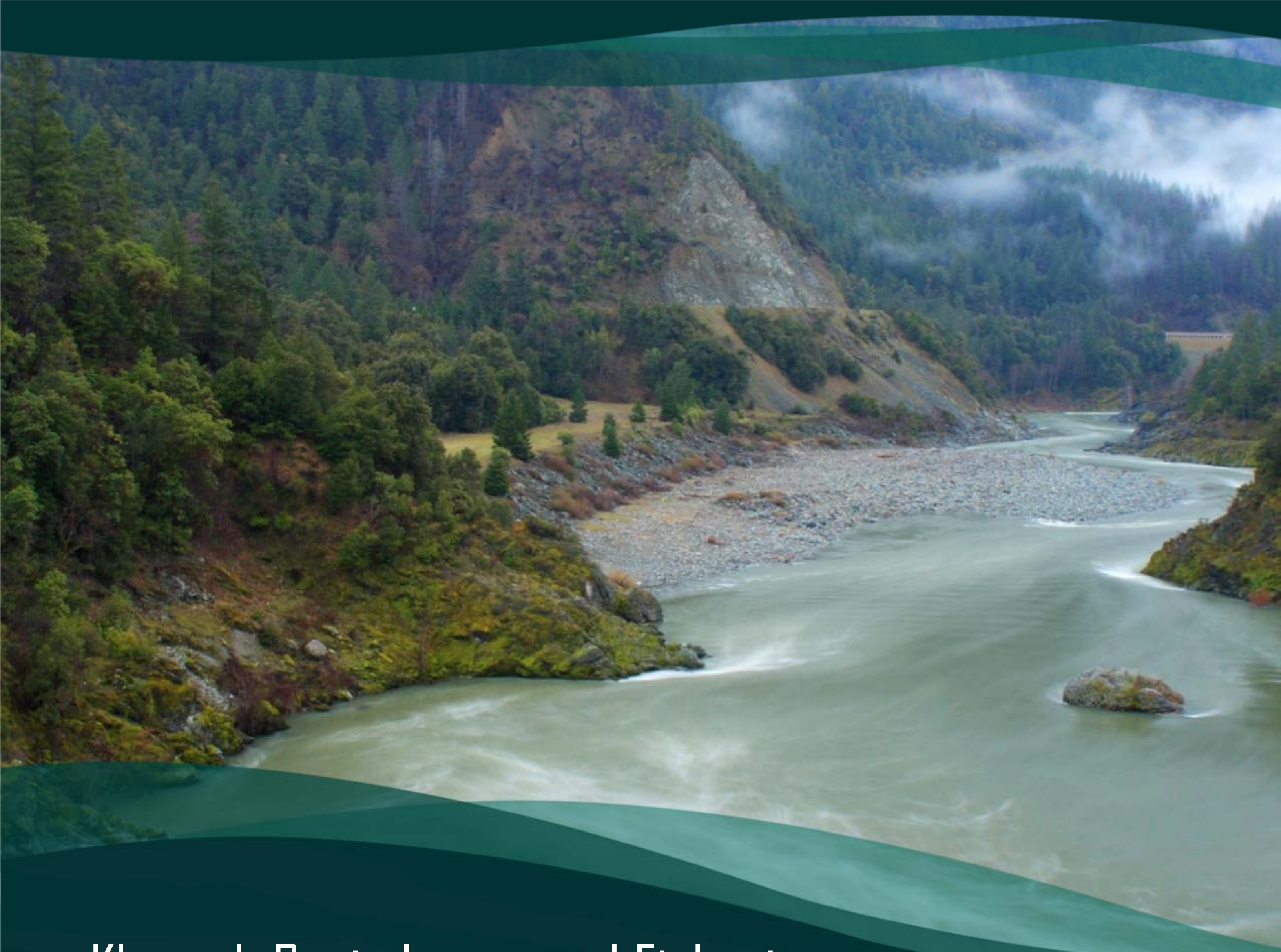

Klamath Basin Integrated Fisheries Restoration and Monitoring Plan (IFRMP) Phase 2 (Task 1.2)

In Progress Chapters & Annotated Report Outline

August 24, 2018

Prepared for the Pacific States Marine Fishery Commission

Prepared for:
Pacific States Marine
Fishery Commission

Klamath Basin Integrated Fisheries Restoration and Monitoring Plan (IFRMP) Phase 2 (Task 1.2)

Initial Rough Draft Plan

August 24, 2018

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Cover Photo:
Confluence of Salmon and Klamath Rivers, courtesy of USFWS

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List of Abbreviations

ACCCNRS	Advisory Committee on Climate Change and Natural Resource Science
ACL	Annual Catch Limit
AEQ	Adult Equivalent
AM	Adaptive Management
AMA	Agricultural Management Assistance
AMIP	Adaptive Management Implementation Plan
BACI	Before-After-Control-Impact
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
CALFED	Collaboration Among State and Federal Agencies to Improve California's Water Supply
CCLS	Community Capacity and Land Stewardship
CCP	Comprehensive Conservation Plan
CDFW	California Department of Fish and Wildlife
CDOJ	California Department of Justice
CEQA	California Environmental Quality Act
CHRPD	California Habitat Restoration Project Database
CMP	Coastal Salmonid Monitoring Program
COPCO	California Oregon Power Company
CPUE	Catch Per Unit Effort
CPVI	Conservation Population Viability Index
CRITF	Columbia River Inter-Tribal Fish
CSP	Conservation Stewardship Program
CSS	Commercial Salmon Stamp
CWA	Clean Water Act
CWT	Coded Wire Tag
DIDSON	Dual Frequency Identification Sonar
DNR	Department of Natural Resources
DPS	Distinct Population Segment
DQO	Data Quality Objectives
DSS	Decision Support System
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPIC	Environmental Protection Information Center
EQIP	Environmental Quality Incentives Program
ERO	Ecosystem Restoration
ESA	Endangered Species Act

ESU	Evolutionary Significant Unit
FACA	Federal Advisory Committee Act
FERC	Federal Energy Regulatory Commission
FGDC	Federal Geographic Data Committee
FLAR	Forest Land Anadromous Restoration
F_{MSY}	Fishing Mortality Rate at Maximum Sustainable Yield
FPA	Federal Power Act
FRGP	Fisheries Restoration Grant Program
FRIMA	Fisheries Restoration and Irrigation Mitigation Act
FSC	Fire Safe Council
FWS	Fish and Wildlife Service
GCMRC	Grand Canyon Monitoring and Research Center
GMU	Geographic Management Unit
GSI	Genetic Stock Identification
HGMP	Hatchery and Genetic Management Plan
HVT	Hoopa Valley Tribe
IAP	Integrated Assessment Plan
ICDT	Integrated Costs Database Tool
IFIM	Instream Flow Incremental Methodology
IFM	Instream Flow Model
IFR	Institute for Fisheries Resources
IFRM	Integrated Fisheries Restoration and Monitoring
IFRMP	Integrated Fisheries Restoration and Monitoring Plan
IGH	Iron Gate Hatchery
INSE	Institute for Natural Systems Engineering
IRCT	Interior Redband Conservation Team
ISAB	Independent Science Advisory Board
ISAC	Independent Science Advisory Committee
ISRP	Independent Science Review Panel
KBAC	Klamath Basin Advisory Council
KBCC	Klamath Basin Coordinating Council
KBMP	Klamath Basin Monitoring Program
KBRA	Klamath Basin Restoration Agreement
KBRT	Klamath Basin Rangeland Trust
KFHAT	Klamath Fish Health Assessment Team
KHSA	Klamath Hydroelectric Settlement Agreement
KMP	Klamath Mountain Province
KNF	Klamath National Forest
KRBFTF	Klamath River Basin Fisheries Task Force
KRFC	Klamath River Fall Chinook

KRITFWC	Klamath River Inter-Tribal Fish and Water Commission
KRRC	Klamath River Renewal Corporation
KRTAT	Klamath River Technical Advisory Team
KTAP	Klamath Tracking and Accounting Program
KTWQC	Klamath Tribal Water Quality Consortium
LCM	Life Cycle Monitoring
LRMP	Land and Resource Management Plans
LWD	Large Woody Debris
MFMT	Maximum fishing mortality threshold
MRRIC	Missouri River Recovery Implementation Committee
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
NCCFF	Northern California Council Federation of Fly Fishers
NCRWQCB	North Coast Regional Water Quality Control Board
NDSI	National Spatial Data Infrastructure
NEPA	National Environmental Policy Act
NFMS	National Marine Fisheries Service
NFP	National Forest Plan
NFWF	National Fish and Wildlife Foundation
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAAF	National Oceanic and Atmospheric Administration Fisheries
NPCC	Northwest Power and Conservation Council
NPPC	Northwest Power Planning Council
NRC	National Research Council
NRCS	Natural Resource Conservation Service
NRDAR	Natural Resource Damage Assessment and Restoration Program
NRRSS	National River Restoration Science Synthesis
OCSRI	Oregon Coastal Salmon Restoration Initiative
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OPSW	Oregon's Plan for Salmon and Watersheds
ORAFS	Oregon Chapter of the American Fisheries Society
OSU	Oregon State University
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Water Resources Department
PCFFA	Pacific Coast Federation of Fishermen's Associations

PCSRF	Pacific Coastal Salmon Recovery Fund
PERC	Property and Environment Research Center
PFMC	Pacific Fisheries Management Council
PFW	Partners for Fish and Wildlife
PIT	Passive Integrated Transponder
PNW	Pacific Northwest
PSFMC	Pacific States Fisheries Management Council
PSMFC	Pacific States Marine Fisheries Commission
RMU	Regional Management Units
ROD	Record of Decision
RTK	Real Time Kinematic
RWQCB	Regional Water Quality Control Board
SAB	Scientific Advisory Board
SALMOD	Salmon Population Model - a conceptual model that simulates the dynamics of freshwater salmonid populations, both anadromous and resident
SALMODII	Salmon Population Model - a conceptual model that simulates the dynamics of freshwater salmonid populations, both anadromous and resident
SARP	Sucker Assisted Rearing Program
SDM	Structured Decision Making
SHIRA	Spawning Habitat Integrated Rehabilitation Approach
SHRRC	Steelhead Report and Restoration Card
SIAM	System Impact Assessment Model
S_{MSY}	Number of adult spawners (S) at maximum sustainable yield
SMU	Species Management Unit
SOCC	Southern Oregon and Coast
SONCC	Southern Oregon/Northern California Coast
SQRCD	Siskiyou Resource Conservation District
SRCD	Siskiyou Resource Conservation District
SRCRMPC	Shasta River Coordinated Resource Management and Planning Committee
SRRC	Salmon River Restoration Council
SRWC	Scott River Watershed Council
STEP	Salmon and Trout Enhancement Program
SVRCD	Shasta Valley Resource Conservation District
SWCD	Soil and Water Conservation District
TAC	Technical Advisory Committee
TAMWG	Trinity Adaptive Management Working Group
TAT	Technical Advisory Team
TL	Total Length
TMC	Trinity Management Council
TMDL	Total Maximum Daily Load

TNC	The Nature Conservancy
TRRP	Trinity River Restoration Program
TSS	Total Suspended Sediments
UBT	Upper Basin Team
UFWS	United States Fish and Wildlife Service
UKBCA	Upper Klamath Basin Comprehensive Agreement
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USDC	United States Department of Commerce
USDI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UWRL	Utah Water Research Laboratory
VSP	Viable Salmonid Population
VSS	Vane shear strength
WCB	Wildlife Conservation Board
WELC	Western Environmental Law Center
WG	Work Group
WIT	Watershed Improvement Tracking
WPMP	Water Quality Management Plan
WQ	Water Quality
WQCP	Water Quality Control Plan
WQMP	Water Quality Management Plan
WSFR	Wildlife and Sport Fish Restoration
WTP	Water Transactions Program
WUA	Weighted Useable Area
YOY	Young of Year
YTEP	Yurok Tribe Environmental Program
YTFP	Yurok Tribal Fisheries

Unit Conversion Table

Note: Units are presented in the text in the form they are cited in supporting references.

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

Executive Summary

TO DO

Roadmap to the Report

TO DO / UNDER DEVELOPMENT

NOTE TO REVIEWERS: This outline includes various straw examples, comments and questions to stimulate creativity and feedback. This in progress draft document is intended to be a repository for ideas and options – feel free to add yours as comments. Critical filtering and editing of these ideas and options is essential, but will happen later. Each major section has an Introduction to provide some context, which describes the Purpose, Challenges, and Proposed Approach.

1 Overview

1.1 Overall Vision

TO DO / IN PROGRESS

NOTE TO REVIEWERS: Several chapters and sections of the Initial Rough Draft IFRMP are in outline form with various straw examples, comments and questions to stimulate creativity and feedback. This in progress draft document is intended to be a repository for ideas and options – feel free to add yours as comments. Critical filtering and editing of these ideas and options is essential, but will happen later. Each major section has an Introduction to provide some context, which describes the Purpose, Challenges, and Proposed Approach.

- This section would draw from the introduction to the Plan Vison document (pages 1-2), including the map.
- Need to provide enough of an overview to support rest of the Plan without duplicating what appears in detail in later sections.
- The following vision statement allows for futures with or without dams, though the latter is certainly preferable ecologically:
    - The overall vision for the Klamath River Basin is to advance the restoration and recovery of native fish species from the headwaters to the Pacific Ocean, while improving flows, water quality, habitat and ecosystem processes.

1.1.1 Focal Species of Restoration

TO DO / IN PROGRESS

- Borrow from Section 4.3 of Synthesis Report.
- Address how focal species approach is consistent with ecosystem-based management.

1.1.2 Key Assumptions of this Plan

TO DO / IN PROGRESS

- The intent of the Plan is to achieve the overall vision described at the start of Section 1.1, either with or without the removal of four dams on the Klamath River.
- The Plan builds on, complements, and helps to integrate, other restoration plans and species recovery plans in the Klamath Basin, including the Integrated Assessment Plan for the Trinity River, the Upper Klamath Basin Action Plan, and other sub-regional plans, as well as species

recovery plans developed by NOAA, the USFWS, and state agencies. This Plan **does not in any way override or replace other existing plans**.

- The Klamath IFRMP process will be primarily focused on habitat restoration and monitoring. Fish populations (both existing and to be recovered), will be broadly defined and qualitative objectives for population recovery will also be incorporated into the Plan.
- Since the development of numerical objectives for fisheries is generally well defined in federal or state law or determined by sovereign tribes, developing new quantitative objectives will not be part of the IFRMP planning process. Instead, where a federal agency, state, or tribe has already adopted such a numerical target or management/listing unit delineation, these quantitative population objectives will be referenced in the Plan.
- Where a federal agency, state, or tribe will be developing quantitative goals for a species, this process will also be referenced in the Plan.

1.1.3 Study Area, Sub-regions, and Organizational Structure

TO DO / IN PROGRESS

- Discuss Map and sub-regions (Figure 1).
- Discuss organizational structure.

Figure 1. Map of the Klamath Basin, including major dams, and showing the organizational structure of the entities collaborating on the development of the Plan.

1.2 Purpose of the Plan

TO DO / IN PROGRESS

- IFRMP = The Plan
- Will provide guidance to the entities that are involved in the restoration of the Klamath River basin and the recovery of fish species by:

  - Identifying key stressors and the types of restoration actions required to reduce them, for each functional species group and sub-region.
  - Developing a hierarchy of goals and objectives to guide the detailed development of restoration actions, key performance indicators, and decision triggers.
  - Identifying critical uncertainties affecting decisions on restoration actions, including design, implementation, and effectiveness.
  - Describing a set of activities to reduce the identified uncertainties, including research, adaptive management of implemented actions, monitoring the effectiveness of actions, and monitoring the status and trend of habitats and populations.
- Reiterate that the Plan is intended to complement and build on other plans that have already been developed, not to replace them.
- Describe collaborative process of Plan development (various stages) and organizational structure.
- Provide an overview of what's in Synthesis Report; note that this Plan builds on the Synthesis Report but doesn't repeat that information.

1.2.1 Principles Guiding the Development of the Plan

TO DO / IN PROGRESS

The following principles have guided the development of this Plan:

1. Take an integrative, whole-basin approach to fisheries restoration actions and monitoring needs.
2. Use best available science, leveraging (rather than re-inventing) past efforts at synthesis.
3. Return native fish species to the upper basin either through removal of the four lower Klamath River dams[1] or by adding the required fish passage infrastructure.
4. Use a broadly inclusive, transparent, collaborative process involving representatives of all interested participants, with peer review.
5. Focus scientific information to assist decisions on how to prioritize fisheries restoration actions and monitoring activities.
6. Apply an Adaptive Management (AM) mindset and best practices to guide the collaborative design and prioritization of restoration work, and to promote iterative learning and adjustment.
7. Express differences of opinion in how to best achieve restoration objectives as alternative hypotheses, and explore ways to test those alternative hypotheses.
8. Use the process of developing the Plan to organize and sustain scientific momentum as policy priorities evolve.

---

[1] Iron Gate, Copco I, Copco II and J.C. Boyle

These principles are consistent with recommendations from the National Research Council (2004, 2008).

Principle 1 (an integrative whole-basin approach) is especially relevant given the ongoing and substantial restoration work being undertaken in the Trinity River sub-basin, the largest sub-basin in the Klamath Basin. The Trinity River Restoration Program (TRRP), created in 2000, is a large-scale, adaptive management program intended to recreate the geomorphic processes required to create and maintain salmonid habitat in the 40 miles below Lewiston Dam (USDI 2000; TRRP and ESSA 2009). An Integrated Assessment Plan (IAP) was developed for the TRRP to guide restoration and monitoring activities in the Trinity River (TRRP and ESSA 2009). While the Klamath faces unique challenges (e.g., dam removal, water quality) that require unique solutions, the Klamath Plan's objectives, actions and monitoring activities need to be well-integrated with those attributes of the Trinity IAP.

Since the ecosystems in the two rivers are interdependent, close coordination is essential to the achievement of an integrative whole-basin approach. Connectivity with the Trinity means that the success of any recovery efforts in the Klamath Basin will be partly dependent on TRRP management decisions affecting flows, fluvial geomorphic processes, habitats and fish populations. Additionally, hatchery and harvest management are intricately connected between the Klamath and Trinity rivers. Hatchery and natural stocks are managed collectively in an integrated harvest management process for ocean and in-river fisheries. The Trinity will benefit from improved downstream conditions in the Klamath River (e.g., lower levels of disease) as the Klamath Plan is implemented (Nichols et al. 2003; True et al. 2010; Bolick et al. 2012).

Principle 4 (a broadly inclusive, transparent, collaborative process involving representatives of all interested participants, with peer review) is extremely important. Successful implementation of the Plan over several decades will require strong collaboration among many entities, and strong personal relationships.

- Adapt text from the "A Collaborative Approach" section of the Plan Vision Pamphlet.
- Summarize material from Section 1.2 of the Synthesis Report.
- Briefly summarize the collaborative process used to develop the Synthesis Report.
- Borrow text from Public Input Processes box on last page of Plan Vision Pamphlet.

Implementation of Principle 4 requires interaction with a number of parallel and often overlapping programs focused on the restoration and management of watersheds and fish populations. The process used to develop the Klamath Plan will defer to the processes in other programs and attempt to interweave their most relevant features into the integrated plan. The Klamath Plan will integrate the goals and objectives of other programs into a holistic restoration and monitoring approach.

1.2.2 Process and Steps to Create the Plan]

TO DO / IN PROGRESS

Idea: create a IFRMP version of a figure along these lines..

e.g., p6 in
http://www.therrc.co.uk/DesignatedRivers/Designsummary71212.pdf

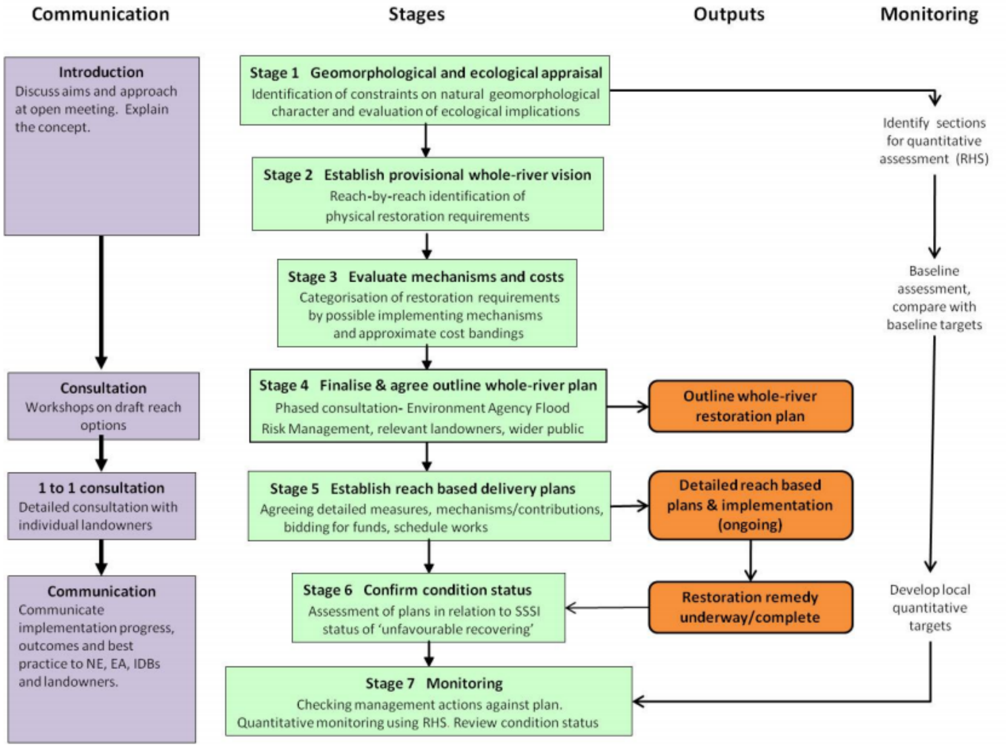

Figure 1 Key technical stages in the development of a SSSI physical restoration Strategy (green), communication aspects (purple) and main outputs (orange)

1.3 Phases of Restoration & Overall Goals

TO DO / IN PROGRESS

Introduction to watershed process tiers.

Brief introduction of level 1 goals and overview of objectives hierarchy and CPIs in Chapter 3. Point readers to Chapter 3 for details.

1.4 Challenges

TO DO / IN PROGRESS

High dimensionality: Similar to other aspects of the Plan (see Section 2), a key challenge in mapping key candidate restoration actions is the high dimensionality of the problem. Candidate actions must be characterized across multiple species functional groups (6), sub-regions (3), restoration phases (2) and stressors (~70).

Dependencies across sub-regions: Dependencies in both upstream and downstream directions are also important to consider since migratory species require habitats in each subregion and the ability to migrate between sub-regions. Downstream habitats and species require properly timed upstream inputs of adequate water quality and supply, nutrients, wood, and coarse sediment. Disease can also affect species in both upstream and downstream directions. Table 4 in Section 2 provides examples of possible biophysical dependencies across subregions.

Dependencies across restoration actions: Dependencies across restoration actions affect decisions about sequencing. Some actions cannot occur until other actions have been completed. In considering sequencing, biophysical dependencies across watershed inputs, fluvial geomorphic processes, habitat, and species must be acknowledged. Dependencies across these 'tiers' (detailed in Section 2) and restoration phases will not always follow a linear sequence. Negative and positive feedback loops can exist across biophysical tiers and phases in more than one direction.

