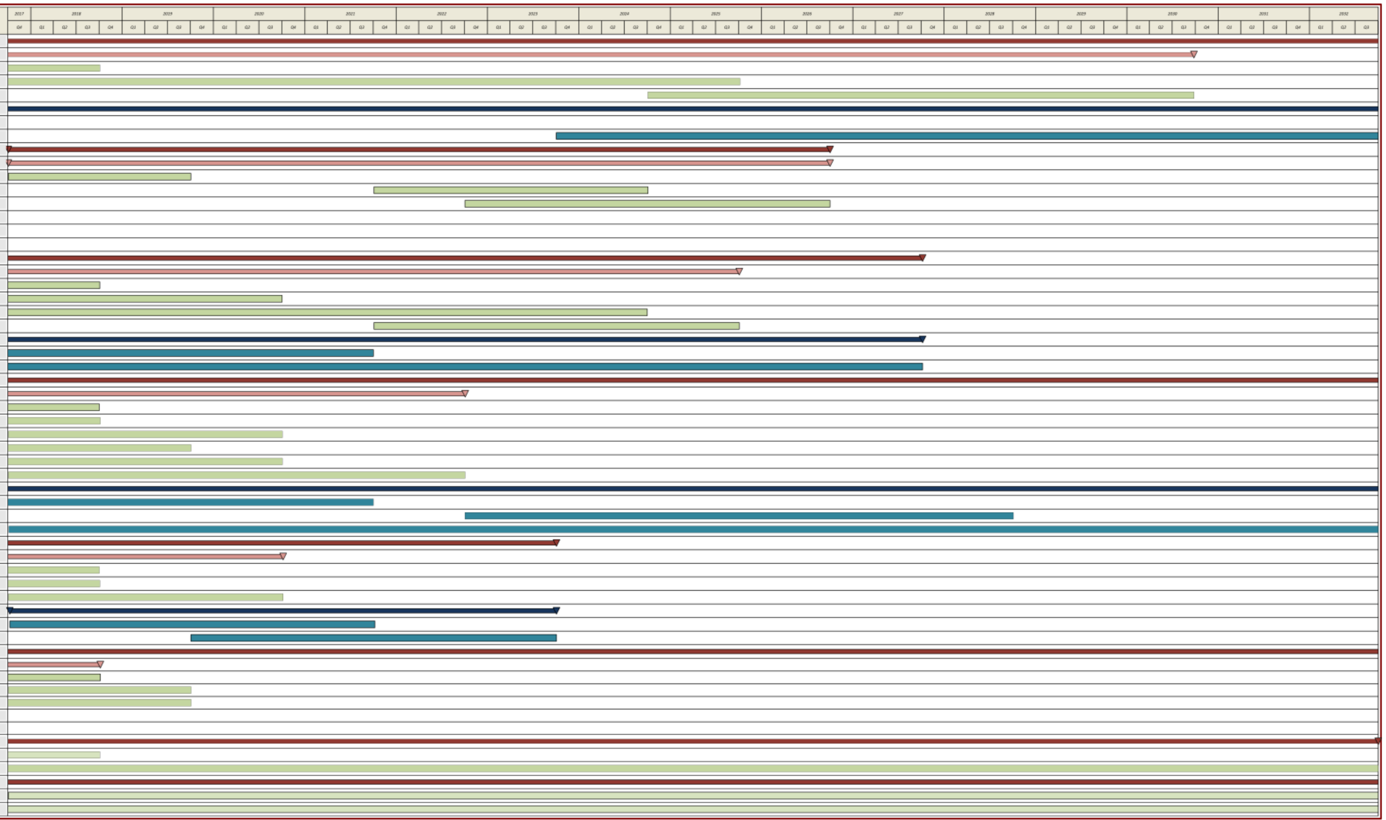


Table F 5:. Planned timing of Level 1 and Level 2 activities for the Lower Missouri River during the first 15 years, based on the prioritization process described in section F.4.

F.3 Discussion

The estimates provided here are intended to provide general understanding of the scope and timing of investment in pallid sturgeon science under the adaptive management plan, with the prioritization efforts described below. As noted in the Approach section, numerous caveats apply to these estimates. In particular, it should be emphasized that as learning progresses under adaptive management some anticipated information needs will diminish whereas some unanticipated needs may arise. In addition, a modest level of contingency funding is included to address surprises from new information. It is important to note that the net costs presented to not account for agency overhead costs, which may add substantially (50% or more) to the final costs.

The sequence of science investment indicates a rapid rise from 2015 to a peak in 2018 (Figure F 1). This sequence reflects the assumption that the MRRMP would be complete with a record of decision in 2017. If the record of decision and implementation of the new plan are delayed, the sequence of science investment would also be delayed. Nevertheless, the sequence of investment supports the notion of the “science surge” to quickly address fundamental level 1 science questions in the first 4-6 years of implementation. The surge in science investment is intended to provide the foundation for relevant and cost-effective management actions to avoid jeopardy to the pallid sturgeon.

F.4 Prioritization of Level 1 and Level 2 Components for the First 5 Years

As described above and in Appendix C, 74 science components have been identified that could potentially be implemented to reduce key uncertainties related to decisions on which actions are most likely to improve the survival and recovery of pallid sturgeon, to test the effectiveness of actions, and to assess progress towards defined objectives and sub-objectives for the population. These components include Level 1 (foundational research) and Level 2 (field experimentation) activities to test efficacy of priority management actions. These components are organized by the way in which they address critical information categories (i.e., big questions) and the 21 management hypotheses that emerged from the stepwise hypothesis filtering process (see Section 4.1.2.4,). The following considerations were used in developing these science components:

- need to address information for critical decisions (i.e., focus on need to know, not nice to know);
- must be cost effective;
- should include technical/engineering questions about implementation, including understanding some effects on Human Considerations;

- need to establish cause/effect, as much as possible, to support management decisions;
- implementation needs to be adaptive and flexible;
- should complement Level 3/4 activities and population level monitoring;
- multiple components and lines of evidence will be needed to address inherent challenges, given the rarity of pallid sturgeon and the very large size of the Missouri River; and
- need to support the population model by providing data to inform model structure and parameterization.

Sequential implementation of science components was explored in V3 of the AM Plan and was considered by the ISAP, the USFWS and other entities to take too long. To speed up the learning process, V4 of the AM Plan proposed implementing most Level 1 science components concurrently; this was considered by the ISAP to be overwhelming. Hence, the AM team undertook a prioritization exercise to clarify the immediate information needs and activities for the science and adaptive management program (i.e., within the first 5 years).

F.4.1 Prioritization Criteria

Given the need to prioritize the longer list of research components in Appendix C, a set of evaluation criteria were identified to assess the relative priority of components, the appropriate sequencing in time, the value of information provided, and the feasibility of implementation. The mix of criteria that were considered recognized that there are trade-offs involved when choosing one set of research activities versus another set. There needs to be a balance between research to reduce critical uncertainties and enhance learning about which *possible* future actions might address limiting factors, versus research to evaluate the effectiveness of actions that will *definitely* be implemented in the near term to benefit pallid sturgeon. The following criteria were used for prioritizing research components:

- **Relevance to current decisions/actions:** This criterion forces consideration of whether a research component contributes to thorough effectiveness evaluations of L2 or L3 actions that are included in the EIS, and therefore will be implemented. If an L3 action is already underway, then there may not need for all of the L1 / L2 work to justify it. In these instances, the primary value of the research may be to understand cause-effect links, evaluate effectiveness, and make adjustments to a Level 3 action. The relative priorities of actions being considered in the AM Plan are summarized in Table 41 (see Chapter 4). Level 3 actions have been identified in the EIS, informed by technical feasibility studies, and/or supported by policy and planning priorities provided by the USFWS through Planning Aid Letters.

- **Biological value of information:** An important consideration is whether a research component provides strong evidence to inform decisions on actions in terms of either their biological benefit or feasibility (i.e., high information value relative to cost). It is more important to focus on key branches in the decision trees for the Upper and Lower Missouri which simplify the decision problem (see Section F.4.2 and figures F2 and F3). Answering key questions in the decision trees provides relatively valuable information by reducing critical uncertainties on which actions to pursue, simplifying decision trees, and identifying necessary modifications to existing actions. The rationale for these decision trees is provided below.
- **Minimize risk to species:** Some federal actions may potentially impose a high risk to pallid sturgeon. There's a benefit to gaining information which helps to avoid taking actions that pose a high risk to pallid sturgeon.
- **Progress towards compliance:** This criterion relates to how a research component contributes to an evaluation of the status and trend of pallid sturgeon populations and progress towards USFWS objectives. Science to improve the valuation of status and trend may or may not also contribute to improved evaluation of action effectiveness (and vice versa).
- **Timeliness of learning:** If all other things are equal, components that provide fast answers are favored over components that take longer to provide answers. More specifically, if time lags for learning are longer than the USFWS deadlines for implementing a management action, is it still worth doing the work?
- **Cost feasibility:** This factor evaluates the varied benefits against the costs of research when setting research priorities.
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F.4.2 Decision Trees

A key consideration in the prioritization process was the need to assess the relative value of information provided by each research component in terms of its ability to reduce one or more critical uncertainties. The critical uncertainties to be addressed are illustrated in the expanded decision trees in Figure F2 and Figure F 3.

Simplified decision trees were introduced in the Effects Analysis (AM) (Jacobson and others, 2016a) and reproduced in Chapter 4 of the Missouri River Science and Adaptive Management Plan (MRSAM). The decision trees provide a graphical and logical approach to thinking about prioritization and sequence of science components to inform decision making. The trees presented in the EA and Chapter 4 were constructed to illustrate how specific science information may constrain subsequent need for science information and may limit consideration of future management actions. The EA and Chapter 4 trees addressed a subset of the hypotheses in the upper and lower rivers. The following presents expanded decision trees that encompass all of the 21 EA hypotheses.

The decision trees are meant to illustrate the hypotheses and actions that prevail at this point in time (spring 2017). We expect hypotheses and decisions trees to change as additional learning takes place.

Hypotheses in the decision trees are presented in question form in yellow diamonds with yes/no or Boolean (and/or) results. The notation "&&" means that two or more questions need to all be in the affirmative. The notation OR means that any one of two or more of the linked questions needs to be in the affirmative. The blue boxes indicate the associated management actions related to yes/no decisions; some boxes have multiple management possibilities. Orange boxes are labeled "Likely recruitment failure", indicating that if the information progresses to these terminal boxes, there are likely no additional means to accomplish recruitment and avoid jeopardy. Some terminal blue boxes indicate that new hypotheses will need to be developed to explain observed data.

In practice, the decision trees will probably need to be employed iteratively. For example, one pass through the tree may address limitations of one factor (for example, food production), resulting in population growth. When that one factor is no longer limiting to the population yet a sustainable, genetically diverse population has not been achieved, it may be necessary to address a factor that has become the next limiting factor (for example, foraging habitat). Alternatively, it may be necessary to develop a new hypothesis for limiting factors that have not yet been identified.

F.4.3 Emerging Research Priorities

- The above criteria were applied by the AM team to identify priority research activities for the first 5 years of the AM program. The relevance of a research component to current decisions/actions and the biological value of the information (as articulated by the decision trees) were the most heavily weighted criteria in setting priorities. The complete list of components and their relative priority is summarized below in Table F6 and Table F7. The subset of components that are expected to begin in the first 5 years are identified in Tables 44 and 45 (see Chapter 4). Going forward there is an expectation that these priorities may be adjusted as knowledge is gained from these science components and, where appropriate, new information emerges around other hypotheses and related science components. There is an expectation, however, that the criteria to guide the evaluation of priority research components will generally remain the same as those listed above.

Table F6 :. Overview of priorities for Level 1 and Level 2 science components for the Upper Missouri River in the first 5 years of the Adaptive Management program. Priorities in the first 5 years are also listed in Table 44.

Research Component	***Priority in first 5 yrs?***	***Comments/rationale***
Big Question 1: Spawning Cues		
Level 1		
Component 1 Design complementary passive/active telemetry network	Y	Critical to the evaluation of Intake and also spawner responses to flow variation.
Component 2 Opportunistic tracking of reproductive behaviors	Y	Critical to evaluation of Intake, and may provide information around potential benefits of flow manipulation at Fort Peck. Continue this ongoing work unless information value is low due to little variation in flow.
Component 3 Mesocosm experiments, reproductive behaviors	N	Not necessary in first 5 years after ROD. Need to first determine if drift-dispersal distance is sufficient to make spawning below Fort Peck something to be encouraged.
Level 2		
Component 4 Engineering study effects on other authorized purposes	N	Not necessary in first 5 years after ROD (see above discussion of Upper Missouri decision tree).
Component 5 Experimental flow releases, Ft. Peck	N	First need to determine if Intake is working, so not necessary in first 5 years after ROD (see above discussion of Upper Missouri decision tree).
Big Question 2: Flow Naturalization and Productivity		
Level 1		
Component 1 Engineering models, interactions with authorized purposes	N	Not necessary in first 5 years after ROD. Postpone until drift dispersal studies complete.
Component 2 Screening: limitations of food or forage habitats	N	Not necessary in first 5 years after ROD. Dispersal distance more likely to be limiting. Postpone until drift dispersal studies complete.
Component 3 Field studies along gradients, food and forage habitats	N	
Component 4 Mesocosm studies: quantitative habitat – survival relations	N	
Level 2		
Component 5 Design flow experiments	N	Not necessary in first 5 years after ROD. Dispersal distance more likely to be limiting. Postpone until drift dispersal studies complete.
Component 6 Experimental naturalization of flows, Fort Peck	N	
Big Question 3: Temperature manipulations at Fort Peck		
Level 1		

Research Component	*Priority in first 5 yrs?*	*Comments/rationale*
Component 1 Screening: Feasibility, modeling of effects	N	Not required in short term based on Upper Missouri decision tree; drift dispersal distance more likely to be limiting, assess first. Temperature management not included in EIS. Not required in first 5 years after ROD.
Component 2a Screening: is food limiting to age-0 survival?	N	Dispersal distance is more likely to be limiting, assess first. Not required in first 5 years after ROD.
Component 2b Are Lake Sakakawea conditions limiting to age-0 survival?	Y	Important part of addressing drift-dispersal distance, so include in first 5 years of studies.
Component 3a Field gradient, temperature and food production	N	Temperature management not included in EIS. Dispersal distance is more likely to be limiting, assess first. Not required in first 5 years after ROD.
Component3b Field experiment drift/dispersal advection/dispersion validation	Y	Advection and dispersion are critical to free embryo survival. Already planned to occur in 2016.
Component 4a Mesocosm studies: temperature, food, survival relations	N	Dispersal distance is more likely to be limiting. Postpone until evaluation of Intake is complete or if new information suggests food is limiting.
Component 4b Development rates of embryos, free embryos, larvae	Y	Important part of drift-dispersal issue, so include in first 5 years of studies.
Level 2		
Component 5 Construct, test water temperature mechanisms	N	Temperature management not included in EIS. Postpone until evaluation of Intake is complete.
Component 6 Manipulative field experiments with water temperature	N	
Big Question 4: Sediment bypass		
Level 1		
Component 1 Feasibility study sediment bypass and turbidity	Already complete	Study completed for EIS. Sediment bypass infeasible. No need to do further work on this.
Component 2 Mesocosm study of turbidity-limited survival	N	Postpone until evaluation of Intake is complete. Predation appears to be less critical as limiting factor than dispersal distance and time for embryos in U. Missouri.
Component 3 Mesocosm study of turbidity-limited survival rates	N	
Level 2		
Component 4 Pilot test of sediment bypass	N	Postpone until evaluation of Intake is complete. Predation appears to be less critical as limiting factor than dispersal distance and time for embryos in U. Missouri.
Component 5 Field experiment sediment bypass and turbidity	N	
Big Question 5: Passage, drift, and recruitment		
Level 1		

Research Component	*Priority in first 5 yrs?*	*Comments/rationale*
Component 1a Model integration, drift and development	Y	Highest priority, planned for 2017. Critical to evaluation of Intake (and existing L3 action) as well as other possible Fort Peck actions.
Component 1b Modeling location and rate of change of headwaters	Y	
Component 2a Patchiness of anoxic zone	Y	Highest priority, planned for 2017. Critical to evaluation of Intake (existing L3 action); also important input to design of spawning habitat.
Component 2b Spawning habitat distribution on the Yellowstone River	Y	
Component 3 Field experiment drift/dispersal, advection/dispersion validation	Y	Highest priority, planned for 2016. Critical to evaluation of Intake (existing L3 action) as well as other possible Fort Peck actions.
Component 4 Mesocosm studies to quantify transport	Y	Highest priority after field drift/dispersal experiment. Complements and conditional upon field study to improve advection / dispersion models and improve insights on mgmt actions.
Level 2		
Component 5 Engineering studies for effects of low flows	N	Contingent upon outcomes of related L1 components and Intake performance. Low flow not included in EIS. Beyond 5-year planning horizon.
Component 6a Drift experiments, Fort Peck flows and drawdowns	N	
Component 6b Adult translocation experiment, Yellowstone	N	
Big Question 6: Population Augmentation		
Level 1		
Component 1 Engineering feasibility hatchery needs, facilities, operations	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.
Component 2 Retrospective study survival linked to hatchery operations	Y	
Component 3 Simulation models, population sensitivity to size, health, genetics	Y	
Level 2		
Component 4 Field experimentation with varying size, location of stocking	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.

Table F7:. Overview of priorities for Level 1 and Level 2 science components for the Lower Missouri River in the first 5 years of the Adaptive Management program. Priorities in the first 5 years are also listed in Table 45.

Research Component		
Big Question 1: Spawning Cues	***Priority in first 5 yrs***	***Comments/rationale***
Level 1		

Component 1 Design complementary passive telemetry network	Y	Spawning cues are part of LMR framework L3 actions. Critical for evaluating spawner responses to flow variation. Within 5-year planning horizon.
Component 2 Opportunistic tracking of reproductive behaviors	Y	May provide information around potential benefits of flow manipulation, which is important given high year to year variations and challenges observing rare fish in a big river.
Component 3 Mesocosm experiments, reproductive behaviors	N	Postpone beyond 5-yr planning horizon. Cost could be high due to size of mesocosms needed. Depends on outcomes from components 1 and 2.
Level 2		
Component 4 Engineering study effects on other authorized purposes	Already complete	Already done as part of EIS.
Component 5 Experimental flow releases, Gavins Point	N	Beyond 5-yr planning horizon; need to first mitigate possible flood impacts in Fort Randall reach. Implementation of this action depends on outcome of Level 1, Component 2, and the decision criteria described in the evidentiary framework, Table 49 in section 4.2.6.6 of AM Plan).
Big Question 2: Temperature Control		
Level 1		
Component 1 Model water temperature management options, Ft. Randall	Y	Worth exploring to determine if temperature manipulations benefit spawning cues.
Component 2 Field studies temperature and reproductive behaviors, surrogates	N	Contingent upon component 1 outcomes or may not be possible if temperature management is infeasible.
Component 3 Mesocosm studies temperature and reproductive behaviors	N	
Level 2		
Component 4 Field tests of water temperature management, Gavins Point	N	Contingent upon component 1 outcomes or may not be possible if temperature management is infeasible.
Component 5 Experimental warm water releases, Gavins Point	N	
Big Question 3: Food and Forage		
Level 1		
Component 1 Screening: limitations of food or forage habitats	Y	IRCs are in EIS and underway. Important for evaluation of IRC effectiveness, as well as existing chutes and SWH. Continue existing studies.
Component 2 Technology development for IRC sampling, modeling, measurement	Y	
Component 3 Field studies along gradients, food and forage habitats	Y	

Component 4 Mesocosm studies: quantitative habitat – survival relations	?	Contingent upon alternative methods of estimating survival in the field under component 2. Moves to "Y" if field methods of estimating survival rates of age 0 fish not feasible.
Level 2		
Component 5 Design studies for IRC experiments	Y	IRCs are in EIS and underway. Important for evaluation of IRC effectiveness. Within 5-year planning horizon - moving forward quickly.
Component 6 Manipulative field experiments with IRCs	Currently underway	
Big Question 4: Drift Dynamics		
Level 1		
Component 1 Technology development surrogate particles, particle tracking	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Component 2 Resilience, stamina in turbulent flows (lab or mesocosm study)	Y	
Component 3 Field studies on free embryo exit paths	Y	
Component 4 Field gradient study, age-0 survival and complexity	Y	
Component 5 Free embryo transport to Mississippi River	?	Possibly within 5-yr planning horizon. Need to first assess feasibility since sampling is challenging and expensive. Contingent upon progress with other methods (e.g., microchemistry); information valuable for population model and providing an unbiased estimate of hybridization.
Component 6 Field experiments with particle tracking, embryos, models	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Level 2		
Component 7 Engineering designs for interception experiments	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Component 8 Field experiment: discharge and dispersion	N	Not currently planned - beyond 5-yr planning horizon.
Component 9 Field experiment: IRC complexes	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Big Question 5: Spawning Habitat		
Level 1		
Component 1 Study of functional spawning habitat, Yellowstone River	Y	Spawning habitat is in EIS. Important for design of effective spawning habitat. Within 5-yr planning horizon.
Component 2 Field gradient study, habitat conditions LMOR	Y	
Component 3 Mesocosm studies on spawn conditions, behaviors	Y	

Level 2		
Component 4 Engineering studies for sustainable design	Y	Spawning habitat is in EIS. Important for design of effective spawning habitat. Within 5-yr planning horizon.
Component 5 Manipulative field experiment for spawning habitat	Y	
Big Question 6: Population Augmentation		
Level 1		
Component 1 Engineering feasibility hatchery needs, facilities, operations	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.
Component 2 Retrospective study survival linked to hatchery operations	Y	
Component 3 Simulation models, population sensitivity to size, health, genetics	Y	
Level 2		
Component 4 Field experimentation with varying size, location of stocking	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.
Technical Development: Modeling and Monitoring Needs		
Adaptive design and optimization of population monitoring	Y	Critical for the evaluation of action effectiveness and determining progress towards species objectives and sub-objectives.
Continued integration, refinement, and maintenance, collaborative population model	Y	

F.4.3.1 Upper River Decision Tree

The population augmentation section was added to both decision trees to illustrate hypotheses and information related to stocking of pallid sturgeon. It is important to note that population augmentation is considered a temporary measure to help avoid jeopardy to the species by providing better opportunity for population recovery. Stocking is intended to increase population to a size that is resilient to perturbations and to address potential depensation effects (that is, effects of low fish density leading to a small probability of mates finding one another), while maintaining the natural genetic diversity of the population. Whereas more specific hypotheses are likely to evolve through the Pallid Sturgeon Recovery Team and USFWS, the three general hypotheses shown are considered fundamental to population augmentation decisions.

Note that the third diamond “Is there sufficient food availability for growth, reproduction?” articulates a hypothesis that did not evolve through the EA, namely that adult population size and reproductive capacity may be limited by available food or carrying capacity of the river. This hypothesis has been in the reserve in both the upper and lower river and is likely to get additional attention.

The structure of the decision tree begins with the population augmentation hypotheses. This reflects the idea that if the population is not prevented from going extinct, the remainder of the tree does not matter. The green box articulates that goal: attainment of a sufficient population of genetically diverse reproductive adults within the carrying capacity of the river. Having achieved this, the next series of questions relates to recruitment of young fish into the population.

The first diamond articulates to the presently (summer 2016) dominant hypothesis for mortality and recruitment failure in the upper river: that drift distance is inadequate and dispersal into Lake Sakakawea is lethal because of anoxic bottom sediments in the headwaters. If this is not the case, additional hypotheses will be needed to explain recruitment failure in the upper river. If the hypothesis is confirmed, attention turns to conditions that will allow for adequate drift and dispersal distance. In general, adequate dispersal distance is a function of spawning site (which needs to be sufficiently far upstream), drift rate, (controllable to some extent by velocity and channel condition), development rate (controlled in part by water temperature), and Lake Sakakawea level.

If the lethality of Lake Sakakawea is established, the next most influential question is whether reproductive adults elect to migrate a sufficient distance up the Yellowstone River. This hypothesis relates directly to the management action of providing passage at Intake Diversion Dam, as that dam limits most upstream migration to the lower 71.5 miles of the Yellowstone River. This is a major decision point, as it determines whether actions are likely to be beneficial or necessary on the Upper Missouri River.

If fish do not migrate at least past Intake Diversion Dam, then questions on the Upper Missouri River become more relevant (Upper Missouri Options). These are shown as two questions, both of which need to be affirmative. The first of these is sufficient upstream migration, which may be influenced by implementing attractive flows from Fort Peck. In addition, present EA models for downstream dispersal (Fischenich and others, 2014) indicate that net drift rates will likely need to be substantially less than would be indicated by water velocities. That is, there would need to be a combination of abiotic and biotic processes that would retard drift to allow more time in the free-flowing river. If both of those questions are answered affirmatively, then two additional questions become relevant to recruitment: is there sufficient food for age-0 pallid sturgeon and are they (embryo and free-embryo stage) subject to turbidity-mediated predation? Affirmative answers to either of these questions present additional potential management actions. Negative answers, indicating that these are not limiting factors, combined with previous affirmative responses, indicate additional potential, relevant management actions on the Upper Missouri River.

The Yellowstone Options part of the decision tree relates to conditions where fish do pass upstream of Intake Diversion Dam. The next most relevant question is then whether the reproductive fish migrate far enough upstream to provide sufficient dispersal distance. The diamond indicates that 500 km is indicated as a minimum threshold for upstream migration, although more distance may be required depending on velocities and temperatures. To the extent that pallid sturgeon migrate shorter distances upstream or fail to find suitable spawning habitat, drift rates will need to be retarded below mean water velocity. Distance may still be limiting, however, indicating the potential to manage drawdown of Lake Sakakawea to increase distance. The EA (Fischenich and others, 2014) indicates probabilities of adequate drift distance calculated with present models.

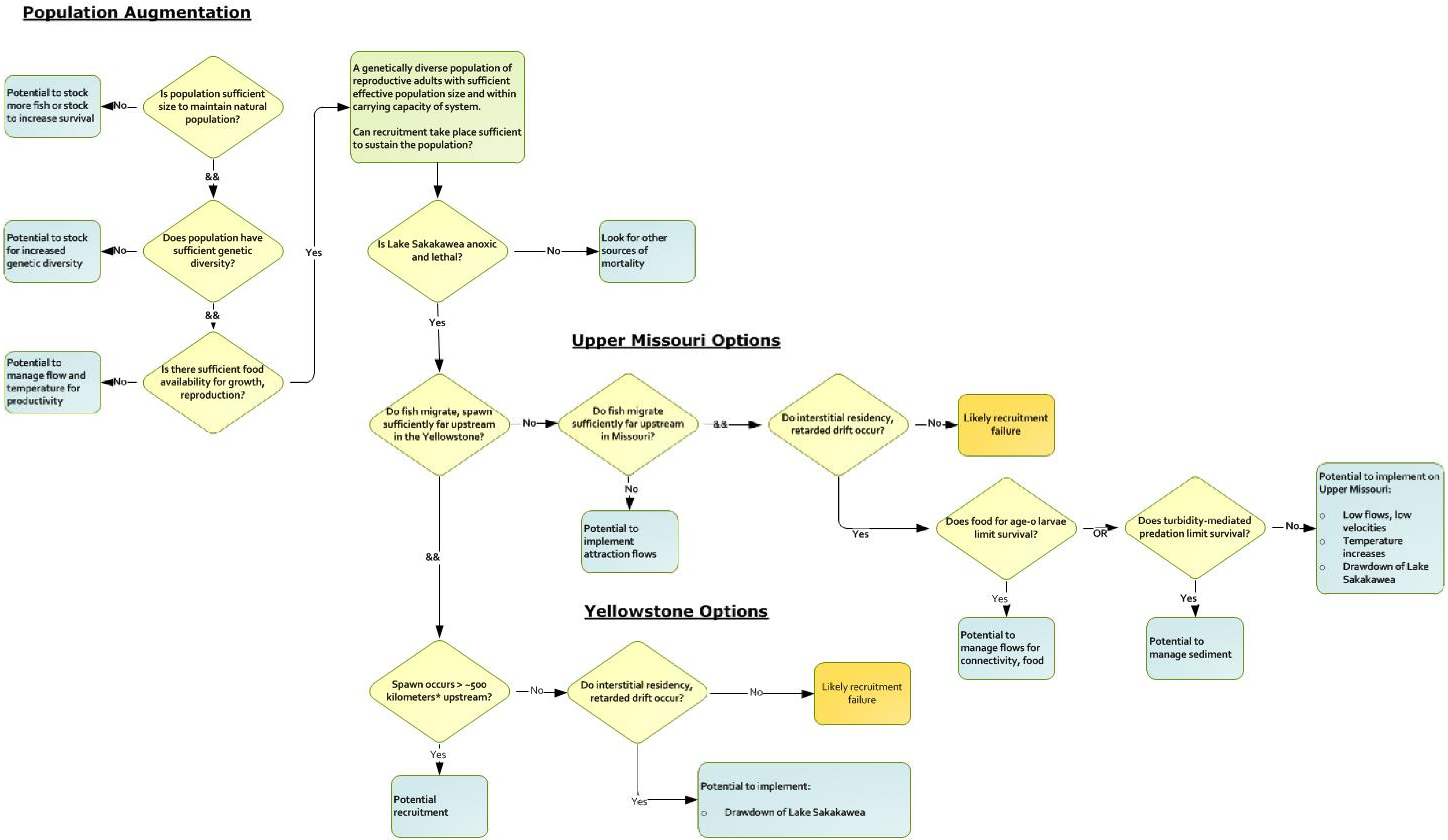
F.4.3.2 Lower River Decision Tree

The left hand side of the Lower River tree is identical to the Upper River, although the details and importance of the hypotheses are likely to vary among the two river areas. The question about sufficient food for growth and reproduction was not among the EA hypotheses, but emerging information on fish condition has prompted the EA to consider the carrying capacity hypothesis in more detail.