Interactions across and within species groups: Generally what benefits one species will assist other fish species, but in some cases may be detrimental. For example, restoring passage for migratory salmonids by removing dams in small tributaries may also clear a path for invasion by exotic species. Anadromous species may also compete with resident fish that have adapted to current conditions. Within species tradeoffs may exist when different life stages have temporal overlap, thus requiring divergent operations of existing dams and diversions.

1.5 Role of Adaptive Management

TO DO/IN PROGRESS

This will be a high-level section that describes the overarching role of AM in the Plan.
Borrow key material from Section 8.2 of Synthesis Report.

OLD TEXT BELOW/UPDATE TO DO:
Because there are many scientific and technical uncertainties associated with dam removal and reintroduction of anadromous fish, it is important to develop the IFRMP in accordance with an Adaptive Management (AM) approach. AM is a formal, systematic, and rigorous program of improving management by learning from implementation outcomes and accommodating change (Holling 1978). Applying AM best practices can guide the technical work needed to inform restoration efforts by clearly framing objectives and science needs around systematically reducing critical uncertainties. The AM approach means embracing uncertainty as a constant and focusing on those uncertainties that have the most influence for decision making, that are feasible to learn about, and that can contribute to improving implementation once resolved by making adjustments to implementation plans.

In practice, the 'AM mindset' encompasses a continuum of scientific approaches for testing hypotheses – from traditional experiments using a control and treatment(s) to extended programs of learning via rigorously designed monitoring of implemented actions. Using this latter approach, actions that are uncertain in terms of their effectiveness can be implemented and monitored in a way that that reduces critical uncertainties over time. Examples in the Klamath Basin might include comparing different wetland improvements to understand effects on nutrient filtering capacity, examining the effects of different flow release strategies on polychetes in a non-dam removal scenario, assessing different conservation grazing options, evaluating alternative riparian vegetation strategies (e.g. different species compositions, buffer widths), or different approaches for upland sediment control. Further details about effectiveness monitoring under an AM approach are presented in Section 5.

2 Conceptual Models

2.1 Purpose

Ecological systems are inherently complex. A large number of natural and human drivers can interact with a system's components to affect its form and function. A conceptual model is a simplified representation of a complex system which explicitly illustrates its parts and the cause-effect relationships among the parts. At the most basic level, conceptual models are communication tools that help an audience (e.g., scientists, managers, and the public) develop a common understanding about how a system works (Fischenich 2008). Conceptual models can also be used to help provide direction to management activities, including restoration activities, by defining the current understanding of the most important variables and interactive processes (Stanford et al. 2011). The models help to identify problems and establish the range of appropriate solutions, given recognition of uncertainties in the science (Ralls and Starfield 1995, Lichatowich et al. 2006, NRC 2008 as cited in Stanford et al. 2011). Well-designed conceptual models can thus provide a basis for informed decision making, if they accurately describe key relationships between ecosystem attributes and processes in relation to environmental stressors (Stanford and Poole 1996, NRC 2008 as cited in Stanford et al. 2011).

This Chapter:

Presents a range of conceptual models that:

- Illustrate Klamath IFRMP participants' common understanding of the problems that are the focus of the Plan.
- Express system understanding in a form that integrates across multiple dimensions (e.g., management actions, ecosystem components, sub-regions, and focal fish species).
- Provide a parsimonious representation of system components that is sufficient to stimulate collaborative discussions and decisions on three critical elements of the Plan:
    1. **Key stressors** which are most strongly constraining the productivity, abundance, distribution and diversity of each functional group of fish species in each sub-region;
    2. **Restoration actions** that could be implemented in each sub-region to reduce or eliminate the stressors defined in element 1:
    3. **Core performance indicators and associated informative indicators** required to assess progress towards habitat and species thresholds/triggers, and to assess the effectiveness of actions defined in element 2.

Conceptual models can be presented in a variety of forms that draw upon a variety of modeling approaches (see Nelitz et al 2012, Jorgensen 1988, and Gucciardo et al. 2004 for summaries of different approaches for developing conceptual models). There is no *best* form for a conceptual model because the form and approach depends on its purpose. Schematics used for conceptual models vary widely, ranging from simple box and arrow diagrams to more sophisticated illustrations. Box and arrow diagrams are meant to aid in the development of explicit hypotheses about these relationships, which can be tested through monitoring or direct experimentation. Conceptual models are generally supported by narratives in tables or matrices, which provide a text description of the proposed hypotheses or pathways of effect represented and further characterize the nature of the model linkages (e.g., Jones et al. 1996).

2.1.1 Challenges in conceptual model development

Restoration of the Klamath Basin is a complex problem with multiple dimensions. Attributes of the system which need to be represented in Basin conceptual models include:

- Five tiers of the ecosystem: 1) watershed inputs (e.g., water, coarse and fine sediments, nutrients, wood), 2) fluvial geomorphic processes, 3) habitat attributes, 4) biological interactions, and 5) fisheries actions;
- Stressors within each of these five tiers or domains that can directly or indirectly result in the decreased abundance, productivity, distribution and/or diversity of focal species; and
- Restoration and other management actions across Basin sub-regions which can reduce the identified stressors.

Different participants in the Klamath IFRMP process will have different preferences for the best form of conceptual models, some preferring simpler representations of system components (the ‘lumpers’) while others will prefer more complex representations (the ‘splitters’). While detailed conceptual models may be helpful for certain purposes (e.g., description of a key process; development of a quantitative simulation model; detailed design of specific restoration action) simpler models will be more helpful in other cases to achieve the multi-purposes described above, particularly achieving a common understanding of the system. Many conceptual models of varying complexity have been developed previously in the Klamath for different sub-systems or within particular areas of the Basin or for particular species (e.g., USBOR 2011, Kendall et al. 2014, Som et al. 2016). These provide useful background for informing the structure and content of the conceptual models developed here to support the Plan, but these past conceptual models are not easily merged.

We need conceptual models of intermediate complexity, neither too simple nor too complex. They should provide acceptable representations of Klamath Basin issues in a format that is relatively easy to understand, fulfill the stated purposes (described above), and stimulate collaborative engagement in technical workgroup and workshop settings. Attributes of the problem may vary across the 10 focal fish species (i.e., shortnose and Lost River suckers, redband trout, bull trout, coho, Chinook, steelhead, Pacific lamprey, green sturgeon, eulachon), four defined Basin sub-regions (Upper Klamath Lake, Middle/Upper Klamath River, Lower Klamath River, Klamath River Estuary) and different phases/time periods of restoration. As this level of dimensionality has the potential to be overwhelming some degree of simplification is essential.

2.1.2 Approach

Our collaborative approach to development of conceptual models for the Klamath Basin attempted to establish clear connections between ecosystem elements and environmental stressors, so as to clarify the focus of restoration actions. We went through the following steps:

1. We assembled and reviewed all existing conceptual models for the Klamath sub-basin (some of these were previously described within the Synthesis Report (ESSA 2017)).
2. We developed a draft generic conceptual model structure that's generally applicable to all focal fish species, sub-regions and major system components, so as to provide a common conceptual foundation. The generic conceptual model:
    a) has numbered/coded boxes for both actions and stressors within each of the five tiers described above (i.e., watershed inputs, fluvial geomorphic processes, habitat attributes, biological interactions, fisheries actions);
    b) includes both those stressors which are currently constraining the focal species' productivity, abundance, distribution and/or diversity; and those stressors which could become limiting in future restoration phases;
    c) visually clarifies how the effects of various restoration actions are expected to propagate through the system (by using colored dots and action codes within each stressor box to show which actions affect which stressors);
    d) provides an accompanying table which describes the hypothesized linkages between restoration actions, reductions in stressors, and expected biological responses;
    e) allows readers to easily distinguish between actions and stressors (e.g., by having them on different rows within each of the four tiers);
    f) allows readers to quickly ascertain the relative importance of different stressors (i.e. by different thicknesses of the borders around each stressor box – key proximate stressors with thicker borders); and
    g) avoids excessive complexity (i.e., "spaghetti" diagrams) and excludes arrows, instead noting in the supporting tables information about the key linkages affecting a given component, and the associated critical uncertainties.
3. We adapted the draft generic conceptual model into a set of *draft sub-regional conceptual models* for each of the focal species/functional species groupings found within that sub-region, either currently or potentially in the future (noting that not all species will be in all sub-regions, even if system connectivity is fully restored);
4. We used the draft generic and sub-regional conceptual models as a focus for the *conceptual modelling workshop,* catalyzing conversations by sub-regional work groups before, during and after the workshop, revising both the conceptual models and associated tables, and working towards agreement on:
    a) the *most important proximate stressors* for each functional species group within each sub-region; and

   b) the *types of restoration actions* required to reduce or eliminate the key stressors.

5. Working collaboratively with regional scientists, we developed more detailed sub-models for fluvial geomorphic processes and water quality problems, to enable better specification of restoration actions and monitoring indicators.
6. As model development proceeded, we organized the evolving conceptual models into a a hierarchy, with the top of the hierarchy providing a common understanding the whole system, and successive layers of the hierarchy enabling an increasingly detailed understanding of particular stressors or specific types of actions; and
7. We included all forms of models in the Plan (fluvial geomorphic, water quality, species/sub-regional).

In the future, it will be important to revise the conceptual models as more is learned from research, restoration and monitoring activities.

2.2 Application of the Focal Species Generic Conceptual Model

We developed conceptual models for all focal fish species currently present within each sub-region or potentially present if fish passage is restored in the future. We combined some species with similar life-histories and presumed sensitivities into species functional groups to simplify the modeling exercise across species and sub-regions, converging to six distinct models: salmon (coho, Chinook, and steelhead combined), trout (redband and bull trout, combined for UKL sub-region), endangered suckers (Lost River and shortnose sucker combined), Pacific lamprey, green sturgeon, and eulachon. The conceptual model for the Klamath Estuary sub-region combines all focal species using the estuary into a single model. We used symbols to identify particular stressors or actions that are specific to a particular species (for functional species group models) and/or life history stage.

Figure 2 shows the attributes of the generic conceptual model for Klamath focal species/functional species groups as described above under Section 2.1.2. The basic model is organized by four primary tiers: watershed inputs (WI), fluvial geomorphic processes (FG), habitat (H) and biological interactions (BI). Additional tiers (i.e. fisheries actions (FA) and ocean conditions (OC)) are added to the species model where applicable (i.e. for currently harvested and/or anadromous species). Stressors are listed within each tier as are restorations that would be enacted within a particular tier (with the exception of ocean conditions). The sequence of cause-effect linkages flows from the top to the bottom of the figure for the first four tiers, so **actions in a given tier have potential benefits to both that tier and the other tiers listed below it**. Further considerations:

- **Watershed inputs** (top row)**:** While actions on the top row are essential to restoration of the tiers below it (i.e., increase supply of water, coarse sediment and wood to create and maintain habitat; decrease nutrients and fine sediment), it may be that some other actions need to occur first (e.g., floodplain re-contouring, removal of vulnerable buildings in floodplain) before those actions can occur. Decisions on the sequencing of actions will happen later in the process of developing the Plan.

- **Fluvial Geomorphic Processes** (second row): Actions that enable fluvial geomorphic processes which create and maintain habitat are listed here, addressing such stressors as channelization or lack of shallow, low velocity habitats.
- **Habitat** (third row): Actions to construct or manipulate fish habitat are included on this row, directly addressing such stressors as a shortage of spawning or rearing habitat, or water quality problems (e.g., high temperatures, low dissolved oxygen, and algal toxins).
- **Biological interactions** (fourth row): This tier applies to biological interactions which may be limiting fish populations (e.g., predation, competition with exotic species, hybridization), and the actions intended to decrease such stressors.
- **Target Fish** (fifth row): The yellow boxes represent various indicators of population response (e.g., the four criteria for Viable Salmonid Populations in McElhany et al. 2000, additional criteria for species with hatchery operations). These indicators will logically be near the top of the Objectives Hierarchy described in Section 3.
- **Fisheries Actions** (sixth row, if applicable to a species): This row lists actions to manage take of currently *harvested* focal fish species (e.g., fisheries management improvement, increased anti-poaching enforcement).
- **Ocean Conditions** (seventh row, if applicable to a species): For *anadromous* focal fish species (i.e., coho, Chinook, steelhead, Pacific lamprey, green sturgeon, eulachon) this row lists stresses that they may face during their period of ocean residency (e.g. predation, competition, food supply, environmental conditions). Defining potential restoration actions for these ocean stressors is outside the scope of the Plan.

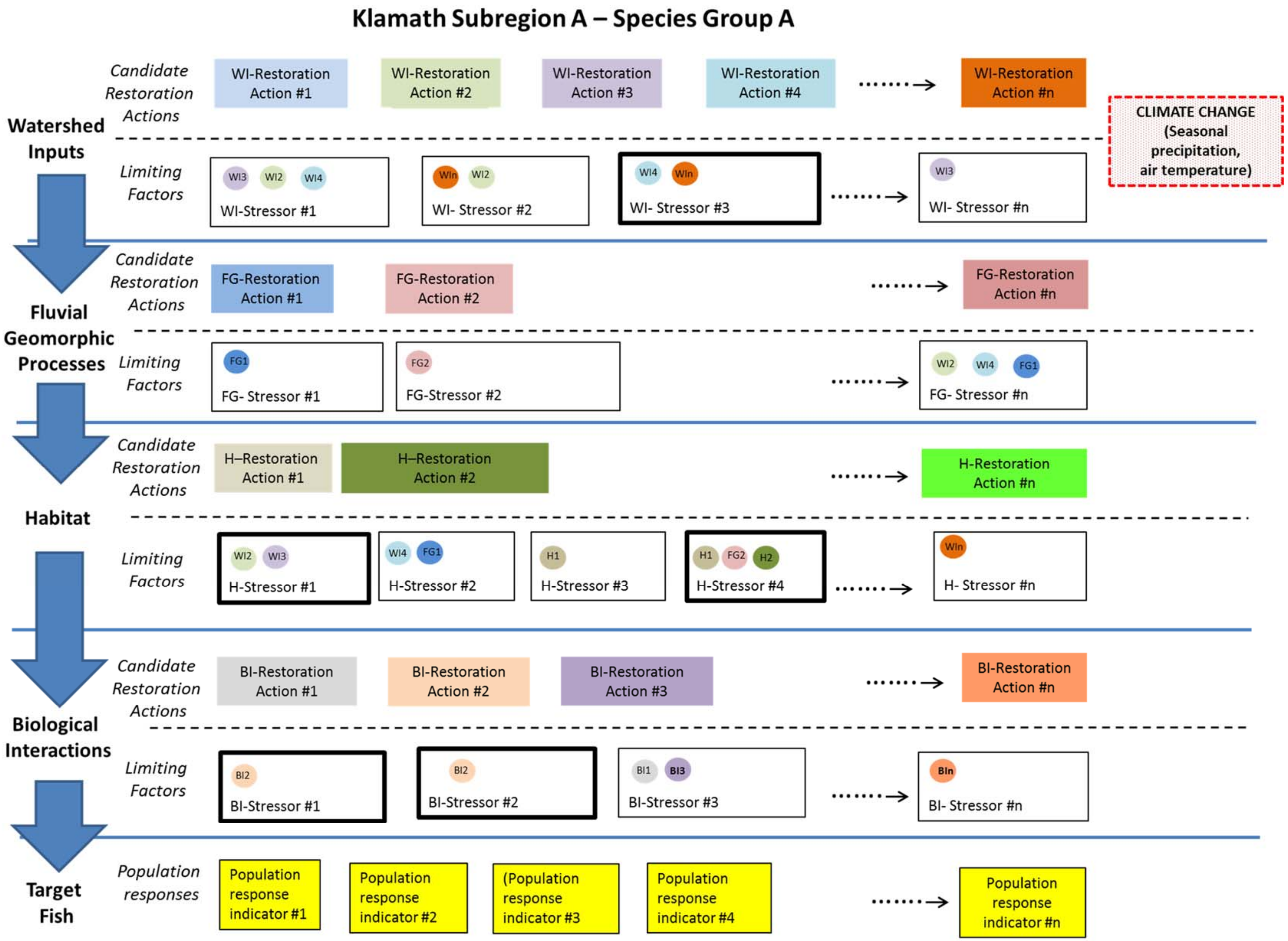

Figure 2. Draft Generic Conceptual Model for a fish species functional group within a sub-region (listed here as "Sub-region A – Species Group A". Colored boxes represent actions and are organized by the four primary tiers shown at the left side of the conceptual model. Circles within each box listing a stressor indicate that the action with the matching color and code is hypothesized to reduce the magnitude of that stressor. Abbreviations: WI = Watershed Inputs; FG = Fluvial Geomorphic Processes; H=habitat; BI = Biological Interactions). Key "proximate" stressors for a species are identified by darker/thicker box lines.

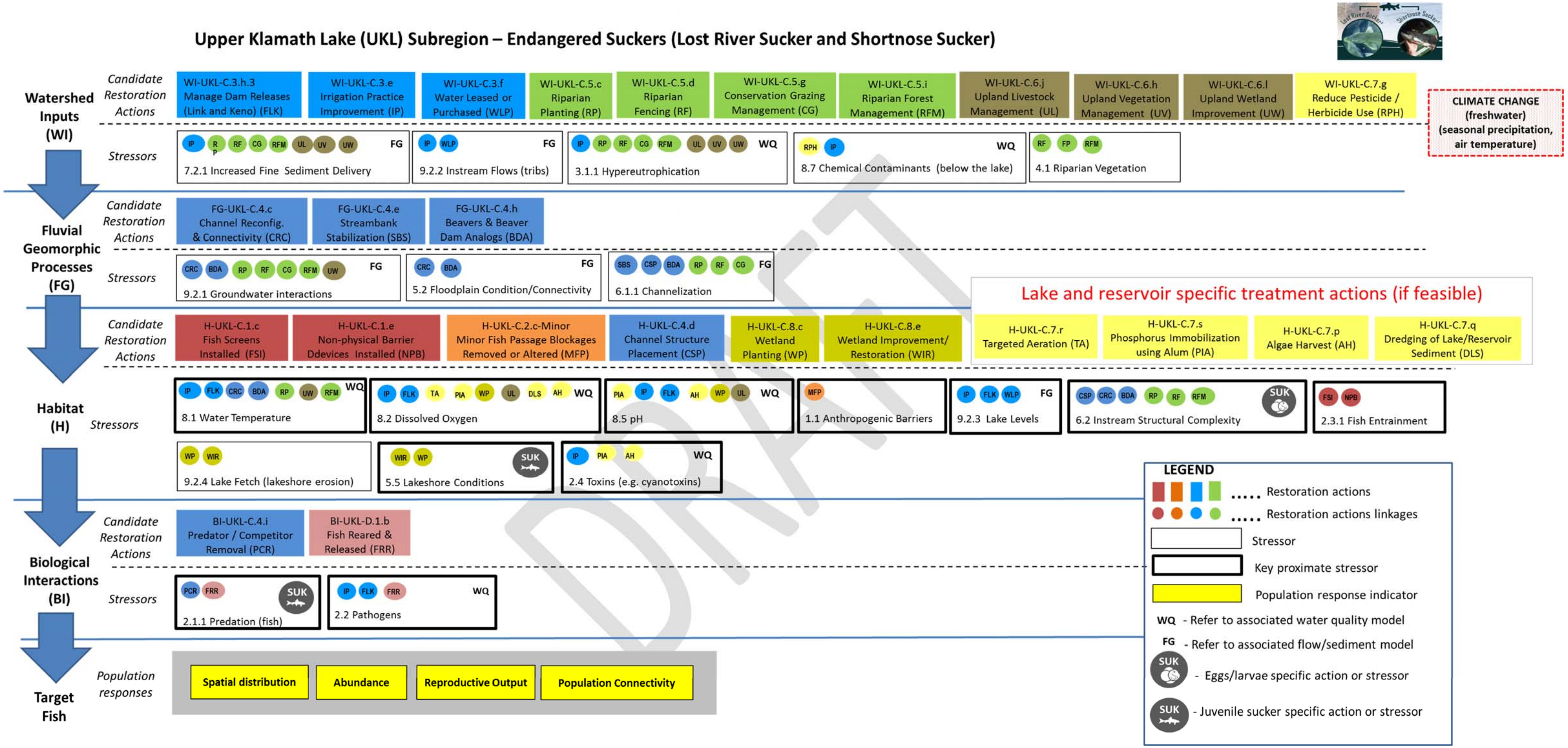

Figure 3. Example of the draft generic conceptual model applied to endangered suckers (Lost River sucker and shortnose sucker species) in the Upper Klamath Lake (UKL) sub-region. See Figure 2 for explanation of abbreviations.

For each conceptual model, we developed a table (example in Table 1), describing the stressors in the species models, and the linkages to candidate restoration actions intended to reduce the stressors. Codes are used to save space. We identified the key "proximate" stressors (i.e., those considered most immediately responsible for causing direct effects on the fish) based on our review of the literature and discussions with sub-regional working groups. Finally, we developed a Restoration Actions Dictionary (Appendix B) which identifies the hypothesized mechanism(s) by which each candidate restoration action would reduce the stressors, and critical uncertainties in either implementation or effectiveness of the action.

Multiple actions can work together to alleviate each identified stressor. Similarly, a single action may alleviate multiple stressors, either within a tier or across multiple tiers. Once we completed conceptual models for all focal fish species within in a sub-region, we were able to distinguish stressors that were common across species, from those that were unique to particular species. We were also able to identify restoration actions that could help address stressors across multiple focal fish species, versus those actions focused only on particular species. Figure 3 illustrates an example application of the generic conceptual model structure for a species functional group, endangered suckers.

Table 1. Summary of tabular information accompanying conceptual models for a sub-region (listing of stressors affecting the focal fish species/functional groups in the sub-region and the candidate restoration actions that could help alleviate/mitigate each stressor); draft example shown for Upper Klamath Lake (UKL) sub-region. Detailed descriptions/definitions for the coded restoration actions, hypothesized mechanisms regarding how the actions can minimize or mitigate stressors, and the critical uncertainties around each restoration action are described in the Klamath IFRMP Master Restoration Actions Dictionary (Appendix B).

Upper Klamath Lake Focal Species Models Summary (Stressors and Candidate Restoration Actions)			
Tier	Stressors	Candidate Restoration Actions to Alleviate Stressor	Restoration Action Code
Watershed Inputs	7.2.1 Increased fine sediment input/delivery	Upland livestock management (UL)	FG-UKL-C.6.j
		Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.g
		Riparian forest management (RFM)	WI-UKL-C.5.i
		Upland wetland improvement (UW)	WI-UKL-C.6.l
		Upland livestock management (UL)	WI-UKL-C.6.j
		Upland vegetation management (UV)	WI-UKL-C.6.h
	9.2.2 Instream flow (tribs)	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Water leased or purchased (WLP)	WI-UKL-C.3.f

	3.1.1 Hypereutrophication	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.j
		Riparian forest management (RFM)	WI-UKL-C.5.j
		Upland livestock management (UL)	WI-UKL-C.6.j
		Upland vegetation management (UV)	WI-UKL-C.6.h
		Upland wetland improvement (UW)	WI-UKL-C.6.l
		Wetland improvement/ restoration (WIR)	WI-UKL-C.8.e
	8.7 Chemical contaminants (below the lake)	Reduce pesticide/herbicide use (RPH)	WI-UKL-C.7.g
		Irrigation practice improvement (IP)	WI-UKL-C.3.e
	4.1 Riparian vegetation	Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Riparian forest management (RFM)	WI-UKL-C.5.i
Fluvial Geomorphic Processes	9.2.1 Groundwater interactions	Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c
		Beavers and beaver dam analogues (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.g
		Riparian forest management (RFM)	WI-UKL-C.5.i
		Upland wetland improvement (UW)	WI-UKL-C.6.l
	5.2 Floodplain condition/connectivity	Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c
		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
	9.2.3 Channelization	Streambank stabilization (SBS)	FG-UKL-C.4.e
		Channel structure placement (CSP)	H-UKL-C.4.d
		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.g
Habitat	8.1 Water temperature	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3
		Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c

		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Upland wetland improvement (UW)	WI-UKL-C.6.l
		Riparian forest management (RFM)	WI-UKL-C.5.i
	8.2 Dissolved oxygen	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3
		Targeted aeration (TA)	H-UKL-C.7.r
		Phosphorus immobilization using alum (PIA)	HI-UKL-C.7.s
		Wetland planting (WP)	H-UKL-C.8.c
		Upland livestock management (UL)	WI-UKL-C.6.j
		Dredging of lake/reservoir sediment (DLS)	H-UKL-C.7.q
		Algae harvest (AH)	H-UKL-C.7.p
	8.5 pH	Phosphorus immobilization using alum (PIA)	H-UKL-C.7.s
		Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3
		Algae harvest (AH)	H-UKL-C.7.p
		Wetland planting (WP)	H_UKL-C.8.c
		Upland livestock management (UL)	WI-UKL-C.6.j
	1.1 Anthropogenic barriers	Minor fish passage blockages removed or altered (MFP)	H-UKL-C.2.c-Minor
	9.2.3 Lake levels	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3
		Water leased or purchased (WLP)	WI-UKL-C.3.f
	6.2 Instream structural complexity	Channel structure placement (CSP)	H-UKL-C.4.d
		Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c
		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Riparian forest management (RFM)	WI-UKL-C.5.i
	2.3.1 Fish entrainment	Fish Screens Installed (FSI)	H-UKL-C.1.c
		Non-physical barrier devices installed (NPB)	H-UKL-C.1.e
	9.2.4 Lake fetch	Wetland planting (WP)	H_UKL-C.8.c
		Wetland improvement (WIR)	H-UKL-C.8.e
	5.5 Lakeshore conditions	Wetland planting (WP)	H_UKL-C.8.c

		Wetland improvement (WIR)	H-UKL-C.8.e
	2.4 Toxins (e.g., cyanotoxins)	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Phosphorus immobilization using alum (PIA)	H-UKL-C.7.s
		Algae harvest (AH)	H-UKL-C.7.p
Biological Interactions	2.1.1 Predation (fish)	Predator / Competitor Removal (PCR)	BI-UKL-C.4.i
	2.1.1 Competition	Fish Reared & Released (FRR)	BI-UKL-D.1.b
	2.2 Pathogens	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage Dam Releases (Link and Keno) (FLK)	WI-UKL-C.3.h.1
		Fish Reared & Released (FRR)	BI-UKL-D.1.b

2.3 Fluvial Geomorphic Processes

Fluvial geomorphic processes are a foundational consideration affecting the creation and maintenance of habitat for all fish species in the Klamath basin. We therefore created separate conceptual sub-models (included in Figure A1 of Appendix A) to help guide the selection of basin restoration actions and associated monitoring indicators. The fluvial geomorphology sub-models are at a more detailed level of organization than the sub-regional/focal species models (i.e., lower in the hierarchy of conceptual models), providing greater specificity in the description of stressors and restoration actions. Issues defined through development of the fluvial geomorphology models have helped to inform the content of the broader sub-regional/focal species models. This section provides an overview of the factors that have altered fluvial geomorphic processes, both historically and currently, as a foundation for the description of the conceptual model.

The dynamic fluvial geomorphic processes of a river ecosystem involve the interaction of flow, sediment, and riparian vegetation (Trush and McBain 2000). These processes impact erosion and mass wasting events, as well as sediment transport and sediment deposition, and are affected by precipitation, soil saturation, and the exchange of surface water and groundwater. Spatial and temporal variability in fluvial geomorphic processes govern patterns of disturbances that influence ecosystem structure and dynamics (VanderKooi et al. 2011). These processes are conspicuous in streams, rivers, and floodplains and dictate the formation and evolution of key landscape features like terraces and alluvial fans at the reach scale and riffles, pools, and cascades at the habitat scale. As such, the condition of habitats used by fish is either directly or indirectly linked to the suite of hydrologic and geomorphic processes operating in a basin.

The Klamath Basin is very large (>31,000 km^2) with a fluvial geomorphic setting that varies across different sub-basins, based on the physical environment, regional geography, reach-specific channel geometry, climate, precipitation, and local flow availability and timing. The Klamath River’s headwaters begin in gently sloped desert, marshlands and open valleys. Downstream of Upper Klamath Lake, these waters coalesce into the river’s mainstem and proceed toward the Pacific Ocean at a much steeper gradient (Stanford et al. 2011). Flow regimes in the lower basin are more variable than in the upper basin. In the upper basin, peak flows occur during snowmelt in late spring/early summer (NMFS 2015). In the lower basin, peaks occur from November to March when rainfall is highest (NMFS 2015). Creeks in the lower basin commonly dry up during summer low-flow conditions (Voight and Gale 1998), and flash flood events frequently occur in winter (NMFS 2015).

Water diversion and the mainstem Klamath dams have had geomorphic effects on the river. The dams have trapped coarse sediments, resulting in bed coarsening downstream as smaller gravels are transported out of the area without being replaced by gravels supplied from upstream (PacifiCorp 2004, as cited in NRC 2008). The river bed downstream of Iron Gate Dam has become dominated by larger gravels and cobbles unsuitable for use by spawning fish (Hetrick et al. 2009). Similarly, the operation of the Reclamation’s Klamath project, as well as PacifiCorp’s hydroelectric facilities, have altered the natural flow regime of the Klamath river, attenuating peak flow magnitude, duration and frequency at various locations throughout the basins. These hydrologic changes hamper the amount of geomorphic work high flow events are able to achieve, constraining the ability of channel forming processes to create and maintain the complex habitats fundamental to the success of focal fish species.

2.3.1 Management/restoration actions in the Klamath River basin directly affecting fluvial geomorphic processes

The management actions directly affecting fluvial geomorphic processes can broadly be categorized as flow management, which includes operation of Reclamation's Klamath Project for water deliveries and groundwater pumping, as well as coarse and fine sediment management.

Current management/restoration actions

Water allocation within the basin is not affected by the six dams (USBR 2011). However, management of water released through the dams does affect flow timing and magnitudes of peak releases. Reclamation's Klamath Project operations are directed by provisions in the 2013 Biological Opinion to prevent jeopardy of ESA listed species in Upper Klamath Lake and the Klamath River.

The volume of water available to fish species throughout the basin is affected primarily by Reclamation's Klamath Project water deliveries to upper basin water users. Even with potential future dam removal, water deliveries will continue. During water year (WY) 2015, a recent dry year, water deliveries constituted 36% of allocated water managed by the Klamath Project, even with drought conservation measures in effect (USBR 2015). During WY 2017, under extremely wet hydrologic conditions, water deliveries comprised 25% of allocated water (USBR 2017) (Table 2).

Table 2: Compared balance of water allocated to core uses in the Klamath Basin under Reclamation's Klamath Project for WY 2015 and WY 2017, under dry and extremely wet hydrologic conditions, respectively (sources: USBR 2015 and 2017).

	WY 2015 **Dry Hydrologic Conditions**		**WY 2017** **Extremely Wet Hydrologic Conditions**	
	(acre-feet)	*Percent of total*	*(acre-feet)*	*Percent of total*
Upper Klamath Lake Reserve	120,845	18%	142,208	11%
Environmental Water Allocated for Klamath River releases	320,000	47%	801,617	64%
Water deliveries	245,500	36%	309,000	25%

Groundwater pumping is extensive in the upper Klamath Basin and heavily relied on to support water deliveries managed by the Klamath Project and other out-of-basin uses. Groundwater is an important component of inflow to Upper Klamath Lake (NMFS and USFWS

2013). Groundwater pumping also occurs in other primary tributaries, such as the Scott River (S.S. Papadoplos & Associates 2012).

Wetlands in the Upper Klamath Basin are heavily associated with groundwater. Water diversions in the Klamath Basin have drained 75 percent of the original wetlands (NRC 2004, as cited in Stanford et al. 2011). The loss of upper basin wetland-habitat interactions associated with groundwater pumping, and water deliveries in general, is a significant factor in the decline of focal fish species across the basin, as well as fundamental ecological functions.

Instream flow management, as regulated by the 2013 Biological Opinion to protect endangered fish species, establishes minimum lake elevations in Upper Klamath Lake and flows in the Klamath River, largely for fish habitat availability and water temperature management purposes. These minimum flows released to the river do not guarantee that high flow releases of significant magnitude and duration to result in geomorphic work will also occur. Under the 2013 Biological Opinion, even flood releases are counted against the annual water allocation dedicated to the mainstem Klamath River for Coho salmon protection. Daily average flows during spring months, when peak flows would naturally be higher under an unaltered snowmelt hydrograph, are suppressed for water allocation purposes and are modeled on a daily average target of 37.5 cms (m^3/s) or less, far below that needed for a geofluvial flow event.

High flow releases downstream of Iron Gate Dam are entirely dependent on flood-related releases for upstream flood control purposes or tributary accretion in the reaches downstream of Link River Dam at the outlet of Upper Klamath Lake. During dry years, such as WY 2015, peak flows downstream of Iron Gate Dam increased as high as 90.3 cms for a single day, but generally remained at or near the minimum flow thresholds established in the 2013 Biological Opinion. Comparatively, during WY 2017—an extremely wet water year – peak flows during winter and spring months remained well above the minimum flow thresholds and reached as high as 286.0 cms (Figure 4). It is during these wetter water years when flood-related releases and tributary accretion are greatest that high flows are available to the river downstream of the four dams to support geofluvial processes and reduce the risk of habitat simplification.

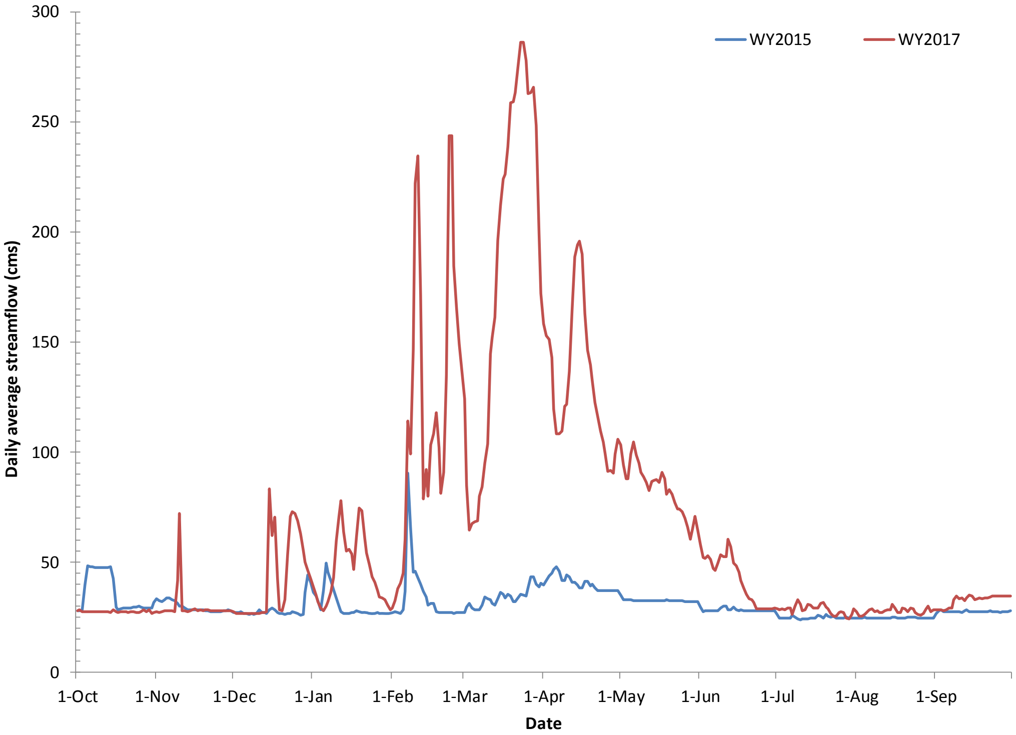

Figure 4. Daily average flow releases downstream of Iron Gate Dam during WY 2015 and WY 2017, constituting relatively dry (blue line) and extremely wet (brown line) hydrologic years, respectively.

Fish disease suppression is managed through flow releases from Iron Gate Dam, as well as Trinity River releases from Lewiston Dam. Peak flows of sufficient magnitude and duration, sometimes timed to coincide with natural hydrologic events, have been implemented in the Klamath River to help deter the establishment of aquatic vegetation and disrupt the life cycle of fish pathogens and their polychaete host (Hetrick et al. 2009). Research is ongoing to determine which flow timing events and peak discharge thresholds may be most effective in polychaete suppression.

Fine sediment inputs from upslope and tributary sources and related fine sediment reduction efforts are part of the Klamath Basin fluvial geomorphic setting. Fine suspended sediment concentrations are a concern in the mainstem Klamath River and basin tributaries, especially where fires (NRC 2008) or wide-scale timber harvest has occurred (NMFS and USFWS 2013). High concentrations of fine sediment can fill pools and simplify instream habitats used by fish (NRC 2008). High concentrations of suspended sediment can also disrupt normal feeding behavior by fish, reduce growth rates, and affect survival of juvenile salmonids by interfering with normal development and emergence (Berg and Northcote 1985; Chapman 1988). Currently, concentrations and duration of exposure to fine suspended sediment in the Klamath has been implicated in creating major physiological stress and associated reduced growth of coho salmon in most years for certain life stages (NMFS and USFWS 2013). Sedimentation arising from harvest-related landslides and extensive road networks continues to impact habitat even from modern-day harvesting operations, although at much reduced levels compared to early logging in the Klamath Basin (NMFS and USFWS 2013).

Coarse sediment is a fundamental building block of river systems, providing material for construction of riffles, bars, banks, and floodplains. Coarse sediment within a river is supplied from upstream sources (e.g., hillslopes, tributaries) and then transported and deposited downstream. The mobility of available coarse sediments through high flows is essential for establishing and maintaining floodplain connectivity and floodplain forming process, especially in the reaches downstream of Iron Gate dam. Because high flows and coarse sediment availability have been altered by the six existing dams on the Klamath River mainstem, the availability and quality of fish habitats created and maintained in the lower river have also been impaired.

In addition to the six dams, natural inputs of coarse sediment have also been depleted, and the movement and deposition of coarse sediment has been affected historically by multiple past geomorphic alterations in the Klamath Basin (NRC 2008). These have included historical mining, floating of logs, building of splash dams to push logs downstream, and blasting rock outcrops in the river bed to improve log passage (NRC 2008). Placer gold mine workings in the basin often included displacing the channel and excavating down to bedrock. These past activities had the effect of simplifying the river channel through the elimination of bedrock and other channel irregularities that interfered with the efficient flow of water and through the physical effect of the logs themselves battering the banks (NRC 2008), resulting in changes to sediment routing. Dredging of gravels on the floodplains also simplified the river channel through direct modification, while mine dredging and processing of placer deposits released fine sediments into the water column, with associated damage to fish habitats (NRC 2008). The negative effects of mining on fish abundance were observed as early as 1930 (NMFS and USFWS 2013). Since the 1970s, however, large-scale commercial mining operations have been eliminated in the basin due to stricter environmental regulations, and in 2009 California suspended all instream mining using suction dredges (NMFS and USFWS 2013).

Potential future management/restoration actions

Removal of the major Klamath River dams will restore natural sediment processes in the downstream reaches. Floodplain forming processes downstream of Iron Gate Dam are expected to improve after dam removal. Modeled post-dam hydraulics estimate a slight increase in peak flood flows for the 18 miles of river immediately downstream of Iron Gate Dam due to the elimination of storage in the upstream reservoirs which currently attenuates floods (USBR 2011). Increased flood peaks will result in increased sediment mobility downstream to Cottonwood Creek and, over time, will also see a return to the natural gravel supply (USBR 2011). After dam removal, USBR (2011) predicted the frequency of gravel mobilization will increase from once every four years to every other year.

Estimates vary as to the amount of sediment stored behind the four dams that would be removed. Analysis previously developed for PacifiCorp estimated that 20.4 million cubic yards of sediment is trapped in three of four reservoirs considered for removal and noted that sediments stored behind Copco 2 are negligible (GEC 2006, as cited by Hetrick et al. 2009). USBR (2011) conversely estimated that 15 million cubic yards of sediment will be stored in the reservoirs by 2020, over 80% of which are fine sediments. Dam removal is predicted to release 1/3 to 2/3 of that volume, depending on the water year type immediately following dam removal (USBR 2011). Sediment concentrations are expected to return to background levels by the end of the summer following dam removal (USBR 2011). The bed material within the reservoir footprints is expected to have a high sand content (30% to 50%) and will require a flushing flow of at least 6,000 cfs sustained for several days to weeks before the substrate will return to a cobble and gravel bed (USBR 2011).

Changes in flow management, independent of future major dam removal, are also a key factor in the restoration of geofluvial processes in the basin. Managing peak flow magnitude, frequency, and duration are fundamental to flushing of fine sediments from the system, fish disease management, gravel mobilization for habitat forming processes, and the creation and maintenance of suitable spawning habitat in all reaches accessible to salmonids. Changes in flow management will need to account for water deliveries obligated by the Klamath Project and required water elevations in Upper Klamath to protect and recover focal fish species in the upper Klamath Basin. Initial negotiations between the Department of Interior and Basin stakeholders on a new long term water-use agreement in this regard are currently underway (Dillemuth 2018).

The **restoration of geomorphic processes** can be achieved through the combined management of flow and sediment related activities to mobilize coarse sediments to target thresholds necessary to activate fossilized bars, form new alluvial habitat features, maintain a complex riparian corridor, and provide spawning habitat for salmonids. Restoration of geomorphic processes can be prioritized at varying scales (site-specific, reach, or river wide) based on a spatial needs assessment (e.g., where are existing geomorphic processes most constrained or where is spawning habitat most limited?). In the event of major dam removal, geomorphic processes downstream of JC Boyle reservoir and Iron Gate Dam will likely experience a period of initial rapid adjustment as retained sediments are released and begin to route downstream. In general, however, and depending on the magnitude and frequency of high flow events and correlated coarse sediment availability and grain size, the restoration of geomorphic processes in the river may occur on a much longer-term time scale. In the event a major dam removal does not occur, **augmentation of coarse sediment** may be necessary to supplement geomorphic processes in specific reaches.

The restoration of geomorphic processes, combined with site-specific mechanical habitat restoration as needed, would contribute to the **restoration of channel complexity** and channel forming processes, such as channel avulsion and channel migration. High flows and coarse sediment can be managed to reconnect floodplains, as well as build and maintain side channels and other off-channel habitats, including wetlands. In some reaches, the channel remains impacted by the legacy effects of mining impacts, such as channelization. A combination of natural riverine processes and mechanical habitat restoration may be necessary to recover full geofluvial function and habitat attributes in these areas.

Management of fine sediment deposition and transport is also fundamental to restored fluvial geomorphic processes, consideration of both the significant volume of small grained material that would be released after dam removal and ongoing upslope inputs of sediments from the mainstem and tributary watersheds. Fine sediments accumulate in spawning gravels and other habitats, impacting salmonids and providing desirable conditions for fish disease pathogens. Watershed fine sediment source control activities, such as forest road removals, erosion control efforts, and restoration of burn areas, will help reduce future fine sediment inputs into the Klamath River.

The **management of land uses that affect tributary flows**, relative to both water quantity and quality, is fundamental to the recovery of the Klamath River. Improving the quantity of flow and associated water quality of tributary inputs will have a beneficial effect on the tributaries themselves as well as Klamath River mainstem habitats and geomorphic processes in the river.

2.3.2 Conceptual diagram(s) of key fluvial geomorphology processes

Fluvial geomorphic processes in the Klamath Basin and the current and/or potential future restoration actions that could improve impaired elements in this regard (described generally in Section 2.3) are represented through detailed conceptual diagrams (presented in Figure A1 in Appendix A). These conceptual diagrams lay out the specific cause-effect pathways that lead from current and potential future Klamath Basin restoration actions through the effects on hydrological, physical and biological stressors and the broad possible responses of the Basin ecosystem to these actions.

2.3.3 Hypotheses/linkages

Statements of cause and effect linkages illustrated in the fluvial geomorphology conceptual diagrams (Figure A1 in Appendix A) for the Klamath Basin are presented in Table A1, with the hypothesized mechanisms of each possible restoration action.

The key hypotheses identified propose that fluvial geomorphology-related restoration actions will have a beneficial effect on focal fish species by increasing the amount of water available for fish needs and by increasing the diversity, complexity and extent of fish habitats. It is further hypothesized that fluvial geomorphology-related restoration actions will reduce impairments to fish habitat caused by excessive fine sediments, water temperature, and other water quality stressors.

While broad, these hypotheses can be evaluated in the future via specific performance indicators to assess success of implemented restoration actions or other system needs within an adaptive management framework. Some candidate performance indicators for fluvial geomorphology actions can be qualitative but the majority of those identified should be largely quantitative, allowing for clearer tracking and comparisons over time.

Tracking the benefits of restoration actions can be used to evaluate the degree to which the four target fluvial geomorphology-related systemic responses in the Basin (see Appendix A) are being achieved:

1) Do restoration actions promote self-maintaining physical processes to support channel complexity?
2) Have fish habitat objectives been achieved?
3) Were water temperature criteria met?
4) Was fish disease minimized?

2.3.4 Critical fluvial geomorphic uncertainties

Of the critical uncertainties facing fluvial geomorphic processes in the Klamath River, major dam removal is clearly the most obvious. The future restoration of the fluvial geomorphic environment will be significantly more challenging under a dams-in scenario. While efforts to mitigate the geomorphic impacts downstream of large dams are not uncommon, the challenge is an entirely distinct experiment. As has been observed elsewhere in the Basin, substantial efforts to restore geomorphic processes and improve fish habitats on the Trinity River downstream of Lewiston Dam (by combining high flow releases and large quantities of coarse sediment augmentation with extensive mechanical habitat restoration over the course of more than a decade) has yet to produce satisfactory results (e.g., Buffington et al. 2014; Boyce et al. 2018).

Furthermore, should major dam removal occur, the accuracy of the modeled sediment release estimates is uncertain. The rate of geomorphic response to dam removal will depend on the magnitude and duration of high flows the following water year as well as the sequences of high geomorphic-effective flows across multiple future years. USBR (2011) predicts that the majority of the fine sediment stored behind the reservoirs will flush out of the river within a year following dam removal; however, the actual fine and coarse sediment signature of the removal of four major dams remains to be seen. Copco 1, the first of the four dams, was built in 1918, with Copco 2, and J.C. Boyle following; Iron Gate was built in 1962. Is it plausible that a hundred years of sediment accumulation can be flushed through 190 miles of mainstem channel to the Pacific Ocean in a single year without somehow altering the geomorphic setting of the Klamath River, for at least some period of time?