In contrast to the Upper River, the Lower River does not have a dominant hypothesis for mortality and recruitment failure, hence the sequence of diamonds is more arbitrary. They are presented in life-stage sequence based on the rationale that recruitment to a given life stage ultimately requires survival from preceding life stages.

The first question, then, relates to spawning and asks whether fertilization, incubation, and hatch are successful. If the answer is negative, then there are action options related to aggregation flow pulses (spawning cues), increased number of adults, and reconfiguring the channel to provide more effective spawning habitats. The next question addresses whether once hatched, the free embryos can survive turbulence. This hypothesis was a specific corollary to the general drift dynamics (hypothesis 14) that flows affect drift distance and condition of free embryos.

If free embryos survive turbulence, the next question is whether they can transition to first feeding and find food in the thalweg (or instead, whether they require retention in more suitable, channel-margin habitats). If the answer is yes, they can feed efficiently in the thalweg, then they may still require sufficient food, but they won’t necessarily need to be intercepted and retained. If the answer is no, a series of three questions about limiting conditions in Interception-Rearing Complexes (IRCs) is relevant. These are related with Boolean OR statements as any one, or a combination, of the conditions could be limiting to free-embryo survival. Each condition also has specific management actions related to it, consisting of potential to manage flow regime, channel configuration, water temperature, or a combination. If information is available to move completely through this tree and determine that none of these conditions is limiting, it will be necessary to develop new hypotheses to explain recruitment failure.



* 500 km is used as an estimate of the minimum drift distance needed for development to first feeding. Additional studies are needed to refine this estimate.

Figure F 2: Diagram of an expanded decision tree addressing the sequencing and contingency of information in the Upper Missouri River. A simpler decision tree can be found in Figure 62 (see Chapter 4).

Population Augmentation

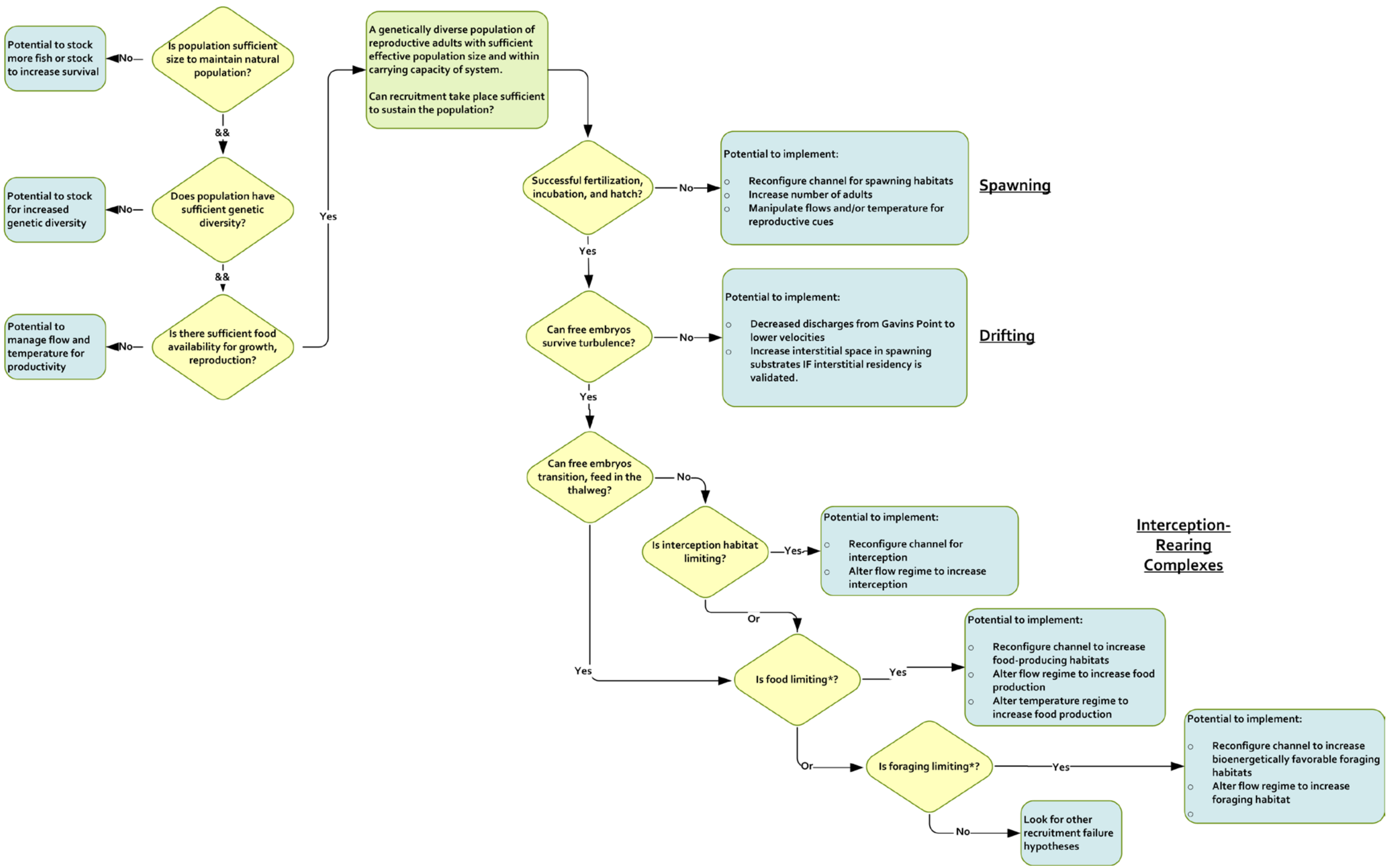


Figure F 3: Diagram of an expanded decision tree addressing the sequencing and contingency of information in the Lower Missouri River. A simpler decision tree can be found in Figure 63 (see Chapter 4).

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Appendix G. Monitoring and Assessment Protocols for the Birds

Note: This appendix will present common monitoring protocols employed by the program for the Plover and Tern. Additional content is TBD, but may include discussion guiding development of protocols for specific projects, which may require preparation after the project objectives, location, design, etc., are known.

Populating this appendix with the appropriate information will be an ongoing objective for activities following AMP V6 and continuing to the Final Draft AMP.

Attachment G.1 - Safety for Field Crews

Safety is critical to all USACE activities. Safety is everyone's responsibility. It is important that crew members be conscious of all possible safety hazards while they are working. Any time a potential safety hazard is discovered that cannot addressed by the crew it must be reported to the immediate supervisor so that proper action may be taken to correct the hazard. There are three areas of safety that are of particular importance in monitoring work. They are boat & all-terrain vehicle (ATV) safety, water safety and survey safety. Each will be discussed in detail below.

G.1.1. Boat & ATV Safety

All operators of USACE motorboats must obtain a boat operator's license. A license is acquired by passing the Corps' boat operators training course. When in a boat or on a personal watercraft that is under way, a personal flotation device (PFD), will be worn at all times.

- Before leaving, the boat, the boat trailer and the tow vehicle will be inspected so that all required equipment is in place and all equipment is working properly.

- Before taking out a watercraft, a float plan will be filed to ensure that if the crew does not come back from the survey, someone will come looking for the crew. The float plan needs to include the boat number, the boat operator, the names of the personnel on board, the launch location, itinerary, estimated time of return, time to activate a search, a contact person and the radio call number and/or cell phone number. The boat operator is responsible for closing out the float plan by notifying the appropriate personnel that the boat is off the water.

- Weather Conditions: Be cognizant of weather conditions when operating watercraft, especially on a reservoir. White caps will appear with wind speeds of around 13 – 15 mph. When wind speeds approach 25 mph it is time to abandon the survey and head for home. Likewise if a storm appears to be building it is time to terminate the survey and get off the water.

- For reservoir operation ensure that the proper type of boat is used for the survey. Generally a V-shaped hull boat or a personal watercraft is preferable to a flat bottom boat. Both of these boat types can handle waves better than a flat bottom boat.

- Operating watercraft on the river can be quite different from reservoir operation. A major difference is the river's current. The Missouri River generally flows around two to four miles per hour and the current must be taken into consideration as one navigates up and down the river. When trying to land on a sandbar or island it is better to go down river a short distance and then come back up the river against the current. Going against the current gives the operator better control of the boat as it approaches the shore. The same technique should be used when loading the boat onto the trailer at the boat ramp.

- When boating on the Missouri River, the operator should try to stay in the ten to twenty foot deep thalweg or main channel of the river. Crew members need to stay alert while in areas with silver carp and should avoid snags, and floating objects. Snags are trees that have toppled into the river and have become anchored to the river bottom. They come in a variety of sizes and positions in the river. Snags are more commonly found in shallow areas, but can also be located in the thalweg. They may be submerged and just barely visible underwater or they may be just barely below the water surface with a V-shaped ripple of water being the only clue to their presence. The river must be scanned continuously for the presence of snags.

- Crews operating boats on the river below Gavins Point Dam face an additional hazard – silver carp (*Hypophthalmichthys molitrix*). The danger to boaters from silver carp comes from the tendency of the fish to jump out of the water when startled by a passing boat. Silver carp can weigh up to 40 pounds and leap as high as ten feet in the air. They act as a projectile that could seriously injure an unwary boater. Crew members need to remain alert for the possibility of being struck by a leaping silver carp.

- All-Terrain Vehicle Safety: As with boats, operators of ATVs are required to take and pass the ATV operators' training before being allowed to conduct a survey using an ATV. ATV operation presents its own dangers from uneven surfaces, rock and log obstacles to quicksand. ATVs will be operated in a safe and prudent manner at all times with a helmet on when the vehicle is in motion.

G.1.2. Water Safety

It is highly recommended, but not required, that personnel doing monitoring work be capable swimmers. Walking in water can be especially dangerous as the river bed can be irregularly shaped with deep holes and shorelines can quickly drop off from shallow to deep areas. No matter what a person's swimming proficiency is, from non-swimmer to highly skilled, all personnel are required to wear a PFD when going into the water or where there is a possibility that the person might fall into the water. Likewise, to protect the feet, approved footwear will be worn while walking through water.

G.1.3. Survey Safety

First aid kits should be readily available to all survey crews, along with sunscreen and bug spray. Drinking water is also a pertinent resource for ensuring safety.

Footwear: Protective footwear will be worn at all times. Personnel are not allowed to go barefoot when conducting surveys. While unloading and loading the boat at the dock, standard steel-toed safety boots will be worn. When operating the boat and conducting surveys, with project approval, sandals or water shoes may be worn in lieu of safety boots.

Clothing: Crews should carry proper clothing to protect against sudden temperature and weather changes. Wearing proper clothing will provide protection against a sudden temperature drop, high winds and precipitation, all of which can lead to hypothermia. Rain gear should be stored in a duffel bag and taken into the field as insurance against inclement weather.

Personal Safety: If a crew is threatened or assaulted by a member of the public, disengage as quickly as possible and leave. Report the incident immediately to the supervisor and the appropriate law enforcement agency. If an area is deemed unsafe to survey, the crew will be so advised by the supervisor and the area will not be surveyed.

Attachment G.2 - ESA Section 10 Permit Survey Conditions

G.2.1. Endangered Species Permit:

Prior to 2003, the U.S. Fish & Wildlife Service (USFWS) granted the USACE a permit that included conditions and restrictions for the Corps' monitoring work. After 2003, the USFWS 2003 Amended Biological Opinion took the place as the permit for the Corps' endangered species work. The conditions and restrictions from previous endangered species permits remain in force and must be observed when surveys are conducted.

G.2.2. Temperature:

Surveys will not be conducted when the ambient (air) temperature is at or above 90^{o} Fahrenheit (32 ^{o} Celsius). The temperature can be monitored through the use of a thermometer. With an air temperature above 90 ^{o} F, the ground temperature on a sand-gravel substrate could easily be forty to fifty degrees (F) hotter. Ground temperatures this hot can cause heat stress and death for recently hatched chicks that cannot thermoregulate themselves. Likewise a high ground temperature can kill the embryo in an overheated egg. The adult must be allowed to stay on the nest during times of high ambient temperatures and this will not happen if surveys are conducted during these periods.

G.2.3. Wind:

When the wind speed is at or above 25 mph (40 kph) or if sand is observed blowing across a sandbar or beach, monitoring work will be terminated and the site will be vacated. Blowing sand can quickly fill in an exposed nest bowl and bury the eggs. The adults need to be able to return to the nest to prevent sand from filling in the nest bowl.

G.2.4. Precipitation:

If there is a threat of imminent precipitation (rain, sleet, hail, snow) in the area, a survey will not be done. If precipitation begins while a survey is underway, work will cease immediately and the area will be vacated. The adult must be given the opportunity to get back on the nest to protect the eggs or newly hatched chicks. If the precipitation ends and the time restriction has not been met, (see below) then surveying can resume.

G.2.5. Time Restriction:

When conducting a survey, the maximum amount of time adults and/or chicks can be disturbed or an adult can be kept away from a nest is twenty (20) minutes. A large colony site cannot be surveyed within twenty minutes; however the key is to make sure that the birds are not disturbed for more than twenty minutes. As the crew goes through the colony, the birds that were first disturbed will settle back down to the nests after crew moves on. However, after twenty minutes have passed, personnel cannot go back and re-enter the previously disturbed part of the colony.

In areas where multiple crews (researchers) are working, a minimum of two hours must pass after one crew has left a site before a new crew can enter that site. Every effort will be made to coordinate surveys with researchers so that site visits do not overlap.

G.2.6. Visitation frequency:

Monitoring crews are not to return to a nesting site any sooner than five (5) days after their last visit. The purpose of this restriction is to minimize disturbance to the birds so as not to attract attention of predators to the site by frequent human disturbance.

G.2.7. Handling of Chicks and Eggs:

Handling of eggs and chicks will be kept to a minimum and will be done only in the performance of monitoring duties and management actions. Prior to handling an egg or chick, crew members will either wash their hands with no-scent soap or wipe their hands with a no-scent towelette.

G.2.8. Training:

All personnel conducting least tern and piping plover monitoring work are required to receive training prior to conducting surveys. The training will include information on the Endangered Species Act, life histories of the two species, monitoring techniques, data collection, management activities and safety.

G.2.9. Trespass:

An endangered species permit does not grant monitoring crews the right to trespass onto private property. Crews will be informed by their supervisor, prior to the beginning of monitoring, what areas are not to be surveyed due to private landowner refusal.

Attachment G.3 - Survey Segments

The Missouri River is divided into fifteen segments for monitoring purposes. Least terns and piping are found in 9 segments.

G.3.1. Segment 1. Fort Peck Lake

Segment 1 consists of the eastern part of Fort Peck Lake extending from river mile (RM) 1785.0 to Fort Peck Dam at RM 1771.0. Fort Peck Lake represents the northwestern most range of the interior population of the least tern.

Piping Plover Critical Habitat: Piping plover critical habitat includes all shorelines and islands on Fort Peck Lake north of RM 1780.0 including the Dry Arm.

Monitoring Responsibility: Fort Peck Project

G.3.2. Segment 2. Missouri River below Fort Peck Dam

Segment 2 extends from Fort Peck Dam at RM 1771.0 to the headwaters of Lake Sakakawea at RM 1568.1. This segment of the river runs a little more than 200 miles, primarily in an easterly direction.

Piping Plover Critical Habitat: Piping Plover Critical Habitat for this segment has been designated for the Missouri River from RM 1712.0 in Montana to RM 1568.1 in North Dakota

Monitoring Responsibility: Fort Peck Dam (RM 1771.0) to the Montana/North Dakota border (RM 1586.6) is monitored by the Fort Peck Project.

The Montana/North Dakota border (RM 1586.6) to the headwaters of Lake Sakakawea (RM 1568.1) is monitored by the Williston Office, Garrison Project.

G.3.3. Segment 3. Lake Sakakawea & Lake Audubon

Segment 3 extends from the headwaters of Lake Sakakawea at RM 1568.1 to Garrison Dam at RM 1389.6. Lake Sakakawea is located in north central North Dakota and extends 178 miles in a northwesterly direction from Garrison Dam. The reservoir covers 364,000 acres at the full pool elevation of 1850.0 feet msl. Lake Audubon is located ten miles northeast of the dam and was created by the placement of a three mile long causeway for U.S. Highway 83 across the eastern end of Lake Sakakawea.

Piping Plover Critical Habitat: All of Lake Audubon and all of Lake Sakakawea except for the Little Missouri Arm west of Little Missouri River Mile 15.0 (Wolf Chief Bay) is designated Piping Plover Critical Habitat.

Monitoring Responsibility: Garrison Project

G.3.4. Segment 4. Missouri River below Garrison Dam

Segment 4 extends from Garrison Dam (RM 1389.6) to the northern boundary of the Oahe Project (RM 1304.0). The river flows in a southerly direction from Garrison Dam before turning eastward south of Stanton ND at RM 1367. The river then turns south again east of Washburn ND at RM 1350. The river travels primarily south through the rest of the segment. Between RM 1320 and 1310 the river passes through the Bismarck/Mandan metropolitan area.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Garrison Dam (RM 1389.6) to the Washburn Bridge (RM 1355.0) is monitored by the Garrison Project, Riverdale Office.

The Missouri River from the Washburn Bridge (RM 1355.0) to the northern boundary of the Oahe Project (RM 1304.0) is monitored by the Oahe Project, Bismarck Office.

G.3.5. Segment 5. Lake Oahe

Segment 5 extends from the northern boundary of the Oahe Project at RM 1304.0 to the Oahe Dam at RM 1072.3.Lake Oahe, impounded by Oahe Dam, extends 220 miles northward from central South Dakota to central North Dakota. The lake spreads over 359,000 acres at the full pool elevation of 1617.0 feet msl. The Grand, Moreau and Cheyenne Rivers all flow into the reservoir from the west.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibilities: The Oahe Project is responsible for all monitoring of Lake Oahe. The Pierre Office, the Mobridge Office, and the Bismarck Office share the responsibility.

G.3.6. Segment 7. Lake Francis Case

Segment 7 extends from Big Bend Dam at RM 987.4 to Fort Randall Dam at RM 880.0. The segment encompasses Lake Francis Case, the reservoir formed behind Fort Randall Dam. Lake Francis Case is kept at a constant pool during the nesting season and has very little shoreline habitat.

Piping Plover Critical Habitat: None of the segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Fort Randall Project

G.3.7. Segment 8. Missouri River below Fort Randall Dam

Segment 8 extends from Fort Randall Dam at RM 880.0 to the Niobrara River's confluence with the Missouri River at RM 844.0. The Missouri River flows in generally a southeasterly direction in this segment. The entire segment has been designated the Missouri National Recreation River, which is administered by the National Park Service. There are several residential developments along the river, primarily on the Nebraska side.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Fort Randall Project

G.3.8. Segment 9. Lewis and Clark Lake

Segment 9 extends from the Niobrara River/Missouri River confluence at RM 844.0 to Gavins Point Dam at RM 811.1. Lewis & Clark Lake, impounded by Gavins Point Dam extends 34 miles in a westerly direction along the South Dakota-Nebraska border. The lake contains 28,000 acres at the full pool elevation of 1806 feet msl. The segment from the confluence with the Niobrara River at RM 844.0 to the Running Water boat ramp at RM 840.0 is a part of the Missouri National Recreation River. The upper part of the lake is riverine in nature due to an extensive sedimentation zone formed from sediment being deposited by the Niobrara River. An island complex was constructed to the east of the sedimentation zone at RM 827 in 2007.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Fort Randall Project

G.3.9. Segment 10. Gavins Point River

Segment 10 extends from Gavins Point Dam at RM 811.1 to Ponca State Park, Nebraska at RM 753.0. The Missouri in this segment flows in an east to southeast direction along the South Dakota-Nebraska border. The entire segment has been designated the Missouri National Recreation River, which is administered by the National Park Service. Several residential developments have sprung up on both sides of the river.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Gavins Point Project

Attachment G.4 - Habitat monitoring protocols

The habitat monitoring program has several purposes. The first purpose of habitat monitoring is to assess the efficacy of our management actions for maintaining quality tern and plover nesting habitat. The second purpose is to examine the differences in sandbar habitat where nesting does and does not occur in order to better understand suitable habitat characteristics. And finally, these data are used for accuracy assessment of the remote sensing habitat classifications.

G.4.1. Objectives

1. Examine the effects of management actions on sandbar habitat characteristics by comparing characteristics before and after treatment and comparing treatment sandbars to controls.
2. Evaluate the differences in habitat quality by comparing habitat characteristics between these sandbars used for nesting and unused sandbars.
3. Evaluate the accuracy of landcover habitat classifications by comparing percent vegetation from the line intercept data to landcover classifications.

G.4.2. Study Area

Habitat management actions will be implemented on the river segments below Gavins Point Dam from river mile 811 to 753, Fort Randall dam from river mile 880-844, and Garrison Dam from river mile 1389 to 1277 and on Lewis and Clark Lake from river mile 845-825. USACE habitat monitoring crews collect line intercept data on representative sandbars within the above mentioned segments annually.

G.4.3. Methods

Sampling design – Sampling design will be dependent on the specific management action being evaluated. We are currently evaluating spraying actions on sandbars. We systematically selected sandbars on each river segment and of those randomly selected 20 on each segment for sampling. We selected 10 treatment and 10 control that also represent used and unused sandbars. Random points are generated for each sandbar and used as starting points for transects. We sampled 16 transects per sandbar. We attempt to sample the same transects annually however if transects are lost due to erosion or missing markers new transects are added as needed. Number of transects per bar may be adjusted based on study needs.

Habitat characteristics - Habitat conditions are quantified by measuring percent vegetation coverage of dominant and secondary vegetation categories, average vegetation height, percent coverage of dominant and secondary substrate categories, and percent of coverage of small and large debris.

Analysis

General linear mixed effects models are used to detect a change in habitat characteristics and productivity between treatment and control sandbars before and after treatment.

Attachment G.5 – ESH Toolbox Application

The ESH toolbox is designed to automate much of the data preparation, extraction and calculation necessary to compute emergent sandbar habitat (ESH) using the geodatabases provided by Larry Strong (USGS). This document serves as a general tutorial on how to use the toolbox to compute ESH.

This example uses images of Gavin's Reach from the summer of 2006. Specifically, we will use images collected from May 12th May 30th, July 5th July 18th and to compute ESH for the entire reach (Figure G 1).

G.5.4. Warning: avoid "Batch" applications of this toolbox

In most cases, the user will need to run the tools described here on multiple feature sets. Unfortunately, there are known issues with running user models with the ArcGIS "batch" function[1]. To ensure the calculations are done properly, the user must run the tools individually on each feature class.

G.5.5. Warning: Long file paths

Some of the tools in the ESHtoolbox may return error 000670. If you encounter this error, try using a shorter filenames/paths for the input and output files. This error occurs because ArcGIS truncates long filenames, which can result in duplicate names for intermediate files created by the tools.

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[1] See http://gis.stackexchange.com/questions/36891/does-calculate-value-model-only-tool-work-correctly-in-tools-run-in-batch, https://geonet.esri.com/thread/15090 and https://geonet.esri.com/thread/28898 for more information.

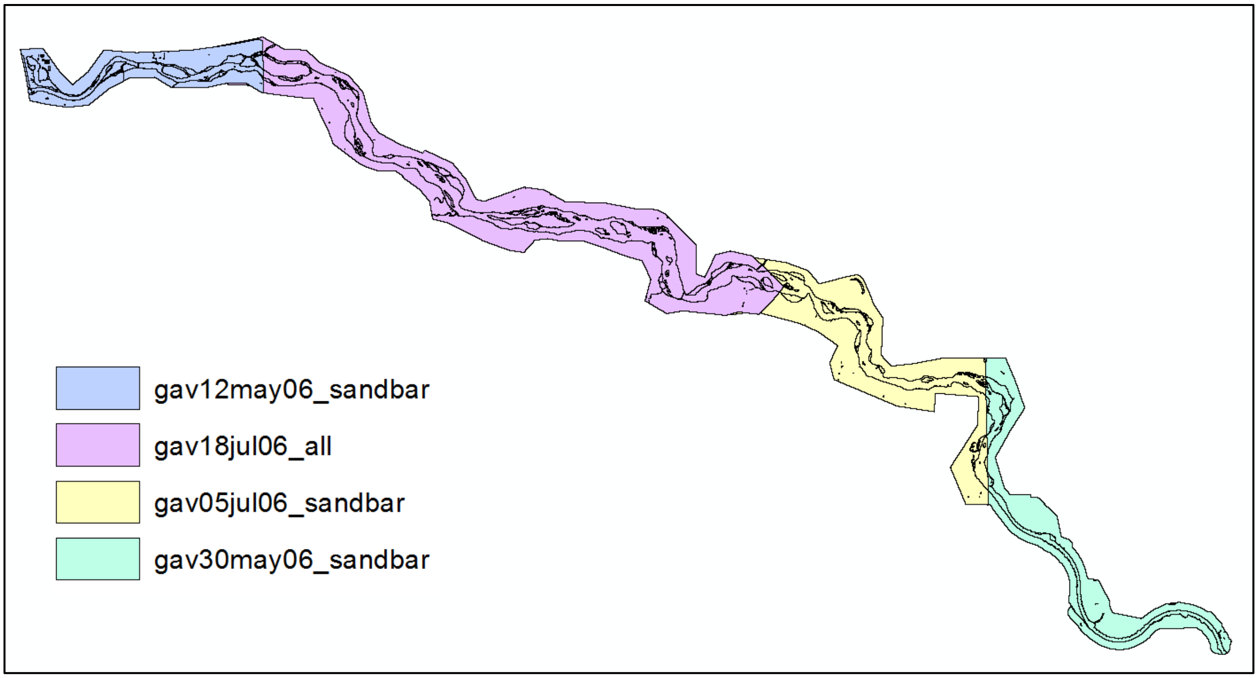


Figure G 1: Imagery of Gavin's Reach in Spring/Summer of 2006.

G.5.6. Step 1: Clip feature sets to river mile markers

In some cases, feature sets must be clipped to certain regions of interest, e.g. between two river mile markers. The **clipAndUpdateArea** tool can be called directly to achieve this. The user needs to provide a clip polygon specifying the area of interest as an input to the tool (Figure G 2). In general, this tool only needs to be applied to the end members of the image set (i.e. the furthest upstream and furthest downstream feature sets).

In order to update the ESH land cover class areas, certain assumptions must be made. Because land cover class areas are associated with geomorphic objects, rather than being explicitly represented in the geodatabases, **clipAndUpdateArea** simply scales down the areas of each land cover class in proportion to the reduction in area of a given geomorphic object due to clipping.

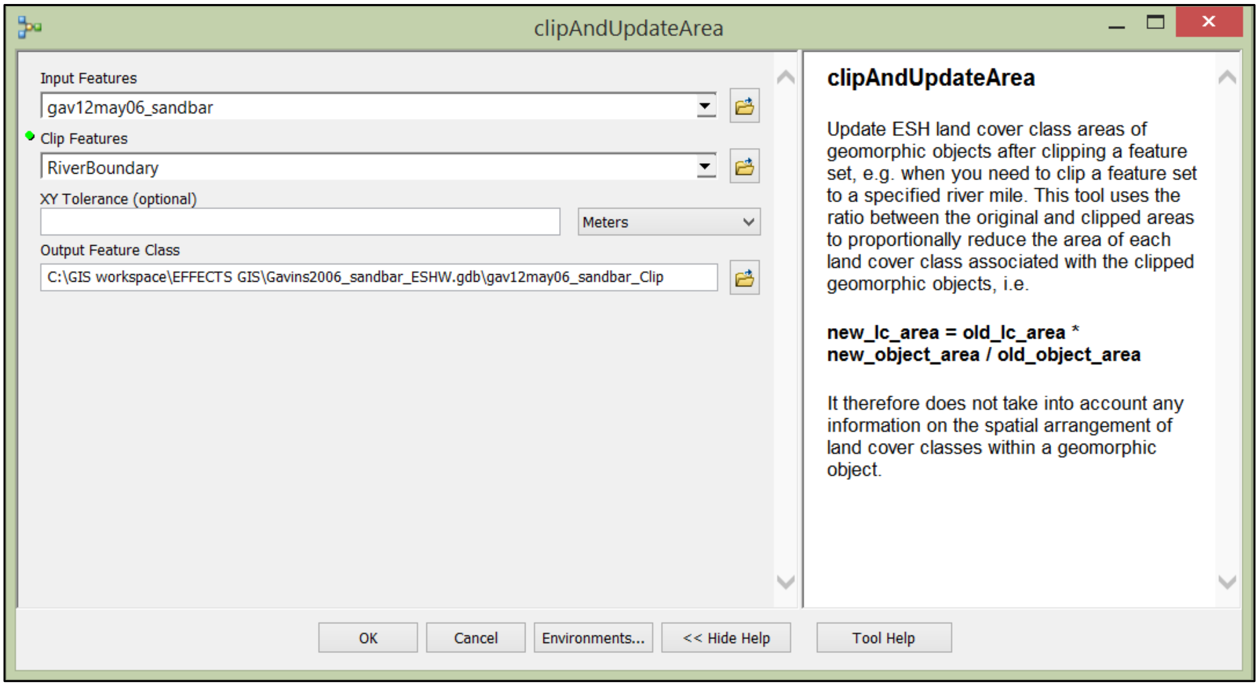


Figure G 2: Clip a feature set to a region of interest using clipAndUpdateArea. In this case, RiverBoundary is a single polygon defining a box around the region of interest.

G.5.7. Step 2: Extract Emergent Sandbar Habitat

Emergent Sandbar Habitat is a vague concept, and care must be taken to explicitly define it. The ESH toolbox provides two tools that calculate ESH based on different definitions. The tool **extractESH** extracts polygons identified as ESH objects and calculates ESH area using the definition in the ESH Adaptive Management Plan, http://moriverrecovery.usace.army.mil/mrrp/f?p=136:175:0::NO::: , whereas the tool **extractESHWEST** (Figure G 3) extracts and computes ESH following the definition of WEST (2014). The AM and WEST definitions of ESH are described below. Both **extractESH** and **extractESHWEST** output feature classes containing only those objects in the input feature classified as ESH, with the additional attribute table field *a_ESH*. The tools also provide an interface for adding discharge and date information to a feature set. The tool creates the fields *TOTAL_DISCHARGE_CFS* and *IMAGE_DATE*, accepting a numeric (decimal) value for discharge (cfs) and an integer (long) value for date, i.e. in the form YYYYMMDD. While this information can easily be added to an attribute table using the field calculator, using this tool ensures consistent and correct naming of the fields across the feature sets. Discharge information is usually included in the item description of each feature set.

Classifying ESH objects according to the Adaptive Management plan

The ESH Adaptive Management Plan defines ESH as areas of un-vegetated and sparsely vegetated dry and wet sand land cover classes on two island sandbar classes and two floodplain sandbar classes (i.e., dry sandbar, wet-dominated sandbar, dry floodplain sandbar, and wet-dominated floodplain sandbar), and on wet sandbars and herb shrub and woodland (i.e. more than 50% vegetated) islands and floodplains that have a fuzzy membership possibility values for a ESH sandbar class. The Adaptive Management program makes the assumption that wet sandbars with no membership for drier sandbar classes are not be used for nesting. The conditions for identifying ESH geomorphic objects in the USGS geodatabases are listed below:

1. Dry sandbar (drysb)
2. Wet-dominated sandbar (wdsb)
3. Floodplain dry sandbar (FPds)
4. Floodplain wet-dominated sandbar (FPwsd)
5. Wet sandbar (wsb)
    - If fuzzy membership for 1or 2
6. Herb shrub island (hsisl)
    - If fuzzy membership for 1or 2
7. Woodland island (woodisl)
    - If fuzzy membership for 1or 2
8. Floodplain wet sandbar (FPws)
    - If fuzzy membership for 3 or 4
9. Floodplain herb shrub
    - If fuzzy membership for 3 or 4
10. Floodplain woodland
    - If fuzzy membership for 3 or 4

ESH geomorphic objects are extracted and using the following Attribute Selection query:

```
(m_drysb + m_wdsb + m_FPds + m_FPwsd) > 0
```

Classifying ESH objects according to WEST (2014)

WEST (2014) described ESH slightly differently in their surveys. First of all, surveys were limited to unattached inter-channel sandbar features, i.e. floodplain sandbars were excluded from the analysis. Furthermore, sandbars smaller than one acre were excluded. It is important to realize that this is different than the procedure used to estimate ESH in the ESH Adaptive Management Program. The WEST method does not discriminate dry and wet sandbars; any exposed sandbar is assumed suitable for nesting. Calculating ESH based on the WEST (2014) survey methods should correspond reasonably well to the conditions listed below:

1. Dry sandbar (drysb)
   - If Area_ha > 0.404686
2. Wet-dominated sandbar (wdsb)
   - If Area_ha > 0.404686
3. Wet sandbar (wsb)
   - If Area_ha > 0.404686
4. Herb shrub island (hsisl)
   - If non-zero fuzzy membership for any 1—3
   - If Area_ha > 0.404686
5. Woodland island (woodisl)
   - If Area_ha > 0.404686
   - If non-zero fuzzy membership for any 1—3

ESH objects are extracted and total ESH area is calculated by **extractESHWEST** using the following Attribute Selection query:

```
( (m_drysb + m_wdsb + m_wsb) > 0 ) AND ( Area_ha > 0.404686
)
```

Note that feature objects do not have non-zero memberships for both island and floodplain classes, i.e. they are classified as either “island” or “floodplain” exclusively.

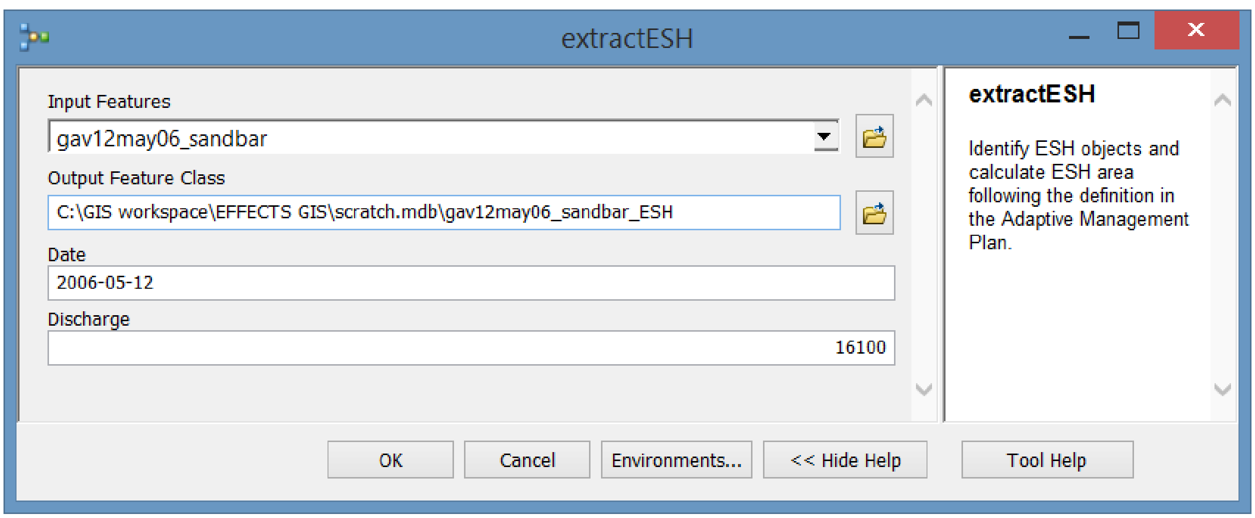


Figure G 3: using extractESH(WEST). Note the date is formatted as YYYY-MM-DD and discharge is in cubic feet per second. Discharge information is usually specified in the feature class metadata.

G.5.8. Step 3: Separate overlapping objects

The ESH features classes will often overlap to some extent, as shown in Figure G 4. These overlapping regions must be accounted for when calculating ESH for the entire reach. One strategy is for the user to manually edit the feature sets and combine them into a composite feature class. However, this strategy is time consuming and difficult to reproduce. Furthermore, complications arise when overlapping images are associated with different discharges. The **separateESH** tool helps automate this procedure by identifying ESH objects in adjacent feature sets that overlap and extracting them. Once the overlapping features are extracted, the user can choose which features to reject and which to maintain. For sets of three or more images, **separateESH** must be used sequentially to separate all overlapping regions.

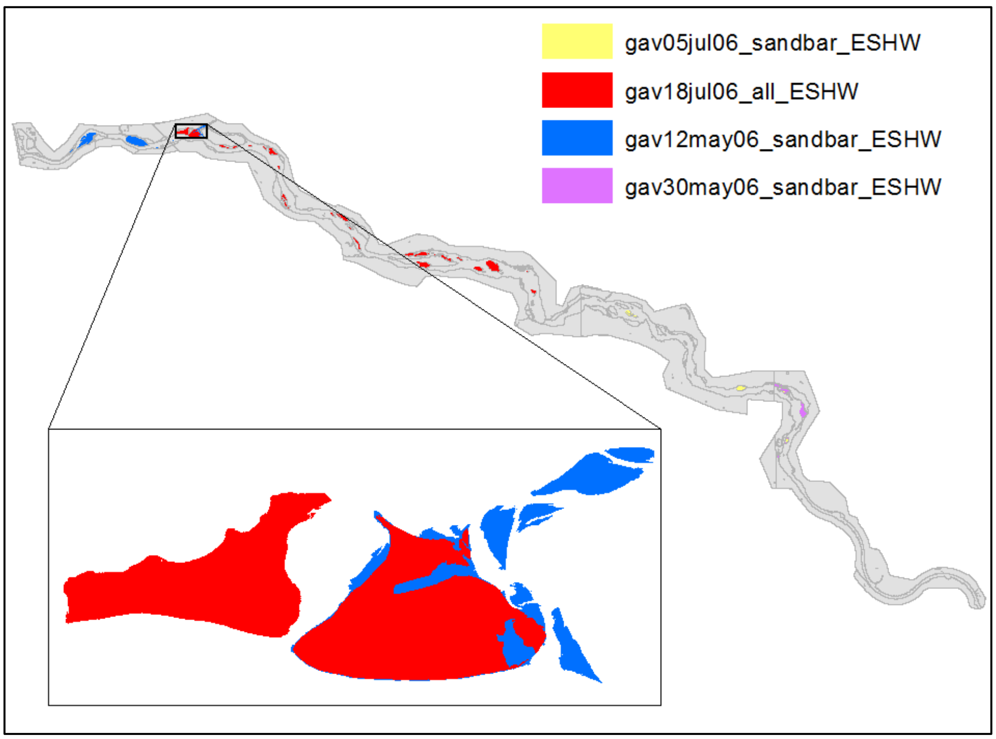


Figure G 4: ESH objects extracted from the original feature sets using extractESHWEST. The overlapping features shown in the inset can be separated from their parent feature sets using separateESH.

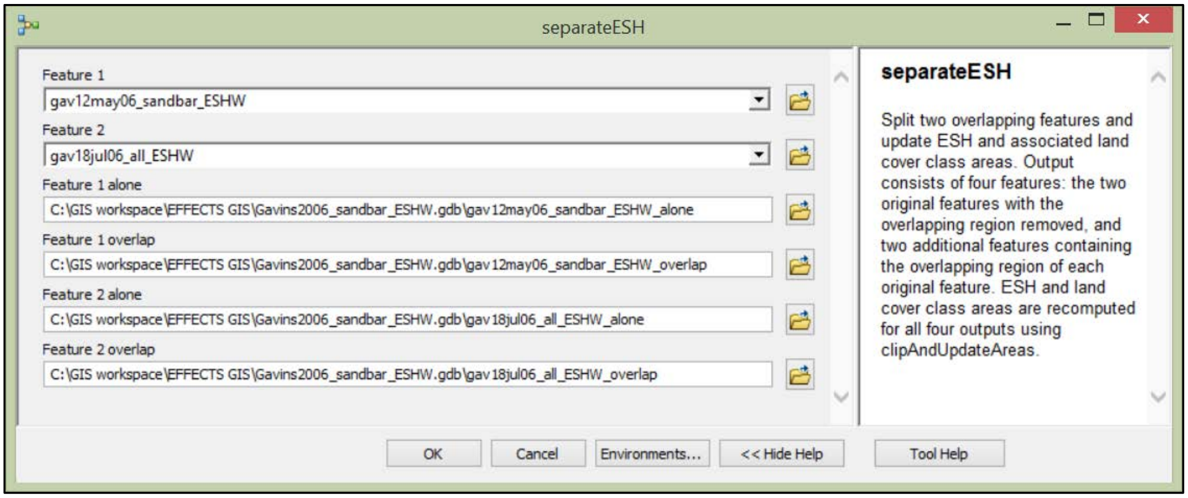


Figure G 5: Use separateESH to separate two overlapping feature sets.

G.5.9. Step 4: Select and discard overlapping features

Once the overlapping objects have been isolated, the user must select which version of each overlapping polygon to use and which to discard. While the choice of which features to use and which to discard is somewhat subjective, the following hierarchical approach is recommended for each pair of overlapping features to maximize reproducibility:

1. If one of the overlapping features occurs at the boundary of an image and is cut off or otherwise incomplete (e.g. due to cloud interference), this feature will be discarded in favor of the more complete feature (completeness).
2. If both overlapping features are complete, the feature associated with a flow closest to the baseline flow (~31,000 cfs) will be retained over the other feature (representativeness).
3. If the overlapping features have similar discharges, then the feature associated with the image that contains the larger number of features will be retained (concurrence).

G.5.10. Step 5: Account for edge features

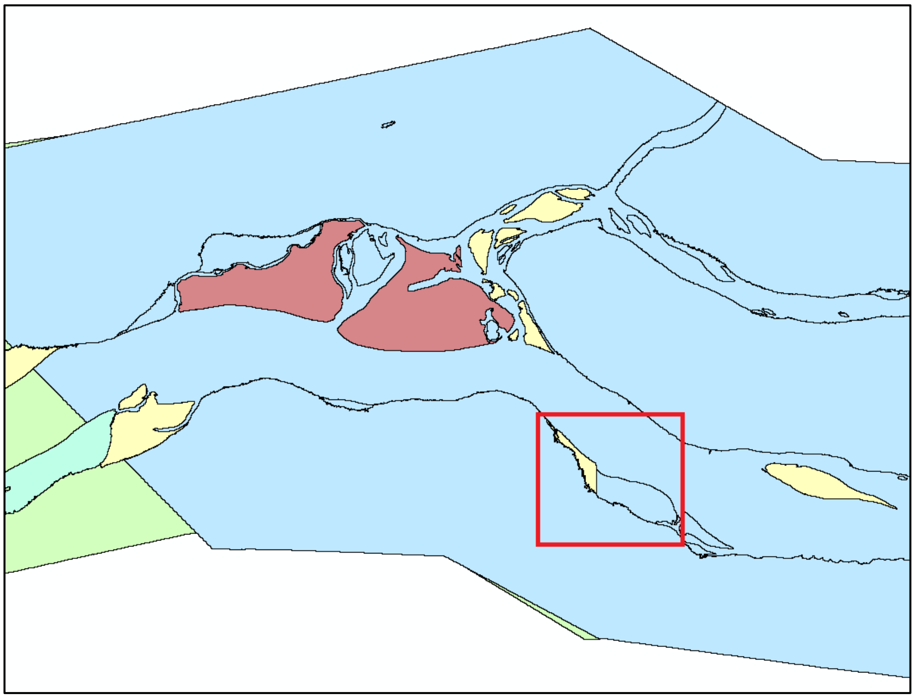


Figure G 6: ESH objects extracted from the original feature sets using extractESH. As shown in the red box, part of a floodplain object at the border of one feature set (green background) is classified as ESH (yellow) while the object captured in the adjacent feature set (blue background) is not.

Care must be taken to account for objects that are split between adjacent feature sets but do not overlap. Due to the way object memberships are calculated, there may be instances where a portion of an object in one feature set meets the ESH classification requirements, but the portion of the object in the adjacent image does not. The following hierarchical approach is recommended for each split feature to maximize reproducibility:

1. If the object is mostly contained in one feature set and is not classified as ESH in that set, then the portion in the adjacent feature set classified as ESH will be discarded.
2. If the object is split more or less equally between two adjacent feature sets and only one of the portions is classified as ESH, the portion classified as ESH will be discarded.
3. If the object is split between two adjacent feature sets and both are classified as ESH, then both objects will be retained. The user may choose to combine these features manually.

G.5.11. Step 6: Recombine feature sets

Once all overlapping polygons have been accounted for, the user can merge the ESH feature sets using the **merge** tool. In cases where there are three or more overlapping images, it may be easier to perform steps 3—6 iteratively; that is, take the first two overlapping images and extract the ESH objects, separate overlapping features and select which features to use in the overlapping region, and then merge them back together and repeat the process with the third overlapping image.

Figure G 7: ESH objects collected into one feature class using merge.

G.5.12. Step 7: Calculate ESH

Each ESH object is comprised of one or more land cover classes. For instance, a “dry sandbar” object may include “dry sand”, “dry sand sparse vegetation”, and “wet sand” land cover classes. The actual ESH habitat associated with an ESH object is the sum of multiple land cover classes. The following land cover classes are used to determine ESH area:

- un-vegetated dry sand (ds: a_FPds, a_ISLds)
- sparsely vegetated dry substrate (dssv: a_FPdssv, a_ISLdssv)
- un-vegetated wet sand (ws: a_FPws, a_ISLws)
- sparsely vegetated wet substrate (wssv: a_FPwssv, a_ISLwssv)

Total ESH area is calculated by **calcESH** using the following Field Calculator expression:

```
ESH = (a_FPds + a_ISLds) + (a_FPdssv + a_ISLdssv)
```

```
        + (a_FPws + a_ISLws) + (a_FPwssv + a_ISLwssv)
```

The **calcESH** tool also adds an additional field *ESHCLASS* which is identifies each feature as either a floodplain (FP) or island (ISL) object. This is achieved based on a comparison of the total floodplain land cover area to the total island land cover area, i.e.

```
IF (a_FPds + a_FPdssv + a_FPws + a_FPwssv) > (a_ISLds + a_ISLdssv
        + a_ISLws + a_ISLwssv)
        ESHCLASS = "FP"
ELSE
        ESHCLASS = "ISL"
```

In a small number of cases, a floodplain geomorphic object may contain both ISL and FP land cover classes. As a result of the calculations and logic described above, the ISL area component is reclassified as FP area in these cases as the ISL area component is much smaller than the FP area component. If the ESH objects were extracted using extractESHWEST, the value of *ESHCLASS* will always be "ISL".

G.5.13. Step 8: Adjust ESH area to baseline discharge

The Adaptive Management plan uses a scaling factor to adjust measurements of ESH area to a baseline discharge of 31,500 cfs. The formula is based on the survey data collected by WEST (2014) and is defined as

$$ESH_{base} = \frac{ESH_q}{a} e^{bQ}$$

where ESH_{base} is the adusted "baseline" ESH, Q is the discharge in kcfs, ESH_q is ESH area measured at that discharge, and the parameters a and b are empirical. The tool **calcBaseESH** computes the baseline ESH using the attribute fields a_ESH and $TOTAL\_DISCHARGE\_CFS$, and adds the field $a\_baseESH$ to the attribute table. The tool automatically adjusts the discharge units from cfs to kcfs, and allows the parameters a and b to be overridden (Figure G 8).

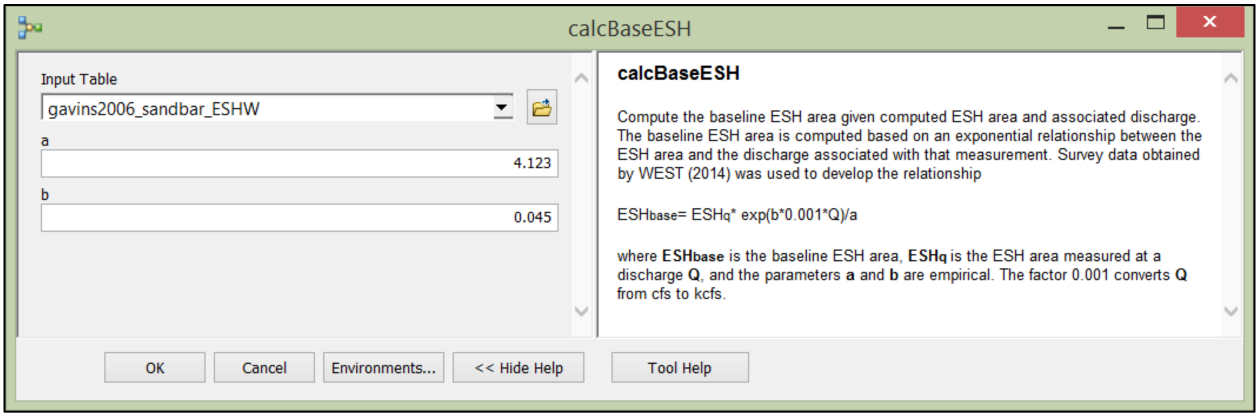


Figure G 8: Compute the baseline ESH area using calcBaseESH.

G.5.14. Step 9: Summarize ESH

In most cases we are interested in computing summary statistics of ESH, such as the total ESH area and the total number of ESH objects in the reach. The tool **summarizeESH** computes summary statistics for ESH including the total ESH area, the minimum and maximum ESH area associated with a single geomorphic object; and the average and standard deviation of ESH area across the geomorphic features (Figure G 9). By default the statistics are computed for the field *a_baseESH*, but statistics of other fields such as the raw ESH area or specific land cover classes can also be computed.

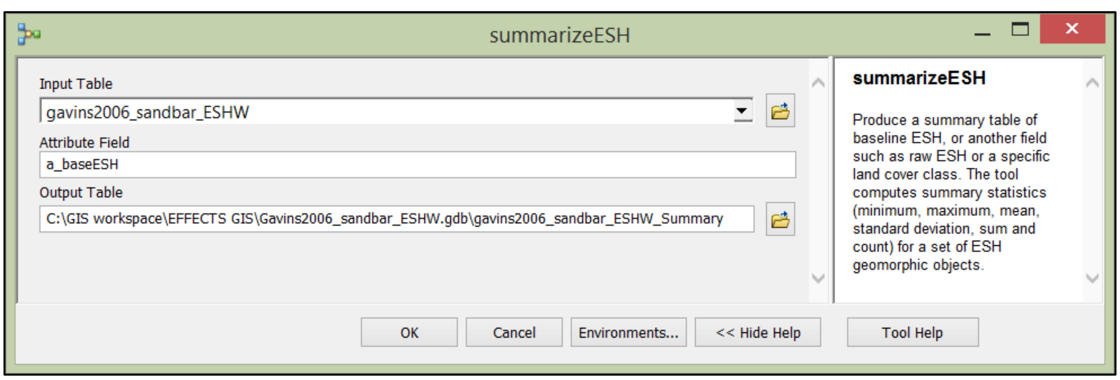


Figure G 9: Using summarizeESH to compute summary statistics for baseline ESH area.

Attachment G.6 Missouri River Emergent Sandbar Habitat Evaluation and Ranking system (ESHER)

The ESHER is a spatial decision support tool developed for evaluating and selecting new ESH restoration sites according to the 2003 BiOp. This attachment describes ESHER, contains detailed descriptions of all the default variables that can be used in an ESHER assessment, and provides instructions on applying and making modifications to the tool.

G.6.15. Description of ESHER

G.6.15.1. General Overview

ESHER is a spatial decision support system (SDSS) that was created using the ArcGIS ModelBuilder application and is run out of the ArcToolbox program (Figure 1). The tool consists of 7 distinct modules. Three of the modules (Calculate Variable Values, Scale Variables (Site Evaluation) and Scale Variables (Reach Evaluation)) are for pre-processing data; these modules need to be run before the 2 primary modules (ESHER Site Evaluation and ESHER Reach Evaluation) can be run. The last 2 modules (Create Site Scaled Variable Output, Part 1 and Part 2) are used to create an optional site evaluation output that depicts the un-weighted, scaled variable scores for each of the sites being evaluated. The Calculate Variable Values pre-processing module requires an ArcINFO level license in order to be run, all other modules can be run using the basic ArcView level license.

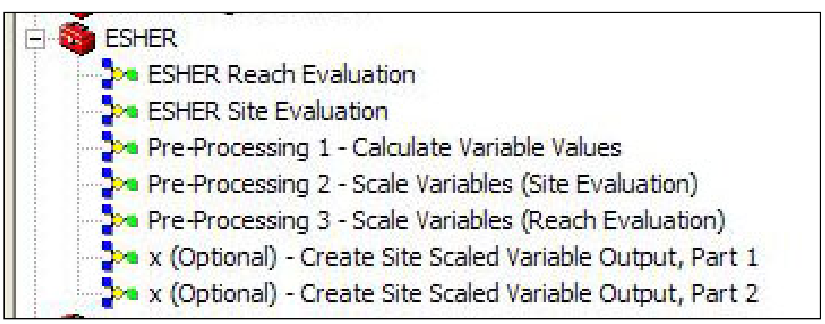


Figure G 10:. The ESHER ArcToolbox interface.

The ESHER Site Evaluation (ESE) module is used to score and rank potential ESH restoration sites that have already been pre-selected by the end-user. The ESHER Reach Evaluation (ERE) module calculates scores for every 10 meter x 10 meter cell contained in the Fort Randall, Fort Peck, Gavins Point, Garrison, and Lewis and Clark Lake segments. The output from the ESHER Reach Evaluation can then be used as a basis for identifying additional ESH restoration sites (which in turn can then be further evaluated with the ESE module).

The ESE and ERE modules allow the basic end-user to assign weights to pre-scaled, model variables. The ESE module includes 25 variables while the ERE module contains 18 variables. The ERE has less variables because it does not include any site-specific variables (size of restoration area, for instance). More advanced users can adjust the scaling of these variables by making edits to the "Scale Variables" (Pre-Processing 2 and Pre-Processing 3) modules (See Chapter 4).

2. ESHER Variables

The following section contains information on each of the variables that are included in the ESE and ERE modules. The variables chosen for inclusion in the model were based on input from a multi-agency project delivery team (PDT), which included personnel from the USACE, National Park Service, US Fish and Wildlife Service, Natural Resources Conservation Service, US Geological Survey, Nebraska Game and Parks Commission, South Dakota Department of Game, Fish, and Parks, North Dakota Game and Fish Department, and North Dakota State Water Commission. These variables are indicators of various management preferences for site selection, such as sandbar sustainability, nesting and habitat suitability, and limiting impact to other environmental and anthropogenic resources.