Managers have yet to have opportunity to test the ability of high flows to mobilize fossilized bars currently limiting habitat downstream of Iron Gate Dam (Hetrick et al. 2009). The extent to which removal of the dams will support channel forming and channel maintaining processes, given the future hydrologic setting is unlikely to significantly change, is questionable. It is possible the grain size of the contemporary channel surface and fossilized bars is not suitably scaled to the corresponding high flows, under a future water allocation agreement. Thus, desired scour and mobility might not be fully achievable within the desired time period.

Additionally, fish habitat objectives remain largely undeveloped. To date, the scientific analyses used to support dam removal has primarily focused on fish passage, hypothesizing that the amount of new mainstem and tributary habitats, in their present condition, being made available will help recover focal fish species. An evaluation of habitat condition, the potential quantity of habitat, and overall habitat availability relative to a likely flow regime remains largely outstanding, especially in the reaches upstream of Iron Gate Dam. Thus, when managers express the need for “more habitat,” the bookends remain undetermined and the physical potential of the channel, even in a restored fluvial geomorphic setting, to offer up the requisite amount of useable habitat required to assist recovery, remains unassessed.

With the removal of the four dams, upper basin habitats should again be accessible to previously excluded anadromous salmonids and lamprey. However, it is unclear if the existing fluvial geomorphic environment of the mainstem river upstream of Iron Gate Dam will again be welcoming for salmonids. The Keno reach is largely recognized as a significant constraint for fish—the dam is unpassable and the resulting water quality is hostile at best. Efforts to arrive at a Keno solution are underway, but their outcome is far from determined. In addition to the concerns surrounding the Keno reach, the riverine environment between Link River Dam and Iron Gate Dam has never been managed for anadromous fisheries purposes under the modern framework of environmental regulation and science and additional future challenges related to habitat condition and function may remain unidentified.

Similarly, while efforts to restore and reconnect upper basin wetlands are already underway, remaining wetland habitats in the upper basin represent only a small fraction of their former extent and are heavily constrained by land use, groundwater pumping, and private ownership. The degree to which former wetlands associated with Upper Klamath Lake and Lake Ewauna can be reconnected to the Klamath River to support the biological needs of all focal fish species in the Klamath Basin, as well as provide gains in water storage capacity, remains undetermined.

The potential future removal of the four major dams does not guarantee a future flow regime that is beneficial for Upper Klamath Lake suckers or target riverine species. Future assessment and negotiation between federal agencies, tribes, and water users will be required to arrive at an updated flow regime. Given the pervasive over-allocation of water throughout the basin, it is unlikely a future flow regime would be any more beneficial for fish. In fact, a flow allocation that further reduces instream flows, mitigated with additional habitat availability and compounded by less water availability due to climate change, is also plausible.

Like the mainstem Klamath River, tributary flows are also over allocated. Throughout the basin, many key tributaries such as the Scott and Shasta River are parsed out across numerous landowners. Land uses in many of these watersheds are heavily dependent on instream flows and groundwater pumping associated with agriculture, grazing, and marijuana cultivation, among other water dependent uses. Some watersheds remain heavily impacted from legacy logging and mining impacts, as well as more contemporary fire-related effects. Combined, fine sediment contributions can be significant, instream flows are impaired during low flow periods, and water temperatures can exceed lethal thresholds for fish survival. Managers and communities are working together currently to address these outstanding impairments, but the outcome remains uncertain.

2.4 Water Quality Processes

Water quality processes are considered a key cross-cutting issue affecting habitat conditions for all focal fish species in the Klamath Basin and therefore are described here within separate conceptual sub-models and associated discussion to help guide the selection of both restoration actions and associated monitoring indicators. The water quality sub-models (developed collaboratively with experts in basin water quality issues) are at a more detailed level of organization than the sub-regional/focal species models, providing greater specificity in the description of stressors and restoration actions. This is consistent with the concept of having a hierarchy of conceptual models. Issues defined through development of the water quality models are used to inform associated content within the broader sub-regional/focal species models.

A legacy of large-scale development of mining, forestry, agriculture and ranching operations in the Klamath Basin has degraded water quality with impacts on fisheries and other resources (NMFS and USFWS 2013). Excessive loading of phosphorus linked to watershed development has been a key factor driving the massive blooms of the nitrogen-fixing cyanobacteria *Aphanizomenon flos-aquae* that dominate Upper Klamath Lake (Walker et al. 2012). Phosphorus enters surface waters in the upper basin both naturally (e.g., from groundwater discharge) and through land-disturbing activities such as farming, grazing, timber harvest, and road building (KTWQC 2016). A number of restoration actions have either been implemented or are proposed with an objective to reduce nutrient loading to water courses, ultimately lowering rates of biological production and associated decomposition of organic matter that imparts poor conditions for migration, rearing, and spawning of the many fish populations throughout the Klamath Basin. These actions are required to meet total maximum daily loads (TMDL's) of various chemicals to water courses as defined in the Clean Water Act (e.g., Kirk et al. 2010, Rounds et al. 2009).

2.4.1 Management/restoration actions in the Klamath River basin directly affecting water quality processes

Upper Klamath Lake sub-region (UKL)

The many stressors affecting water quality in the Upper Klamath Lake sub-region were described in the Synthesis Report (ESSA 2017). Restoration actions in this sub-region are focused on limiting nutrient release from land and changing water use patterns. Cumulatively, these groups of actions may change water temperature, water flow, trophic state of Upper Klamath Lake, organic matter processing in streams and lake waters, production of toxins, dissolved oxygen concentration, and extreme shifts in pH, all of which affect the quality of habitat supporting fish (Stillwater et al. 2013, ESSA 2017).

There are three distinct but connected hydrologic parts in the Upper Klamath River (UKL) sub-region. **Tributaries** draining from basin headwaters to the inflow floodplain of Upper Klamath Lake form one part. These tributaries directly receive nutrient loads and changed flows from water use patterns and thus are the conduit that changes downstream water quality. The next part is **Upper Klamath Lake** itself that responds to the upstream nutrient loading and water use, modified by internal lake biogeochemstry. The third part is **Keno Reservoir** wherein flow control exacerbates hypereutrophic conditions induced by nutrient loading from upstream.

In the UKL sub-region water has been withdrawn from the upper basin to meet agricultural demand, potentially lowering annual inflow to Upper Klamath Lake. This can increase water temperature in surface streams and increase water residence time in Upper Klamath Lake, thus exacerbating the hypereutrophic state at present rates of nutrient loading to the lake. In response, a first group of potential restoration actions focused on changes to water use such as a buy back of water leases that presently supply water to agriculture. This action can lead to a reduction in intensive agriculture and a return to wetlands in many areas where they were historically present. Decreased water use for crops and grazing lands could lead to a more natural hydrograph in rivers and streams and a potential decline in water residence time in Upper Klamath Lake. Streams could then be reconnected with the lake floodplain rather than be channelized. This reconnection can restore biological connectivity and enhance nutrient uptake in complex and longer stream lengths woven through wetlands. Reconnection to cool groundwater within the floodplain can help to expand thermal refugia for fish.

Where agriculture remains active, water that presently drains from managed soils to channelized ditches may be pumped back to fields, not only providing water for agricultural needs but also reducing a nutrient load that is contained in the drainage, particularly from cattle grazing lands. High water temperature from solar heating may be lowered by changing from existing open ditches that are exposed to solar heating to underground piping that is not exposed to heating. This reuse of water in combination with strategies to lower overall water use by agriculture may reduce agricultural demand for water and increase flows in natural stream channels. These actions as a package could increase natural stream flows and lower overall stream temperature, making habitat in headwaters through to floodplain streams more suitable to support fish populations.

A second focus of restoration actions deals with nutrient loading, the main cause of hypereutrophy and poor water quality (Stillwater et al. 2013, ESSA 2017). A buy back of water rights from agricultural operations could lead to less use of land for cattle grazing and less loading of land with manure, the main source of nutrient loading. This change in ownership of water rights could lead to wetland construction and reclamation and rehabilitation of riparian vegetation corridors along presently exposed ditches and streams (settlements in water rights agreements may involve continued use of some lands for cattle grazing but not in all years, thereby rotating a fixed head of cattle among different fields between years. This action is essentially a type of crop rotation to reduce present rates of nutrient loading from manure over all agricultural lands in the UKL sub-region. Crop rotation can also involve using some areas for agriculture in some years but leaving as wetlands in other years as a strategy to retain nutrient load and limit downstream nutrient transport over time. Where cattle grazing remains active, fencing around water courses can be used to prevent direct nutrient loading. Within urban areas (e.g., Klamath Falls), storm-water management can include filtering of water through bio-swales and small wetlands before discharge to natural water courses. This strategy may reduce nutrient and other chemical loading downstream. For suburban areas where wastewater is treated in septic tank and field systems, mandatory repair and maintenance along with regulatory checks of treatment performance can be used to lower nutrient. This action is necessary because many septic systems may not be maintained and thus become ineffective in controlling nutrient discharge over time.

There is a third group of actions that are directly associated with Upper Klamath Lake: algae harvest, dredging of hot spots, and targeted aeration for sucker refugia. These actions are part of lake management that do not target the source of poor water quality. They only target symptoms and thus represent potential stop gap measures to protect fish populations until effects of the larger causal actions associated with nutrient loading and water use are realized. For a variety of reasons these suggested Upper Klamath Lake-focused restoration actions may also not be feasible (see critical uncertainties for these actions in Appendix B - Klamath IFRMP Master Restoration Actions Dictionary)

Similarly to Upper Klamath Lake, a group of actions may be considered to treat symptoms in Keno Reservoir directly, as opposed to upstream causes. Production of algal biomass within the reservoir produces large variation in dissolved oxygen concentration (higher concentration during the day during photosynthesis, lower at night when respiration consumes oxygen), resulting in diurnal periods of oxygen stress on fish. This symptom of hypereutrophication may be treated with alum (e.g., Huser et al. 2011) to immobilize phosphorus thereby reducing availability of phosphorus for biological production in the reservoir, dredging the reservoir sediment to remove a source of phosphorus that has accumulated from the legacy of nutrient loading from upstream, and/or targeted aeration to facilitate fish passage and avoid fish kills during times of fish migration (e.g., anadromous salmonids). While many participants in the UKL regional workgroup have suggested that these actions are likely impractical (see critical uncertainties in Appendix B) they have been retained in the conceptual models as currently we are not aware of documented evidence to refute any consideration of these actions. This is also the case for potential actions to treat symptoms within Upper Klamath Lake. Until further documented evidence is available in the form of an assessment of treatment viability (not opinion), potential actions to treat in-lake and in-reservoir symptoms are retained in the conceptual models.

Superimposed on all potential restoration actions across Klamath basin sub-regions is climate change. Models in the literature for the Klamath River basin hypothesize that mean annual temperature will increase, more precipitation will be as rain rather than snow, resulting in a smaller snowpack and an earlier snowmelt progressing over time (Walsh et al. 2014). The Klamath IFRMP water quality conceptual models (see Appendix A) developed for the UKL sub-region (Figure A2) as well as the MUK (Figure A3) and LKR (Figure A4) show climate change patterns potentially modifying the effectiveness of all water quality-related restoration actions. Uncertainty around climate change means that monitoring of action effectiveness requires a design that separates effects of climate change from other treatment actions so as to learn over time what restorations will be most effective in the face of changing patterns of temperature, amounts and kind of precipitation, and trends in snowpack.

Mid/Upper Klamath River sub-region (MUK)

There is one large proposed restoration action in the Mid/Upper Klamath River sub-region (MUK): removal of Iron Gate, Copco I, Copco II and J.C. Boyle dams. Removal of impoundments associated with these dams is expected to: 1) lower heating of water that is released downstream in summer and fall, 2) reduce or eliminate oxygen demand at the sediment-water interface that affects oxygen concentrations in the overlying water column, 3) eliminate phosphorus return from trapped sediments (presently occurring during anoxia or other form of oxygen depletion) that contributes to excess production of organic matter that induces oxygen demand, and 4) improve flows for resident and migrating fishes. Any bioconcentration of mercury would also be eliminated in a change from storage reservoirs to a free-flowing river. The Klamath River will continue to be affected by nutrient loading from upstream if the dams are removed and thus will likely continue to produce large algal mats. Removal of impoundments will be a benefit even with this continued nutrient loading and transport however by eliminating key water quality limits to fish passage: conditions fostering disease, episodic low dissolved oxygen concentrations, conditions supporting hypereutrophication and related toxin production.

Superimposed on dam removal is climate change. Among potential changes shown in climate models, less snowpack may have greatest influence in the MUK sub-region. Freshet flows may decline with reduced amount of snow although it is unknown if mean annual flow in the Klamath River will be modified. If annual amounts of precipitation decline, river flow may decline proportionately. Climate variation may shift the timing of the annual hydrograph but this change is small compared to change from lentic to lotic conditions that would be caused by the removal of dams in the MUK sub-region.

Lower Klamath River sub-region (LKR)

With respect to water quality issues in the Lower Klamath River sub-region (LKR), episodic cooling flows from the Trinity River can be applied as a directed restoration action. Benefit from this action will be dependent on the amount of water available to supply cooling given concurrent water needs for irrigation in the Trinity River basin. Reduced amounts of precipitation that may result from future climate change may mean that offsetting flows from the Trinity River may be less reliable in the future than at present for assistance in cooling the lower Klamath River.

2.4.2 Conceptual diagram(s) of key water quality processes

Many restoration strategies are currently being used or else are being considered for the future to improve water quality throughout the Klamath River Basin. Causal links between potential restoration actions and hypothesized effects on processes that determine quality of water for fish in the Klamath Basin (described generally in Section 2.4.1) are represented through detailed conceptual diagrams presented in Figure A2 (UKL - Upper Klamath lake, tributaries to Upper Klamath Lake, and Keno Reservoir), Figure A3 (MUK - Mid/upper Klamath River), and Figure A4 (LKR - Lower Klamath River).

2.4.3 Hypotheses/linkages

Pathways of potential water quality-related cause and effect linkages that are presented in the conceptual diagrams for UKL, MUK, and LKR in Figure A2, Figure A3, and Figure A4 respectively are described in a single supporting table across sub-regions (Table A2). These potential cause and effect pathways can be considered hypotheses of change to water quality and are considered plausible based on existing knowledge of ecological processes in the Klamath River Basin. As hypotheses, they must be tested in a monitoring plan to actually determine effectiveness. Key hypotheses (see more detail in Table A2) are explored in the following paragraphs.

Proposed changes in water use and reduced loading of nutrients to tributaries that flow to Upper Klamath lake, may be expected to do two things: One is to lower water temperature and increase stream flows through a connected floodplain; the second is to lower availability of nutrients that drive biological production in those streams and through the floodplain of Upper Klamath Lake. These actions will be the first step in curtailing the hypereutrophic state of Upper Klamath Lake. By limiting nutrient transport, the mobility of agricultural chemicals other than nutrients in manure and other sources would also be reduced, leading to reduced incidence of aquatic toxicity.

An overall response in Upper Klamath Lake will be reduced nutrient loading over time leading to a potential decline in production of phytoplankton and a decline in organic matter settlement to sediments that causes an exacerbation of hypereutrophication via oxygen demand and phosphorus release from sediments. While a decline in nutrient loading from external sources could happen in the short term (i.e., less than 10 years depending on scale of implementation of restoration actions), an actual change in trophic state of Upper Klamath Lake may not be apparent for much more than 10 years and potentially decades. This discrepancy will occur because Upper Klamath Lake presently contains nutrients in its sediments due to uptake and sedimentation processes occurring since the lake was formed and particularly since nutrient loading from land use started in the early 1920's. Given that waters of the Klamath Basin are naturally rich in phosphorus due to weathering of volcanic parent materials in the headwaters, external phosphorus loading will continue, and internal nutrient loading will contribute a large part of the pool of phosphorus that is used for biological production in the lake each year. The internal phosphorus loading will occur in places where anoxia is present or dissolved oxygen concentrations decline to low enough levels to favour phosphorus release from sediments. These sources and conditions will not go away. As a result, Upper Klamath Lake will change from a hypereutrophic lake at present to a eutrophic lake once restoration actions take effect. A further change to a mesotrophic state will not occur because of continued high external loading of naturally occurring phosphorus and long lasting internal loading from sediments. The result will be a highly productive lake with continued oxygen demand but less extreme than at present. Diurnal pH fluxes will moderate but will still be present. Water temperature will remain high in summer and fall, potentially in a range too high to support salmonids because heating from solar irradiance will not change and potentially increase with climate forcing.

Keno Reservoir can be considered the water quality and fish passage bottleneck of the Klamath River. With continued nutrient loading from Upper Klamath Lake even with full implementation of restoration actions upstream of the lake and continued nutrient return from sediments, production of organic matter leading to anoxia over a shallow water column will continue to limit suitability of the reservoir to support fish. This hypothesis is particularly relevant to salmonids that favour cooler water than is found in Keno Reservoir in summer and early fall and need oxygen that is absent for much of the same period. This condition is not expected to change over decades of upstream restoration actions. Aggressive actions such as dredging, aeration, and alum treatments may alleviate some of the stresses on fish but they are disruptive in themselves (e.g., dredging). They also only would treat the symptoms not the cause, which is external nutrient loading from upstream and internal nutrient loading from sediments. An hypothesis is that Keno Reservoir will continue to be a bottleneck for passage of fish even if major dam removal occurs, effecting salmonids during upstream migration to spawning areas and downstream migration of smolts. Some adults will successfully migrate if they attempt passage late in the run when dissolved oxygen is present, albeit at low concentrations. Some smolts will successfully migrate if they attempt passage early in the spring when dissolved oxygen is present, again at low concentrations. As a result, the Keno bottleneck will not completely block fish passage but the neck of the bottle is slim and may only open within tight time windows. This conundrum will limit upstream passage of fish and potentially limit use of spawning and rearing habitat in upper reaches of the Klamath Basin.

Greatest response in the shortest time will come from removal of the four dams in the mid/upper Klamath River. The shear magnitude of change from hypereutrophic lentic dominated reaches to a completely connected river is expected to lower water temperature, reduce diel variation in pH and dissolved oxygen concentration, reduce toxins, and support a highly productive fish food web downstream of the dams. High concentrations of fine particulate organic matter and low intergravel dissolved oxygen concentrations that presently favour parasites of salmon (e.g., *C. shasta*) should not be present after dam removal, thus reducing incidence of mortality in migrating salmon caused by parasitism and disease. While long-term recovery of water quality in the mid/upper Klamath River is expected to occur, there will likely be short term issues with poor water quality. Dam removal is expected to produce turbid conditions in the river as fine sediment trapped behind the dams currently is released and transported downstream. Strategies must be developed to release water and sediment in ways to prevent acute lethality in fish and prevent undue embeddedness in river substrata that may inhibit production of fish food organisms. If undue effects on fish and fish habitat do occur, they are however expected to quickly dissipate and lead to rapid recolonization by fish and the fish food web as sediment load from the reservoirs is transported downstream.

Dam removal in the mid/upper Klamath River is also expected to be the main driver of improved water quality in the Lower Klamath River. Main changes from dam removal include lower water temperature because heating in reservoirs will be removed and lower incidences of disease and parasitism because organic matter that is conducive to parasite hosts will be removed with the increased fluvial transport of sediments.

2.4.4 Critical water quality uncertainties

There is little uncertainty about the causes of the hypereutrophic state of Klamath River waterways or about the need to reduce nutrient loading to improve water quality. There is also little uncertainty about potential downstream water quality benefits from the proposed removal of the Klamath mainstem dams because the effects of such dam removal projects have been assessed previously in other jurisdictions (e.g., Elwa dam removal, Peters et al. 2017). In contrast, there is much uncertainty about the broader effectiveness of the many restoration actions that have or could be applied to the Upper Klamath sub-region. For example, one action dealing with water return to a single cattle grazing field is unlikely to be detectable with respect to change to water quality in Upper Klamath Lake and may only be detectable in a stream immediately downstream of the field. Even effects from many such actions may not be detectable in the short term or even long term. While the water quality-related actions in each of the UKL conceptual models are considered important and practically useful, much uncertainty remains in regard to broader effectiveness. As with dam removal, a large and forceful action or group of actions will be required to generate a broad effect, particularly in Upper Klamath Lake that has a built-in latency of response to nutrient loading. Uncertainty about detecting broad response can be reduced by assessing effects of cumulative restoration actions, not just one or two but across many actions covering the entire upper watershed. Multiple lines of evidence may be required to determine potential change in nutrient loading downstream, as nothing may be detectable in that regard over a number of years in Upper Klamath Lake itself. Separation of assessments of effects of change in land uses vs. effects of internal lake biogeochemistry is required for long term lake management and in support of broader decisions on managing water quality and fish populations further downstream.

2.5 Focal Fish Species Subregional Conceptual Models

The focal fish species found in the defined Klamath IFRMP sub-regions are:

- **Upper Klamath Lake (UKL) sub-region:** Trout (Bull Trout, Redband Trout), and endangered suckers (Lost River Sucker and Shortnose Sucker). Additional focal fish species that may be present in the UKL sub-region in the future (if passage can be successfully restored through dam removal or other actions) are Salmon (Chinook, Coho, Steelhead), and Pacific Lamprey.
- **Middle/Upper Klamath River (MUK) sub-region:** Salmon (Chinook, Coho, Steelhead), Pacific Lamprey, Redband Trout, endangered suckers (Lost River Sucker and Shortnose Sucker), and Green Sturgeon.
- **Lower Klamath River (LKR) sub-region:** Salmon (Chinook, Coho, Steelhead), Pacific Lamprey, Green Sturgeon, and Eulachon.
- **Klamath River Estuary (KRE) sub-region:** Eulachon, Green Sturgeon, Pacific Lamprey, and Salmon (Chinook, Coho, Steelhead)

General Issues of current concern within each of the defined Klamath IFRMP sub-regions include:

Upper Klamath Lake (UKL) sub-region:

The UKL sub-region is largely semi-arid with the hydrology of the tributaries upstream of Klamath Lake driven by spring snowmelt, although significant cold-water springs also contribute to flow throughout the area and provide refuge habitat for resident fish (Stanford et al. 2011). The aquatic habitats of the region are dominated by large shallow lakes, extensive marshlands, and relatively low gradient rivers (Adams et al. 2011). Extensive water diversions in the UKL sub-region for agriculture within USBR's Klamath Project and other smaller irrigation districts, however, have reduced flow inundation events, eliminated wetlands, and disconnected stream channels from their floodplains, while years of grazing have reduced riparian vegetation that provided shading for streams (Stanford et al. 2011). Upper Klamath Lake is Oregon's largest lake but is hypereutrophic with massive blooms of blue-green algae occurring annually, owing to intrinsic fertility related to shallow water, warm climate, and accelerated inputs of nutrients from agricultural runoff. These blooms produce poor water quality including elevated pH and low dissolved oxygen (Kann and Smith 1999; Kann and Welch 2005). Much of the water column if hypoxic or anoxic during periods of thermal stratification (NRC 2004 as cited in Stanford et al. 2011). The section of the mainstem Klamath River from Keno Dam to Upper Klamath Lake also suffers from poor water quality and is often dominated by blue-green algae and characterized by seasonal low DO concentrations. High water temperatures and degraded water quality in the Keno Reservoir may represent barriers for fish migration during mid-summer even if passage over dams is created (Stanford et al. 2011). Greater detail on these water quality issues in the UKL sub-region is provided above in Section 2.4.1 - Upper Klamath Lake sub-region (UKL)Upper Klamath Lake sub-region (UKL).