Information on each of the variables is included in the following format:

Relevant module: ESE, ERE, or both.

Data source and processing: Where the data layer was derived from, and a basic description of the process used to derive it.

Purpose: Justification for why the variable is included in the module(s).

Scaling: Default scaling that is used in the module(s), and an explanation as to how that scaling was determined.

Limitations: Any significant factors which could potentially affect the accuracy of the variable.

Three additional notes – 1) all raster geoprocessing functions (such as Euclidian Distance) were run using 10 meter x 10 meter cell sizes, 2) the distance of potential restoration sites to a given feature was calculated as the average distance of all cells within that site to the feature, and 3) reach habitat delineations and "sensitive resource" spatial data were provided by a USACE contractor, David Miller and Associates (DMA).

C.5.1.1.1 2.1. Channel Width

Relevant Module: ESE, ERE

Data source and processing: Channel widths were derived from the 2005 reach habitat delineations, using the following process: Channel "top" and "bottom" banks were created as polylines based on the outer edges of the habitat delineation, excluding riverine forest and shrub habitats. If there were large islands (categorization of island size was a subjective judgment) within the channel, additional top and bottom channels were created within the primary channel banks to account for these islands. The "Euclidian Distance" geoprocessing function was run using each bank as a source. The two resulting rasters were then added together. Finally, an extraction on the combined raster was performed using the original habitat delineation as a mask. Channel width for a potential site was measured as the average channel width across the length of the site. Widths derived from Elliott and Jacobson (2006) were used to cross-check this methodology to ensure that results of the ESHER processing method are similar to those used to establish the scaling for this variable.

Purpose: The channel width is an important variable for creation of sandbar habitats, as width of the channel will affect the erosion rates at the sandbar. Additionally, existing emergent sandbars and shallowly submerged sandbars occurring in depositional areas are often used as a base on which to construct ESH in order to limit the potential for changes to channel geomorphology as a result of the project and reduce the amount of fill needed for construction.

Scaling: The scaling of this variable is specific to each reach, and is shown in **Error! Reference source not found.**.

Table G 1: Scaling of Channel Width variable.

	Channel Width (m)				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	Width	Width	Width	Width	Width
10	975	All	800	693	327
9	945		778	686	319
8	914		756	679	311
7	884		734	672	303
6	853		711	665	295
5	822		689	658	287
4	792		667	651	279
3	761		645	644	271
2	731		623	637	263

1	700		600	630	255
0	< 700		< 600	< 630	< 255

Elliott and Jacobson (2006) reported mean channel widths that had sustained sandbars and transition zone channel widths below which sandbars are not likely to exist for Gavins Point and Fort Randall reaches. Biedenharn et al. (2001) reported similar information for Garrison and Fort Peck reaches. Channel widths that are the mean value for sustained sandbars or higher for a given reach receive a score of 10, while widths that are less than the transition zone width receive a score of 0. Because Lewis & Clark reach is a lake, erosion is not an issue and all potential restoration sites in that reach receive a score of 10 for the variable. Variable scaling for the remaining scores was determined according to a linear distribution of widths between the mean high value and the transition zone value.

Limitations: Scaling is based on channel widths that were determined by Elliott and Jacobson (2006) and Biedenharn et al. (2001). Although some spot checking was done, these widths may not always correspond with the channel widths that were calculated in this model.

2.2. Total Cumulative Historical Tern and Plover Nests

Relevant Module: ESE

Data source and processing: Nest counts were based on field surveys done from 1998 to the present. Only points with a high location accuracy (meaning a GPS position of the point was taken) are used in this analysis. Nests per site are calculated using the Spatial Join geoprocessing function to join the nest points input shapefile to the potential restoration sites input shapefile.

Purpose: It is assumed that sites with more nests historically will also have more nests in the future, once the area is restored. Additionally, one of the two target species (piping plover) is known to give preference to previously used sites when undertaking nest site selection (Haig and Oring, 1988).

Scaling: The scaling of this variable is specific to each reach, and is shown in Table G 2.

Table G 2: Scaling of Total Cumulative Tern and Plover Nests variable.

	Total Cumulative Historical Tern and Plover Nests				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	Nests	Nests	Nests	Nests	Nests
10	308	35	129	79	33
9	274	31	115	70	29
8	240	27	101	62	26
7	206	24	86	53	22
6	172	20	72	44	19
5	137	16	58	36	15
4	103	12	44	27	12
3	69	9	29	18	8
2	35	5	15	10	5
1	1	1	1	1	1
0	0	0	0	0	0

For each reach, the maximum number of cumulative historical nests that were found at a single site was measured. Potential restoration sites within the reach that have this many historical nests or greater receive a score of 10. Potential sites with no historical nests receive a score of 0, and sites with at least one nest receive a score of 1. Variable scaling for the remaining scores was determined according to a linear distribution of historical nests between 1 and the maximum number of historical nests.

Limitations: None

C.5.1.1.2 2.3. Size of Potential Restoration Area

Relevant Module: ESE

Data source and processing: Areas are determined within ArcGIS, based on the estimated footprint of the potential restoration site.

Purpose: Larger restoration sites provide the potential to construct sandbar complexes of optimum size. Additionally, there is increased cost efficiency with larger construction projects as a large percentage of construction costs are attributable to mobilization of equipment. This means it is less expensive to construct one 60 acre complex when compared to two geographically separate 30 acre complexes.

Scaling: The scaling of this variable is shown in Table G 3.

Table G 3: Scaling of Size of Potential Restoration Area variable.

Size of Potential Restoration Area (Acres)	
ALL Segments	
Score	Acres
10	60
9	54
8	48
7	41
6	35
5	29
4	23
3	16
2	10
1	4
0	< 4

The USFWS 2003 Amended Biological Opinion recommends 60 acres as the optimum size and 4 acres as a minimum size for emergent sandbar habitats. Therefore, potential sites 60 acres or larger receive a variable score of 10, and sites smaller than 4 acres receive a score of 0. The rest of the variable scaling was determined according to a linear distribution of sizes between the minimum and optimum site sizes among the remaining scores.

Limitations: Due to the dynamic nature of the Missouri River, potential site polygons may not accurately reflect the actual footprint of a complex at the time of construction.

C.5.1.1.3 2.4. Primary Site Condition

Relevant Module: ESE

Data source and processing: This score is manually assigned to potential restoration sites based on its existing characteristics as derived from site visits and/or the most recent available aerial photography.

Purpose: This variable is an indicator of the amount of work and cost (adding sand and removing vegetation) that would be required to restore or create a site, as well as previous levels of success that have been achieved in restoring sites of a given condition.

Scaling: The scaling of the variable is shown in Table G 4.

Table G 4. Scaling of Primary Site Condition variable.

Primary Site Condition		
ALL Segments		
Score	Condition	Code
10	Shallow Water	SW
7	Sparsely Vegetated Existing Bar	SVB
5	Existing Vegetated Bar	EVB
0	Open Water	OW

The shallow water condition would require a medium amount of sand for construction but would not require initial vegetation removal, and there has been previous success under these conditions. Sparsely vegetated and existing vegetated bars would require minimal sand for construction, but would require initial vegetation removal, and there has been no previous success in restoring these condition types. Open water areas would require a maximum amount of sand, and there have been no previous successes in this condition type.

Limitations: None

2.5. Distance to Existing Nest Site Complexes

Relevant Module: ESE, ERE

Data source and processing: Existing nest counts were based on field surveys done in the prior year (i.e., a 2009 site evaluation would be based on 2008 nest counts). Existing nests that were part of a complex that included at least 5 total nests were selected, and the "Euclidian Distance" function was used to determine the distance from each cell in a reach to the nearest one of these nest complexes. Defining a complex as having a minimum of 5 nests was based on best professional judgment, using the rationale that this number would eliminate outliers and would be some indication of nesting site quality and/or preference.

Purpose: One of the priorities for restoration is to restore habitats in areas that do not have an abundance of existing nesting habitat.

Scaling: The scaling of the variable is shown in Table G 5.

Table G 5: Scaling of Distance to Existing Nest Site Complexes variable.

Distance (miles) to Existing Nest Site Complexes
ALL Segments

Score	Distance
10	20
9	18
8	16
7	14
6	12
5	10
4	8
3	6
2	4
1	2
0	0

In the reach with the most distance between nest sites, Fort Peck, nests can be 20 miles apart or greater. Therefore, cells that are ≥ 20 miles away from existing nest site receive a score of 10. Cells that are adjacent to existing sites (less than 2 miles) receive a score of 0. The rest of the variable scaling was determined according to a linear distribution of distances between 1 and 20 miles among the remaining scores.

Limitations: None

2.6. Presence of Wetlands

Relevant Modules: ESE, ERE

Data source and processing: Wetlands were identified in the 2005 habitat delineations. For potential restoration sites, the percentage of the site that consisted of wetlands was calculated within ArcGIS.

Purpose: ESH restoration should ideally minimize impacts to wetland areas, as they are protected under Section 404 of the Clean Water Act. With regard to this variable alone, the ideal ESH project would not impact any existing wetlands.

Scaling: The scaling for the ESE module is shown in Table G 6. For the ERE module, a simple presence/absence scale is used: if a cell contains wetland a score of 0 is assigned, if a cell does not contain wetland, a score of 10 is assigned.

Table G 6: Scaling of Presence of Wetlands variable for ESE module.

Presence of Wetlands	
	ALL Segments
Score	Percentage of Wetland
10	0%
9	10%
8	20%
7	30%
6	40%
5	50%
4	60%
3	70%
2	80%
1	90%
0	100%

Potential restoration sites that contain no wetlands receive a score of 10, while sites that are entirely wetland receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of percentages between 0 and 100.

Limitations: Habitat delineations indicating the presence of wetlands at a proposed site do not necessarily indicate the presence of jurisdictional wetlands subject to the provisions of the Clean Water Act.

2.7. Distance to Protected Shoreline

Relevant Modules: ESE, ERE

Data source and processing: Protected areas were identified from the National Park Service Landowner Database, and will be updated in the near future with lands owned by States, the Federal government, and conservation groups that limit development. The "Euclidian Distance" geoprocessing function was run to determine the distance from each cell within a reach to nearest one of these features.

Purpose: Human disturbance of nesting sites is a concern for the ESH program, as is public perception of erosion caused by the placement of projects. While there has been no conclusive evidence of erosion being caused by the restoration of ESH, restoration activities adjacent to publicly owned lands or parcels protected by easements are seen as preferable because this is seen to limit the potential for disturbance due to human development as well as reducing the potential for perceived erosion issues.

Scaling: The scaling of the variable is shown in Table G 7.

Table G 7. Scaling of Distance to Protected Shoreline variable.

Distance to Protected Shoreline (m)	
	ALL Segments
Score	Distance
10	402
9	764
8	1,127
7	1,489
6	1,851
5	2,213
4	2,575
3	2,937
2	3,299
1	3,661
0	4,023

A general assumption was made that sites within ¼ mile (402 meters) of a protected shoreline are more likely to be bordered by this type of shoreline on at least one bank, while sites greater than 2.5 miles (4,023 meters) from a protected shoreline are unlikely to be bordered by this type of shoreline on either bank. Therefore, cells that are ≤ 402 meters away from a protected shoreline receive a score of 10, and cells that are ≥ 4,023 meters from a protected shoreline receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 402 and 4,023 meters.

Limitations: This variable acts as an approximate surrogate for a "percentage of adjacent shoreline that is protected" variable. That variable was not used in the model due to the difficulty of automating the calculation.

2.8. Potential for Backwater Restoration

Relevant Module: ESE

Data source and processing: Potential restoration sites were manually designated as being either associated or not associated with historic backwater areas, based on field determinations and/or analysis of aerial photography.

Purpose: The presence of historic backwaters provides the potential for floodplain features to be restored in conjunction with ESH restoration. While these features are beneficial to the general riverine ecosystem, they also represent a habitat type important to the food source of one of the two target species, least tern. When coupling backwater restoration with ESH creation, it is assumed that least terns will benefit from this increase in foraging habitat adjacent to the nesting site.

Scaling: Sites that have the potential for backwater restoration are given a score of 10, sites without that potential are given a score of 0.

Limitations: None

2.9. D50 Sediment Size

Relevant Module: ESE

Data source and processing: This variable was generated based on sediment samples that had been taken at various locations within the reaches between 1984 and 2007. The "Near" geoprocessing function is used to determine the sample that is closest to the potential restoration site, and the sediment size of that sample is assigned to the site.

Purpose: This variable is assumed to be representative of the abundance of "suitable" material in the vicinity of a proposed restoration site. In areas where suitable material is not abundant, targeted surveys have been necessary in order to identify potential borrow areas. This leads to increases in project cost and time needed for construction activities.

Scaling: The scaling of this variable is specific to each reach, and is shown in Table G 8.

Table G 8. Scaling of D50 Sediment Size variable.

	D50 Sediment Size (mm)				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	D50	D50	D50	D50	D50
10	> 0.38		> 0.27	> 0.21	> 0.25
5	0.30 - 0.38		0.20 - 0.27	0.20 - 0.21	0.22 - 0.25
0	< 0.30	All	< 0.19	< 0.20	< 0.22

Biedenharn et al (2001) reported by reach the average D50 sediment sizes for both plover habitat and non-plover habitat sandbars. For the Gavins, Fort Randall, Garrison, and Fort Peck reaches, sites that are associated with D50 sediment sizes that are greater than the reach average for habitat sandbars receive a score of 10, sites with sediment sizes less than the reach average for non-habitat sandbars receive a score of 0, and sites with sediment sizes that are between the habitat and non-habitat averages are given a score of 5. All potential sites within the Lewis and Clark reach are given a variable score of 0, since previous efforts in that reach have required surveys in order to identify borrow sources with suitable material.

Limitations: The assumption is being made that the sediment size at the closest sediment sample point is representative of the borrow area adjacent to the potential restoration site. Due to the sporadic distribution of sediment points, this assumption may not always be accurate.

2.10. Distance to Mainstem Dam

Relevant Module: ESE, ERE

Data source and processing: River distance from each reach cell to the nearest mainstem dam was calculated using the "Cost Distance" geoprocessing function on a rasterized version of the 2005 reach habitat delineations, with all cells assigned a value of 1.

Purpose: Directly downstream of dams there is limited nesting activity and potential for restoration is limited due to degradation and/or increased influence of power-peaking flows.

Scaling: The scaling of this variable is specific to each reach and is shown in Table G 9.

Table G 9. Scaling for Distance to Mainstem Dam variable.

	Distance to Mainstem Dam (m)				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	Distance	Distance	Distance	Distance	Distance
10	17,678	9,449	49,987	28,651	93,299
9	16,256	8,568	45,375	27,059	84,728
8	14,834	7,688	40,762	25,468	76,156
7	13,411	6,807	36,149	23,876	67,584
6	11,989	5,927	31,537	22,284	59,013
5	10,566	5,046	26,924	20,693	50,441
4	9,144	4,166	22,311	19,101	41,869
3	7,722	3,285	17,699	17,509	33,298
2	6,299	2,405	13,086	15,917	24,726
1	4,877	1,524	8,473	14,326	16,154
0	< 4,877	< 1,524	< 8,473	< 14,326	< 16,154

For each reach, the river distance from the dam to the first major mainstem tributary was measured. Cells that are this distance or greater from a dam receive a score of 10. For each reach, the closest recorded nest to each dam was also determined. Cells that are less than this distance away from a dam receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the closest nest distance and the distance to the nearest major tributary.

Limitations: None

2.11. Historic Predation Events

Relevant Module: ESE

Data source and processing: Field survey nest counts also contain a record of which nests experienced predation. This information is used to determine the number of historical nests that had been predated at each potential restoration site.

Purpose: It is assumed that sites with less historical predation will likely experience lower levels of future predation.

Scaling: The scaling of this variable is specific to each reach and is shown in Table G 10.

Table G 10. Scaling for Historic Predation Events variable.

	Historic Predation Events				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fortt Peck
Score	Events	Events	Events	Events	Events
10	0	0	0	0	0
9	4	2	2		
8	8	5	5		
7	13	7	7		
6	17	10	9	1	
5	21	12	12		
4	25	14	14		
3	29	17	16		1
2	34	19	18	2	
1	38	22	21		
0	42	24	23	3	2

For each reach, the highest number of predated nests at any one historical site was determined. Proposed restoration sites that had this many events or more receive as score of 0. Sites with no historical predation receive a score of 10. Variable scaling for the remaining scores was determined according to a linear distribution of predation events between 0 and the historical maximum.

Limitations: As nest surveys at individual sites may be conducted a week apart or more, it is difficult to accurately capture when a nest is predated. Thus, predation records may not be entirely representative of the rate of predation at various sites.

2.12. Distance to Treeline

Relevant Module: ESE, ERE

Data source and processing: For all reaches with the exception of Lewis & Clark, treelines were obtained from the DMA sensitive resources data. For Lewis & Clark reach, the treeline was defined by the riverine forest habitat class due to unavailability of the treeline shapefile for this reach. The “Euclidian Distance” geoprocessing function is used to determine the distance of every cell within a reach to the nearest treeline.

Purpose: Analysis of nesting data conducted as part of the Programmatic Environmental Impact Statement for the Emergent Sandbar Habitat Program (PEIS) indicate that terns and plovers displayed preferential nesting site-selection of areas farther away from treelines. It is assumed that nests on restored sites that are further away from a treeline will be less susceptible to predation from raptors.

Scaling: The scaling of this variable is shown in Table G 11.

Table G 11. Scaling for Distance to Treeline variable.

Distance to Existing Tree Line (m)	
	All Segments
Score	Distance
10	290
9	249
8	208
7	168
6	154
5	141
4	128
3	115
2	102
1	88
0	< 88

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a treeline. Cells that are the average separation distance or further from a treeline receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a treeline) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.13. Distance to Boat Ramp

Relevant Module: ESE, ERE

Data source and processing: Boat ramps were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest boat ramp.

Purpose: Boat ramps are a source of human disturbance, and plovers and terns tend to nest further away from these areas. It is assumed that selecting potential sites farther away from boat ramps will reduce the potential for human disturbance at a restored site.

Scaling: The scaling of this variable is shown in

Table G 12. Scaling for Distance to Boat Ramp variable.

Distance to Boat Ramp (m)	
	All Segments
Score	Distance
10	743
9	571
8	400
7	229
6	209
5	189
4	170
3	150
2	130
1	111
0	< 111

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a boat ramp. Cells that are the average separation distance or further from a boat ramp receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a boat ramp) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.14. Distance to Boat Dock

Relevant Module: ESE, ERE

Data source and processing: Boat docks were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest boat dock. Selecting potential sites farther away from boat docks will reduce the potential for human disturbance.

Purpose: Boat docks are a source of human disturbance, and plovers and terns tend to nest further away from these. It is assumed that selecting potential sites farther away from boat docks will reduce the potential for human disturbance at a restored site.

Scaling: The scaling of this variable is shown in Table G 13.

Table G 13. Scaling for Distance to Boat Dock variable.

Distance to Boat Dock (m)	
	All Segments
Score	Distance
10	542
9	417
8	292
7	168
6	157
5	146
4	136
3	125
2	115
1	104
0	< 104

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a boat dock. Cells that are the average separation distance or further from a boat dock receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a boat dock) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.15. Distance to Domicile

Relevant Module: ESE, ERE

Data source and processing: Domiciles were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest domicile.

Purpose: Domiciles are a source of human disturbance, and plovers and terns tend to nest further away from these. Potential sites farther away from domiciles are assumed to have a reduced potential for human disturbance.

Scaling: The scaling of this variable is shown in Table G 14.

Table G 14. Scaling for Distance to Domicile variable.

Distance to Domicile (m)	
	All Segments
Score	Distance
10	682
9	541
8	400
7	259
6	251
5	243
4	235
3	227
2	218
1	210
0	< 210

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a domicile. Cells that are the average separation distance or further from a domicile receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a domicile) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.16. Distance to Water Intake

Relevant Module: ESE, ERE

Data source and processing: Water Intakes were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest water intake.

Purpose: It is desirable to avoid restoration in areas that have the potential to impact water intakes through either sedimentation or changes in water quality.

Scaling: The scaling of this variable is shown in Table G 15.

Table G 15. Scaling for Distance to Water Intake variable.

Distance to Water Intake (m)	
	All Segments
Score	Distance
10	713
9	562
8	410
7	259
6	253
5	246
4	240
3	234
2	228
1	221
0	< 221

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a water intake. Cells that are the average separation distance or further from a water intake receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a water intake) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.17. Distance to Recreation Area

Relevant Module: ESE, ERE

Data source and processing: Recreation areas were identified from the DMA sensitive resources data. The “Euclidian Distance” geoprocessing function is used to determine the distance of every cell within a reach to the nearest recreation area.

Purpose: Recreation is a source of human disturbance, and plovers and terns tend to nest further away from these areas. Potential projects farther away from recreation areas have a higher potential for reduction in human disturbance.

Scaling: The scaling of this variable is shown in Table G 16.

Table G 16. Scaling for Distance to Recreation Area variable.

Distance to Recreation Area (m)	
	All Segments
Score	Distance
10	398
9	336
8	275
7	213
6	189
5	164
4	139
3	114
2	90
1	65
0	< 65

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a recreation area. Cells that are the average separation distance or further from a recreation area receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a recreation area) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.18. Distance to Urban Zone (Bismarck)

Relevant Module: ESE, ERE

Data source and processing: The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the heavily urbanized zone of the river near the city of Bismarck, ND.

Purpose: Heavily urbanized areas along the river present the highest risk of human disturbance. The only heavily urbanized area relevant to this tool is that of Bismarck, ND. Projects located away from this urban zone are assumed to have a decreased risk of human disturbance.

Scaling: The scaling of this variable is shown in Table G 17.

Table G 17. Scaling for Distance to Urban Zone (Bismarck) variable.

Distance to Urban Zone (m)	
	All Segments
Score	Distance
10	32,187
9	28,968
8	25,750
7	22,531
6	19,312
5	16,093
4	12,875
3	9,656
2	6,437
1	3,219
0	0

Anecdotal evidence suggests that recreational boaters will travel up to 20 miles (32, 187 meter) along the river away from Bismarck. Cells farther than 32,187 meters away receive a score of 10, while cells adjacent to Bismarck receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 0 and 32,187.

Limitations: None

2.19. Distance to Bald Eagle Nest

Relevant Module: ESE, ERE

Data Source and Processing: The "Euclidian Distance" geoprocessing function is used to determine the distance between every cell within a reach to the closest bald eagle nest. Bald eagle nest locations are from National Park Service field surveys and will be updated in the near future with records from states and other agencies.

Purpose: Restoration activities should avoid impacts to bald eagle nests, in accordance with the Bald and Golden Eagle Protection Act.

Scaling: The scaling of this variable is shown in Table G 18.

Table G 18. Scaling for Distance to Bald Eagle Nest variable.

Distance to Bald Eagle Nest (m)	
	All Segments
Score	Distance
10	1,609
9	1,448
8	1,287
7	1,127
6	966
5	805
4	654
3	503
2	352
1	201
0	< 201

Written comments by the USFWS (2004) to the Omaha District recommended a separation distance of 1 mile (1,609 meters) between bald eagle nests and construction activities. Following the removal of the Bald Eagle from the Endangered Species List, the USFWS National Bald and Golden Eagle Management Guidelines (2007) recommended separation distances of ½ mile (805 meters) for construction activities producing loud noises, and 1/8 mile (201 meters) for construction activities that would be visible from a nest. Based on the 2004 and 2007 guidelines, cells that are ≥ 1,609 meters from a bald eagle nest receive a score of 10, cells that are 805 meters from a nest receive a score of 5, and cells < 201 meters from a nest receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 805 and 1,609 meters, and between 201 and 805 meters.

Limitations: None

2.20. Distance to Cultural Resources

Relevant Module: ESE, ERE

Data Source and Processing: The “Euclidian Distance” geoprocessing function is used to determine the distance between every cell within a reach to the closest cultural resource. Cultural resource locations are from internal USACE databases.

Purpose: Cultural Resources and historic properties are protected by numerous federal and state laws, and impacts to known sites should be avoided if possible. Potential sites that are farther from known cultural resources would require less intensive efforts to comply with applicable laws, resulting in reduced time and cost for program implementation.

Scaling: The scaling of this variable is shown in Table G 19.

Table G 19. Scaling for Distance to Cultural Resources variable.

Distance to Cultural Resources (m)	
	All Segments
Score	Distance
10	1,609
9	1,448
8	1,287
7	1,127
6	966
5	805
4	704
3	604
2	503
1	402
0	< 402

Based on expert opinion (Barnum 2009), activities greater than 1 mile (1,609 meters) away from a cultural resource are unlikely to have any impact on it; activities half a mile (805 meters) away are also unlikely to have an impact but on-site investigations may be warranted; activities within a quarter-mile (402 meters) would likely warrant an on-site investigation and potentially the supervision of construction activities. Based on these recommendations, cells ≥ 1,609 meters away from a cultural resource receive a score of 10, cells 805 meters away receive a score of 5, and cells < 402 meters away receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 805 and 1,609 meters, and between 402 and 805 meters.

Limitations: None

2.21. Distance to Bridges

Relevant Module: ESE, ERE

Data Source and Processing: Bridges were identified from the DMA sensitive resources layer. The “Euclidian Distance” geoprocessing function is used to determine the distance between every cell within a reach to the closest bridge.

Purpose: Restoration projects should avoid bridges in order to prevent any accidental damage that may occur to the bridge during construction. Bridges also present a form of potential noise and visual disturbance to nesting birds.

Scaling: The scaling of this variable is shown in 20.

Table G 20. Scaling for Distance to Bridges variable.

Distance to Bridges (m)	
	All Segments
Score	Distance
10	823
9	741
8	658
7	576
6	494
5	411
4	329
3	247
2	165
1	82
0	0

On the Missouri River, the closest distance a successful nest on record was to a bridge was 823 meters. Cells that are this distance or further away from a bridge receive a score of 10. Cells adjacent to a bridge receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 0 and 823 meters.

Limitations: None

2.22. Distance to Industrial Facilities

Relevant Module: ESE, ERE

Data Source and Processing: Industrial facilities were identified from the DMA sensitive resources layer. The “Euclidian Distance” geoprocessing function is used to determine the distance between every cell within a reach to the closest industrial facility.

Purpose: Restoration projects should avoid industrial facilities in order to prevent any accidental damage that may occur to the facility during construction. Industrial facilities also present a form of potential disturbance to the habitat.

Scaling: The scaling of this variable is shown in Table G 21.

Table G 21. Scaling for Distance to Industrial Facilities variable.

Distance to Industrial Facilities (m)	
	All Segments
Score	Distance
10	205
7	168
1	160
0	< 160

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to an industrial facility. Cells that are the average separation distance or further from an industrial facility receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from an industrial facility) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Due to the limited range of distance values, additional scores were not utilized for this variable.

Limitations: None

2.23. Distance to Power Stations

Relevant Module: ESE, ERE

Data Source and Processing: Power stations were identified from the DMA sensitive resources layer. The "Euclidian Distance" geoprocessing function is used to determine the distance between every cell within a reach to the nearest power station.

Purpose: Restoration projects should avoid power stations in order to prevent any accidental damage that may occur to the station during construction. Power stations also present a form of potential disturbance to the habitat.

Scaling: The scaling of this variable is shown in Table G 22.

Table G 22. Scaling for Distance to Power Stations variable.

Distance to Power Stations (m)	
	All Segments
Score	Distance
10	3,810
9	3,598
8	3,387
7	3,175
6	2,963
5	2,752
4	2,540
3	2,328
2	2,117
1	1,905
0	< 1,905

The Montana-Dakota Utility agency has requested a separation distance of at least 3,810 meters between power stations and restoration sites. Also, the closest distance a successful nest on record was to a power station was 1,905 meters. Therefore, cells that are ≥ 3,810 meters away from a power station receive as score of 10, while sites < 1,905 meters away receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 1,905 and 3,810 meters.

Limitations: None

2.24. Distance to Utilities

Relevant Module: ESE, ERE

Data Source and Processing: Utilities (pipelines, powerlines, and cables) were identified from the DMA sensitive resources layer. The “Euclidian Distance” geoprocessing function is used to determine the distance between every cell within a reach to the nearest utility.

Purpose: Restoration projects should avoid utilities in order to prevent any accidental damage that may occur to the station during construction. Utilities also present a form of potential disturbance to nesting birds.

Scaling: The scaling of this variable is shown in Table G 23.

Table G 23. Scaling for Distance to Utilities variable.

Distance to Utilities (m)	
	All Segments

Score	Distance
10	1,609
9	1,456
8	1,303
7	1,149
6	996
5	842
4	689
3	535
2	382
1	229
0	< 229

A separation distance of one 1 mile (1,609 meters) was deemed a reasonable separation distance for avoiding accidental impacts to utilities from construction activities as this represents the maximum distance dredged material can be transported before an additional “booster” pump is needed and is also likely to be the maximum extent of a borrow area in any one direction from a restoration site. Additionally, this distance should be adequate for reducing impacts to birds from overhead power lines. Also, the closest distance a successful nest on record was to a utility was 229 meters. Therefore, cells that are ≥ 1,609 meters away from a utility receive as score of 10, while sites < 229 meters away receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 229 and 1,609 meters.

Limitations: None

2.25. Pallid Sturgeon Samples Within ½ Mile

Relevant Module: ESE

Data Source and Processing: Pallid sturgeon locations are based on field sampling data from 2003-2009, provided by the Pallid Sturgeon Population Assessment team. A ½ mile radius buffer, representing an average sediment borrow area at an ESH construction site, is created around each of the potential restoration sites, and then the Spatial Join geoprocessing function is used to determine the number of pallid sturgeon samples located in each buffer zone.

Purpose: Pallid sturgeons are a federally endangered species. Construction of restoration sites should avoid impacts to pallid sturgeon habitat. This variable uses the presence of multiple pallid sturgeons in a limited area (or recurring use by a single individual within the same area) as an indicator of pallid sturgeon habitat.

Scaling: The scaling of this variable is shown in Table G 24.

Table G 24. Scaling for Pallid Sturgeon Samples variable.

Number of Pallid Samples	
	All Segments
Score	Distance
10	0
9	9
8	17
7	26
6	35
5	44
4	52
3	61
2	70
1	78
0	87

A GIS analysis was performed to determine the highest number of pallid sturgeon samples found within any half-mile radius area surrounding a single pallid sturgeon sample. The half-mile radius was used to represent a typical borrow area for an ESH project. The highest number of samples found within one of these areas was 87, which represents the least desirable situation with regard to this variable. Therefore, potential restoration sites that have 87 or more samples within ½ mile receive a score of 10. Sites with no samples within ½ mile receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of samples between 0 and 87.

Limitations: The assumption is being made that the repeated presence of pallid sturgeon in a given area is indicative of that area having some degree of suitability as habitat for the species. However, this assumption has not been tested. This variable is being used because data on locations of actual pallid sturgeon habitat and spawning areas is not currently available; if these data do become available in the future the variable should be modified in order to incorporate it.

2.3 Variable Weighting

The primary ESHER user interfaces (ESE and ERE) allow the user to give weights to each of the variables described in this chapter. Weights are a way of assigning relative importance or priority values to each of the model variables.

The initial variable weights used for the first model run will be decided upon by the PDT, using a multi-step process. Initially, a survey of PDT members will be conducted to gauge the group's general sentiment as to the importance (low, medium, high) of each of the variables. The survey results will be used as starting point for discussion at a future PDT meeting, where numerical weights will be assigned to each of the variables. ESHER will then be run using these weights, and the results will be reviewed and discussed by the PDT to determine if any changes to the weights should occur. The weights decided upon in the initial year will be used as the basis for generating a weighting scheme in subsequent years. Weights may change in future years due to such things as shifts in management priorities, availability of new scientific/technical information, and level of success of previous year restoration efforts.

G.6.16. ESHER Outputs

All final ESHER output files are saved in the C:\ESHER\ESHER Outputs folder. The first output, created by the "Pre-Processing 1 – Calculate Variable Values" module, is the "pot_sites_values" shapefile. This shapefile contains the raw variable values (i.e. distances) for all the proposed restoration sites that were input into the module. The following is a description of fields in the attribute table:

Acres: Size of restoration site
Condition: Primary site condition – shallow water (SW), existing vegetated bar (EVB), sparsely vegetated bar (SVB), open water (OW)
SiteName: Site identification number (river mile)
Backwater: Potential for backwater restoration (0 = no potential, 1 = potential)
C_Width: Channel width (meters)
Nests: Number of historical nests on site
Condition2: Condition coded as numbers(0 = OW, 5 = EVB, 7 = SVB, 10 = SW)
Nest_Dist: Distance to nearest nest complex (meters)
Cottonwood: Distance to cottonwood restoration sites. This variable is currently not included in ESHER, the intention is to add it when the location of cottonwood restoration sites becomes available.
Wetlands: Percentage of site that is wetland
Protected: Distance to protected shoreline (meters)
D_50: Sediment size (mm)
Dam: Distance to mainstem dam (meters)
Predation: Number of predated nests
Pallid: Number of pallid sturgeon samples within ½ mile buffer.
Tree_line: Distance to nearest tree line (meters)
Boat_ramp: Distance to nearest boat ramp (meters)
Dock: Distance to nearest dock (meters)
Domicile: Distance to nearest domicile (meters)

Intake: Distance to nearest water intake (meters)
Recreation: Distance to nearest recreation area (meters)
Urban: Distance to Bismark (meters)
Eagle: Distance to nearest bald eagle nest (meters)
Cultural: Distance to nearest cultural resource (meters)
Industrial: Distance to nearest industrial facility (meters)

Utilities: Distance to nearest utility
Wet_acres: Number of acres of wetland on proposed restoration site
Bridges: Distance to nearest bridge
Power_st: Distance to nearest power station
Size: Size of potential restoration site, rounded to nearest whole number (acres)

Distance values in the table of 0 mean that the resource is not in the reach (or there is no spatial data for the reach on that resource) where the restoration site is located. These sites receive a scaled score of 10 for that variable.

A second output ("ESH_site_scaled_values" shapefile) is created by the "x(Optional) – Create Site Scale Variable Output, Part 2" module. The Pre-Processing 1, Pre-Processing 2, and Create Site Scaled Variable Output, Part 1 modules all need to have been previously run before the Part 2 module will work. The output attribute table contains the scaled variable values (0-10) for all the proposed restoration sites. The attribute fields are identical to those in the "pot_sites_values" file, except there are no "Acres" or "Condition2" fields.

The "ESHER Site Evaluation" module creates the "ESH_site_scores" shapefile output. This output contains the final scores (0-100) of all the potential restoration sites being evaluated.

The "ESHER Reach Evaluation" module creates a separate raster output for each of the reaches (ft_peck, garrison, gavins_pt, land, randall). Cell scores can range from 0-100. An example of a reach evaluation output for Gavins Point reach is shown in Figure G 11.

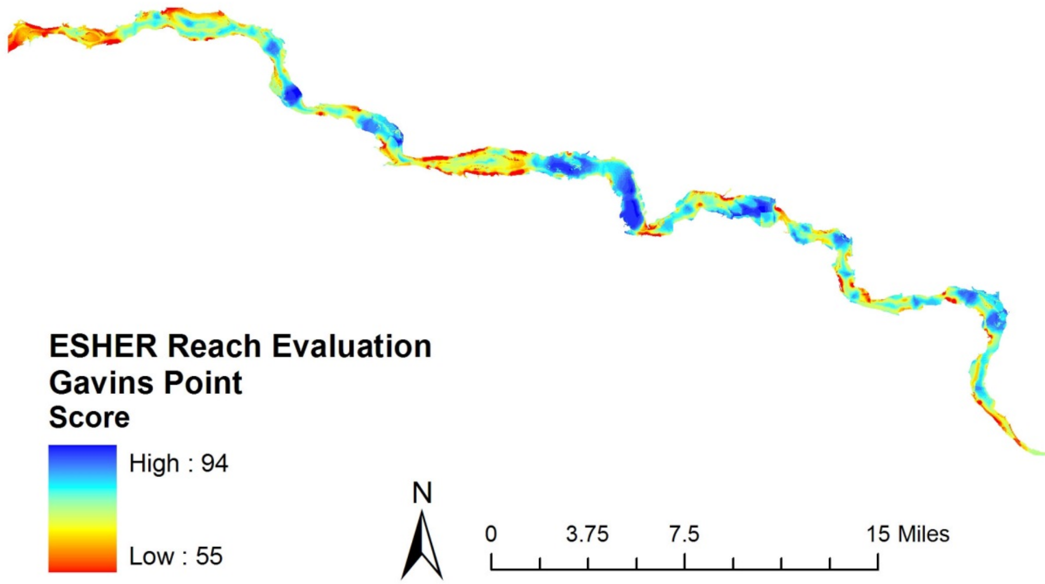


Figure G 11. Example of reach evaluation output for Gavins Point reach.

G.6.17. Modifying ESHER

Modifications to ESHER may occasionally need to be made. This chapter details the process for making changes such as changing input files and re-scaling variables, and provides general information on adding variables to the model. All these changes are made within the ArcGIS ModelBuilder environment, and this chapter assumes the reader has experience building models within ArcGIS ModelBuilder.

G.6.17.1. Changing Input Files

ESHER is hardwired to look for input files that have a specific name and are located in a specific folder. All input files are located within subfolders of the C:\ESHER main folder. Additionally, the model will occasionally select attributes based on specific field names and attribute codes within these input files. Therefore, it is suggested that when these input files are updated that they maintain the same file name and location, as well as keeping relevant field names and attribute codes the same. However, if for some reason these need to be changed, Figures 11-14 indicate where within the model structure the various inputs are located, as well as the original file names and locations, and attribute selection information if relevant. Two caveats, with the potential restoration sites input file, the name and location can be changed, but do not change any of the field names or attribute codes. Also, do not change the following shapefiles located in the C:\ESHER\ESHER Inputs\ folder: “Peck_analysis_area.shp” “Garrison_analysis_area”, and “Gavins_randall_LC_analysis_area”.

With the exception of the potential restoration sites file and the habitat delineation files, all changes to input files are made in the “Pre-Processing 1” module. If the name or location of the potential restoration sites file changes, these changes need to be made in the “Pre-Processing 1”, “Optional…Part 2”, and “ESHER Site Evaluation” modules. Changes to the habitat delineation files need to be made in the “Pre-Processing 1” and “ESHER Reach Evaluation” modules. To make changes to an input file, find the number in the diagram (Figures 11-14) that corresponds to the appropriate input file, and then zoom into that area in the model editing screen. The circles/rectangles that need to be edited should be obvious once the appropriate area is zoomed in on.

1. Potential Restoration Sites Formatting needed - this page & next page

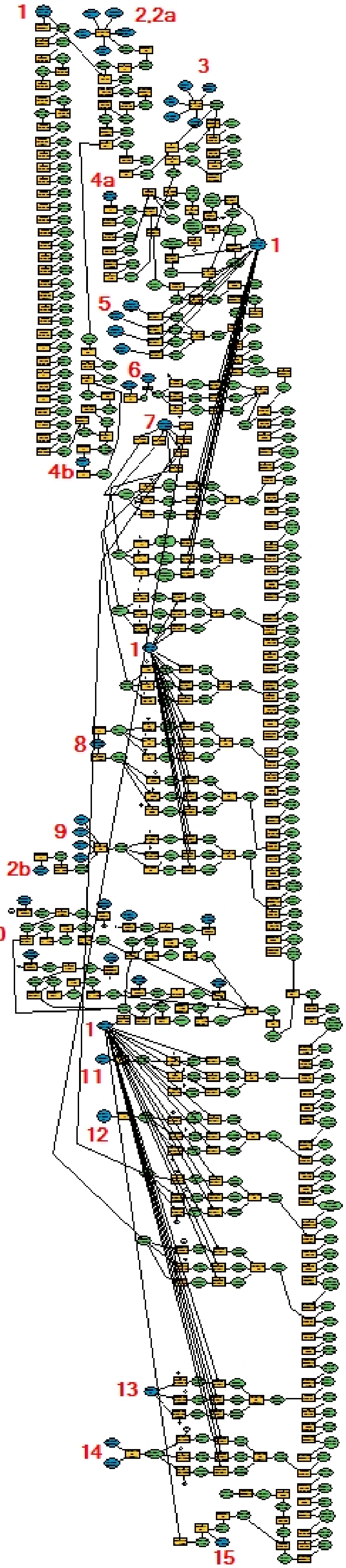


Figure G 12. Pre-Processing 1 model editing diagram

:\ESHER\pot_sites\pot_sites.shp

2. Habitat Delineations

Names and Locations:
C:\ESHER\DMA_Final\Ft Peck\Hab Delin 1998-2005\PeckDelin021507.shp
C:\ESHER\DMA_Final\Ft Randall\Hab Delin 1998-2005\RDL_2005_DELIN.shp
C:\ESHER\DMA_Final\Garrison\Hab Delin 1998-2005\GSN2005_050207.shp
C:\ESHER\DMA_Final\Gavins Point\Habitat Delin 1998-2005\Gavins_2005_050207.shp
C:\ESHER\DMA_Final\Lewis & Clark Lake\Hab Delin 1998-2005\L&C2005_DLN.shp

a) Select Attribute [Select] based on “TYPE” = 11 (Wetland).

b) Select Attribute [Select (11)] based on “TYPE” = 9 (Riverine Forest).

3. Sediments

Names and Locations:
C:\ESHER\sediment\Ft_Peck_1984Sediment.shp
C:\ESHER\sediment\Ft_Randall_2007Sediment.shp
C:\ESHER\sediment\Garrison99sediment.shp
C:\ESHER\sediment\Gavins_point_2002Sediment.shp
C:\ESHER\sediment\Lewis_Clark_2007Sediment.shp

4. Historical Nests

Name and Location: C:\ESHER\tp_nests\allnests.shp

a) Select Attribute [Select (13)] based on field “SURVEY_YR” = 2008. Value will likely need to be changed every year.

b) Select Attribute [Select (14)] based on field “LOC_QUAL” = 1.

5. Dam Distances

Names and Locations:
C:\ESHER\ESHER Inputs\damdist_garr
C:\ESHER\ESHER Inputs\damdist_gavn
C:\ESHER\ESHER Inputs\damdist_peck
C:\ESHER\ESHER Inputs\damdist_ranlc

6. Cultural Resources and Shipwrecks

Names and Locations:
C:\ESHER\cultural resources\cultural_resource.shp
C:\ESHER\shipwrecks\riv_boat_accidents_1839_to_1934.shp

7. Sensitive Resources

Names and Locations:
C:\ESHER\DMA_Final\sensitive\allfeatures.shp
Select Attribute [Select (3)] based on field “Feature” = ‘Boat Ramp’.
Select Attribute [Select (4)] based on field “Feature” = ‘Boat Dock’.
Select Attribute [Select (5)] based on field “Feature” = ‘Domicile’.
Select Attribute [Select (6)] based on field “Feature” = ‘Recreation Area’.
Select Attribute [Select (7)] based on field “Feature” = ‘Irrigation Pump’.
Select Attribute [Select (8)] based on field “Feature” = ‘Industrial Structure’.

8. Sensitive Features Lines

Names and Locations:
C:\ESHER\DMA_Final\sensitive\lines.shp
Select Attribute [Select (9)] based on field “type” = ‘1’ (Bridges).
Select Attribute [Select (10)] based on field “type” = ‘2’ (Utilities).

9. Tree Lines

Names and Locations:
C:\ESHER\DMA_Final\Ft Peck\Sensitive_Resources\Peck_Forest_Line.shp
C:\ESHER\DMA_Final\Gavins Point\Sensitive Features\Gavin_Forestline.shp
C:\ESHER\DMA_Final\Ft Randall\Sensitive Features\RNDL_Forest.shp
C:\ESHER\DMA_Final\Garrison\Sensitive Features\Forrest_Lines2.shp

10. Channel Banks

Names and Locations:
C:\ESHER\ESHER Inputs\Peck_channel_top.shp
C:\ESHER\ESHER Inputs\Peck_channel_bottom.shp
C:\ESHER\ESHER Inputs\Garrison_channel_top.shp
C:\ESHER\ESHER Inputs\Garrison_channel_bottom.shp
C:\ESHER\ESHER Inputs\Gavins_channel_top.shp
C:\ESHER\ESHER Inputs\Gavins_channel_bottom.shp
C:\ESHER\ESHER Inputs\Randall_channel_top.shp
C:\ESHER\ESHER Inputs\Randall_channel_bottom.shp

11. Power Stations

Name and Location:
C:\ESHER\power\powerstations.shp

12. Urban Area

C:\ESHER\DMA_Final\Garrison\Sensitive Features\GarrisonEXCLS.shp
Select Attribute [Select (12)] based on field “Feature” = ‘Bismark Urban Zone’.

13. Eagle Nests

Name and Location:
C:\ESHER\BE_nests\2008.shp

14. Protected Shoreline

Names and Locations:
C:\ESHER\Real_Estate\mn39_stewardship_020409_completed
C:\ESHER\Real_Estate\mn59_stewardship_020409_completed

15. Pallid Sturgeon

Name and Location:
C:\ESHER\pallid\pallid.shp

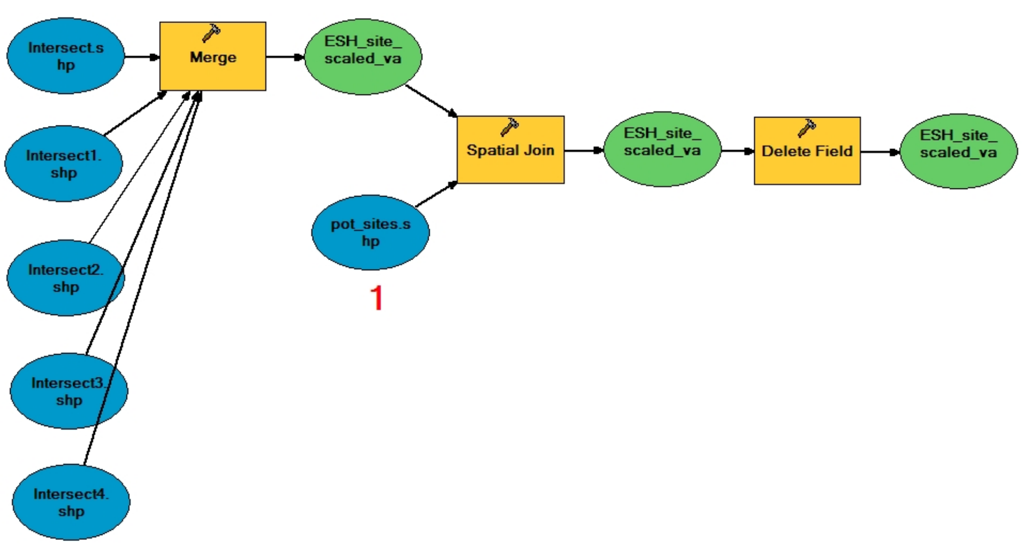


Figure G 13. Optional – Part 2 **model editing diagram.**

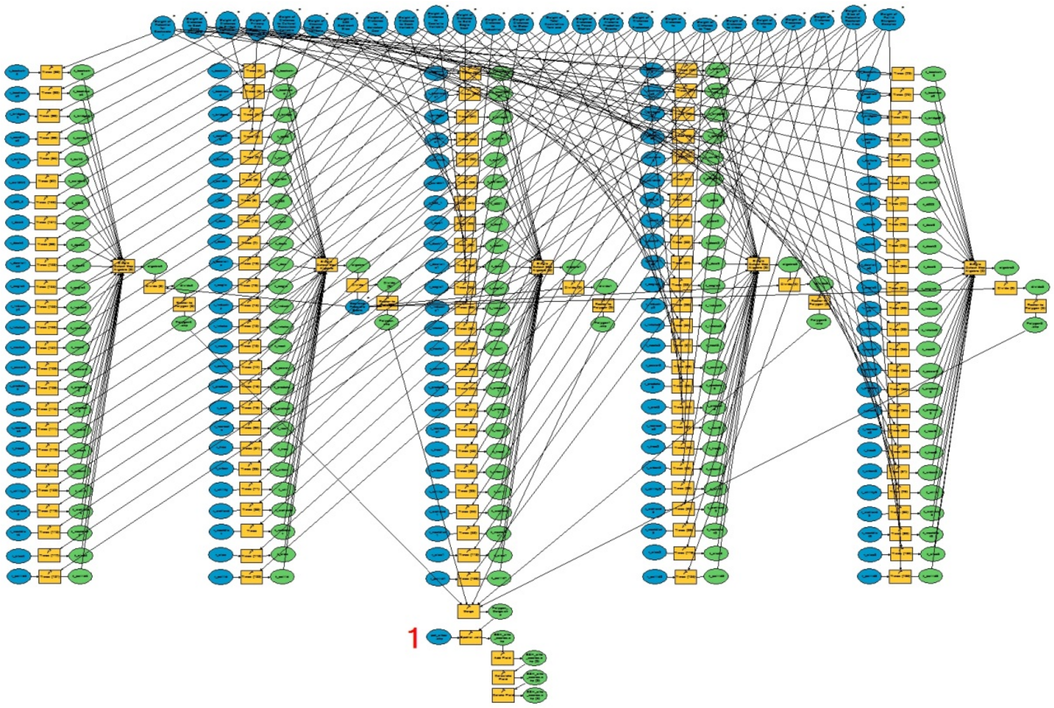


Figure G 14. ESHER Site Evaluation **model editing diagram.**

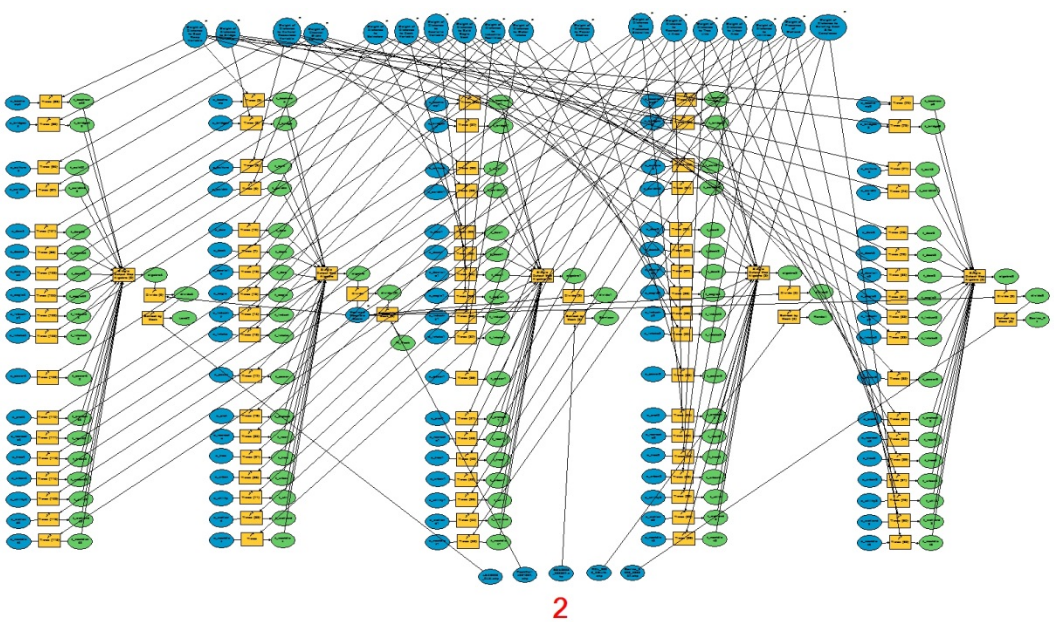


Figure G 15. ESHER Reach Evaluation **model editing diagram.**

G.6.17.2. Scaling Variables

Changes to the default scaling of variables can be made by editing the Pre-Processing 2 and Pre-Processing 3 modules. Variable scaling is assigned using the "Reclassify" tool, and each variable is associated with its own "Reclassify" tool. In both modules, each variable is replicated five times, once for each of the reaches. Therefore, for a variable where the scaling is identical across reaches, changes to that scaling need to be made in each of the replicates. If the scaling of a variable is unique to a specific reach, then a change in scaling only needs to be made in the "Reclassify" tool for that variable in that particular reach.

G.6.17.3. Adding Variables

Adding variables to ESHER should be done by someone who is well experienced with building models within the ModelBuilder environment. Adding a variable requires editing of all 7 modules (or 5 – if the variable is not being used in the reach evaluation then the ESHER Reach Evaluation and Pre-Processing 3 modules do not need to be changed). The structure of the existing modules can be used as a guide for how additional variables should be incorporated. There are two important things to be aware of when adding a variable – 1) when adding a variable to the "Pre-Processing 1 module" the variable field name in the output table should be added during the creation of the variable, rather than at the beginning where many of the existing field names are being created (upper left corner of diagram in Figure 3). Otherwise, the new field name will be lost during several Spatial Joins processes that occur in the module. The alternative is to delete and then re-add these Spatial Join processes in the module. 2) In order to include the new variables in the "ESH_site_scaled_values" output, in the "Optional – Part 2 module", the Merge and Spatial Join processes should be deleted and then re-added to the module.

G.6.17.4. Creating new Potential Restoration Sites

It is anticipated that ESHER will be run on an annual basis in order to analyze a group of potential restoration sites generated by the ESH PDT. This will involve updating the Potential Restoration Sites shapefile (C:\ESHER\pot_sites\pot_sites.shp) on an annual basis. The following steps outline the process of completing this task.

1. Use a combination of field knowledge from site visits, aerial/satellite imagery, and the outputs of the ESHER ERE tool to select locations with a high potential of restoration success.

2. Edit the pot_sites.shp file by using the most current imagery to draw a polygon over the most likely footprint of an ESH complex at the potential restoration site.

3. Fill out all the attributes for the polygon as follows:

Acres: Calculate the acreage of the polygon utilizing the measure tool.

SiteName: Nearest Whole Missouri River Mile

Condition: Indicate the primary (>50%) site condition within the polygon based on the imagery, habitat delineations, field knowledge or other sources of information using the following codes: **SW** –Shallow Water, **OW** –Open / deep Water, **EVB** –Existing Vegetated Bar consisting of dense vegetation, **SVB** – Sparsely Vegetated Bar

Backwater: Based on imagery or site knowledge, assess the potential for restoring a backwater or other floodplain feature in conjunction with the potential ESH restoration site. Backwater restoration sites should be within 1 mile of the potential ESH restoration site. Assign the following codes to the attribute: **0** – No potential for backwater / floodplain restoration, **1** – Potential exists for restoration of a backwater / floodplain feature.

Attachment G.7 Piping Plover Cages, Nest Moving/Raising, Chick Relocation & Chick Platform

In addition to surveying the birds, monitoring crews will often perform management actions to increase the productivity of the two species. Other actions will be performed to learn more about the two species, including measures to protect the birds from predators, relocating nests endangered by rising water or erosion, and collecting specimens for research and necropsy.

G.7.18. Piping Plover Cages

Construction: The cages should be constructed using wire mesh with two inches by four inches openings. Bird netting may be used for the top of the cage. The cage dimensions should be three feet by three feet by three feet and constructed so that they fold down flat for easy transportation. The cage will be anchored to the ground using stakes.

Where and When to Place a Cage: Tern nests should never be caged. Piping plover nests at risk of inundation on riverine or reservoir segments may be caged prior to nest moving. Caging nests prior to a nest move gives the adults time to habituate to the cage, which may aid in their finding the nest after it has been moved to a new location. Cages may also be placed over plover nests if crews have documented losses to predators during the current or past years or if it is suspected that a predator may be in the vicinity of a nesting site. These situations should be addressed on a case by case basis, as there is some evidence that the presence of a cage attracts predators. In situations where nesting habitat is limited, however, a cage may be an effective tool to protecting the nest.