Middle/Upper Klamath River (MUK) sub-region:

The MUK sub-region is more bedrock in nature creating more incised river channels and along with a wetter, more marine climate has higher flows and cooler temperatures than the UKL sub-region. Processes in the upper section of the Klamath River in the MUK sub-region are strongly influenced by the presence of four reservoirs behind small hydropower dams that currently block the upstream passage of anadromous fish. While high nutrient concentrations from the upper basin are ameliorated somewhat by flows below Keno Dam, poor water quality can occur in the major reservoirs resulting in toxin-producing cyanobacteria blooms and anoxic hypolimina (Stanford et al. 2011). Timing and magnitude of flows into the mainstem Klamath River below the reservoirs are regulated by Iron Gate Dam and this can have significant influence on geomorphic processes and conditions in the river, as well as affecting the survival of juvenile and adult salmon (Stanford et al. 2011). Greater detail on fluvial geomorphic issues in the Klamath River below the major dams is provided in Section 2.3.1. The absence of flushing flows, long durations of low flows and high water temperatures in the river are all considered factors contributing to the often high rates of disease in Klamath salmon resulting from pathogens like the myxosporean parasites *C. Shasta* and *P. minicornis*, as well as by bacterial and parasitic gill infections. Anthropogenic impacts across the MUK sub-region include dams and hatcheries, land and water management, and mining and forestry practices (Adams et al. 2011). Impacts to tributary systems in the MUK sub-region include fish strandings from dewatering, grazing impacts on stream riparian areas, the diversion of water from numerous small dams/water withdrawals for agriculture, and the presence of extensive logging road networks. Historical impacts from suction dredging for gold are also present in the Scott and Salmon watersheds with associated issues with fine sediment deposition in spawning reaches (Stanford et al. 2011).

Lower Klamath River (LKR) sub-region:

The LKR sub-region includes the largest tributary of the Klamath, the Trinity River, and the South Fork Trinity, which is California's largest unregulated watershed. Inter-basin diversion of water into California's Central Valley can take approximately 51% on average of the Trinity's historic annual flow at Lewiston Dam, the diversion point (NRC 2008). Water diversions are based on five water-year types as described in USFWS/HVT (1999) and are currently managed by the Trinity River Management Council. The largest effect of this diversion is on spring flows (Vanderkooi et al. 2011). Reduced flows have caused channel degradation, impeded channel forming processes, and created floodplain disconnection. Other issues include inaccessible upper river salmon habitat, lack of gravel recruitment, and erosion of fine sediments into streams from logging, grazing, and past placer mining (Stanford et al. 2011). The Trinity River hatchery was established in order to mitigate for the loss of historical salmon production in 160km upstream of the dam sites (Vanderkooi et al. 2011). Cool streams entering the lower reach of Klamath River below the confluence with the Trinity represent important refugia habitat for fish in the LKR sub-region (Vanderkooi et al. 2011) but can be prone to excessive fine sediment loading due to erosive soils and the heavy logging activity and associated high road densities in the area (Stanford et al. 2011).

Klamath River Estuary (KRE) sub-region:

The Klamath River estuary is relatively small and short, in relation to the size of its watershed in comparison to other large river systems (although the overall size of the estuary varies and may have been larger historically). Deltaic processes are not evident and the estuary is small and similar to a pulsating or protected lagoon (Vanderkooi et al. 2011). Tidal influence only extends upriver to about river km 6.5 during typical high tides with saltwater intrusion ranging from only 4 to 6 km upstream of the mouth. Despite these limitations, the estuary is considered to serve an essential role to many Klamath River fishes as nursery and rearing habitat. It also functions as a critical staging area for anadromous species as they transition between freshwater and marine environments. Within the estuary, wetland, slough, and off-channel habitats provide important foraging areas for juvenile salmon and other brackish water fishes (Vanderkooi et al. 2011). Beaver ponds in many of the small tributaries to the estuary are known to be important seasonal habitat for juvenile coho salmon and steelhead (Patterson 2009). Water quality within the estuary is likely a critical factor in the suitability of estuarine habitat fish, particularly juvenile salmonids. High water temperatures, as well as elevated nutrient and POM loads from the river upstream may be impairments to the estuary (Stanford et al. 2011). Although the Klamath River estuary is located far downstream of Klamath River dams, water quality in the estuary can be affected by dam operations. Estuarine water temperature is linked to salinity, upstream hydrology, and periods of estuary mouth closure. Small changes in summer baseflows from the current operation of dams and water diversions on the Klamath and Trinity Rivers may affect mouth closure dynamics in the Klamath River estuary (Stillwater Sciences 2009). Mouth closure (caused by formation of a sand berm across the mouth of the estuary) can reduce the size of the estuary's salt water wedge, decrease overall salinity, and subsequently increase water temperatures in the estuary (Hiner 2006). Isolation of the estuary from the ocean for more than a few days can be detrimental to water quality and biota by allowing water temperatures to increase beyond optimal growth thresholds or critical thermal maxima for outmigrating salmonids and remain at untenable levels until the mouth is breached again (Stillwater Sciences 2009). Potential impacts to estuarine habitats associated with increased sedimentation from timber practices and past mining upstream are not well understood (Adams et al. 2011). Nor is the role of the estuary in the transmission of diseases to migratory anadromous fishes. The largest concerning impact on the Klamath Basin estuary for the future may be projected climate change-induced sea level rise which could have profound effects on the estuary and lower river habitats (Adams et al. 2011).

Description of the range of stressors affecting focal fish species in the Klamath Basin are provided in greater detail in Chapter 3 of the Klamath IFRM Synthesis Report (ESSA 2017). Land uses, unique characteristics, TMDLs established (if applicable) and other environmental stressors specific to each of the subbasins defined for the UKL sub-region (i.e., Upper Klamath Lake, Williamson, Sprague, Lost, and Butte), MUK sub-region (i.e., Shasta, Scott, Salmon, Upper Klamath River, and Mid Klamath River) and LKR sub-region (i.e. Lower Klamath River, Trinity, and South Fork Trinity) are also identified within sub-basin profiles included in the Synthesis Report (ESSA 2017).

Detailed conceptual diagrams identifying the specific stressors on focal species fish groupings found in the Upper Klamath Lake (UKL), Mid/Upper Klamath River (MUK), Lower Klamath River (LKR), and Klamath River Estuary (KRE) sub-regions and the potential restoration actions that could help to mitigate/minimize these stressors are presented in Appendix A – Figure A5, Figure A6, Figure A7, and Figure A8, respectively. Text descriptions of cause and effect links between stressors and restoration actions that are illustrated within the focal species conceptual diagrams are also described in more detail in supporting sub-region-specific tables in Appendix A. For the UKL sub-region conceptual diagrams are provided both for focal species that are currently present in the sub-region and for focal fish species that may be present in that sub-region in the future (if passage for anadromous fish should be restored) (i.e., Chinook, Coho, Steelhead, and Pacific Lamprey). For the KRE sub-region only a single, combined conceptual diagram is presented of the stresses/associated potential restoration actions for the suite of focal fish species found in the estuary, as information available at this time does not allow clear separation of stressors by species.

2.6 Synthesis of Key Stressors from Focal Species Conceptual Models

Stressors on fish and fish habitats that were identified within each of the individual conceptual diagrams presented in Appendix A are summarized in Table 3 across the suite of focal species/functional groups found within each sub-region. Potential stressors for Chinook, coho, steelhead, and Pacific lamprey are also included in the summaries for the UKL sub-region, given their expected future movement into this sub-region once passage is re-established for these species. The key “proximate” stressors by focal fish species/functional group as identified within the conceptual diagrams are presented in Table 3 as yellow highlighted cells. The summary thus provides an overview of key stressors that are unique to a particular fish species/group or else are common across multiple species/functional groups. This initial summary of key sub-regional stressors (supplemented and further validated through continuing IFRMP discussions) is intended to help to focus design considerations for IFRMP restoration actions that can alleviate multiple stressors and potentially benefit multiple focal fish species.

Table 3: Synthesis of suggested key "proximate" stressors affecting focal fish species/functional groups across Klamath Basin sub-regions (as identified through IFRMP Synthesis Report and technical group conceptual modeling exercises).

(A) Upper Klamath Lake (UKL) sub-region						
Stressor Tier	Stressor	Focal Fish Species[1],[2]				
		SU	RT	BT	CH/CO/ST (future)	PL (future)
Watershed inputs (WI)	9.2.1 Klamath River flow regime		X		X	X
	9.2.2 Instream flow (tribs)	X	X	X	X	X
	9.2.4 Lake disturbance (e.g. fetch)	X	X		X	
	8.7 Chemical contaminants (below UKL)	X				
	3.1.1 Hypereutrophication	X	X		X	
	7.2.1 Increased fine sediment input/delivery	X			X	
	7.1.1 Decreased coarse sediment input/delivery				X	
	4.2 Large woody debris		X	X	X	X
Fluvial-geomorphic processes (FG)	9.2.1. Groundwater interactions	X	X	X	X	X
	6.1.1 Channelization		X	X	X	X
	6.2.3 Fine sediment retention		X	X		X
Habitat (H)	8.1 Water temperature	X	X	X	X	X
	8.2 Dissolved oxygen	X	X	X	X	X
	8.5 pH	X	X	X		X
	1.1 Anthropogenic barriers	X	X	X	X	X
	6.2 Instream structural complexity	X	X	X	X	X
	9.2.3 Lake levels	X				
	2.3.1 Fish entrainment	X	X	X	X	X
Biological Interactions (BI)	2.1.2 Predation (fish)	X	X	X	X	X
	2.1.2 Predation (mammals/birds)				X	X
	2.2 Pathogens	X	X		X	
	3.2 Competition				X	
	10.1 Hybridization			X		
	3.3.1 Salmon prey		X	X		
Fisheries Actions (FA)	11.1 Overharvest (& bycatch)		X		X	X

(B) Mid/Upper Klamath River (MUK) sub-region							
Stressor Tier	Stressor	Focal Fish Species					
		PL	CH	CO	ST	RT	GS
Watershed inputs (WI)	9.3.1 Klamath River flow regime	X	X	X	X	X	X

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[1] SU = endangered suckers (Lost River and Shortnose suckers), RT = Redband Trout, BT = Bull Trout, CH = Chinook, CO = Coho, ST = Steelhead, CH/CO/ST = Chinook, Coho & Steelhead combined, PL = Pacific Lamprey, GS = Green Sturgeon, EU = Eulachon

[2] Yellow highlighted cells in this table represent suggested key stressors for a focal species or species group within a particular sub-region

	9.2.2 Instream flow (tribs)	X	X	X	X	X	
	7.2.1 Increased fine sediment input/delivery	X	X	X	X		X
	7.1.1 Decreased coarse sediment input/delivery	X	X	X	X		
	4.2 Large woody debris	X	X	X	X	X	
	3.1.2 Marine nutrients	X	X	X	X	X	
	3.1.1Hypereutrophication					X	
	8.7 Chemical contamination						X
Fluvial-geomorphic processes (FG)	9.2.1. Groundwater interactions	X	X	X	X	X	
	6.1.1 Channelization	X	X	X	X	X	
	6.2.3 Fine sediment retention	X	X	X	X	X	X
	8.4 Total suspended sediment						
Habitat (H)	8.1 Water temperature	X	X	X	X	X	X
	8.2 Dissolved oxygen	X	X	X	X	X	X
	8.5 pH	X	X	X	X	X	
	1.1 Anthropogenic barriers	X	X	X	X	X	X
	6.2 Instream structural complexity	X	X	X	X	X	
	2.3.1 Fish entrainment		X	X	X	X	X
	6.2.2 Suitable (cobble) substrate						X
	6.2.1 Deep pools						X
	7.3.Contaminated sediment						X
Biological Interactions (BI)	2.1.1 Predation (fish)	X	X	X	X	X	X
	2.1.2 Predation (mammals/birds)	X	X	X	X		X
	2.2 Pathogens		X	X	X	X	
	3.2 Competition		X	X	X		
	3.3.2 Abundance of invertebrate prey						X
Fisheries Actions	11.1 Overharvest (& bycatch)	X	X	X	X	X	X
(C) Lower Klamath River (LKR) sub-region							
Stressor Tier	Stressor	Focal Fish Species					
		GS	EU	CH	CO	ST	PL
Watershed inputs (WI)	9.3.1 Klamath River flow regime	X	X	X	X	X	X
	7.2.1 Increased fine sediment input/delivery	X	X	X	X	X	
	3.1.2 Marine nutrients			X	X	X	X
	8.7 Chemical contaminants	X	X				
	3.3.3 Nutrient influx		X				
	3.1.2 Marine nutrients			X	X	X	X
	4.2 Large woody debris			X	X	X	X
	9.2.2. Instream flows (tribs)			X	X	X	X
	7.1.1 Decreased coarse sediment input/delivery			X	X	X	X
Fluvial-geomorphic Processes (FG)	8.4 Total suspended sediments	X	X				
	6.1.1 Channelization			X	X	X	X
	9.2.1 Groundwater interactions			X	X	X	X
Habitat (H)	8.1 Water temperature	X	X	X	X	X	X
	8.2 Dissolved oxygen	X		X	X	X	X
	8.5 pH			X	X	X	X
	1.1. Anthropogenic barriers	X		X	X	X	X
	6.2.1 Deep pools	X					
	6.2.2 Suitable (cobble) substrate	X					
	6.2.3 Fine sediment retention			X	X	X	X
	2.3.1 Fish entrainment (larvae/juveniles)	X	X				

	7.3.1 Contaminated sediment	X	X				
	6.2 Instream structural complexity			X	X	X	X
	6.2.3. Fine sediment retention			X	X	X	X
Biological Interactions (BI)	2.1.2 Predation (fish)	X	X	X	X	X	X
	2.1.2 Predation (mammals/birds)	X		X	X	X	X
	3.3.2 Abundance of invertebrate prey	X					
	2.2 Pathogens			X	X		
	3.2 Competition			X	X	X	
Fisheries Actions	11.1 Overharvest (& bycatch)	X	X	X		X	X

(D) Klamath River Estuary (KRE) sub-region

Stressor Tier	Stressor	All focal species in sub-region combined
Watershed inputs (WI)	9.3.1 Klamath River flow regime	X
	7.2.1 Increased fine sediment input/delivery	X
	8.7 Chemical contaminants	X
	3.3.3a Nutrients	X
	3.3.3.b Particulate organic matter	X
	9.2.2 Instream flows (estuarine tributaries)	X
	4.1 Riparian vegetation	X
Fluvial-geomorphic Processes (FG)	6.2.3 Fine sediment retention	X
Habitat (H)	8.1 Water temperature	X
	8.6 Salinity	X
	8.5 pH	X
	8.4 Total suspended solids (TSS) (deposits/turbidity)	X
	8.2 Dissolved oxygen	X
	7.3.1 Contaminated sediment	X
	2.4 Toxins (e.g. cyanotoxins)	X
	4.2 LWD	X
	3.1 Altered primary productivity	X
	6.2 Instream structural complexity	X
	5.1 Wetland condition (estuarine wetlands)	X
	5.3.1 Estuary size	X
	5.3.2 Estuary lagoon depth	X
	5.3.3 Macro algae/macrophyte abundance & distribution	X
	5.5.3 Salt wedge (size & location)	X
	5.3.5 Estuary “perching” (frequency & duration)	X
	5.3.6 Estuary mouth closure (frequency & duration)	X
	5.3.7 Estuary plume (size)	X
	5.4 Nearshore conditions	X
Biological Interactions (BI)	2.1.1 Predation (fish)	X
	2.1.2 Predation (aquatic mammals)	X
	2.2 Pathogens	X
	3.2.2a Abundance of invertebrate prey	X
	3.3.2b Abundance of forage fish	X
	3.2 Competition	X
Fisheries Actions	11.1 Overharvest (& bycatch)	X

2.7 Dependencies Across Sub-regions

The stressors affecting focal species summarized in Section 2.6 are categorized within Klamath Basin sub-regions. In reality there will be multiple biophysical interdependencies across the sub-regions relating to these stressors and their affects on focal fish species (see examples in Table 4). Habitats in lower river sub-regions will require sufficient inputs of water, nutrients, wood, and coarse sediment at the right times from upstream areas to maintain suitable conditions for resident fish. Migratory species will require suitable life history-stage specific habitats potentially across every sub-region and the ability to migrate successfully between the sub-regions. It must also be recognized that while generally there will be an expectation that actions reducing stressors to the benefit of one species will also assist other fish species, there will be some cases where such actions may be detrimental to another species (e.g., restoring passage for migratory salmonids if major dams were removed may also clear a path for invasion by exotic species not previously present in areas above the dams). Such potential trade-offs between fish species across the sub-regions will need to be considered for fully evaluating the benefits and risks of potential restoration actions. Within-species considerations may also exist and will also need to be identified (e.g., implications of temporal aspects of current and future dam/diversion operations that can/could benefit or impede upstream and downstream migration conditions for various populations of anadromous fish (e.g., spring vs. fall Chinook).

Table 4: Examples of possible biophysical interdependencies across sub-regions. Greyed cells represent interactions within a region. Off-diagonal cells represent movement of something from the sub-region listed on that row to the sub-region in that column. This table assumes that spawning and rearing of anadromous salmonids and Pacific Lamprey will become re-established in the Upper Klamath Lake (UKL) sub-region.

To➔ From⬇	Klamath Estuary (KRE) / Ocean	Lower Klamath River (MUK)	Mid/Upper Klamath River (MUK)	Upper Klamath Lake (UKL)
Klamath Estuary / Ocean		• Marine survival rates • Import of marine nutrients • Disease organisms	• Marine survival rates • Import of marine nutrients • Disease organisms	• Marine survival rates • Import of marine nutrients • Disease organisms
Lower Klamath River (LKR)	• Outgoing migration of salmon smolts • Delivery / timing of freshwater • Fine and coarse sediment • Water quality		• Upstream migration of adult salmon • Disease organisms	• Upstream migration of adult salmon • Disease organisms
Mid/Upper Klamath River (MUK)	• Outgoing migration of salmon smolts	• Hydrological flow regime • Transport of LWD, fine sediment, coarse sediment, food organisms • Water quality (e.g., nutrients, temperature,		• Upstream migration of adult salmon

		pH, DO) • Outgoing parr and smolts		
Upper Klamath Lake (UKL)	• Outgoing migration of salmon smolts	• Hydrological flow regime • Transport of LWD, fine sediment, coarse sediment, food organisms • Water quality (e.g., nutrients, temperature, pH, DO, toxic algae) • Outgoing parr and smolts	• Hydrological flow regime • Transport of LWD, fine sediment, coarse sediment, food organisms • Water quality (e.g., nutrients, temperature, pH, DO, toxic algae) • Outgoing parr and smolts	

3 Hierarchy of Objectives & Key Performance Indicators

3.1 Purpose and Approach

This chapter presents the overarching goals, objectives, and performance indicators that form the foundation of the IFRMP. Restoration goals are statements of broad outcomes to be achieved, while restoration objectives represent specific and measurable tasks that must be completed to attain the related goal (Beechie et al. 2008, 2013). While restoration goals and objectives of particular organizations or initiatives may be narrowly focused on a specific area or species, the goals and objectives for the IFRMP are focused on recovery of overall ecological and biological integrity throughout the Klamath basin in support of self-sustaining focal fish populations. Ultimately, goals and objectives are specific, measurable, achievable (i.e., recognize socioeconomic constraints), and associated with a timeframe (Beechie et al. 2008, 2013).

This Chapter:

- Presents the overarching goals and objectives that will guide implementation of the IFRMP.
- Links objectives to performance indicators that can be used to track progress towards goals.
- Identifies core performance indicators (CPIs) and *why* they are important. The details of monitoring design (where, when and how to measure these indicators, how to analyze the data to answer key questions and test hypotheses, who will do the monitoring, and what monitoring data are available) are addressed in Chapter 5 of this plan.
- Compiles information on possible suitability thresholds for CPIs that can be used to track improvements relative to current scientific understanding about the desired state of those variables.
- Discusses further considerations related to goals, objectives, and CPIs.

This Chapter also proceeds with the understanding that the goals and objectives presented here are *not intended to supersede the original species-specific goals and objectives within existing recovery plans*, but instead offer a common framework of goals and objectives for planning and tracking overall watershed recovery. While we anticipate that the relative emphasis on each of these goals and objectives will vary by subregion, subbasin, and species this hierarchy provides an organizing framework at the whole-basin scale.

3.2 Goals & Objectives Hierarchy

Overview

To ensure that the IFRMP is aligned with existing initiatives, the goals and objectives of this IFRMP drew on the most commonly recurring goals and objectives within a range of existing basin-specific restoration plans and species recovery plans relevant to the focal fish species of the IFRMP (reviewed in our prior Synthesis Report), and were compared to conceptual models (Chapter 2) to ensure that they encompassed all major stressors identified as limiting factors for focal fish species. These initial goals and objectives were further refined and validated with a diverse group of regional participants in a workshop setting on July 10-11 in Klamath, CA, and all participants agreed that the final list is representative of the major ecological issues that need to be addressed to achieve recovery of focal fish species in the Klamath basin. Validating restoration goals and objectives in a workshop process is critical to successful restoration planning because it gives all interested participants a common understanding of management targets and trade-offs (Beechie et al. 2008).

Selected Goals and Objectives

These goals and objectives are organized into a hierarchy which reflects the major tiers of watershed function (Table 5), following the structure of the conceptual models presented in Chapter 2 and best practices for functional restoration planning outlined by the EPA (2012). In this scheme, fluvial and geomorphic processes form the base of the hierarchy and support functions in all tiers above them, such that improvements in function of these lower tiers are also expected to benefit habitat and biological functions in all tiers above them.