When cages are used, they should generally be placed over a plover nest that has a full clutch (generally four eggs for first nests) and where incubation has been started. Nests with incomplete clutches and no incubation should not be caged on the initial visit. The reason for waiting for a complete clutch is that the more time the plovers have spent on the nest, the more likely it will be that they will return to a nest that has had a cage placed over it.

How to Place a cage: Cages and anchors need to be cleaned before placement around a nest. This can be done by placing the cages and anchors in the water near the shore upon arrival at a site in order to remove any foreign materials and odors that may have been picked up while transporting the cages and anchors.

Before removing the cages and anchors from the water, the person or persons handling the cages needs to wash their hands with no-scent soap or use a no-scent towelettes to preclude human scent being transferred to the cages.

The cage should be assembled near the boat or ATV away from the nest site and then carried to the nest. The cage is placed over the nest so the nest is centered in the cage. Anchors (metal stakes) should be placed at each of the four corners of the cage and driven flush into the ground.

After the cage is secure, the cage should be watched through binoculars to determine if the adult will return to the nest. If the adult will not go inside the cage and resume sitting on the nest within fifteen minutes, the cage is to be removed. In the Comments Section of the Nest Record a note should be written stating that the attempt to cage the nest failed.

After the nest has been terminated, the cage will be removed from the nest.

G.7.19. Nest Moving

No matter which method is used to move the nest, there are certain procedures that need to be followed. Hands and any tools used for nest moving need to be washed in biodegradable scent-free soap. Footprints and other signs of nest moving activities need to be removed by brushing the area with a hand or with a whisk broom. In moving nests this work needs to be done quickly to minimize stress both to the eggs and the attending parents. However, do not be in such a hurry that the eggs may be damaged or destroyed during the move.

After moving, a nest needs to be watched from a distance to see if the adult returns to the nest. Least terns generally do not have a problem finding the new nest. Plovers, being ground oriented, tend to have greater difficulty in finding the new nest location. If this occurs, the plover can be gently “herded” toward the nest site so that it can relocate the nest.

If the adult cannot relocate the nest or will not go to the new nest site, the nest may need to be relocated again back closer to the original nest site. However, a nest will not be relocated to an area that will subsequently be inundated or eroded.

G.7.19.1. Obliterate/Recreate Method

In this method the original nest bowl is destroyed and a new nest bowl is created at a safe site. First, a new nest bowl is created by scooping out a shallow depression. This new nest bowl should be in a location safe from sandbar erosion and high enough to prevent loss from inundation. Piping plover nest moves should be no greater than fifteen feet from the original nest bowl. Because least terns are flight oriented, a new nest site can be located at greater distances.

After a new nest bowl has been created the eggs are removed from the original nest bowl and placed at a secure temporary location. Anything in the original nest bowl, such as twigs and debris in tern nests and pebbles in plover nests are collected and put in the new nest bowl. Also any visual cues around the original nest bowl, such as rocks, sticks, vegetation, are removed and placed in the same orientation around the new nest bowl. If the nest was caged before the move, the nest needs to be re-caged after the move. The original nest bowl is then completely obliterated and the eggs are placed in the new nest bowl.

G.7.19.2. Obliterate/Platform Method

This method is similar to the obliterate/recreate method with the major difference being that the nest is re-created on top of a buried wooden platform. The platform should be at least twenty inches, but not more than thirty inches square and should be made of ¼ to ½ inch thick plywood. Small holes need to be drilled into the platform to allow water to drain through. The platform needs to be buried from 1½ to 3 inches deep at the new nest site with excavated material. The new nest is then reconstructed on top of the platform. The advantage of this method is that if more moves are subsequently needed the platform can be excavated and the nest can be moved intact to a new location.

G.7.19.3. Cylinder/Plate/Platform Method:

This method uses a cylinder made from a coffee can, or similarly shaped object, with both the top and bottom cut out, and an eight to fifteen inch square aluminum plate (or a restriction sign could also be used). The cylinder is pressed or screwed into the substrate around the nest to a depth of 1½ to 3 inches. The substrate is then excavated from one side of the cylinder. The plate is slid under the nest and cylinder with the plate remaining perpendicular to the cylinder. Once the plate is positioned under the nest to form a platform, the remaining substrate may be removed from around the cylinder and the cylinder and plate is lifted from the ground and transported to the new nest site location.

At the new location, material is excavated and the plate is slid out from underneath the cylinder. Substrate is then built up around the can and the can is removed. Substrate material is sprinkled over the new nest site to blend it into the landscape.

If it is anticipated that the nest may have to be moved again, the cylinder and plate is placed on a platform at the new nest site and the plate is carefully slid from under the nest. Substrate material is then placed on the platform and around the cylinder. The cylinder is then removed from around the nest. As with the other methods, substrate material is used to blend the new nest into the surrounding landscape. If additional moves are needed to relocate the nest, the platform can be excavated and moved as described in the obliterate/platform method.

G.7.20. Nest Raising

Nest raising is used when it is not possible to move the nest. Before the nest can be raised, the eggs need to be removed from the present nest site. The preferred method is to use the cylinder/plate method described above. Once the eggs are safely set aside, the nest location should be built up to a height to withstand the anticipated increase in water. After the mound has been built, the nest is recreated on top of the mound as described before. All of the visual surroundings to the nest such as driftwood, rocks and small vegetation are relocated on top of the mound in their same orientation. For plovers, there may need to be a more gradual slope up to the top of the mound and they may need to be herded toward the top of the mound.

Staking down the Cage

Moving a Nest using the Cylinder/Platform Method

Attachment G.8 Human Deterrence Measures

There are several measures that can be done to reduce disturbance of the birds, including gating and fencing off beaches to prevent vehicle access, restricting access to nesting grounds, law enforcement, and public education.

G.8.21. Restricting Access

To protect nesting and brood rearing sites from the public, sometimes access needs to be restricted. This is most commonly done by the placement of barricades and endangered species restriction signs.

1. **Barricades:** Barricades are used to prevent vehicular access to nesting sites located along reservoir shorelines, and are most commonly placed next to recreation areas to prevent off road vehicle access to the beaches. Barricades can be constructed using natural features such as rocks and logs. If a more permanent deterrent is required, a fence with a gate should be constructed to restrict access. Endangered species restriction signs should be placed in combination with the barricade. Crews need to consult with their supervisor and receive approval before any barricade construction is done.

2. **Endangered Species Restriction Signs**: The need to place restriction signs should be evaluated on a case-by-case basis. If a site is remote with little chance for human disturbance, it usually is better not to put up signs, as signs at a remote location might attract a person to the site out of curiosity.

   Generally, all river sites that contain five or more nests should be posted with restriction signs. All reservoir sites that have the potential for human visitation, especially those adjacent to recreation areas should be signed.

   The restriction signs should be visible to the public at all entry points to the nesting area. For sandbar and beach shorelines, the signs need to be placed near the water to forestall boaters from landing.

   The restriction signs need to be monitored constantly throughout the nesting season. Restriction signs that are down need to be re-installed before a crew leaves a site. When the birds have completed nesting and chick rearing and have left a site, the restriction signs should be removed and stored back at the office.

Endangered Species Restriction Sign

G.8.22. Law Enforcement

The USACE position on law enforcement is to use only the amount necessary to correct the problem. If a minor violation is observed such as people inside a restricted area, contact the individuals, ask them to leave the restricted area and explain to them the importance of not disturbing the birds.

If a major violation is observed, for example a person is pulling up the restriction signs, overturning predator exclosures, driving in the nesting area or smashing eggs, action needs to be taken. This does not necessarily mean that the individual is to be confronted. At all times the personal safety of the crew is of primary importance. If it is deemed not safe to approach the person or persons, observation should be done from a safe distance and as much information as possible should be gathered including a description of the individual or individuals, the boat or vehicle license number and what the individual is doing. If a camera is available, pictures of the violation should be taken. At the same time, crews should contact their supervisor or office via a radio or cell phone and advise them of the incident. The crew should also contact via the cell phone a law enforcement officer to report the incident.

If an ESA violation has been found after it has happened, all pertinent information will be recorded including who, what, where, when, why and how in regard to the incident. Take pictures of the violation and write a brief caption for each picture. The crew's supervisor will be contacted and informed of the incident. If circumstances warrant at the scene, the appropriate law enforcement officer will be contacted to determine if the officer should come out to the site. Upon returning to the office an incident report will be written, including a map of the site. The report will be given to the supervisor for review. The supervisor will send copies of the report to the TPMP coordinator and to the U.S. Fish & Wildlife Service special agent for the area.

G.8.23. Education & Outreach:

An important part of human deterrence measures is educating the public. This can be as simple as one-on-one conversations with people at the boat ramp, handing out endangered species materials, giving campground talks, putting up endangered species information signs and public service messages broadcast via television and radio stations. Another avenue to get the word out on endangered species is to contact the local media, such as newspapers, radio and TV stations, to set up interviews about the importance of the work.

Attachment G.9 Egg Floating

Determining the egg incubation stage provides valuable data both short and long term for least tern and piping plover recovery. In the short term, knowing the egg incubation stage provides a probable nest hatch date. The egg incubation stage, when combined with the clutch size, can be used to calculate a nest initiation date (the date the female laid the first egg of the clutch). This data is important in determining long-term nesting trends.

G.9.24. When to float an Egg

Upon nest discovery, one egg from the clutch should be floated to determine incubation stage. There is one exception to this rule - an egg will not be floated if any of the eggs in the clutch are pipping. A pipping egg is an egg that is close to hatching. Do not touch a pipping egg as the egg shell has fractured and could easily break if handled.

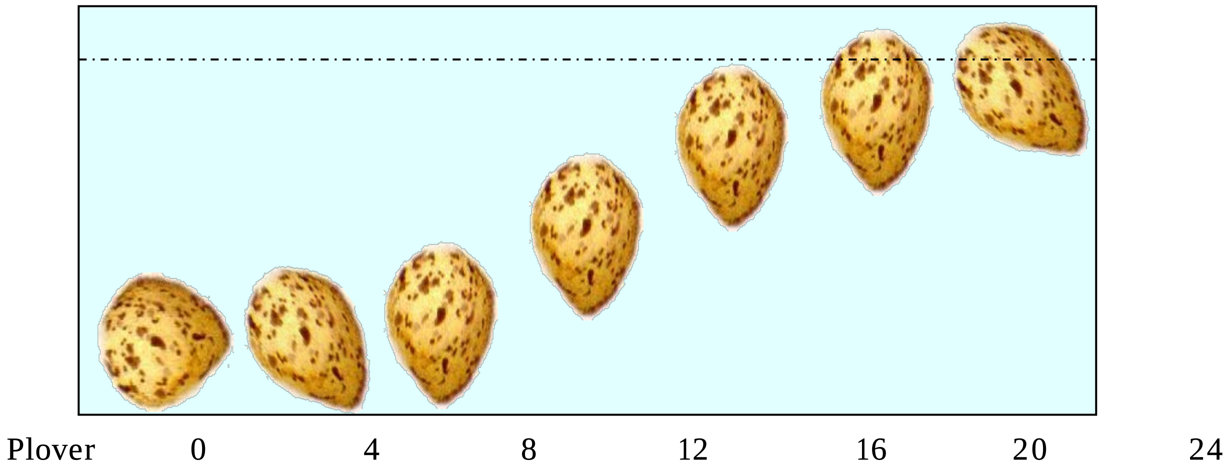
G.9.25. How to Float an Egg

Prior to handling an egg, hands must be washed with no-scent soap or a towelette to ensure human scent is not left on the egg. The preferred method is to use a no-scent towelette that can be carried during the survey and used to wipe hands prior to egg handling. A second method is to wash hands with no-scent soap where water is available.

Float cups should be made of transparent plastic (a glass cup should never be used). The cup should be filled three-quarters full with water taken from the river or reservoir and allowed to warm up for a few minutes. The cup of water should be good for all the nests on the site; it does not have to be refilled for each new egg.

Select an egg that is free of fecal or any other foreign material. When transferring the egg to the cup, have the cup a short distance above and to the side of the nest. Place the egg at the bottom of the cup and let it float. **Do not drop the egg into the cup.** After the egg stabilizes, compare its position to that of the egg float chart. Determine the incubation stage by looking at the number below the position selected on the float chart. After the incubation stage has been determined, gently remove the egg from the cup and place it back in its original position in the nest. It is not necessary to dry the egg before returning it to the nest; never shake the egg to remove excess water.

Egg Incubation Stage Float Chart



Generally, one egg will be floated from a nest. There are circumstances however where it may be necessary to float more than one egg. If the egg selected for floating floats to the top of the water with the pointed end up rather than down, this indicates an addled egg (an egg where the embryo has died). The egg should then be placed back into the nest and another egg should be floated. If this occurs, include this information in the nest comment.

Additional eggs may also be floated if a tern or plover lays an unusually large amount of eggs in the nest. The maximum clutch size for least terns is usually three eggs, and for piping plovers, four eggs. If a tern nest is found with four eggs or a plover nest with five or more eggs, the additional egg or eggs may have been laid by a different bird and could have a different incubation stage from the rest of the clutch. In the case of oversized clutches at least two eggs and possibly three should be floated. If, after floating two eggs, the eggs have the same incubation stage; record that as the incubation stage for the clutch. If the two eggs have different incubation stages, float a third egg and if its incubation stage agrees with one of the two previous eggs, record that as the incubation stage for the clutch.

After the incubation stage has been determined it is not necessary to re-float an egg on subsequent nest visits.

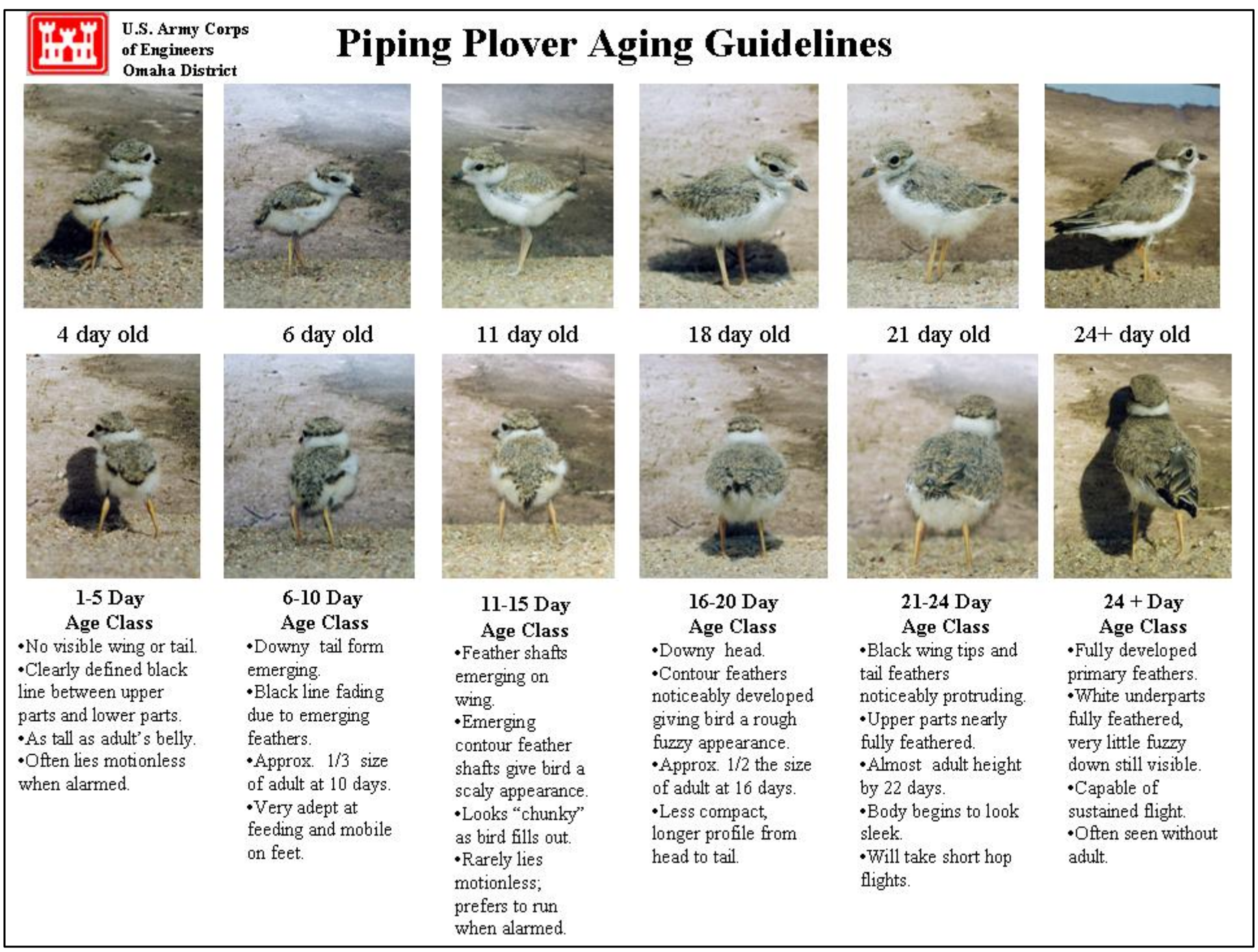
Attachment G.10 Tern and Plover Chick Aging

After hatching, it takes from 21-28 days for piping plover chicks to fledge (able to fly). Least tern chicks begin to fly at 18-22 days after hatching.

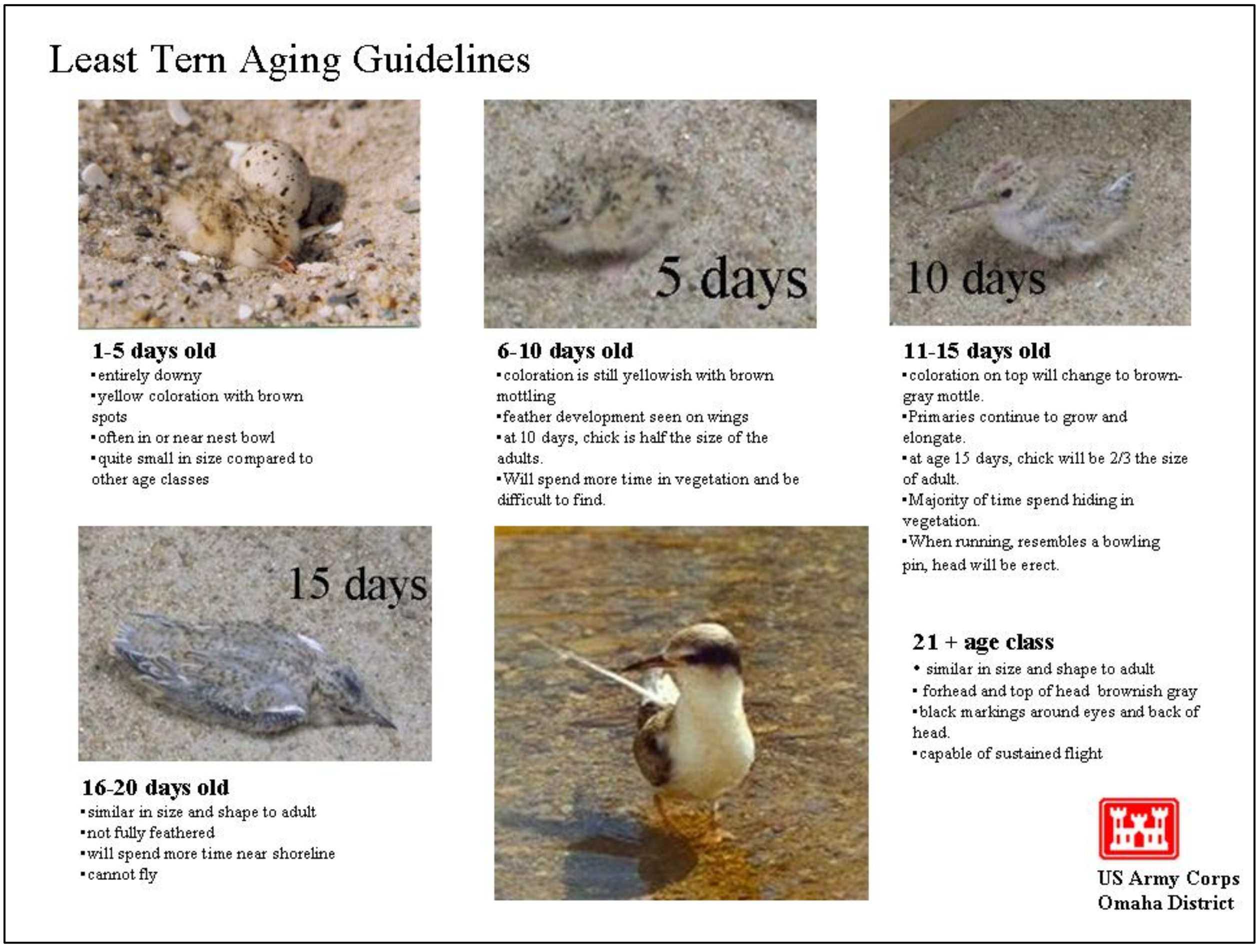
In addition to counting chicks, crew members need to determine the approximate ages of the chicks. Piping plover chicks are divided into five age classes: 1-5 days, 6-10 days, 11-15 days, 16-20 days and 21-24 days. Least tern chicks are divided into four age classes: 1-5 days, 6-10 days, 11-15 days and 16-20 days.

G.10.26. How to Determine if a Chick has Fledged

A chick is considered fledged when it is able to fly. There are two ways to determine if a chick is fledged. The first is straightforward— the chick is observed flying. This need not be sustained flight. A juvenile that performs short-hop flights is considered fledged. Do not harass a chick in any way to force it to try to fly by running toward the chick, making noises, throwing objects in the direction of the chick, or doing anything to disturb the chick.



The second way of determining fledging is more subjective and based on the size of the chick. If the chick appears to be the correct size of a fledgling, comparable in size to an adult, then the chick should be counted as fledged.



Attachment G.11 2015 Adult Band Resighting Plan

Banding has occurred on the Missouri River (MR) system for the last ten years and over 5000 plover and tern adults and chicks have been banded during that time period. Just last year 95 adult plovers and 400 plover chicks were banded on Gavins and Lewis and Clark Lake as well as 17 tern adults and 296 tern chicks. Band resighting data is used from the MR for a multitude of reasons including tern and plover adult and juvenile survival estimates, predicting plover population size and growth, and for an ongoing piping plover metapopulation study. It is important to continue to resight these birds in order to get tern and plover adult and juvenile survival estimates for the flood science study and the effects analysis, to get estimates of movement between the upper and lower rivers for the metapopulation study, and to attempt to estimate plover population size and growth in order to estimate carrying capacity.

G.11.27. Methods

We will attempt to resight least tern and piping plover adults from May through August of the 2015 field season with the majority of the work occurring from May 11-July 3. We will resight piping plover adults using high resolution point and shoot cameras and we will attempt to camera trap each nesting tern and plover adult using Kodak PixPro video cameras and Reconyx game cameras at least once during the nesting season. Our methods have been adapted from those developed by USGS Northern Prairie Wildlife Research Center and the Virginia Tech Shorebird program for tern and plover band resighting. All resighting and camera trapping efforts will comply with USFWS permit conditions outlined in Appendix 1.

We will deploy two resight crews of two individuals to conduct surveys and camera trap nests. For large sandbars, the two crews will combine in order to cover the sandbar in the time allowed. The river segments have been broken up into reaches based on number of nests in 2014 and boat ramp locations. There are three reaches on Gavins and two on Lewis and Clark Lake (LCL). Resight crews will operate separately from the Tern and Plover Monitoring Program (TPMP) crews although the TPMP crews may be utilized to retrieve game cameras on occasion. Camera Standard Operating Procedures (SOP's) have been developed and are attached in Appendix 2. Crews will be trained and required to adhere to camera protocol, permit conditions, and TPMP protocol. All resight crew members will carry a GPS displaying the location of nests to reduce the risk of accidentally stepping on a nest. If new nests are found by the resight crew they will record the location and collect data on the nest following the TPMP protocol. They will also share fate evidence such as chicks in bowl or predated egg shells with the TPMP program manager who will provide that information to the TPMP crews.

Resighting Methods

All sandbars on the Gavins Point and Lewis and Clark Lake segments will be searched for banded piping plovers at least three times during the between May 11-July 3 and ideally once a week. If time allows we may resight on the Fort Randall segment if the TPMP crews identify sites with banded birds. We will walk line transects through each sandbar, the number of transects will depend on sandbar size and number of surveyors. One crew member will use a spotting scope to locate banded individuals and direct the other crew member(s) to those groups to take pictures. Crew members with cameras will attempt to get within 25-50 meters of adults, choose a location to stop at, and take as many photos as time allows. Crew members actively photographing will not move while taking photos to prevent accidentally stepping on a nest. Number of photos will depend on the skill of the crew member and the activity level of the birds.

Camera trapping Methods

Camera trapping will occur once nesting begins which will be under way as we start our field season. In 2014 the majority of the plover nests were initiated the second and third weeks of May while the majority of tern nests were initiated during the fourth week of May and the first week of June. There is some overlap in nest initiation between terns and plovers although the majority of nest initiation occurred at different times. In the case where there are not enough cameras to trap all nests that require trapping, priority will be given to plover nests and nests that are further along in incubation and could potentially hatch prior to the next visit. Cameras will only be set on nests that have a full clutch, where incubation is more than 48 hours and the eggs are not pipping. We will rely on nest locations from the TPMP to locate nests that require trapping. Crew members will set video camera traps at a predetermined set of nests and then conduct resighting while the cameras capture video for a minimum of 30 minutes. Cameras will be mounted to stakes that can be easily placed in the ground. It should take no longer than one minute to place the camera and focus in on the nest. Camera traps will be retrieved after finishing the resighting survey. After resighting is complete trap cameras may be moved to another part of the sandbar or if the trapping effort is complete they will be completely removed from the sandbar. Video cameras will be placed on a maximum of 10 nests per sandbar at any one time. Permit conditions and sandbar layout will dictate the number of nests that can be trapped on any given visit.

We will attempt to video trap both adults associated with each nest. For this effort trapping is defined as capturing video of the adults, birds will not be handled. We will make a maximum of two attempts with the video cameras to trap each nest. After reviewing the video, if we determine both adults were not trapped on the first attempt we will return the following week and make a second attempt. If after the second attempt we still have not trapped both adults we will deploy a game camera. In the event that too many nests are failing/hatching prior to trapping using this two attempt approach we may switch to one attempt with the video camera or only use the game cameras. As with the video camera setup, camera placement will take no longer than 1 minute as they will be set up prior to deployment. The game cameras are activated by motion and capture still photos. They will be deployed at the nest for a minimum of 48 hours. We will attempt to retrieve the cameras within 72 hours however that may not always be possible depending on weather and schedule. We will deploy up to 15 game cameras at any one time but will not place more than three game cameras per sandbar at a time. Due to high predation risk, use of still cameras on LCL will be limited. If necessary we will only use them if we are unable to get a band reading after two attempts using the video camera and we will only place one per sandbar. We may utilize the Virginia Tech research crews working on the upper portion of Lewis and Clark Lake to assist with camera deployment and retrieval.

G.11.28. Data Collection and Management

Data collected in the field will be limited to collecting site visit information using the GPS unit. All other data will be written on a white board and photographed or captured on video. The River mile of the site, the date, the camera type, and the operator of the camera will be written on a white board and each camera will take a photo of it prior to resighting. At each nest prior to setting a trapping camera we will video/photograph a whiteboard that displays the site river mile, set date, set time, camera type, and camera operator. When the trap is retrieved another photo or video will be taken that includes the retrieval time.

Photos and video will be viewed on a daily basis when possible. If viewing is not completed at the end of the day we will use weather days to complete viewing. If this proves to be unattainable we will utilize TPMP crew members once their season slows down or utilize seasonal staff that stay longer than the bird monitoring season. Band resight training will be provided to all individuals reviewing photos and video. Viewing video camera trap data will take priority over still photographs from both the Game Camera and the point and shoot cameras as that data is necessary to determine if a trap reset or a change in approach is required. Photos/video from each camera will be downloaded and stored in a folder labeled with the day's date. Any photos deemed unusable will be stored in a separate location.