Table 5: Klamath IRFMP Goals and Objectives Hierarchy

Whole-Basin Nested Goals	Whole-Basin Nested Core Objectives
Fish Populations 1. Achieve naturally self-sustaining native fish populations with healthy demographic traits capable of providing harvestable surplus	1.1 Increase juvenile production
	1.2 Increase juvenile survival and recruitment to spawning populations
	1.3 Increase overall population abundance and productivity, particularly in areas of high existing abundance or potential future abundance or in special or unique populations
	1.4 Maintain or increase life history and genetic diversities
	1.5 Maintain or increase spatial distributions as necessary
Fisheries Actions 2. Regulate harvest so as to support achievement of goal #1.	2.1 Improve management and regulations/enforcement of harvest, bycatch and poaching of naturally produced fish such that populations do not decline and can recover
Biological Interactions (BI) 3. Reduce biotic interactions (ecological, genetic) that could have negative effects on native fish populations	3.1 Do not generate adverse competitive or genetic consequences for native fish when carrying out conservation-oriented hatchery supplementation as needed
	3.2 Minimize disease-related mortality by reducing vectors and factors known to lead to fish disease outbreaks
	3.3 Reduce impacts of exotic plants and animals species on native fish
Habitat (H) 4. Improve freshwater habitat access and suitability for fish and the quality and quantity of habitat used by all riverine life stages	4.1 Restore fish passage and re-establish channel and other habitat connectivity, particularly in high-value habitats (e.g., thermal refugia)
	4.2 Improve water temperatures and other local water quality conditions and processes for fish growth and survival
	4.3 Enhance & maintain community and food web diversity supporting native fish
	4.4 Reduce fish mortality due to entrainment, scour, stranding
	4.5 Enhance and maintain estuary, mainstem, tributary, lake and wetland habitats for all freshwater life stages and life histories of resident and anadromous fish
Fluvial Geomorphic Processes (FG) 5. Create and maintain spatially	5.1 Increase and maintain coarse sediment recruitment and transport
	5.2 Increase channel and floodplain dynamics and interconnectivity

Whole-Basin Nested Goals	Whole-Basin Nested Core Objectives
connected and diverse channel and floodplain morphologies	5.3 Promote and expand establishment of diverse riparian and wetland vegetation that contributes to complex channel and floodplain morphologies
Watershed Inputs (WI) 6. Improve water quality, quantity, and ecological flow regimes	6.1 Improve instream ecological flow regimes year-round for the Klamath River mainstem and tributary streams
	6.2 Reduce anthropogenic fine sediment inputs while maintaining natural and beneficial fine sediment inputs
	6.3 Reduce external nutrient and pollutant inputs that contribute to biostimulatory conditions

Additional Considerations for Goals and Objectives

It should be noted that this hierarchy *does not take into account* the goals and objectives of two key restoration plans that are still under development and thus not yet available for consultation, namely the **ODFW's Draft Implementation Plan for Reintroducing Anadromous Fishes into the Oregon Portion of the Upper Klamath Basin** (draft anticipated by the end of 2018) and the **KRRC "Definite Plan"** (anticipated July 2018). As these documents or components thereof become available, the IFRMP will align and integrate features of these parallel initiatives.

3.3 Linking Restoration Objectives to Key Monitoring Questions

Overview

For each of the objectives outlined above, there are many possible hypotheses about the outcomes of corresponding restoration actions on core performance indicators. These hypotheses and related uncertainties are often translated into a variety of possible monitoring questions where the focus shifts to tracking the overall progress towards the desired state.

We have found it useful to begin by identifying a set of simple and high-level monitoring questions (Skaha Lake re-introduction, Alexander and Pickard 2009; Platte River Recovery Implementation Program, Smith et al., 2011; Missouri River Recovery Program, Fischenich et al. 2017). Such questions provide focus on bigger pictures issues and facilitate communication, decision-making, and organization of the monitoring components of large-scale restoration programs.

Table 6 lists an early draft set of 16 high level monitoring questions for the IFRMP. Of these 16, we have identified 7 which we think are most important questions which will be asked of the IFRMP based on our understanding of key stressors in conceptual models (Chapter 2) and workshop feedback on the most important performance indicators to monitor (described in the next section). These questions will guide the design of the overall IFRMP monitoring program to track progress against objectives both in terms of status and trends and action effectiveness monitoring. The application of these questions and other aspects of monitoring are discussed further in Chapter 6.

Table 6: Initial Draft Big Monitoring Questions (BMQs) rated by importance to the IFRMP. Primary importance = 1, Secondary importance =2. Questions rated as secondary importance are considered less critical for evaluating the effectiveness of the IFRMP. *(final importance to be determined in subregional working group conference call)*

Initial Draft Big Monitoring Questions	Objectives Hierarchy Tier	Objectives Hierarchy link(s)	Importance[3]
1. Are abundances of focal resident fish species increasing within and across Klamath subregions to levels adequate to support harvest?	Fish populations	1.3, 2.1	1
2. Is juvenile production and survival (to ocean entry) of focal anadromous fish species increasing within and across Klamath subregions?	Fish populations	1.1, 1.2	1
3. Are the spatial distribution of focal fish species increasing towards their historical extent?	Fish populations; Habitat	1.5, 4.1	1
4. Are life history and genetic diversity of focal fish populations being maintained or increasing?	Fish populations; Biological interactions	1.4; 3.1	1
5. Is pathogen prevalence and associated disease-related mortality in salmonids decreasing in the lower Klamath River?	Biological interactions	3.2	1
6. Are control and removal methods reducing the impacts of exotic/invasive species on focal fish species?	Biological interactions	3.3	2
7. Are general water quality issues (e.g., high temperatures, DO, pH, hypereutrophication, etc.) improving across the Basin, especially in UKL?	Habitat	4.2	1
8. Are the aquatic invertebrate communities (maintaining fish populations) in a healthy state across the basin?)	Habitat	4.3	2
9. Has there been a reduction in fish mortality from entrainment, scour, and stranding?	Habitat	4.4	2
10. Is the physical suitability and capacity of stream and lake spawning and rearing habitats for focal fish species improving across the basin?	Habitat	4.5	1
11. Are fine and coarse sediment recruitment and transport processes in the Klamath mainstem below the dams returning to natural patterns?	Fluvial geomorphic processes	5.1	2
12. Has there been an increase in channel and floodplain connectivity in the mainstem Klamath River?	Fluvial geomorphic processes	5.2	1
13. Have there been increases in the extent and diversity of riparian vegetation and wetland areas across the basin (especially in UKL)?	Fluvial geomorphic processes	5.3	2
14. Are instream ecological flow regimes improving for the Klamath River mainstem and tributary streams?	Watershed inputs	6.1	1
15. Are inputs of fine sediment into streams decreasing across the Basin?	Watershed inputs	6.2	2
16. Have inputs of nutrients and pollutants been reduced across the Basin (especially in UKL)?	Watershed inputs	6.3	1

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[3] 1 = primary priority, 2 = secondary priority

3.4 Identifying Performance Indicators

Overview

Objectives and their associated monitoring question(s) are associated with performance indicators that are directly monitored to track progress towards the overall goal. **While the objectives and high-level monitoring questions may be largely qualitative, the associated performance indicators need to be *specific* and *measurable*.**

These performance indicators may be related to overall status and trends or specific project effectiveness, may generally track aspects of either habitat or fish populations, and may be qualitative or quantitative (Table 7).

Table 7. Broad categories of indicators used for tracking watershed health, with *illustrative* examples.

Type of Indicator	Habitat		Fish Population	
	Action Effectiveness	*Status/Trends*	*Action Effectiveness*	*Status/Trends*
Qualitative or Proxy indicators	• Ratings for specific types of created habitat features: poor, fair, good, etc. • Qualitative ratings of fish passage actions	• # reported dewatering events in each sub-region • # farms with nutrient reduction	• Observations of fish presence in areas of restored access (Y/N) • Observations of successful spawning in restored tribs (Y/N)	• # streams in sub-region X with local observations of species Y • Qualitative statements of population trends e.g., “no apparent increase”.
Quantitative indicators	• % of sampled locations with acceptable gravel permeability at spawning restoration sites • % area of restoration site X meeting suitability criteria for rearing habitat (flow/depth/cover)	• Trends in area of suitable spawning and rearing habitat by sub-region, based on a statistical sample • % reduction in annual nutrient load (t/yr) in Upper Klamath	• Quantitative fish population indicators include metrics such as total abundance, juveniles per spawner, and proportion of hatchery influence (pHOS). • These indicators are monitored by fisheries management agencies including PSFMC, NOAA-NFMS, USFWS, CDFW, and ODFW, and species-specific performance metrics for these indicators are specified in species management and recovery plans released by these agencies. • Where quantitative population indicators and benchmarks already exist, they will be referenced by this plan, but it is outside of the scope of this planning process to derive new quantitative population indicators and benchmarks.	

Although a wide range of potential indicators of watershed function are available in the literature, only a few can be reliably tracked over time given constraints on time and resources. The indicators selected for this purpose are known as Core Performance Indicators (CPIs) and meet the following criteria:

(1) **relevant** to management decisions,

(2) **feasible** to monitor and provide cost-effective and unambiguous information,

(3) **foundational** to tracking the progress of the overall IFRMP.

CPIs can be thought of as the ‘vital signs’ of a watershed, those fundamental measures that can provide an overall snapshot of basin health in the same way that heart rate, blood pressure, and body temperature provide an overall snapshot of human health. CPIs are more likely to be primarily associated with monitoring the status and trend of habitats and populations (i.e., are we moving towards the objectives, targets and triggers?), though they will also contribute to the evaluation of the cumulative effectiveness of restoration on a broader basin-wide scale.

Indicators that do not meet these criteria may still be monitored as Supplemental Indicators to provide additional context for interpretation of CPIs. For example, poor performance for any given CPI might prompt additional monitoring of a Supplemental Indicator to identify the root cause, just as additional medical tests might be ordered to diagnose the cause of a fever. However, regular monitoring of the Supplemental Indicators themselves would not be considered essential for supporting the overall IRFMP implementation. Similarly, an additional suite of indicators will be required for monitoring the effectiveness of specific actions (e.g., monitoring fish distribution before and after removal of a tributary barrier), but may not be CPIs or components of decision rules for restoration.

Selected Performance Indicators

Candidate performance indicators for each objective were proposed by diverse group of regional participants at a workshop during a series of open brainstorming sessions in a workshop setting on July 10-11 in Klamath, CA. Discussions during the brainstorming process imposed additional constraints on the process. For example, participants decided that proportion of days in exceedance of a regulatory limit (e.g., TMDLs) should not be used as a performance indicator, because these limits are policy instruments tied to specific compliance sites and can be changed. Instead, the actual metrics underpinning the regulatory instrument (e.g., dissolved oxygen, pH, temperature) should be used as the indicator for monitoring progress. Following generation of candidates, participants voted on those performance indicators they felt were best suited as Core Performance Indicators, with a high degree of agreement on those indicators considered to be more important than the others. The candidate and core performance indicators generated through this participatory process are shown in Table 8. *This list will be iteratively revised through additional input from regional participants not able to attend the workshop, and through a public peer-review comment process.*

Table 8. Nested Core Objectives of the Plan with corresponding candidate performance indicators, with those selected by workshop participants as core performance indicators bolded and underlined.

Whole-Basin Nested Core Objectives	Proposed *Candidate* and *Core* Performance Indicators
1.1 Increase juvenile production	• *Juveniles per Adult* • *Presence / Absence of Juvenile Larvae*
1.2 Increase juvenile survival and recruitment to spawning populations	• *Loss of Tagged Fish by Reach Over Time (to pinpoint spatial survival constraints)*

Whole-Basin Nested Core Objectives	Proposed *Candidate* and *Core* Performance Indicators
1.3 Increase overall population abundance and productivity, particularly in areas of high existing abundance or potential future abundance or in special or unique populations	- *Overall Abundance (by species)* - *Whether or not there is harvestable surplus*
1.4 Maintain or increase life history and genetic diversities	- *Genetic Diversity Indicators* - *Age Structure & Demographics*
1.5 Maintain or increase spatial distributions as necessary *(i.e., expansion may not be appropriate goal for all species)*	- *Habitat Occupancy (presence/absence; total river miles occupied, overall and above prior dam site(s))*
2.1 Improve management and regulations/enforcement of harvest, bycatch and poaching of naturally produced fish such that populations do not decline and can recover	- *N/A*
3.1 Do not generate adverse competitive or genetic consequences for native fish when carrying out conservation-oriented hatchery supplementation as needed.	- *pHOS (proportion of hatchery origin spawners, identified in Hatchery and Genetic Management Plans)*
3.2 Minimize disease-related mortality by reducing vectors and factors known to lead to fish disease outbreaks	- *Prevalence of Infection* - *Prevalence of Mortality* - *Occurrence of fish kills*
3.3 Reduce impacts of exotic plants and animals species on native fish	- *Distribution and abundance of non-native species* - *CPUE of non-native species in culling programs*
4.1 Restore fish passage and re-establish channel and other habitat connectivity, particularly in high-value habitats (e.g., thermal refugia)	- *Number of fish passage barriers*
4.2 Improve water temperatures and other local water quality conditions and processes for fish growth and survival	- *Temperature* - *Site Shade Potential* - *% of days TMDL objectives met*
4.3 Enhance and maintain community and food web diversity supporting native fish *(more holistic?)*	- *SWAMP (Surface Water Ambient Monitoring Program) macroinvertebrate and community diversity metrics* - *Stream Condition Index (SWAMP can be used to derive this)* - *Primary productivity (e.g., chlorophyll)*
4.4 Reduce fish mortality due to entrainment, scour, stranding	- *% of diversions unscreened (entrainment)* - *% of days tributaries drop below minimum recommended ecological flows (4.4 and 6.1)*
4.5 Enhance and maintain estuary, mainstem, tributary, lake and wetland habitats for all freshwater life stages and life histories of resident and anadromous fish	- *Area & Occupancy of Suitable Spawning Habitat* - *Area & Occupancy of Suitable Rearing Habitat* o *Habitat suitability would need to be determined for each species using either a suite of key metrics or by using such metrics as inputs to more comprehensive habitat suitability models. Options for determining habitat suitability are discussed later in this section.* - *Acres of cold-water habitat* - *Area & Occupancy of Suitable Migratory Habitat* - *Area & Occupancy of Suitable Foraging Habitat* - *Acres of restored or reconnected wetland habitats*

Whole-Basin Nested Core Objectives	Proposed *Candidate* and *Core* Performance Indicators
	• *# Primary pools deeper than X ft (depth varies by species)*
5.1 Increase and maintain coarse sediment recruitment and transport processes	• *% of days above X cfs per year* *(critical volume able to mobilize coarse sediment)* • *Coarse sediment storage capacity (e.g., by channel structure, large woody debris, is an indicator in the Trinity)*
5.2 Increase channel and floodplain dynamics, stability and interconnectivity	• *Acres of seasonally inundated wetland* • *Area available for channel migration* • *% of river in stage 0 (dynamics)*
5.3 Promote and expand establishment of diverse riparian and wetland vegetation that contributes to complex channel and floodplain morphologies	• *% Site Shade Potential Realized* • *Large Woody Debris Recruitment*
6.1 Improve instream ecological flow regimes year-round for the Klamath River mainstem and tributary streams	• *# cfs returned to stream* *(distinguish between temporary and permanent)* • *Surface-groundwater interaction metrics (metric itself TBD)* • *% diversions metered (reflects actively managed for flows)*
6.2 Reduce anthropogenic fine sediment inputs while maintaining natural and beneficial fine sediment inputs	• *% embedded / % fines (6.2 and 5.1)* • *Source of sediments in the system (e.g., roads vs. mine tailings, etc. Tells you where you need to focus efforts, via for example % of Roads Surveyed)*
6.3 Reduce external nutrient and pollutant inputs that contribute to biostimulatory conditions	• *Core water quality metrics (benchmarks specified in TMDLs)* - *Dissolved Oxygen* - *pH* - *Total Phosphorous (concentration)* - *Total Nitrogen (concentration)* • *# acre-feet tailwater return flows* • *# of harmful algae blooms*

Additional Considerations for Tracking Performance

The greatest challenge in development of candidate performance indicators related to habitat, given that this plan is intended to address many focal species with widely varying habitat needs that are difficult to express using a single metric, particularly at a whole-basin scale. Participants in the planning process determined that the best path forward was to use the common overarching metrics of Area of Suitable Habitat and Occupancy of Suitable Habitat by life stage (spawning, rearing, foraging, migration, with a focus on the first two life stages) to measure progress against habitat objectives, with the understanding that the metrics determining suitability would vary by species.

Area of suitable habitat can be determined through one of two general approaches:

Habitat Suitability Criteria

In the short-term, analysis of field data from past or new field-based or remote-sensing surveys can be carried out to determine the proportion of habitat within a watershed or basin that fall within published *habitat suitability criteria (HSC)* for each focal species. This method is faster and more cost-effective but best suited to assessing habitat suitability at localized scales. As, such, it can be considered a **useful interim approach** to determining proportion of selected sampling sites or reaches that offer suitable habitat and are occupied by focal species.

Habitat Suitability Modelling

In the longer-term, existing field data and suitability thresholds can inform a broader habitat suitability modelling exercise. This method is more time consuming and data-intensive, but can provide a more accurate assessment of the area of suitable habitat at larger basin scales, and is the preferred approach for long-term performance tracking against habitat objectives. Two complementary approaches to habitat suitability modelling discussed at the workshop show promise for this purpose, particularly if used together. These approaches are:

- Intrinsic Potential (IP) Modelling

  Used by NOAA's National Marine Fisheries Service, this approach estimates the area of physical habitat potential based on geomorphic variables including value width with constraint, discharge, and stream gradient derived from digital elevation models (DEMs) or LiDAR data (Sheer et al. 2009). This type of modelling has already been carried out for coho in the Klamath Basin (for the SONCC Recovery Plan), but can be adapted to other species and multiple life stages if habitat use curves are defined using spatial fish abundance data for the focal species from past or future field surveys. Increasing abundance in areas of high IP is an indicator of improvement in habitat suitability, in other words, of potential being fulfilled. This is a simplistic metric that does not take into account biological variables contributing to habitat suitability, but it can be used in combination with more biologically-oriented Habitat Capacity Output modelling. Intrinsic potential suitability curves have been developed for coho, Chinook, and steelhead (Sheer et al. 2009), and steelhead intrinsic potential has been proposed as a conservative surrogate for Pacific lamprey intrinsic potential due to similarities in preferred habitat across species (Luzier et al. 2011).

- Habitat Area and Capacity Modelling

  Used by the USGS and USFWS, Habitat Capacity Output is itself an output of the Stream Salmonid Simulator (S3 or SSS) model. This model cross-references species-specific habitat suitability criteria inputs and weighted useable area (WUA) curves against a broader range of variables including flow, temperature, water quality, and habitat type maps of the region of interest, to simulate the area (m^2) and capacity (number of fish) of overall usable habitat (Perry et al. 2018). This model has currently been calibrated for both Chinook and coho in the Klamath Basin, but could be extended to additional species and life stages with additional effort and data.

More work is needed to determine the level of data availability and subsequent level of effort needed to extend these models to other focal species. For both modelling approaches, extension to other species could be accelerated by leveraging remote sensing data or by using data from other regions to calibrate habitat occupancy curves when this data is not available within the the Klamath Basin.

Habitat area and capacity outputs can be compared to intrinsic potential calculated from geomorphic attributes to tell a broader story. While IP suggests the area of potential habitat based on meeting geomorphic criteria alone, habitat capacity and area can indicate how much of the physical habitat potential is realized based on riparian and in-stream conditions. Furthermroe, adding data on focal fish abundance indicates which of these realized habitat areas are occupied and actively used. In combination, IP, habitat area and capacity, and fish occupancy and abundance could be diagnostic for limiting factors in a system undergoing restoration. For example:

- If intrinsic potential is naturally low, restoration may not be appropriate, but if intrinsic potential is low due to anthropogenic watershed alteration or degradation, stream channel structure and function may first need to be restored to enable further restoration.
- If intrinsic potential is high, but realized habitat area is low, other limiting factors such as riparian processes or water quality may need further improvements before potential habitats can be fully realized.
- Finally, if both intrinsic potential and habitat area and capacity is high, but fish occupancy or abundance remains low, then fish passage, competition, or predation may need to be addressed for fish to fully benefit from the existing suitable habitat.

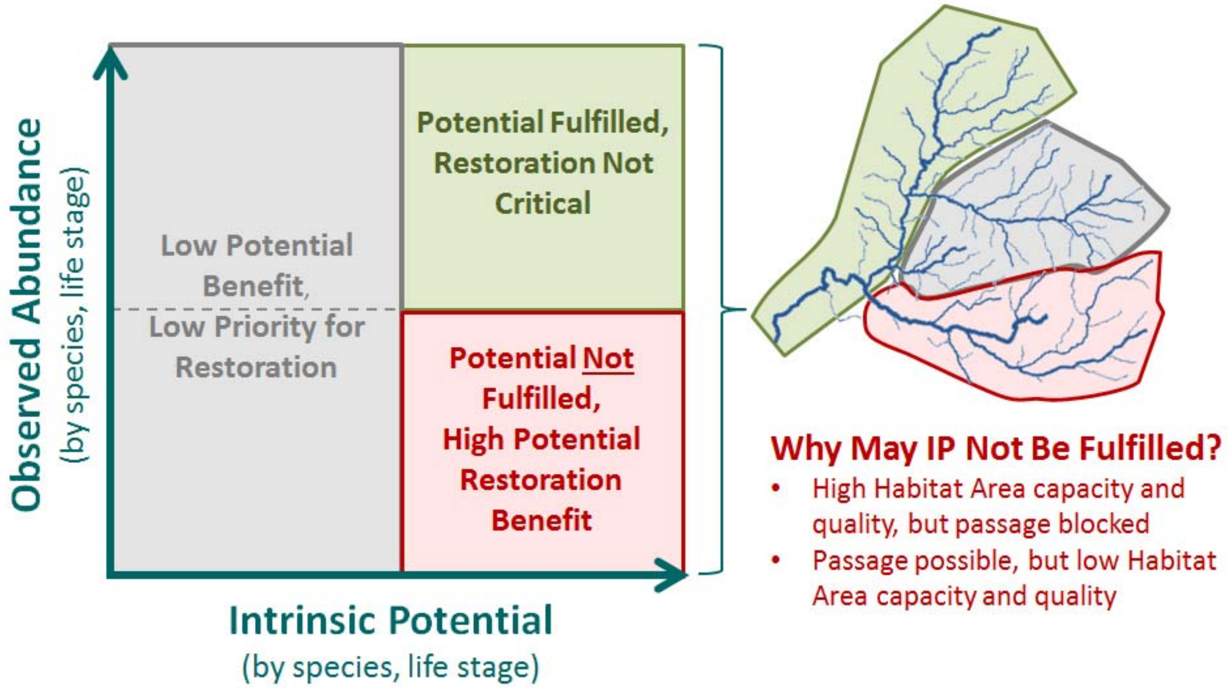

Figure 5. Schematic showing the utility of measures of habitat potential and fulfilled capacity for their role in prioritizing restoration and tracking restoration benefits.

3.5 Identifying Suitability Thresholds

Overview

For each indicator, suitability thresholds or benchmarks must be identified to contextualize broad changes in status and the degree of progress towards particular goals and objectives (e.g., poor, fair, or high habitat suitability for a given species) that can be used to inform the **phasing** of classes of restoration actions. For example, where a performance indicator in a given area reaches a favourable status, managers may choose to shift focus onto a different class of restoration action addressing a stessor that is still in poor or fair status. Broad principles for phasing restoration are discussed further in Chapter 4 on Candidate Restoration Actions.

This plan defers to established suitability thresholds where they exist, particularly in the case of quantitative suitability thresholds for fish populations that have been developed and proposed or formally adopted by federal, state or tribal agencies. Where such population thresholds do not already exist in a formally adopted document, this planning process will seek to ultimately develop interim qualitative suitability thresholds that are sufficiently specific to be testable (e.g., fall-run Chinook are able to migrate upstream as far as Upper Klamath Lake; fall-run Chinook are able to successfully spawn and rear in tributaries to Upper Klamath Lake). In this regard, traditional knowledge can provide valuable information on historical conditions against which qualitative benchmarks can be calibrated. Since qualitative criteria can often stimulate efforts to develop quantitative criteria, the Plan’s criteria should be revisited and updated over time based on progress made in other formal processes.

Identifying Candidate Suitability Thresholds from the Literature

The following tables (Table 9 to Table 14) present **published suitability thresholds for proposed CPIs** within each tier of the goals and objective hierarchy, including individual indicators of habitat suitability that might feed future habitat suitability models. Where suitability thresholds were not available for a given CPI, thresholds for a similar CPI are listed if available.

While many of the suitability thresholds identified in the literature apply equally to all species and parts of the basin, some vary widely by species and in some cases cannot be met simultaneously for all species at once. As a result, it will be very important to consider the spatial dimensions of suitability thresholds when interpreting future monitoring data to identify those regions where one suitability threshold might take precedence over another. For example, in an area defined as historical and critical habitat for Pacific lamprey but not other species, suitability thresholds for lamprey make take precedence. This and similar issues will be considered further during the design of a full monitoring and evaluation plan in later phases of this planning process.

Table 9: Proposed core performance indicators (CPIs) and published suitability thresholds for POPULATION related objectives. More detailed tables can be provided in appendices.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			Reference
			Poor	Fair	Good	
1.1 Increase juvenile production	Juveniles per adult	count	N/A	N/A	≥ 1.2 naturally-produced adult offspring per adult in three of the last five years when total abundance was less than average returns of naturally produced fish.	Interim criteria and standards for Oregon salmon and steelhead, ODFW 2005[1] referenced in NMFS 2014[2].
1.2 Increase juvenile survival and recruitment to spawning populations	Loss of Tagged Fish by Reach Over Time *(to pinpoint spatial survival constraints)*	TBD	TBD	TBD	TBD	Could not find benchmarks for any species – likely captured instead by population productivity / growth rate.
1.3 Increase overall population abundance and productivity, particularly in areas of high existing abundance or potential future abundance or in special or unique populations	Overall Abundance	N/A	Coho: Below “low risk threshold” of spawners for each core population Bull Trout: N/A	Coho: Meets “low risk threshold” of spawners for each core population Bull Trout: < 8,250 in Upper Klamath Basin *(based on 10 yrs of data)*	Coho Exceeds “low risk threshold” of spawners for each core population Bull Trout: ≥ 8,250 in Upper Klamath Basin *(based on 10 yrs of data)* Redband Trout: > 1,250 (per population)	Coho: Table 4-1 and Table 4-2 in NMFS 2014 Bull Trout: Recovery Criteria, p. vi in USFWS 2002[3] Redband Trout: p.20 in IRCT 2016[4]
	Density	varies	Coho: < 4 spawners per IP-km for each non-core population. Redband Trout: ≤ 0.059 fish/m^2 or ≤ 0.2 g/m^2	Coho: N/A Redband Trout: 0.060 – 0.19 fish/m^2 or 2.1 – 4.9 g/m^2	Coho: ≥ 4 spawners per IP-km for each non-core population. Redband Trout: ≥ 0.20 fish/m^2 or ≥ 5.0 g/m^2	Coho: Coho: Table 4-1 in NMFS 2014 Redband Trout: Table 1 in Dambacher and Jones 2007[5]
	Productivity *(Slope of regression of geometric mean of wild adults over multiple generations)*	unitless	<0	0-1	≥1	Coho: Table 4-1 in NMFS 2014 Bull Trout: Recovery Criteria, p. vi in USFWS 2002, *(10 yrs of data)* Eulachon: Criteria on p. 89 of NMFS 2016[6]
1.4 Maintain or increase life	Genetic Integrity	%	< 99% unaltered	N/A	≥ 99% unaltered	Redband Trout: p.20 in IRCT 2016

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[1] Oregon Department of Fish and Wildlife (ODFW). 2005a. Oregon Native Fish Status Report. Volume II. Assessment Methods and Population Results. Salem, Oregon.
[2] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*)
[3] USFWS. 2002. Chapter 2, Klamath River Recovery Unit, Oregon. 82 p. In: U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus)* Draft Recovery Plan. Portland, Oregon.
[4] Interior Redband Conservation Team (IRCT). 2016. A Conservation Strategy for Interior Redband (*Oncorhynchus mykiss* subsp.) in the states of California, Idaho, Montana, Nevada, Oregon, and Washington. 106 pp.
[5] Dambacher, J.M. and Jones, K.K., 2007. Benchmarks and patterns of abundance of redband trout in Oregon streams: a compilation of studies. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter, American Fisheries Society, Corvallis, pp.47-55.
[6] NMFS.2016. DRAFT Recovery Plan for Eulachon (*Thaleichthys pacificus*). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, OR, 97232. 120 pp.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			Reference
			Poor	Fair	Good	
history and genetic diversities	Genetic Redundancy	%	≥ 10% introgression	N/A	< 10% introgression	Redband Trout: p.20 in IRCT 2016
	Life History Diversity	count	Only 1 of many historical life history is represented	>1 historical life histories are represented	All historical life histories are represented	Redband Trout: p.20 in IRCT 2016
1.5 Maintain or increase spatial distributions as necessary *(i.e., expansion may not be appropriate goal for all species)*	% of Accessible Habitat Occupied	%	N/A	<80	≥80%	Coho: Table 4-1 in NMFS 2014
	% Historical populations still extant and not at risk		N/A	N/A	≥80%	Interim criteria and standards for Oregon salmon and steelhead, ODFW 2005[7] referenced in NMFS 2014[8].
	# New Local Populations Established in Suitable Habitat	count	0	1 – 2	3 – 5	Bull Trout: Recovery Criteria, in USFWS 2002, 2015[9], *(counts per core conservation area).* Presence in new areas could be determined from archived water samples via eDNA.

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[7] Oregon Department of Fish and Wildlife (ODFW). 2005a. Oregon Native Fish Status Report. Volume II. Assessment Methods and Population Results. Salem, Oregon.

[8] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*)

[9] USFWS. 2015. 2015. Recovery plan for the coterminous United States population of bull trout (*Salvelinus confluentus*). Portland, Oregon. xii + 179 pages.

Table 10: Proposed core performance indicators (CPIs) and published suitability thresholds for BIOLOGICAL INTERACTION related objectives.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
3.1 Eliminate or minimize adverse competitive or genetic consequences for native fish when carrying out conservation-oriented hatchery supplementation as needed.	Proportion of hatchery origin spawners (pHOS)	%	Low Natural Esc.: No limit High Natural Esc: > 50%	N/A	Low Natural Esc.: No limit High Natural Esc: < 50% SONCC Coho Recovery Crterion: <5%	Table 16 inCDFW and PacifiCorp 2014[10] Coho: Table 4-1 in NMFS 2014[11]
	Proportion of natural fish used as broodstock (pNOB)	%	<20 or >50	N/A	20-50	Table 16 inCDFW and PacifiCorp 2014
3.2 Minimize disease-related mortality by reducing vectors and factors known to lead to fish disease outbreaks	Presence of pathogen		C.shasta: > 10 spores / L *(Chinook)* > 5 spores / L *(coho)*	N/A	N/A	Hallett et al. 2012[12], thresholds for 40% mortality
	Prevalence of Infection		TBD	TBD	TBD	TBD
	Prevalence of Mortality		> 10% mortality of sentinel coho salmon juveniles at Beaver Creek confluence in the Klamath River during May and June	NA	≤ 10% mortality of sentinel coho salmon juveniles at Beaver Creek confluence in the Klamath River during May and June	Table 4-6 in NMFS 2014 (for *C. shasta* in coho)
3.3 Reduce impacts of exotic plants and animals species on native fish	Overall abundance	%	0-65% Reduction	≥ 65-75% Reduction	100% Reduction (eradication)	For brook trout, Table 2 in USGS and USFWS 2017[13], see also Buktenica et al. 2013[14]
	Habitat occupancy	count	> 2 non-native species present in watershed, and probability of dispersal high	1 – 2 non-native species present in watershed, and probability of dispersal low to moderate	0 non-native species present in watershed	Redband Trout Conservation Population Viability Index (CPVI) model proposed by Muhlfeld et al. 2015[15] Could be determined from archived water samples via eDNA.

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[10] CDFW and PacifiCorp. 2014. Hatchery And Genetic Management Plan For Iron Gate Hatchery Coho Salmon. 163 pp.

[11] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*)

[12] Hallett, S.L., Ray, R.A., Hurst, C.N., Holt, R.A., Buckles, G.R., Atkinson, S.D. and Bartholomew, J.L., 2012. Density of the waterborne parasite, Ceratomyxa shasta, and biological effects on salmon. Applied and environmental microbiology, pp.AEM-07801. Available from: http://aem.asm.org/content/78/10/3724.full.pdf+html

[13] USGS and USFWS. 2017. Structured Decision Making for Conservation of Bull Trout (*Salvelinus confluentus*) in Long Creek, Klamath River Basin, South-Central Oregon. 40 pp. Available at: https://pubs.usgs.gov/of/2017/1075/ofr20171075.pdf

[14] Buktenica, M.W., Hering, D.K., Girdner, S.F., Mahoney, B.D. and Rosenlund, B.D., 2013. Eradication of nonnative Brook Trout with electrofishing and antimycin-A and the response of a remnant Bull Trout population. North American Journal of Fisheries Management, 33(1), pp.117-129.

[15] Muhlfeld, C.C., D.H. Bennett, and B. Marotz. 2001. Summer habitat use by Columbia River Redband in the Kootenai River drainage, Montana. North American Journal of Fisheries Management 21:223–235.

Table 11: Proposed core performance indicators (CPIs) and published suitability thresholds for HABITAT related objectives that are not species specific.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
4.1 Restore fish passage and re-establish channel and other habitat connectivity, particularly in high-value habitats (e.g., thermal refugia)	Number of fish passage barriers - Total *(inland fish)* - Downstream *(anadromous fish)*	Count	>8 ≥4	5 – 7 3 – 2	0 – 4 0 – 1	Table 4 in Fesenmeyer et al. 2013[16] *(subwatershed scale) See:* ● California Passage Assessment Database (PAD) via CalFish ● Oregon Fish Passage Barrier Standard Dataset via ODFW
	% total stream miles accessible *(anadromous fish)*	%	<30%	30-50%	50-90%	Table 4 in Fesenmeyer et al. 2013 *(indicator at subwatershed scale)*
	Ratio of current to historical stream miles accessible *(inland fish)*	%	<75%	75-90%	>90%	Table 4 in Fesenmeyer et al. 2013 *(indicator at subwatershed scale)*
4.2 Improve water temperatures and other local water quality conditions and processes for fish growth and survival	Temperature	ºC	OR TMDL: >20 ºC (incipent or instantaneous lethal limit for coldwater fish causing mortality over hours to days) CA TMDL: Monthly average at stateline > monthly Temperature Numeric Target SPECIES: Coho & Chinook: ≥ 20 ºC *(lethal to eggs)*, ≥ 25 ºC *(lethal to juveniles, adults)* Steelhead: ≥ 20 ºC *(lethal to eggs)*, ≥ 24 ºC *(lethal to juveniles, adults)*	OR TMDL: 17.8-20 ºC (sub-lethal limit for coldwater fish associated with reduced performance that becomes lethal with long-term exposure over weeks to months) SPECIES: Bull trout: 15 - 18 ºC *(limits adult distributions)* Chinook: 13 – 24 ºC *(suitable for rearing)*	OR TMDL: ≤ 17.8 ºC (below lethal and sub-lethal limits for coldwater fish) CA TMDL: Monthly average at stateline ≤ monthly Temperature Numeric Target SPECIES: Coho: 16-17 ºC is considered good, <16 ºC is very good. Chinook: 13 ºC *(optimal rearing in streams)*	OR: Table 2-4 and 4-3 in ODEQ 2010[17] (threshold set for redband trout based on instantaneous or incipient lethal limits for cold-water fish (21ºC and over). CA: Table 5.3 in NCRWQCB 2010[18] SPECIES: Coho: Table 4-6 in NMFS 2014[19] , Carter 2005[20] *(lethality)*, Chinook: McCullough 1999[21],

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[16] Fesenmeyer, K. Henrery, R., and Williams, J. 2013. California Freshwater Conservation Success Index: An Assessment of Freshwater Resources in California, with focus on lands managed by the US Bureau of Land Management Version 1.0, December 2013. Trout Unlimited Science program. 45 pp. (Note: Spatial extent of indices encompass entire Klamath Basin in CA and OR; 5-point indicator scale lumped to fit into 3 categories).

[17] State of Oregon Dept. of Environmental Quality (ODEQ). 2002. Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP).

NCRWQCB. [18] 2010. Final staff report for the Klamath River total maximum daily loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California the proposed site specific dissolved oxygen objectives for the Klamath River in California, and the Klamath River and Lost River implementation plans.

[19] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (Oncorhynchus kisutch)

[20] Carter, K. 2005. The effects of temperature on steelhead, coho salmon, and Chinook salmon biology and function by life stage: Implications for Klamath Basin TMDLs. Report for California Regional Water Quality Control Board, August 2005. More detailed thresholds per species and life stage which are consistent with TMDLs are available in reference.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
			Bull trout: > 18 ºC *(limit for adult persistence)* Redband trout: >21 ºC *(not suitable for subadult and adult habitat use)* Suckers: < 5.5 ºC *(unsuitable for spawning)* Green sturgeon: > 23ºC *(complete mortality of embryos before hatch)* <u>DISEASE:</u> *C.shasta infection mortality rate* Chinook: > 18 ºC *(85 – 100% mortality)* Coho: > 18 ºC *(80 – 90% mortality)*	Bull trout: 12 – 20 ºC *(lower adult densities)* Redband trout: 0 – 10 and 18 – 21 ºC *(suitable for subadult and adult habitat use)* Suckers: 5.5 – 10 ºC *(suitable for spawning, but below peak spawning activity)* Green sturgeon: ≤ 11 and 19-23ºC *(detrimental to embryos)* Pacific lamprey: 10 – 13 and 17 – 18 ºC *(suitable for spawning)*	>17 ºC *(optimal smoltification in estuary)* <15.5 ºC *(optimal for migration and spawning)* Bull trout: 4 – 10 ºC *(spawning)* 1 – 6 ºC *(egg incubation)* 4 – 4.5 ºC *(optimal fry growth)* 4 – 10 ºC *(optimal juvenile growth)* 4 – 12 ºC *(highest adult densities)* 10-12 ºC *(adult migration)* Redband trout: 10 – 18 ºC *(optimal for subadult and adult habitat use)* Green sturgeon: 14 – 17 ºC *(optimal embryonic development)*	Carter 2005, Allen and Hassler 1986[22] Bull trout: Figure 1 in Buchanan and Gregory 1997[23] Redband Trout: Chandler 2003 *(subadults and adults habitat use)*[24] Green sturgeon: Moser et al. 2016[25]; Israel and Klimley 2008[26] Benson et al. 2007[27] Suckers: NRC 2004 (p194)[28] Cooperman et al. 2010[29] Hewitt et al. 2012[30], 2015[31]

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[21] McCullough, D.A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon. Prepared for the U.S. EPA. Region 10, Seattle, Washington. Published as EPA 910-R-99-010

[22] Allen, M.A. and T.J. Hassler, 1986. Species profiles: life history and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) – Chinook salmon. U.S. Fish and Wildlife Service Biological Report 82 (11.49). U.S. Army Corp of Engineers, TR EL-82-4.

[23] Buchanan, D.V. and S.V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. Proceedings of the Friends of the Bull Trout Conference. Calgary, Alberta, Canada.

[24] Chandler, J.A., ed. 2003. Redband Trout and Bull Trout Associated with the Hells Canyon Complex. Idaho Power Company Technical Report Appendix E.3.1-7 Hells Canyon Complex FERC No. 1971. Available at: https://docs.idahopower.com/pdfs/relicensing/hellscanyon/hellspdfs/techappendices/Aquatic/e31_07_ch01.pdf

[25] Moser, M.L., Israel, J.A., Neuman, M., et al. 2016. Biology and life history of green sturgeon (Acipenser medirostris Ayres, 1854): state of the science. Journal of Applied Ichthyology, 32, pp.67-86.

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Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			🟥 Poor	🟨 Fair	🟩 Good	
				<u>DISEASE:</u> *C.shasta infection mortality rate* Chinook: 13 - 18 °C *(65 – 85% mortality)* Coho: 13 - 18 °C *(65 – 80% mortality)*	19 – 24 °C *(optimal juvenile growth)* 10 – 12 °C *(triggers fall outmigration on the Klamath River)* Suckers: 5.5 – 19 °C *(suitable for spawning)* *> 10 °C (peak Lost River sucker spawning)* *≥ 12 °C (peak shortnose sucker spawning)* 14 – 22 °C *(optimal larval survival)* Pacific lamprey: 14 – 15 °C *(optimal for spawning)* Eulachon:4 – 10 °C *(optimal for migration and spawning)* <u>DISEASE:</u> *C.shasta infection mortality rate* Chinook: < 13 °C *(< 65% mortality)* Coho: < 13 °C *(< 65% mortality)*	Pacific lamprey: CalFish 2018[32] Eulachon: Emmett et al 1991[33] Disease: Figure 3 in Ray et al. 2012[34] (*C. shasta*)
	Dissolved Oxygen	mg/L or % saturation	OR: < 4.0 mg/L Upper Klamath Lake outlet or < 6.0 downstream of Keno Dam OR in Lost River year-round <11 mg/L or		OR: ≥ 4.0 mg/L Upper Klamath Lake outlet or ≥ 6.0 downstream of Keno Dam OR in Lost River year-round ≥11 mg/L or ≥95% saturation downstream of Keno Dam	OR: Table 2-3, Section 3.3.2.1 in ODEQ 2010 CA: Table 5.1 in NCRWQCB 2010 See also Martin et al. 1998[35] for

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Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
			<95% saturation downstream of Keno Dam during salmonid and trout spawning period (Jan 1 – May 15) CA: Monthly mean and minimum <85% saturation at stateline and below Salmon River SPECIES: Chinook: < 1.6 mg / L *(eggs, lethal)* < 4.5 mg / L *(juvenile rearing)* Steelhead: < 5.0 mg/L *(juvenile rearing)* Suckers: < 4 mg / L	SPECIES: Steelhead: 6.5 – 7.0 mg/L *(juvenile rearing)* Bull Trout & Redband Trout: >38 % saturation (at 0 – 11 °C) >39 - 54% saturation (at 11 – 28 °C) *(subadults and adults)* Suckers: 4 - 6 mg / L	during salmonid and trout spawning period (Jan 1 – May 15) CA: Monthly mean and minimum ≥85% saturation at stateline and below Salmon River SPECIES: Chinook: 100% saturation *(eggs)* Coho: > 8 mg/L *(spawning)*, 4 – 9 mg/L *(juvenile rearing)* Steelhead: > 7.0 mg/L Bull Trout & Redband Trout: >76% saturation (at 0 – 15 °C) >77 - 96% saturation (at 16 – 28 °C) *(subadults and adults)* Green sturgeon: > 6.5 mg / L Suckers: >6 mg / L	lower lethal thresholds for suckers, which are below the TMDL thresholds. Table 4-6 in NMFS 2014[36] (for coho, thresholds consistent with those in TMDL). SPECIES: Chinook: Allen and Hassler 1986[37] Coho: NMFS 2001 [38] Steelhead: NMFS 2001 Bull Trout and Redband Trout: Chandler 2003 *(subadults and adults habitat use)*[39] Green sturgeon: Moser et al. 2016[40] Suckers: Burdick et al. 2008 (citing Loftus 2001)[41]
	pH	unitless	OR: <6.5 or > 9.0 at the Upper Klamath Lake outlet, downstream of Keno Dam, or in Lost	OR: N/A	OR: 6.5 – 9.0 at the Upper Klamath Lake outlet, downstream of Keno Dam, or in Lost	OR: Section 2.2.3 in ODEQ 2010[42] Table 4-6 in NMFS 2014[43] (for

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[38] NMFS. 2001. The Effects of Summer Dams on Salmon and Steelhead in California COasta Watersheds and Recommendations for Mitigating Their Impacts. National Marine Fisheries Service, Southwest Region – Santa Rosa Field Office. Available from: http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/c8ef5608-8b41-41b3-bbb7-449bd805399d

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[41] Burdick, S.M., Hendrixson, H.A. and VanderKooi, S.P., 2008. Age-0 Lost River sucker and shortnose sucker nearshore habitat use in Upper Klamath Lake, Oregon: a patch occupancy approach. Transactions of the American Fisheries Society, 137(2), pp.417-430.

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Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
			River SPECIES: NMFS (Coho): >8.5	SPECIES: NMFS (Coho): 8.25 – 8.5	River SPECIES: NMFS (Coho): <8.25	coho
	Total Phosphorous (Average daily concentration)	mg/L	OR: > Target Concentrations at Non-Point Sources (flow-weighted) UKL (baseline): 0.024 Lost River Diversion 0.029 Klamath Straits Drain 0.035 Other NPS: 0.035 Springs (natural): 0.069 CA: >Target Monthly Concentrations Stateline: 0.023 (Oct) to 0.030 (April) Mainstem Downstream of Salmon River: 0.021 (Jan) – 0.027 (Nov)	N/A	OR: < Target Concentrations at Non-Point Sources (flow-weighted) UKL (baseline): 0.024 Lost River Diversion 0.029 Klamath Straits Drain 0.035 Other NPS: 0.035 Springs (natural): 0.069 CA: <Target Monthly Concentrations Stateline: 0.023 (Oct) to 0.030 (April) Mainstem Downstream of Salmon River: 0.021 (Jan) – 0.027 (Nov)	OR: Table 2-9 in ODEQ 2010 CA: Table 5.9, 5.14 in NCRWQCB 2010
	Total Nitrogen (Average daily concentration)	mg/L	OR: > Target Concentrations at Non-Point Sources (flow-weighted) UKL (baseline): 0.31 Lost River Diversion 0.37 Klamath Straits Drain 0.45 Other NPS: 0.45 Springs (natural): 0.31 CA: >Target Monthly Concentrations Stateline: 0.252 (Aug) to 0.395 (April) Mainstem Downstream of Salmon River: 0.173 (Jan) – 0.242 (Oct)	N/A	OR: < Target Concentrations at Non-Point Sources (flow-weighted) UKL (baseline): 0.31 Lost River Diversion 0.37 Klamath Straits Drain 0.45 Other NPS: 0.45 Springs (natural): 0.31 CA: <Target Monthly Concentrations Stateline: 0.252 (Aug) to 0.395 (April) Mainstem Downstream of Salmon River: 0.173 (Jan) – 0.242 (Oct)	OR: Table 2-9 in ODEQ 2010 CA: Table 5.9, 5.14 in NCRWQCB 2010

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[43] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (Oncorhynchus kisutch)

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
	Nuisance Phytoplankton (chlorophyll-a)	mg/m^2	OR: < 0.015 mg/L at the Upper Klamath Lake outlet, downstream of Keno Dam, or in Lost River CA: < 150 mg of chlorophyll-a /m^2 below the Salmon River	N/A	OR: ≥ 0.015 mg/L at the Upper Klamath Lake outlet, downstream of Keno Dam, or in Lost River CA: ≥150 mg of chlorophyll-a /m^2 below the Salmon River	OR: Section 3.3.2.3 in ODEQ 2010 CA: Table 5.1 in NCRWQCB 2010[44]
4.3 Enhance and maintain community and food web diversity supporting native fish	Stream Condition Index (via SWAMP macroinvertebrate monitoring program data)	Unitless	Likely to be intact ≥30th percentile (CSCI ≥ 0.92)	Possibly altered 30th– 10th percentile (CSCI ≥ 0.79) Likely to be altered 1st–10th percentile (CSCI ≥ 0.63)	Very likely to be altered <1st percentile (CSCI < 0.63)	Mazor et al. 201545
	Aquatic Vertebrate IBI	Unitless	< 37	N/A	≥62	EPA 2005 (Mountain Region)46
	Macroinvertebrate IBI	Unitless	< 57	N/A	≥71	EPA 2005 (Mountain Region)
	Aq Macroinverts (EPT)	Unitless	<19	19-25	>25	Table 4-6 in NMFS 2014 (for coho)
	Aq Macroinverts (Richness)	Unitless	<31	31-40	>40	Table 4-6 in NMFS 2014 (for coho)
	Aq Macroinverts (B-IBI)	Unitless	< 60.1	60.1-80	>80	Table 4-6 in NMFS 2014 (for coho)
4.4 Reduce fish mortality due to entrainment, scour, stranding	Miles canals	mi	≥ 20	5-20	1-5	Table 4, Fesenmeyer et al. 2013[47] *(indicator at subwatershed scale)*
	Diversions per stream mile	count / mi	>1	1-0.4	1-0.4	Table 4 in Fesenmeyer et al. 2013 *(indicator at subwatershed scale)*

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[44] NCRWQCB. 2010. Final staff report for the Klamath River total maximum daily loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California the proposed site specific dissolved oxygen objectives for the Klamath River in California, and the Klamath River and Lost River implementation plans.