Data will be recorded in an excel spreadsheet and will be loaded into a resighting table in the TPDMS. Data will be checked on a weekly basis to ensure band combos were accurately read. Where band combos prove difficult to read we will rely on the original banders to provide clarification. All data, photos, and video will be provided to the original banders no later than Nov 1 2015.

Table G 25. Data fields for photos and video.

Field	Description
capture_date	The date the photo is taken/camera trap is set
set_time	The time the photo was taken or the time the video/game camera is set
retrieve_time	The time the video/game camera is retrieved
camera_operator	the initials of the person taking photos or setting the camera
segment_code	River segment where survey is being conducted; Gavins, LCL, Fort Randall
river_mile	River mile of the sandbar where the survey is being conducted
species_code	The host species of the nest; Least Tern, Piping Plover.
nest_id	A unique ID number assigned to each nest. Year|Segment|Unique ID
camera type	The type of camera used; Nikon, Canon, Lumix, video, game
resight_date	The date the photo/video is reviewed
viewer	The initials of the person viewing the photo/video
capture_time	The time in the video when the bands are readable for the first adult
capture_time2	The time in the video when the bands are readable for the second adult
alpha_numeric_code	the code on the alpha numeric flag or band
ULU	upper left leg, upper band
ULL	upper left leg, lower band
LLU	lower left leg, upper band
LLL	lower left leg, lower band
URU	upper right leg, upper band
URL	upper right leg, lower band
LRU	lower right leg, upper band
LRL	lower right leg, lower band
bands missing	Indicate if suspect bands missing; Y = bands missing
comments	Anything notable, e.g., faded bands, injury, feather wear, behavior
file_location	The path to the folder where the file is stored
file_name	The name of the file
checked	The initials of the individual double checking the band combo

Table G 26. Data collected for site visits.

Field	Description
observer	initials of the person entering the site visit
Office	The field office out of which surveys are being conducted.
segment_code	segment where survey is being conducted; Gavins, Lewis and Clark Lake, Fort Randall
river_mile	River mile of the sandbar where the survey is being conducted
signed	Mark “Y” if signs are placed on the site.
latitude	The Y coordinate of the site in decimal degrees.
longitude	The X coordinate of the site in decimal degrees.
elevation	The elevation of the site in meters.
start_time	The time the survey begins.
# of surveyors	The total number of people surveying
finished	Describes whether or not a survey was complete; Complete, Incomplete, Continuation
survey_method	Describes what type of survey was conducted; Stop & Scan, Targeted Search, Grid Search, Partial Grid Search, Resight and Trap, Resight, Trap
end_time	The time the survey ends
visit_comment	Comments about the survey
survey_date	The date of the survey
survey_time	The time of the survey

Table G 27. Band Colors

Color	Color code
Green Flag	GF
Yellow Flag	YF
Light Blue Flag	LF
Black Flag	KF
Red	R
Orange	O
Yellow	Y
Dark Green	G
Mint Green	M
Cobalt blue	C
Light Blue	L
Violet	V
Hot Pink	P
White	W
Black	K
Gray	A
Metal	X
Alpha Numeric Band	AN
Alpha Numeric Flag	ANF
Unknown Band Color	UC

G.11.29. USFWS Permit Conditions

1. If two or more nests are depredated on a single sandbar by the same type of predator, still cameras will be pulled from that sandbar. If this occurs on three or more sandbars, we will stop using still cameras. Camera traps will only be set on nests where adults have initiated full time incubation.
2. An individual bird may not be kept off of a nest for more than 30 minutes. Because of the size of some nesting colonies, an entire sandbar/alkali lake/reservoir shoreline may take much longer than 30 minutes, but surveyors should ensure that they move through quickly enough so that individual birds return to their nests within 30 minutes.
3. Surveyors shall not return to an area less than 120 minutes after previous departure.
4. No more than 40 minutes shall be spent in a nesting area in a 24-hour period, and no more than three visits shall be made to a nesting area daily.
5. Surveys for nests, chicks, and fledglings shall be conducted no more frequently than once every day and to the extent practicable, nests, chicks and fledglings shall be observed from a distance of 200 feet or greater to minimize disturbance. Nests may be checked daily when eggs are observed pipping or if eggs are expected to hatch within 24 hours to determine nest fate.
6. Surveys shall be conducted when the ambient temperature is between 40° and 90° Fahrenheit. Surveys shall not be conducted if it is precipitating. Surveys shall not be conducted if the wind speed is greater than 25 mph or if sand is blowing across the survey area.
7. To the extent possible during surveys, nesting least terns and piping plovers and those observed returning to their nests are not to be disturbed.
8. Incubation stage may be determined using egg floatation by those experienced with the technique. Prior to handling eggs, technicians shall wash their hands using unscented soap or wipe their hands using unscented wet wipes to reduce the risk of leaving residue or scent on eggs.
9. Surveyors may place nest cameras no closer than one meter from piping plover and least tern nests. Cameras shall be placed at a distance from the nest that shall not disturb the normal incubation of nests and shall not provide a perch for avian predators. Following placement, the nest shall be observed to ensure that the parents resume incubation activities. If adults do not resume incubation within 20 minutes, the camera shall be removed.
10. Nests may be marked using inconspicuous methods, e.g. tongue depressors, wooden dowels, driftwood, or rock cairns.

G.11.30. USACE BAND RESIGHTING CAMERA SOP

The following procedures and protocol have been adapted from procedures and protocols developed by USGS Northern Prairie Wildlife Research Center and the Virginia Tech Shorebird Program.

Resighting Camera

Introduction

- All crew members will read the manual for the camera/lens
- Practice these steps prior to doing it in the field

Equipment

- Nikon D5300 or Canon Powershot 50HS or Panasonic Lumix DMC FZ1000
- Fully charged battery
- SD card
- Monopod

Getting Started:

- Make sure the battery is charged nightly and the SD card is in the camera.

Camera Settings

- Nikon D5300
  - Shoot in either Auto mode or Sports mode. Use Sports mode for a rapid series of shots.
  - On the side of the lens turn on VR and put on normal. Use active mode in VR for rapid shooting while in sports mode shooting. Turn off VR at the end of the day.
  - If the satellite is flashing it has not obtained your location yet to embed GPS coordinates into the pictures. Wait for it to quit flashing to shoot.
- Canon Powershot 50HS
  - Shoot in Auto mode or Sports mode. Use Sports mode for a rapid series of shots.
- Lumix DMC FZ1000
  - Shoot in Auto mode “iA” with dial on upper left set to “multiple shot”.

Taking pictures and viewing on camera:

- Before shooting press the shutter button down half way to focus on your subject (On the Nikon, in Sports mode it will only focus on the first shot so try and be as steady as possible when shooting in this mode).
- To see pictures press on the play button and press the arrow keys to scroll through them.

Camera Basics and Maintenance:

- Never take the memory card out while the camera is on.
- Never aim the camera directly at the sun.
- Do not store the camera in the vehicles overnight or for long durations in hot weather.
- Limit exposure to direct sunlight and store in a dry, cool place when not in use.
- Nikon D5300
    - The “hood” attached to the lens can twist off and stored in the Pelican case if it is getting in your way from zooming the lens out. The hood’s use is to keep sand and dirt from blowing into the glass and on really sunny days will help in picture taking by preventing the pictures from looking washed out (too bright).
    - To attach the hood for lens protection or taking pictures, turn it around and align it correctly white dot to white dot and gently twist counter clockwise until it locks into place. Do not force the hood on, if it is not smoothly twisting it is not lined up correctly. The small open circle on the hood should now line up with the white dot on the lens.
    - Never take the lens off while the camera is turned on.

Downloading pictures onto computer:

- With the camera turned off and the memory card inserted, plug the camera into the computer with the supplied USB cable. Turn on the camera.
- When the dialog box pops up select import pictures and video.
- Tag the photos with the name of the camera. Ex Nikon.
- When done transferring pictures delete them from the memory card. On the computer browse to Removable Disc/DCIM/, select the appropriate folder, right click and select delete.
- Turn the camera off first and then unplug the camera from the computer.
- To save geotagged photos from the Nikon
    - Open up the Nikon Transfer 2 program on the desktop.

- Pictures should show up in the program. Unclick pictures you do not want to download and then click on Start Transfer.
- When done transferring pictures turn the camera off first and then unplug the camera from the computer.
- Once the pictures are downloaded, go rename each folder to the date of the pictures (5_20_2014) and then within each folder make additional folders for each segment and place the correct pictures in each folder.
- Pictures with a globe below the file name have embedded GPS coordinates.

Reviewing Photos

- View photos in any viewing software, zoom in to bird if necessary
- Enter band combos and other relevant data into the resight database.

Nest Trap Camera

Introduction

- All crew members will read the manual for the camera
- Practice these steps prior to doing it in the field
- Use bands or something with small lettering to focus on at the proper distance to make sure they are readable

Equipment

- Kodak PixPro SPZ1 HD video camera
- Fully charged battery
- Micro SD card
- Monopod
- A watch or phone to keep track of time

Getting Started

- Install micro-SD card and battery
- Attach camera to monopod/tripod
- Turn on HD Camera – power button is on the side

Camera Settings

- Click settings (top right button that looks like a list)
- Arrow right to the Macro setting (looks like a flower) and turn "ON"
- Click settings again to exit settings, or hit "enter" (center red button)

Deployment at Nest

- Turn the camera on.
- Place camera ~18-24inches from nest.
- Make sure lens is not dirty or smudged. Clean with lens brush or lens cloth before setting.
- Try to have the sun behind the camera (at your back) and, if possible, face camera away from wind or with a cross wind
    - Birds land into the wind so don't block their way
- Zoom in on nest so ~ 2 inches on either side of the eggs are visible. Use the up and down directional buttons to zoom in or out.
    - ***Make sure eggs are in focus*** and in center of the screen
- Click settings again
    - Arrow left to the far left setting and hit enter
- Navigate to "Continuous AF" (auto-focus), hit enter, scroll to "Off" and hit enter again.
- ***This step has to happen after the camera is zoomed in on the nest***
- Click settings again to exit settings
- Hit record button (Red button in center) and make sure it is still focused on the nest
    - Say Nest #, Rivermile, and date so the video will record (in case improper paper record keeping) and/or place a small whiteboard in front of the camera with the proper info
- Retreat from area and continue other activities
- Retrieve camera and hit record button again to STOP recording, then turn camera off.
- Knock the sand off the monopod before storing

Downloading pictures onto computer:

- Remove micro-SD card and place in adapter (or use USB cord to connect to computer)
- Insert SD card in computer and copy all video to computer (not necessary if using the USB cord)
- No special program is needed besides a video player

- Save video files to designated folder
- Delete videos from memory card

Video Review

- Play video and enter data into the resight database
- Record the occurrence of events as time into the video.
- Record any band combos obtained
- When viewing video, grab the "time" scroll bar on the video player
- Slide the "time" scroll bar until a bird or a change in substrate moving from a bird is seen

Reconyx Game Camera

Introduction

- All crew members will read the manual for the camera
- Practice these steps prior to doing it in the field
- Use bands or something with small lettering to focus on at the proper distance to make sure they are readable

Equipment

- Reconyx game camera
- Fully charged battery
- SD card

Camera Settings

- Turn the camera on.
- Make sure the memory cards are empty; this should come up when you turn the camera on (% Full, % Battery). You can also get this information by scrolling to 'Check Status' and hitting OK.
    - If not, scroll to 'Erase Card' – hit OK
    - Scroll to 'Yes' – hit OK
    - Wait for the card to be erased
- If the card is empty, scroll to 'Change Setup'.
    - Under Quickset, scroll to 'Advanced' – hit OK
    - Under Advanced Setup, scroll to 'Trigger' – hit OK
    - Under Motion Sensor, scroll to 'On' – hit OK

    - Under Sensitivity, scroll to 'Very High' – hit OK
    - Under Pics Per Trigger, scroll to '5' – hit OK
    - Under Picture Interval, scroll to 'Rapid Fire' – hit OK
    - Under Quiet Period, scroll to 'No Delay' – hit OK
    - Under Finished – hit OK
- Make sure these settings are correct before deploying cameras in the field the first time and check periodically throughout the season to make sure the settings didn't get changed.

Deployment at Nest

- Turn the camera on.
- Right before placing, scroll to 'Arm Camera' – hit OK and deploy.
- Place camera 1.5-2m from nest cup
- Attempt to aim camera north for optimal lighting
- Pickup camera at following nest check (2-3 days)
- Remove memory card and mark card case with sticker, replace with a new card
- Deploy camera on next assigned nest

Downloading pictures onto computer:

- Remove micro-SD card and place in adapter (or use USB cord to connect to computer)
- Insert SD card in computer and copy all photos to computer (not necessary if using the USB cord)
- Save video files to designated folder
- Delete photos from memory card

Photo Review

- View photos in any viewing software, zoom in to bird if necessary
- Enter band combos and other relevant data into the resight database.

Appendix H. Monitoring and Assessment Protocols for Human Considerations

Note: This appendix will present common monitoring protocols employed by the program for HCs. Additional content is TBD, but may include discussion guiding development of protocols for specific projects, which may require preparation after the project objectives, location, design, etc., are known.

Populating this appendix with the appropriate information will be an ongoing objective for activities following AMP V5 and continuing to the Final Draft AMP.

I.1 Screening of HC Issues

I.2 Monitoring Protocols under the Preferred Alternative

I.3 Monitoring of Test Flows and Extreme Events

I.4 Assessments for HCs

Appendix I. Quality Assurance Project Plan (QAPP)

I.5 Overview

Quality Assurance Project Plans (QAPPs) are required for all data collection activities associated with the MRRP. Most data collections are covered by the programmatic QAPP (reference location). However, project-specific QAPPs may be needed for some activities, and it is the responsibility of all PIs, contractors, etc., to prepare, submit, and obtain approval for any project-specific QAPPs. This appendix provides an overview of the purpose and scope of the QAPPs, which are covered in detail in (reference).

Part I of the Uniform Federal Policy for Quality Assurance Project Plans (the UFP-QAPP Manual) is a consensus document prepared by the Inter-governmental Data Quality Task Force (IDQTF). It provides instructions for preparing QAPPs for any environmental data collection operation. The purpose of' the UFP-QAPP manual is to implement the project- specific requirements of American National Standards Institute / American Society for Quality (ANSI/ASQ E4), Quality Systems for Environmental Data and Technology Programs - Requirements with guidance for use, Section 6 (Part B), The Uniform Federal Policy for Implementing Environmental Quality Systems (UFP-QS) was developed by the IDQTF to implement Section 5 (Part A) of ANSI/ASQ E4.

I.6 Purpose

The purpose of a QAPP is to document the planned activities for data collection operations and to provide a project-specific “blueprint” for obtaining the type and quality of environmental data needed for a specific decision or use. The planning should include the data users, data producers, decision-makers and stakeholders to ensure that all needs are clearly defined and addressed. While time spent on such planning may initially seem unproductive and costly, the penalty for ineffective planning often generates greater conflict and extensive reworking, which results in increased cost and lost time.

The QAPP serves several purposes:

- As a *technical planning document*, it identifies the purpose of the project, defines the project quality objectives, and outlines the sampling, analytical, and quality assurance/quality control (QA/QC) activities that will be used to support environmental decisions.

- As an *organizational document*, it identifies key project personnel, thereby facilitating communication.
- As an *assessment and oversight document,* it provides the criteria for assessment of project implementation and for QA and contractor oversight.

I.7 QAPPs and Quality Management Plans

The *Uniform Federal Policy for Implementing Environmental Quality Systems* requires documentation of an organization's quality system in a quality management plan (QMP). A QMP is a formal document that describes the quality system in terms of the organization's structure, the functional responsibilities of management and staff, the lines of authority, and the required interfaces for those planning, implementing, and assessing all activities conducted. Organizations participating in the project (e.g., Federal agency, prime contractor, laboratory, etc.) must have a QMP or some other documentation of a quality system. The management, organization, and personnel responsibilities outlined in the QAPP should be consistent with that quality system.

I.8 Types of QAPPs

QAPPs can be of two types:

- A *generic QAPP* is an overarching plan that describes the quality objectives and documents the comprehensive set of standard operating procedures (SOPs) for sampling, analysis, QA/QC, and data review that are specific to a site (e.g., facility, base) or to an activity (e.g., compliance with an environmental program such as Safe Drinking Water Act, repetitive groundwater monitoring). A generic QAPP may be applicable to a single site with multiple activities (e.g., soil, groundwater, and surface water sampling) or to a single activity that will be implemented at multiple sites (e.g., same type of air monitoring at several Air Force bases) or at multiple times (e.g., a groundwater monitoring program that will sample the same locations every 3 months for 5 years).

  A generic program QAPP may serve as an umbrella under which project-specific tasks are conducted over an extended period of time. Project or task-specific information not covered by the umbrella is documented in detailed sampling and analysis plans (SAPs) or work plans, which use the generic QAPP as an informational reference whenever appropriate. The use of generic QAPPs, with supplemental project-specific QAPPs as needed, is a significant opportunity to use a graded approach, reducing repetition and streamlining the QAPP development, review, and approval process (see Section 1.2.4).

When a generic QAPP is being developed that will apply across multiple EPA Regions or regulatory approval authorities, the scoping process must involve those entities early in the development of the QAPP. Receiving input early will help streamline review and approval of the generic QAPP.

- A *project-specific QAPP* provides a QA blueprint specific to one project or task. Project-specific QAPPs are used for projects of limited scope and time and, in general, can be considered the work plan for the project. A project-specific QAPP for each site or activity may be needed to supplement a generic QAPP.

I.9 Required QAPP Element Groups and Overview of Submittal/Approval Process

There are four basic element groups addressed in a QAPP: Project Management and Objectives, Measurement/Data Acquisition, Assessment/Oversight, and Data Review. The four basic element groups of a QAPP present a framework consistent with *EPA* Requirements for Quality Assurance Project Plans (EPA QA/R-5), which requires use of a systematic planning process.

Table I1. Required elements in a QAPP and list of supporting worksheets.

Required QAPP Element(s) and Corresponding QAPP Section(s)	QAPP Worksheet #	Required Information
Project Management and Objectives		
2.1 Title and Approval Page	1	- Title and Approval Page
2.2 Document Format and Table of Contents 2.3.1 Document Control Format 2.3.2 Document Control Numbering System 2.3.3 Table of Contents 2.3.4 QAPP Identifying Information	2	- Table of Contents - QAPP Identifying Information
2.4 Distribution List and Project Personnel Sign-Off Sheet 2.4.1 Distribution List 2.4.2 Project Personnel Sign-Off Sheet	3 4	- Distribution List - Project Personnel Sign-Off Sheet
2.4 Project Organization 2.4.1 Project Organizational Chart 2.4.2 Communication Pathways 2.4.3 Personnel Responsibilities and Qualifications 2.4.4 Special Training Requirements and Certification	5 6 7 8	- Project Organizational Chart - Communication Pathways - Personnel Responsibilities and Qualifications Table - Special Personnel Training Requirements Table
2.5 Project Planning/Problem Definition 2.5.1 Project Planning (Scoping) 2.5.2 Problem Definition, Site History, and Background	9 10	- Project Planning Session - Documentation (including Data Needs Tables) - Project Scoping Session Participants Sheet - Problem Definition, Site History and Background - Site Maps (historical and present)
2.6 Project Quality Objectives and Measurement Performance Criteria 2.5.3 Development of Project Quality Objectives Using the Systematic Planning Process 2.5.4 Measurement Performance Criteria	11 12	- Site-Specific PQOs - Measurement Performance Criteria Table
2.7 Secondary Data Evaluation	13	- Sources of Secondary Data and Information - Data Criteria and Limitations Table
2.8 Project Overview and Schedule 2.8.1 Project Overview 2.8.2 Project Schedule	14 15 16	- Summary of Project Tasks - Reference Limits and Evaluation Table - Project Schedule/Timeline Table

Measurement/Data Acquisition		
3.1 Sampling Tasks 3.1.1 Sampling Process Design and Rationale 3.1.2 Sampling Procedures and Requirements 3.1.2.1 Sampling Collection Procedures 3.1.2.2 Sample Containers, Volume, and Preservation 3.1.2.3 Equipment/Sample Containers Cleaning and Decontamination Procedures 3.1.2.4 Field Equipment Calibration, Maintenance, Testing, and Inspection Procedures 3.1.2.5 Supply Inspection and Acceptance Procedures 3.1.2.6 Field Documentation Procedures	17 18 19 20 21 22	- Sampling Design and Rationale - Sample Location Map - Sampling Locations and Methods/ SOP Requirements Table - Analytical Methods/SOP Requirements Table - Field Quality Control Sample Summary Table - Sampling SOPs - Project Sampling SOP References Table - Field Equipment Calibration, Maintenance, Testing, and Inspection Table
3.2 Analytical Tasks 3.2.1 Analytical SOPs 3.2.2 Analytical Instrument Calibration Procedures 3.2.3 Analytical Instrument and Equipment Maintenance, Testing and Inspection Procedures 3.2.4 Analytical Supply Inspection and Acceptance Procedures	23 24 25	- Analytical SOPs - Analytical SOP References Table - Analytical Instrument Calibration Table - Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table
3.3 Sample Collection Documentation, Handling, Tracking, and Custody Procedures 3.3.1 Sample Collection Documentation 3.3.2 Sample Handling and Tracking System 3.3.3 Sample Custody	26 27	- Sample Collection Documentation Handling, Tracking, and Custody SOPs - Sample Container Identification - Sample Handling Flow Diagram - Example Chain-of-Custody Form and Seal
3.4 Quality Control Samples 3.4.1 Sampling Quality Control Samples 3.4.2 Analytical Quality Control Samples	28	- QC Samples Table - Screening/Confirmatory Analysis Decision Tree
3.5 Data Management Tasks 3.5.1 Project Documentation and Records 3.5.2 Data Package Deliverables 3.5.3 Data Reporting Formats 3.5.4 Data Handling and Management 3.5.5 Data Tracking and Control	29 30	- Project Documents and Records - Table - Analytical Services Table - Data Management SOPs
Assessment/Oversight		
4.1 Assessment and Response Actions 4.1.1 Planned Assessments 4.1.2 Assessment Findings and Corrective Action Responses	31 32	- Assessments and Response Actions - Planned Project Assessments Table - Audit Checklists - Assessment Findings and Corrective Action Responses Table

4.2 QA Management Report	33	- QA Management Report Table
4.3 Final Project Report		
Data Review		
1.1 Overview		
1.2 Data Review Steps 1.2.1 Step I: Verification 1.2.2 Step II: Validation 1.2.2.1 Step IIa: Validation Activities 5.2.2.3 Step IIb: Validation Activities 1.2.3 Step III: Usability Assessment 1.2.3.1 Data Limitations and Actions from Usability Assessment Activities	34 35 36 37	- Verification (Step I) Process Table - Validation (Steps IIa and IIb) Process Table - Validation (Steps IIa and IIb) Summary Table - Usability Assessment
5.3 Streamlining Data Review 5.3.1 Data Review Steps To Be Streamlined 5.3.2 Criteria for Streamlining Data Review 5.3.3 Amounts and Types of Data Appropriate for Streamlining		

Appendix J. Integrated Science Program Requirements and Procedures

Attachment J.1 – Research Project Management Plan (PMP) Template

MRRP Research Program
Project Management Plan Template

<u>Background:</u> A project management plan (PMP) is a formal, living document used to define requirements and expected outcomes and guide project execution and control. All continuing MRRP projects are required to develop and maintain a PMP (5- 10 pages). Yearly updates of the PMP will be due at the fall IPR for the program (generally occurring in September). However, the ISP Manager should be informed of significant deviations from the PMP at the earliest possible opportunity during the course of the FY.

1. Project Title and PMP Version Date

2. Project Origin and Purpose
   - 2.1 List the Statement of Need(s) this project is addressing and/or how the need for this project was identified
   - 2.2 Describe the problem or opportunity
   - 2.3 Project Value Statement (concise, 1 or 2-sentence statement on what value the project will create for the MRRP)

3. Objectives and Products
   - 3.1 Describe the objectives of the project (i.e., the capability to be developed or knowledge learned)
   - 3.2 Identify the products (ex. tools, reports, guidance, etc.) that will be delivered
   - 3.3 Detail the scope of benefits (what and for whom) that are expected to be gained from the project

4. Technical Approach
   - 4.1 Provide a detailed, chronological narrative of the tasks, subtasks, and activities to be accomplished to meet the project objectives
   - 4.2 Identify the tools that are expected to be utilized including models, technical equipment, specialized software, etc.

5. Knowledge/Technology Transfer Plan
   - 5.1 Include a description of the strategy to transfer the knowledge gained from the effort or the technology developed and support its use for the MRRP (e.g. technical reports, guidance documents, internet tools, conference presentations, on-site trainings, reach-back support plans). The plan should encompass a three to five-year outlook related to project deliverables and capability.

6. Schedule and Funding

6.1 Schedule:

- Identify the start and end dates of all tasks, subtasks, by using a Gantt-style or similar format, or at a minimum, a basic table may be used (see below).
- Identify planned deliverable completion dates.
- Be sure to provide information regarding any expected overlap into the following fiscal year.

Tasks, Subtasks, Deliverables	Start Date	Task End Date or Deliverable Completion Date

6.2 Funding:

- Identify the proposed budget for current year and any anticipated out years. This section should include listing and description of all leverage and collaborative funding contributing to the project. Your total proposed budget must be listed utilizing the following categories:
    - Labor-Lead Agency/Entity
    - Labor-Other Entity
    - Contracts
    - Other Expenses (Burdens, Travel, Purchases, etc.)
- Present your obligations and expenditures plan for the project. At a minimum, a basic table may be used (see below).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Obl	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K
Exp	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K

7. Risk and Change Management Plan
   7.1 Identify the assumptions, dependencies, and critical risks which may impact execution of the technical approach and maintenance of the schedule and budget.
   7.2 Describe contingency plans associated with identified risks
   7.3 Describe your plan to communicate major changes to the project such as significant schedule adjustments, funding constraints, key personnel modifications, etc.

8. Project Delivery Team (PDT) Roles/Responsibilities
   8.1 Principle Investigator
   8.2 Members
   8.3 Collaborators (Active project participants such as Districts, Federal Agencies, Academia, etc.)
   8.4 Stakeholders (Customers and/or other interested agents)

PDT Member	Org. Code or Agency	Project Role	Financial POC (if project funded)

9. PMP Point of Contact: Name, E-mail, Contact Number

Attachment J.2 – Guidelines for Technical Publications

> Note: This section is under development. The information provided below is a strawman to work from in developing guidelines for subsequent versions.

Introduction

Research reports and findings of monitoring and assessments constitute important products of work under the MRRP. They influence important decisions regarding program implementation. Money, facilities, and talent devoted to research should always result in a formal technical communication of some kind. In addition to the responsibility to the program, there is a duty to the scientific/technical community at large. Whatever new knowledge has been revealed must be made available to all. The only exceptions to this are cases where restrictions are required because of security classification or proprietary rights.

It is important that reports be published in a timely fashion, be clearly and concisely written, and be technically correct. The content of a report and the manner of presenting data are governed by the objectives of the investigation and the distribution intended. The ISP Manager and/or Program Manager are entitled to prescribe the level of detail of a report prepared for their specific needs. However, if the study provides information of broad applicability, the Project Investigators (PIs) should see to it that a complete record is made available. When an investigation consists of several phases and extends over a long period, reports may be prepared on each phase to provide the information as promptly as possible. This sequential reporting often yields additional benefits, such as a better perspective on the total investigation. Phase reports and progress reports can be planned to stand by themselves temporarily, and ultimately to be incorporated into a final or summary report.

The MRRP Web site is the primary means for distributing MRRP products. This method is faster, cheaper, and more flexible than traditional hard-copy printing. However, it doesn't meet all needs, so limited numbers of hard copies of select reports will be printed for archival purposes and limited distribution when there is sufficient justification. Moreover, some study results merit publication in Journal papers, and some PIs are obligated to publish results in agency reports (e.g. USGS reports). Guidance in this appendix is focused on MRRP requirements and are the minimum requirement; publications with other requirements are supplemental to those on the following pages.

Report Categories

Reports prepared under the MRRP will be published in one of the following series. The same report categories are used independent of the species, subject, or funding source.

Supplemental (non-MRRP) reports that result from a collaboration between researchers from more than one agency will be a product of the lead PI’s agency. The responsibility for editing, producing, approving, and distributing the report will belong to the first author's agency.

Technical Report (TR)

A Technical Report documents the results of “a completed notable scientific and technical effort” sponsored by DoD (AR 70-31, para 6.a). It is a required tangible product of investigations performed under basic research, applied research, and advanced development programs (DoDI 3200.12). In addition to providing the final record of a project, the TR is also appropriate for documenting significant technical milestones achieved during a multi-year project. The author may prepare two or more technical reports as a series designated by a single publication number.

The content of a Technical Report is based on the objectives and standards given in AR 70-31 (para 5, 6, 8, and 9). However, the Military Standard presentation format specified in paragraph 6.a of the regulation is superseded by ANSI/NISO Z39.18-2005 (see DoDI 3200.12), which has been in use since 2006.

The Army technical reporting requirement for a sponsored project can be met by publishing the results in a recognized peer-reviewed science or engineering journal (AR 70-31, para 6.d). The procedure for accomplishing this involves management approval from the MRRP.

Technical Note (TN)

A Technical Note is an information- or technology-transfer publication that researchers can use to

- offer prospective users a reader-friendly synopsis of work fully documented in a Technical Report
- document supplementary or spinoff project results of interest to the MRRP
- present user-friendly instructions or specifications for applying or procuring MRRP technology products (e.g. models, design guidance, etc.).

The Technical Note is no more than 15 pages. For purposes of corporate branding, a standardized MRRP design is established. However, when the visual requirements of the technical information warrant, the author can develop MRRP-compatible design variations. (Design variations should be approved by the MRRP Manager, however.)

The TN will not generally serve as the sole documentation of a sponsored research project (see AR 70-31, para 8.a). Also, it is intended for technical topics only, not program work plans, annual reports, outreach, or other nontechnical purposes.

Special Report (SR)

The purpose of this series is to report the conclusion of work within the MRRP that was not the product of a science or engineering research investigation and does not serve the purposes of a Technical Note. The Special Report documents significant applications of MRRP technical expertise and effort outside the scope of a sponsored research, monitoring or assessment project. The following represent examples of Special Reports:

- Proceedings of conferences hosted or co-hosted by the MRRP
- A computer program user guide
- An instruction report
- A consulting study capturing MRRP technical expertise that may be of interest to a wider audience
- A literature review or annotated bibliography
- A white paper on technology applications, innovative designs, monitoring study designs, etc.

The SR is prepared and edited using the standards and formats applied to a Technical Report.

Contract Report (CR)

Studies performed for MRRP under contract are typically incorporated into a final Technical Report. However, there are two reasons a project manager may wish to publish a contractor deliverable as a separate Contract Report:

- to rapidly disseminate partial research results that may independently be of immediate use to technical proponents or peers
- to make a significant contractor study available for use as a formal reference in a Technical Report without labor-intensive reprocessing by authors or technical editors.

Publication of a research deliverable as a Contract Report is an option if the content meets the objectives of the contract's Scope of Work and the document is prepared to a high level of consistency and professionalism. The authors of record are exclusively non-governmental personnel. The individual responsible for accepting the contractor deliverable functions as the technical monitor on behalf of the MRRP.

Miscellaneous Paper (MP)

The purpose of this series is to officially recognize work by MRRP authors that has been published or presented outside of an official federal government publishing program. Examples include articles published in a nontechnical journal, conference presentations, book chapters, and technical reports prepared by MRRP researchers, including those from other agencies using MRRP funding.

Letter Report (LR)

The LR is correspondence pertaining to a research study, but it is not a published MRRP research product. The body of the LR is prepared in accordance with AR 25-50, Preparing and Managing Correspondence (May 2013), and it may be accompanied by one or more technical attachments. The LR may be used to

- summarize project status or interim findings
- present the results of a narrowly focused engineering study performed for operational purposes or as support for others.

When a researcher wishes to have technical correspondence numbered as a Letter Report, that document is subject to distribution limitations and other special handling requirements that can be explained by the MRRP PM. Tracking research correspondence as a Letter Report may be warranted by its relation to matters such as administrative procedure, policy formation, intellectual property protection, vulnerability information, or legal proceedings. However, because Army policy specifies the Technical Report as "the principal document representing the culmination of a completed notable scientific and technical effort" (AR 70-31, para 6.a), a Letter Report may not serve as the MRRP's closeout documentation for any DoD-sponsored research study.

Uniform Content Requirements

The basic content, presentation format, and literary style of MRRP reports are modeled on two widely accepted industry-standard references:

- American National Standard Z39.18-2005, Scientific and Technical Reports—Preparation, Presentation, and Preservation (ANSI/NISO Z39.18-2005
- The Chicago Manual of Style – 15th Edition (University of Chicago Press 2003).

ANSI/NISO Z39.18-2005 and the Chicago Manual shall prevail in all matters of report content and style. However, supplementary industry or government manuals may be consulted to resolve issues that are not addressed either by the ANSI standard or the Chicago Manual. A report should be organized to suit the specific requirements of the topic and the audience. However, all MRRP reports must include the basic content elements specified in ANSI/NISO Z39.18-2005, as described below. Included in the discussion are several optional components, which are clearly designated as such.

Front matter

This is the term for pages that carry information identifying the document, its authors, the funding authorization, report contents, etc. Collectively it includes the cover, title page, table of contents, Figure and table lists, preface, unit conversion factors, and other explanatory text. Page numbering is tracked with lowercase roman numerals. The cover presents basic information about a report's topic, authorship, and authorized distribution. A report number and date are printed on the cover to indicate that the document is an official MRRP technical publication. The title page includes the same information that appears on the cover plus detail about project sponsorship, funding, and author affiliation. The title page is counted as the first numbered page in the report, but the page number is not displayed.

The abstract appears on the reverse side of the title page. It summarizes the research problem, project objective, and outcome of the investigation. It should run no more than 200 words. Also on the reverse side of the title page is the standard disclaimer of any implied government endorsement of products discussed in text.

The distribution statement is a critical component of both the cover and the title page. Every MRRP technical publication must be imprinted with one of the seven primary distribution statements required by Department of Defense Directive (DoDD) 5230.24. Most reports published by the MRRP are intended for unrestricted public access and carry Statement A: "Approved for public release; distribution is unlimited."

The contents pages include the table of contents and lists of figures, tables, plates, etc. The table of contents will usually include the titles and page numbers for at least two levels of text organization (chapter and section). A preface is included in all MRRP reports to present essential non-technical documentation of the project, such as funding authorization, sponsorship, technical contributors to project execution, chain of supervision, and the authors' acknowledgments.

A unit conversion factors table is included in all reports that do not use metric units or dual units. The table should include only those U.S. customary units used in the report. A notation list also may be included to define characters, symbols, and abbreviations used to express technical facts or quantities. It appears after the unit conversion factors.

Introductory chapter

In the introductory chapter the page numbering system changes from roman to arabic numerals, with the numbering restarting at page 1. This is the first chapter in which technical content is introduced. The required sections are background, objective, and approach. ANSI/NISO Z39.18-2005 does not prohibit additional sections in the introductory chapter.

The *background* section defines the problem addressed by the research and its impact on the MRRP. It cites related previous studies and explains why the current research, monitoring or assessment effort is necessary. It also may present other background information that provides essential context for the reader.

The *objective* is a concise statement of what the research or monitoring & assessment effort is intended to accomplish. The *approach* section explains the research methodology. If the methodology is complex or otherwise warrants a chapter of its own, the approach section may simply cross-reference the reader to the appropriate chapter. For example, a scope section may be helpful to explain any limitations, caveats, etc., of which the reader should be aware. In some cases, supplementary technology transfer or contact information also may be appropriate for the intended audience.

Technical reporting and discussion

This portion of the report begins with Chapter 2 and may include any number of additional chapters. It reports all details that the reader needs to understand how the research was conducted, how the findings were documented, and how the results were validated. The technical discussion will often include a chapter of the author's in-depth analysis or interpretation of results to provide a clear context for the concluding chapter.

Concluding chapter

The concluding chapter is the last chapter in the main body of the report before the reference list. The chapter is usually called “Summary,” “Conclusions,” or “Conclusions and Recommendations.” A technical report may conclude with a summary chapter if its purpose is to document empirical observations or straightforward research findings such as the results of a field demonstration or a laboratory test series. A summary typically reviews the research results in more detail than the abstract.

A chapter of *conclusions* differs from a summary chapter in that it presents or reviews the author’s technical interpretation of the research results. Conclusions concisely help the reader to understand how the research objective was met and what the results mean in terms of the MRRP objectives or implementation needs. Conclusions should be included for every secondary objective stated in the introductory chapter.

Most reports will include *recommendations* for the program. Recommendations generally will pertain to (1) how the research product or results should be used to address the problem defined in the first chapter or (2) what the MRRP may do to transition a Level 1 product into Level 2 or 3 efforts.

References

A reference list is presented immediately after the final numbered chapter of the report, but before any appendixes. Formats and styles prescribed in the Chicago Manual of Style should be used. The reference list should include every information source cited in text plus any uncited sources that were drawn upon. The reference list for this Guide, presented on page 56, may be used as a model.

Back matter

This category of report content encompasses appendixes and the report documentation page. Some reports may have other optional types of back matter such as a glossary or a list of acronyms. Appendixes consist of any supporting text, illustrations, or data necessary to clarify or verify research findings but are too detailed or long to incorporate into the main body of the report without distracting the reader. Each appendix is customarily designated by a letter rather than a chapter number.

The report documentation page is prepared by filling out a Standard Form (SF) 298 using information provided by the author. It is the last page in the report, presented after all other back matter. The report documentation page is usually completed by the PI during final draft preparation, after an official report number has been assigned.

Formatting References and Samples

- Technical Note

  Fleming, C., J. Bonneau, and A. Quinn. 2016. *The role of research in adaptive management.* MRRP Technical Notes Collection. MRRP TN-16-1. Omaha, NE: U.S. Army Corps of Engineers.

- Journal Article

  Knocke, W. R., and P. Trahern. 1989. Freeze thaw conditioning of chemical and biological sludges. *Water Research* 23(1):35-42.

- Proceedings of Symposium

  Kovacs, A. 1989. Freezing ice in a harbor. In *Proceedings, 10th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC '89),* 12–16 June, Luleå Sweden, ed. K. B. E. Axelsson and L. A. Fransson, 6:235–242. Luleå Sweden: Univ. of Technology.

- Book

  Sanks, R. L. 1978. *Water treatment plant design*. Ann Arbor, MI: Ann Arbor Science.

  Beranek, L. K., and L. Leo. 1982. *Acoustics*. New York: McGraw Hill.

- Article in Book

  Gillham, R. W., and S. F. O'Hannesin. 1990. Sorption of aromatic hydrocarbons by materials used in construction of ground-water sampling wells. In *Ground water and vadose zone monitoring*. ASTM STP 1053, 108-122. Philadelphia: American Society for Testing and Materials.

  Kling, R., and R. Lamb. 1996. Analyzing alternate visions of electronic publishing and digital libraries. In *Scholarly publishing*, ed. R. P. Peek and G. B. Newby, 17-54. Cambridge, MA: MIT Press.

- Thesis

  Altamirano, M. R. 1991a. Experimental investigation of high and low impact energy absorption of AS-4/3502 graphite/epoxy panels. MS thesis, Univ. of New Orleans.

  __________. 1991b. Experimental investigation of high and low impact energy absorption of AS-4/3502 graphite/epoxy panels. PhD diss., Univ. of New Orleans.

- Foreign Language

  Sewerage Commission of the City of Milwaukee. 1971. Evaluation of conditioning and dewatering sewage sludge by freezing [in Swahili]. Washington, DC: U.S. Department of Commerce.

- Web Site

  Green, M. P. 1995. A history of learning institutions. http://www.ccs.neu.edu/home/distancelearning.html

Style guide for MRRP reports

Table J 1 presents the style tags for material used in MRRP reports.

Table J 1: Principal style tags used in MRRP reports.

Style Tag Name	Application
Block Text	Direct quotation of three or more lines; other text to be emphasized
Body Text	Regular narrative text
Caption	Default style when any caption is created using Insert menu
Caption Figure	For manual application to unnumbered figure caption
Caption Table	Provides correct paragraph drop after a table caption
Equation	Provides correct paragraph spacing for inline equations
Equation Terms	Variation of Body Text with tabs suitable for aligning equation terms
Graphic Callout	For “labels” applied to figures inside movable text boxes
Graphic Inline	For standardized positioning of inline (but not floating) graphics
Heading 0	Chapter title (unnumbered) for appendix, appears in TOC
Heading 02	Appendix main section heading, does not appear in TOC
Heading 03	Appendix subsection heading; does not appear in TOC
Heading 04	Appendix sub-subsection heading; does not appear in TOC
Heading 1	Chapter title (numbered)
Heading 2	Main section heading, appears in TOC
Heading 3	Subsection heading, appears in TOC
Heading 4	Sub-subsection heading, appears in TOC
Hyperlink	Use mainly for formatting URLs
List Bullet	Standard bulleted list
List Number	Standard numbered list
Reference Text	Reference list entries
Sub-paragraph	First-level subparagraph, numbered alphabetically: a., b., etc.
Sub-paragraph 2	Second-level subparagraph, numbered numerically: (1), (2), etc.
Table Column Heading	Variant of Table Text for table column headings
Table Text	Preferred style tag for data presented in a table
Table Text Compact	Alternative style tag for fitting wider tables to page constraints

Attachment J.3 – Template for Study Progress Reports

MRRP Research & Monitoring **Date**

FYXX QX Progress Report

1. PROJECT TITLE:
2. PI NAME:
3. STATUS:

    -
    - Provide an update on the project
    -

4. **PRODUCTS & MILESTONES:**

Product or Milestone	Scheduled Delivery Date (mm/dd/yy)	Actual Delivery Date (mm/dd/yy)	Percent Complete

5. **FISCAL STATUS:**

Present your obligations and expenditures plan for the project.

Current FY	1Q	2Q	3Q	4Q
Obligations	$K	$K	$K	$K
Expenditures	$K	$K	$K	$K

Attachment J.4 – Science Procurement Policy

Introduction

This appendix describes the process for acquiring MRRP-funded science services, predominantly research and monitoring, within the Integrated Science Program. The process outlined below, which is applied and overseen by the ISP Chief, is intended to ensure sound business practice and compliance with applicable laws and policy as well as address the following objectives:

Objectives

1. To the extent possible and reasonable, provide full and open competition for research activities to allow consideration of proposals across the spectrum of qualified entities. This process will allow comparison of technical competence and cost efficiency of potential contractors (e.g. state and federal government, colleges and universities, and the private sector).
2. Maximize consideration of multiple research approaches. This process will allow the ISP (and independent reviewers) to evaluate the relative potential of different research proposals to meet study objectives.
3. Provide needed consistency for longer term monitoring efforts while still allowing for competition and opportunity to increase efficiency and effectiveness (e.g. current approach is to utilize a 5-year contract vehicle for monitoring).
4. Provide a clear and transparent process for acquiring monitoring and research.
5. Enable award of science contracts within the timelines dictated by budget cycles and decision-making needs.

In general, procurement of science services will be the result of open competition. In rare circumstances, unique qualifications or other factors may result in necessary deviations from this approach. In such cases, the rationale for deviation will be clearly articulated. The acquisition approach will likely vary some depending on the type of science activity being contracted. Science activities can be grouped into one of two main categories which differ from each other in several important aspects.

Monitoring

Monitoring efforts typically require longer term consistency (the contractor can't reasonably change on an annual basis) in order to efficiently and effectively accomplish monitoring objectives. Monitoring efforts follow a monitoring plan that, although not static, must remain consistent over time and the execution of that plan must also remain consistent. Monitoring plans are developed by USACE, with input from partners and independent experts, prior to acquisition of monitoring contractors. Contractors will develop proposals to accomplish the predetermined monitoring needs. Differences in proposals will focus predominantly on cost and expertise of the contractor, not on different views of how the monitoring could be conducted since the monitoring plan is not subject to significant modification by individual proposals. Currently, monitoring contracts are awarded as 5-year IDIQ contracts or MIPRs depending on the recipient of the award.

Research

Research efforts are discrete experiments or studies which are often relatively short term (i.e. 1 to 3 years). Unlike longer term monitoring efforts, study designs for research projects will be subject to individual proposals. Although the objectives of the research will be dictated by AM needs (as described in the AM Plan), potential researchers will likely propose differing approaches to meeting those objectives. This will allow the ISP, and independent reviewers, to consider and compare the merits and costs of those multiple approaches in meeting research objectives.

For most research, the ISP will utilize a competitive proposal solicitation process open to government agencies, public sector contractors, and universities through an open Request for Proposals. Only research proposals which address high priority needs will be sought. Research proposals which are submitted to the ISP which do not address a high priority need will not be considered for funding. Research projects will be selected on the basis of their support of MRRP AM needs, demonstrated capabilities of proposers, and cost effectiveness. Selections will be made by USACE but informed by proposal reviews from an independent panel. The review process will vary depending on funding thresholds and/or relation of the research to management decisions and the potential impact of those decisions (see Funding thresholds and review/selection process below). The selected researcher will then become the principal investigator for that particular research project. Solicitation of proposals must occur far enough in advance so that information on potential costs and timelines is available as budgets are being developed. The Integrated Science Program is committed to the use of peer review and will refine peer review guidelines for reviewing research proposals, publications, and other products or deliverables. Further discussion is needed with Contracting and OC to determine what outside review is permissible when reviewing research proposals.

Types of contracts and agreements for procurement of science services

Acquiring the necessary science support from a range of entities including state and federal entities, colleges and universities, and private enterprises will likely require a suite of acquisition tools in addition to those previously utilized by the ISP. Availability of additional acquisition tools should be assessed both within the Districts and through ERDC when needed tools are not available to the Districts. Potential types of useful contracts and agreements may include but are not limited to the following:

1. Military Interdepartmental Purchase Request (MIPR)

MIPRs may be used as a vehicle to obligate funds to other federal agencies for purchasing equipment and services. The process for using a MIPR is described below.

<u>MIPR (Military Interdepartmental Purchase Request)</u>:

1) Complete Federal Agency Independent Government Estimate (IGE);
2) Complete a USACE IGE (determine if it would be cheaper to hire internally);
3) Complete A&E Contract IGE (determine if it would be cheaper to put out for bids);
4) Prepare Scope of Work (SOW) (must have an MOA with the Agency that allows work between both);
5) Receive Federal Agency Proposal;
6) Review proposal with Agency IGE;
7) Complete Determinations & Findings (D&F) document, MIPR document (Form 448) and Interagency Support Agreement (Form 4914-R);
8) Once the Proposals are received and D&F complete, send the complete package (D&F, proposals and all IGEs) for internal review and signature (Supervisor, Budget, Contracting, Office of Council). Then send signed chop sheet with other documents to NWD to review/sign;
9) Award for funding.

2. Indefinite Delivery/Indefinite Quantity (IDIQ) term contract

This type of contract provides for an indefinite quantity of services over a fixed period of time (3-5 years). The government places task orders against a basic contract for individual requirements which are individually negotiated. Minimum and maximum funding limits are specified in the base contract. The government uses an IDIQ contract when it cannot predetermine, above a specified minimum, the precise quantities of services that it will require during the contract period. This process includes creation of a base contract. Market Research is completed in the first year and then precluded for the remainder of the contract. Progress payments are made continuously on annual task orders. This is an exceptionally time-consuming process for the first year of long-term contracts but reduces Market Research requirements for successive years of the contract life.

3. Firm Fixed Price Contract

Under this type of contract, the contractor is required to perform the work described in the contract. The price is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. The total requirement has a fixed price for satisfactory delivery or complete performance. Progress payments can be made based on completion of predetermined deliverable milestones and percentage of contract amount for each. Upon satisfactory completion of the work and delivery of all items required, the contractor is paid the remaining contract amount.

4. Blanket Purchase Agreement (BPA)

A BPA is a simplified acquisition method that government agencies use to fill anticipated repetitive needs for supplies or services. The agreement is for specific line items with a provider who is intermittently called upon for those goods or services; terms and conditions are negotiated up front and any orders against the BPA must comply. This type of contract has been used by the ISP for recurring water quality analyses, for example, where the costs of each analysis is negotiated up front and individual call orders were issued as analysis needs warranted.

5. Grant/Cooperative Agreement

An agreement with a non-profit or public entity which shares interest in the Program's goals to provide services which benefit the interests of both parties. A cooperative agreement is an instrument for basic or applied research that will require substantial Government involvement and the end result benefits the public. A grant is an instrument for basic or applied research that benefits the public, but there will NOT be substantial Government involvement. In either case, the organization doing the work cannot be for profit, or if it is for profit, it waives the fee/profit. The Legal Office reviews every cooperative agreement to ensure that the work is R&D; there will be substantial Government involvement; there is a public benefit; and the funds are appropriate. There are additional reviews if the dollar amounts are >$500,000. And more reviews if the dollar amounts are >$1M.

6. Cooperative Ecosystem Studies Units (CESU)

The Cooperative Ecosystem Studies Units (CESU) Network is a national consortium of federal agencies, tribes, academic institutions, state and local governments, nongovernmental conservation organizations, and other partners working together to support informed public trust resource stewardship. This agreement allows full competition among cooperating universities. To initiate a project with a member CESU University requires the following steps:

1. Identify project and appropriate CESU
2. A statement of interest (SOI) is prepared by the ISP
3. ERDC posts SOI to a CESU website
4. SOI is posted to the CESU website for a minimum of 10 days
5. Initial proposals are reviewed for technical competency and a full proposal is sought from the most qualified entity
6. Technical review by ISP and Contracting representatives
7. Invoicing and reporting requirements determined by the ISP
8. Proposals may include multiple year funding options

Further description of these contracting tools (and potentially others) including availability and usefulness will be provided in AM Plan v6 following further discussions with District and ERDC contracting staff. Acquisition of products and services will be made in the most appropriate manner based on Federal Acquisition Regulations (FAR), USACE Policy and input from Contracting and OC.

Funding thresholds and review/selection process - TBD

This section will describe an increasing level of review and need for independent review as cost increases. The impact research has on major decisions and the potential impact of those decisions will also affect level of review.

Debriefing of unsuccessful contractors and protest procedures - TBD

Appendix K. List of Pallid Sturgeon Metrics

Table K1. Metrics for monitoring status and trend of populations, action effectiveness and ecosystem condition. Some metrics will be measured directly, while others are derived variables (some based on models). Some metrics are used as key performance measures while others are covariates to help explain the observed variability in key performance measures.

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	Both Upper and Lower Missouri		Upper Missouri	Lower Missouri		
	Population / Ecosystem Status and Trends	Augmentation (U & L)	Intake	IRCs	Spawning Habitat	Spawning Sync Flows
Hydrology, water quality and geomorphology						
Water temperature	X	X	X	X	X	X
Water velocity	X	X	X	X	X	X
Water depth	X	X	X	X	X	X
Discharge	X	X	X	X	X	X
Cross-section profile			X	X	X	
Spawning flow characteristics (timing, magnitude, longitudinal spatial distribution)*			X		X	X
Water year conditions (e.g., total inflow, peak flows)*	X	X	X		X	X
Turbidity	X	X				
Suspended sediment			X	X	X	X
Dissolved oxygen (particularly Lake Sakakawea)	X		X	X		
Nutrient loads	X					
Contaminant loads	X					
Habitat						
Spawning habitat chosen vs. habitat available			X	X	X	X
# and area of spawning sites created with suitable characteristics (depth, velocity, substrate, and derivative hydraulic variables)					X	X
Fraction of habitat area with suitable habitat characteristics for IRCs; and trends in these attributes				X		
Habitat complexity in IRCS (e.g. diversity indices, patch shape, patch connectivity)				X		

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	**Both Upper and Lower Missouri**		**Upper Missouri**	**Lower Missouri**		
	Population / Ecosystem Status and Trends	**Augmentation (U & L)**	**Intake**	**IRCs**	**Spawning Habitat**	**Spawning Sync Flows**
Production of food / area in IRCs and control sites				X		
Effective acreage (acre-days/yr of available IRC habitat)				X		
Fish Numbers and Survival						
Density of free embryos and larvae in IRCs, control areas, navigation channel, etc.	X	X	X	X		
Actual survival of hatchery-reared first-feeding pallid sturgeon larvae	X	X	X	X		
Number and survival rates (to age-0, age-1[1], and juvenile stage) for stocked pallid sturgeon by stocked size, hatchery of origin, and condition	X	X	X	X	X	X
Numbers of pallid sturgeon free embryos collected	X	X	X	X	X	X
Capture of age-0 and older juvenile pallid sturgeon (e.g., present / not present, CPUE)	X	X	X	X	X	X
Number of pallid sturgeon by age class and origin (wild vs. hatchery)	X	X				
Survival probabilities for stocked pallid sturgeon by stocked size, age, condition, and hatchery of origin	X	X				
Yearling equivalents (stocking performance based on 3-year running average of annual yearling equivalents)	X	X				
Modelled long-term change in population	X	X	X	X	X	X
Population size structure analysis	X	X	X	X	X	X
Fish Condition and Genetics						
Pallid sturgeon condition – length, weight, Kn, health metrics	X	X	X	X	X	X
Length frequency distribution of age-0 fish	X	X	X	X		
Condition of age-0 fish – % empty/full stomachs, lipid content	X	X	X	X		
Genetics	X	X	X	X	X	X

[1] Age-0 fish become age-1 fish on January 1st

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	Both Upper and Lower Missouri		Upper Missouri	Lower Missouri		
	Population / Ecosystem Status and Trends	Augmentation (U & L)	Intake	IRCs	Spawning Habitat	Spawning Sync Flows
Bioenergetic metrics				X		
Levels of disease	X	X	X		X	X
Fish Movement and Spawning						
Telemetry data showing movement and aggregation of adult fish in reproductive condition			X		X	X
Numbers of adult pallid sturgeon passing over/around Intake Dam (moving upstream)	X		X			
Successful passage of pallid sturgeon downstream over Intake Dam			X			
Telemetry data on selection for created spawning sites vs. control sites					X	X
Measures of fish aggregation and spawning behaviors (e.g. optimum male : female ratios in spawning aggregations)			X		X	X
Confirmed spawning through telemetry and acoustic video			X		X	X
Frequency and location of pallid sturgeon spawning events	X		X		X	X
Site characteristics of pallid sturgeon spawning locations			X		X	X
Spawner selection of different spawning substrates			X		X	X
Site confirmation that eggs are not buried			X		X	X
Hatch rate as a function of habitat availability	X		X		X	X
Capture of eggs and embryos downstream of sites with apparent spawning	X		X		X	X
Confirmed egg release through recapture of female pallid sturgeon			X		X	X
Recruitment (field monitoring & model estimation) to age-1,2,3	X	X	X	X	X	X
Estimated improvement in spawning and recruitment due to management action		X	X	X	X	X

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	Both Upper and Lower Missouri		Upper Missouri	Lower Missouri		
	Population / Ecosystem Status and Trends	Augmentation (U & L)	Intake	IRCs	Spawning Habitat	Spawning Sync Flows
Augmentation						
Number, size, age, location, habitat and origin of captured pallid sturgeon	X	X				
Pallid sturgeon capture method and intensity		X				
Hatchery of origin of released pallid sturgeon		X				
Number, size, age, location, hatchery of origin and date of released pallid sturgeon	X	X				
Proportion of pallid sturgeon from different release groups		X				
Effective population size, empirical and projected		X				
Catch rates of pallid sturgeon/catch efficiency/CPUE		X				
Ecosystem Condition						
Abundance/biomass of direct or indirect competitors	X					
Abundance/biomass of predators of pallid sturgeon	X					
Abundance/biomass of key food sources for each life history stage of pallid sturgeon	X					

Appendix L. Reserved

Appendix M. Distributed Systems Data Management Requirements