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Table 12: Proposed core performance indicators (CPIs) and published suitability thresholds for HABITAT related objectives that ARE species specific. Note that aspects of habitat related to qater quality are addressed in Table 11.

Sub-Objective	Species	Core Performance Indicator	Units	Published Suitability Thresholds			References
				Poor	Fair	Good	
4.5 Enhance and maintain estuary, mainstem, tributary, lake and wetland habitats for all freshwater life stages and life histories of resident and anadromous fish	Coho Salmon	Water Depth	cm	13.72 – 62.48 *(fry rearing)* >22.25 *(juvenile rearing)* 14.33 – 62.18 *(spawning)*	13.72 – 20.42 and 49.68 – 62.48 *(fry rearing)* 22.25 – 39.62 *(juvenile rearing)* 14.33 – 20.73 and 53.95 – 62.18 *(spawning)*	20.42 – 49.68 (fry rearing) > 39.62 *(juvenile rearing)* 20.42 – 53.95 *(spawning)*	Hampton et al. 1997[48] *(thresholds derived by dividing Habitat Suitability Criteria curves into thirds)*
		Water Velocity	m/s	> 0.08 *(fry rearing)* > 0.26 *(juvenile rearing)* 0.09 – 0.64 *(spawning)*	0.04 – 0.08 *(fry rearing)* 0.08 – 0.26 *(juvenile rearing)* 0.09 – 0.15 and 0.52 – 0.64 *(spawning)*	0 – 0.04 *(fry rearing)* 0 – 0.08 *(juvenile rearing)* 0.15 – 0.52 *(spawning)*	Hampton et al. 1997 *(thresholds derived by dividing Habitat Suitability Criteria curves into thirds)*
		Pool Depths	ft	< 3-3.3 ft	3-3.3 ft	>3.3 ft.	Table 4-6 in NMFS 2014[49] (for coho)
		Pool Frequency (length)	%	< 41-50%	41-50%	>50%	Table 4-6 in NMFS 2014 (for coho)
		Pool Frequency (area)	%	< 21-35%	21-35%	>35%	Table 4-6 in NMFS 2014 (for coho)
		D50 (median particle size)	cm	< 5.1 - >11.0	5.1-6.0 & 9.5-11.0	6.0-9.5	Table 4-6 in NMFS 2014 (for coho)
		% Fines	%	N/A	N/A	< 20 (spawning), <15 *(egg, fry survival)*	NMFS 2001[50]
	Chinook Salmon	Substrate size	cm	N/A	N/A	1.3 – 10.2 *(spawning)*	Allen and Hassler 1986[51]
		% Fines (< 6.4 mm)	%	>40 *(emergence)*	30 – 40 *(emergence)*	< 30 *(emergence)* <5 *(spawning)*	Bjornn and Reiser 1991, cited in NMFS 2001
		Water Depth	cm	< 6.4 or > 85.95 *(fry rearing) (a)* < 13.11 *(juvenile rearing) (a)*	6.40 – 14.63 and 58.22-85.95 *(fry rearing) (a)* 13 – 24 *(juvenile rearing) (a)*	14.63 – 58.22 *(fry rearing) (a)* >24 *(juvenile rearing) (a)*	(a) Hampton et al. 1997 *(thresholds derived by dividing Habitat Suitability Criteria curves into*

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[48] Hampton, M., Payne, T.R>, and Thomas, J.A. 1997. Microhabitat Suitability Criteria for Anadromous Salmonids of the Trinity River. USDOI and USFWS Coastal California Fish and Wildlife Office, 1125 16th Street, Room 209, Arcata, California 95521. Available from: https://www.fws.gov/arcata/fisheries/reports/technical/Microhabitat_Suitability_Criteria_for_Anadromous_Salmonids_of_the_TR.pdf

[49] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (Oncorhynchus kisutch)

[50] NMFS. 2001. The Effects of Summer Dams on Salmon and Steelhead in California COasta Watersheds and Recommendations for Mitigating Their Impacts. National Marine Fisheries Service, Southwest Region – Santa Rosa Field Office. Available from: http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/c8ef5608-8b41-41b3-bbb7-449bd805399d

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Sub-Objective	Species	Core Performance Indicator	Units	Published Suitability Thresholds			References
				Poor	Fair	Good	
				< 14.33 or >77.72 *(spawning) (a)*	14.33 – 20.73 and 62.79 – 77.72 *(spawning) (a)*	20.73 – 62.79 *(spawning) (a)* ≥ 24 *(migration & spawning) (b)* 30 – 122 *(juvenile rearing) (b)*	*thirds)* (b) Allen and Hassler 1986
		Water Velocity	m/s	> 0.15 *(fry rearing) (a)* > 0.40 *(juvenile rearing) (a)* 0.20 – 0.77 *(spawning) (a)*	0.08 – 0.15 *(fry rearing) (a)* 0.00 – 0.02 and 0.25 – 0.40 *(juvenile rearing) (a)* 0.20 – 0.29 and 0.61 – 0.77 *(spawning) (a)*	0.00 – 0.08 *(fry rearing) (a)* 0.02 – 0.25 *(juvenile rearing) (a)* 0.29 – 0.61 *(spawning) (a)* ≤ 2.4 *(adult upstream migration, sustained current maximum) (b)* ≤ 6.1 *(adult upstream migration, obstacle current maximum) (b)* 0.3 – 0.91 *(spawning) (b)* 0.06 – 0.24 *(juvenile rearing) (b)*	(a) Hampton et al. 1997 *(thresholds derived by dividing Habitat Suitability Criteria curves into thirds)* (b) Allen and Hassler 1986
	Steelhead	Substrate Size	cm	N/A	N/A	1.3 – 11.7 *(spawning)*	Bjornn 1979, cited in NMFS 2001[52]
		% Fines (< 6.4 mm)	%	>20 *(embryo survival)*	20 – 25 *(embryo survival)*	<20 *(embryo survival)*	Bjornn 1979, cited in NMFS 2001
		Water Depth	cm	< 10.46 or > 44.20 *(fry rearing)* < 34.14 *(juvenile rearing)* < 3.96 *(juvenile overwintering)* < 18.59 or >47.55 *(spawning)* < 32 *(holding)*	10.36 – 14.02 and 34.14 – 44.20 *(fry rearing)* 34.14 – 47.24 and 98.45 – 118.87 *(juvenile rearing)* 3.96 – 7.62 *(juvenile overwintering)* 18.59 – 23.77 and 41.15 – 47.55 *(spawning)* 32.00 – 49.38 *(overwintering)*	14.02 – 34.14 *(fry rearing)* *47.24 – 98.45 (juvenile rearing)* *> 7.62 (juvenile overwintering)* 23.77 – 41.15 *(spawning)* > 49.38 *(spawning)*	Hampton et al. 1997[53] *(thresholds derived by dividing Habitat Suitability Criteria curves into thirds)*
		Water Velocity	m/s	> 0.26 *(fry rearing)* 0.02 – 0.84 *(juvenile rearing)* 0.01 – 0.45 *(juvenile overwintering)* 0.14 – 0.71 *(spawning)* 0.17 – 0.94 *(holding)*	0.20 – 0.26 *(fry rearing)* 0.02 – 0.05 and 0.61 – 0.84 *(juvenile rearing)* 0.34 – 0.46 *(juvenile overwintering)* 0.14 – 0.20 and 0.61 – 0.71 *(spawning)*	0 – 0.20 *(fry rearing)* 0.05 – 0.61 *(juvenile rearing)* 0.01 – 0.34 *(juvenile overwintering)* 0.20 – 0.61 *(spawning)* 0.29 – 0.77 *(holding)*	Hampton et al. 1997 *(thresholds derived by dividing Habitat Suitability Criteria curves into thirds)*

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[52] NMFS. 2001. The Effects of Summer Dams on Salmon and Steelhead in California COasta Watersheds and Recommendations for Mitigating Their Impacts. National Marine Fisheries Service, Southwest Region – Santa Rosa Field Office. Available from: http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/c8ef5608-8b41-41b3-bbb7-449bd805399d

[53] Hampton, M., Payne, T.R>, and Thomas, J.A. 1997. Microhabitat Suitability Criteria for Anadromous Salmonids of the Trinity River. USDOI and USFWS Coastal California Fish and Wildlife Office, 1125 16th Street, Room 209, Arcata, California 95521. Available from: https://www.fws.gov/arcata/fisheries/reports/technical/Microhabitat_Suitability_Criteria_for_Anadromous_Salmonids_of_the_TR.pdf

Sub-Objective	Species	Core Performance Indicator	Units	Published Suitability Thresholds			References
				Poor	Fair	Good	
					0.17 – 0.29 and 0.77 – 0.0.96 *(holding)*		
	Bull Trout	Substrate Size	cm	≥ 7.63 (cobble and boulder) *(spawning)* ≤ 2.54 (pebble and sand) *(subadult and adult rearing)*	<0.64 (sand) and 5.09 – 7.62 (large gravel) *(spawning)* 2.55 – 7.62 (small and large gravel) *(subadult and adult rearing)*	0.65 – 2.54 (pebble) and 2.55 – 5.08 (small gravel) *(spawning)* ≥ 7.63 (boulder and cobble) *(subadult and adult rearing)*	Anglin et al. 2008[54] (Table 1 and Figure 20)*(spawning)* (Table 1 and Figures 30, 31) *(subadult and adult rearing)*
		Water Depth	cm	≥ 100 *(spawning)*	39 - 99 *(spawning)* 50 – 150 and 250 – 850 *(subadults and adults habitat use)*	≤ 40 *(spawning)* 150 – 250 *(subadults and adults habitat use)*	Anglin et al. 2008 (Figure 20)*(spawning)* Chandler 2003 *(subadults and adults habitat use)* [55]
		Water Velocity	m/s	≥ 0.8 *(spawning, water column)*	0.2 – 0.6 *(spawning, water column)* 0 – 0.15, 0.45 – 2.55 *(subadults and adults, water column)* 0.3 – 2.9 *(subadults and adults, bottom)*	≤ 0.2 *(spawning, water column)* 0.15 to 0.45 *(subadults and adults, water column)* 0 to 0.3 *(subadults and adults, bottom)*	Anglin et al. 2008 (Figure 20)*(spawning)*[56] Chandler 2003 *(subadults and adults habitat use), supported by similar values in Anglin et al. 2008 (Figures 28, 29)*
	Redband Trout	Substrate Size	cm	< 2 and > 6 *(spawning)*	N/A	2 - 6 *(spawning)*	Muhlfeld 2002[57] *(spawning)*
		Water Depth	cm	0 – 10 and 51 - 100 *(spawning)*	11-20 and 31 - 50 *(spawning)* 0 – 150 and 150 – 1000 *(subadults and adult habitat use)*	21 - 30 *(spawning)* 150 – 250 *(subadults and adult habitat use)*	Muhlfeld 2002 *(spawning)* Chandler 2003 *(subadults and adults habitat use)*[58]
		Water Velocity	m/s	0-0.2 and 0.71 - 1 *(spawning)*	0.21 – 0.4 *(spawning)* 0 – 0.15, 0.30 – 3.15 *(subadults and*	0.41 – 0.70 *(spawning)* 0.15 – 0.30 *(subadults and adults, water*	Muhlfeld 2002 *(spawning)* Chandler 2003 *(subadults and adults habitat use)*

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[54] Anglin, D.R>, Gallion, D.G., Barrows, M. et al. 2008. Bull Trout Distribution, Movements and Habitat Use in the Walla Walla and Umatilla River Basins. 2004 Annual Progress Report. Prepared by the USDOI and USFWS Columbia River Fisheries Program Office. Available at: https://www.fws.gov/columbiariver/publications/BT_Annual_Progress_Report_2004_FINAL.pdf

[55] Chandler, J.A., ed. 2003. Redband Trout and Bull Trout Associated with the Hells Canyon Complex. Idaho Power Company Technical Report Appendix E.3.1-7 Hells Canyon Complex FERC No. 1971. Available at: https://docs.idahopower.com/pdfs/relicensing/hellscanyon/hellspdfs/techappendices/Aquatic/e31_07_ch01.pdf

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[58] Chandler, J.A., ed. 2003. Redband Trout and Bull Trout Associated with the Hells Canyon Complex. Idaho Power Company Technical Report Appendix E.3.1-7 Hells Canyon Complex FERC No. 1971. Available at: https://docs.idahopower.com/pdfs/relicensing/hellscanyon/hellspdfs/techappendices/Aquatic/e31_07_ch01.pdf

Sub-Objective	Species	Core Performance Indicator	Units	Published Suitability Thresholds			References
				Poor	Fair	Good	
					adults, water column)	*column)*	
	Pacific Lamprey	Substrate Size	cm	≥ 1.7 (large gravel to bedrock) *(ammocoetes)*	0.9 – 1.6 (small gravel) *(ammocoetes)*	< 0.1 – 0.8 (fines) *(ammocoetes)*	Figure 5 in Stone and Barndt 2005
		Water Depth	cm	(a) < 60 *(ammocoetes)*	(a) 60 – 65 and 75 – 80 *(ammocoetes)*	(a) 65 – 75, (b) 40 – 50 *(ammocoetes)* 30 – 400 *(spawning)*	(a) Figure 3 in Stone and Barndt 2005[59] (b) Q3 in Luzier et al. 2009[60]
		Water Velocity	cm / s	> 40 *(ammocoetes)* > 180 (<6 f/s) *(adult migration) (higher velocities inhibit mobility past obstacles)*	10 – 40 *(ammocoetes)*	< 10 – -10 *(ammocoetes)* 50 – 100 *(spawning)* < 180 (<6 f/s) *(adult migration) (higher velocities inhibit mobility past obstacles)*	Figure 4 in Stone and Barndt 2005 *(ammocoetes; negative velocities indicate reverse flow or eddy environments)* Q3 in Luzier et al. 2009 *(spawning)* CalFish 2018[61] *(adult migrants)*
	Lost River and Shortnose Sucker	Lake Level	m / ft	≤1,261.87 m / 4,140.0 ft *(low larval survival)*	1,261.87 m / 4,140.0 ft to 1,262.48 m / 4,142.0 ft *(intermediate larval survival)*	≥1,262.48 m / 4,142.0 ft *(high larval survival)*	Figure 6 in Markle and Dunsmoor 2007[62]
		% Days with High-Wind Events (>16 km / h)	%	> 30	N/A	< 30	Cooperman et al. 2010[63] *(high winds resuspend detrimental bottom sediments)*
		Water Depth	cm	N/A	N/A	10 – 50 cm *(larvae)* 120 – 200 cm *(juveniles)* > 200 cm *(adults)* *(stream spawners)* 11 – 50 cm *(Lost River sucker)* 20 – 60 cm *(shortnose sucker)* *(lakeshore spawners)* 30 – 110 cm *(Lost River sucker)*	USFWS 2012 *(larvae, juveniles, adults)* Buchanan et al. 2011 *(spawners)*

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[59] Stone, J. and Barndt, S., 2005. Spatial distribution and habitat use of Pacific lamprey (Lampetra tridentata) ammocoetes in a western Washington stream. Journal of Freshwater Ecology, 20(1), pp.171-185.

[60] Luzier, C.W. and 7 coauthors. 2009. Proceedings of the Pacific Lamprey Conservation Initiative Work Session – October 28-29, 2008. U.S. Fish and Wildlife Service, Regional Office, Portland, Oregon, USA

[61] CalFish Species Profiles: Pacific Lamprey http://www.calfish.org/FisheriesManagement/SpeciesPages/PacificLamprey.aspx (original references missing)

[62] Markle, D.F. and Dunsmoor, L.K., 2007. Effects of habitat volume and fathead minnow introduction on larval survival of two endangered sucker species in Upper Klamath Lake, Oregon. Transactions of the American Fisheries Society, 136(3), pp.567-579.

[63] Cooperman, M.S., Markle, D.F., Terwilliger, M. and Simon, D.C., 2009. A production estimate approach to analyze habitat and weather effects on recruitment of two endangered freshwater fish. Canadian Journal of Fisheries and Aquatic Sciences, 67(1), pp.28-41.

Sub-Objective	Species	Core Performance Indicator	Units	Published Suitability Thresholds			References
				Poor	Fair	Good	
		Water Velocity	m/s	N/A	N/A	Stream spawners: 0.1 – 0.85 *(Lost River sucker)* 0.80 – 1.20 *(shortnose sucker)*	Buchanan et al. 2011[64]
	Green Sturgeon	Water Depth (pools)	m	0-4 and ≥10	5-7	8-9	Moser et al. 2016[65] and Wyman et al. 2017[66] *(both holding & spawning)*
		Water Velocity	cm/s	< 40 or > 130	50 – 80 or 110 – 112	80 - 110	Figure 5 in Wyman et al. 2017 *(spawning)*
		Discharge	m^3/s	N/A	< 100	100 – 200 *(triggers fall outmigration)*	Benson et al. 2007[67] *(outmigrating)*
	Eulachon	Water Depth	m	N/A	N/A	0.07 – 7.6 m *(spawning)*	NMFS 2016[68]
		Water Velocity	cm/s	N/A	N/A	Spawners: ≤ 40 *(higher flows limit upstream migration)*	NMFS 2011[69]
		Salinity	ppt	Eggs: ≥11 *(detach and die above threshold)*	Eggs: > 5.5 to <11 *(survival to hatch <10%)*	Eggs: 0 – 5.5 *(survival to hatch 21-25%)*	Gordon et al. 2012[70], citing Beak 1995.

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[64] Buchanan, D., M. Buettner, T. Dunne, and G. Ruggerone. 2011. Scientific assessment of two dam removal alternatives on resident fish. Klamath River Expert Panel Final Report prepared for the Secretarial Determination.

[65] Moser, M.L., Israel, J.A., Neuman, M., Lindley, S.T., Erickson, D.L., McCovey Jr, B.W. and Klimley, A.P., 2016. Biology and life history of green sturgeon (Acipenser medirostris Ayres, 1854): state of the science. Journal of Applied Ichthyology, 32, pp.67-86.

[66] Wyman, M.T., Thomas, M.J., McDonald, et al. 2017. Fine-scale habitat selection of green sturgeon (*Acipenser medirostris*) within three spawning locations in the Sacramento River, California. Canadian Journal of Fisheries and Aquatic Sciences, 75(5), pp.779-791.

[67] Benson, R.L., Turo, S. and McCovey Jr, B.W., 2007. Migration and movement patterns of green sturgeon (Acipenser medirostris) in the Klamath and Trinity rivers, California, USA. Environmental Biology of Fishes, 79(3-4), pp.269-279. Available from: http://logontowww.yuroktribe.org/departments/fisheries/documents/KlamathTrinityGreenSturgeonPublication2006_000.pdf

[68] NMFS. 2016. Recovery Plan for Eulachon (Thaleichthys pacificus). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, OR, 97232. 120 pp.

[69] NMFS. 2011. Critical Habitat for the Southern Distinct Population Segment of Eulachon: Final Biological Report. 59 pp. Available from: http://www.westcoast.fisheries.noaa.gov/protected_species/eulachon/eulachon_critical_habitat.html

[70] Gordon, M.R., A. Lewis, K. Ganshorn, and D. McLeay. 2012. Present status, historical causes of population decline, and potential for restoration of the Kitimat River eulachon (Thaleichthys pacificus). Prepared for the Haisla Nation Council (Kitamaat Village, BC) by M.R. Gordon & Associates Ltd., Ecofish Research Ltd., and McLeay Environmental Ltd. 44 pp.

Table 13: Proposed core performance indicators (CPIs) and published suitability thresholds for FLUVIAL AND GEOMORPHIC PROCESS related objectives.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
5.1 Increase and maintain coarse sediment recruitment and transport processes	Flow rate capable of mobilizing coarse sediment to improve spawning gravels (% days / year?)	cfs	0 – 5,000 cfs *(immobile to stable bed)*	5,000 – 11,250 cfs *(surface to deep flushing of surface or in-filled fine sediment)*	11,250 – 15,000 *(movement or individual armour layer particles, including gravels, up to reworking of armor and substrate layers)*	Table 4 in USFWS 2016[71] *(values assessed for the Klamath River downstream of Iron Gate dam, thresholds may vary by reach beyond these general classifications)*
5.2 Increase channel and floodplain dynamics and interconnectivity	Acres of seasonally inundated wetland	TBD	TBD	TBD	TBD	No benchmarks specified. Salwasser et al. 2002[72] proposes setting benchmarks as a % area relative to historical extent, or as % increases per from current baselines to the maximum extent considered feasible, where adequate historical data is not available. For the Klamath Basin, recent historical extent of wetlands from infrared imaging in 1982 are available from the USFWS via: https://www.fws.gov/wetlands/data/mapper.html
	Area available for channel migration which can be expressed as the Freedom Space	m^2 or km^2	Freedom space < L_{min} Space *Where L_{min} represents the minimal space for a river system to operate, i.e., for hydrogeomorphic and ecological processes to proceed.* L_{min} = M_{50} area (short-term mobility zone where there is a high risk of erosion or of avulsion (meander cutoff) over a 50-year period based on	Freedom space ≥ L_{min} Space	Freedom space ≥ L_{min} + L_{func} Space *Where the L_{func} space represents a wider zone beyond the L_{min} space, a corridor which is necessary for essential fluvial processes to operate for full floodplain development or.* L_{func} = $M_{floodplain}$ area (space that will be occupied by the river in the long term through meander migration based on the extrapolation of	Biron et al. 2014[73] See also Kondolf 2012[74]

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[71] USFWS. Response to Request for Technical Assistance – Sediment Mobilization and Flow History in Klamath River below Iron Gate Dam. Response from USFWS Arcata Office to USDOI. 28 pp. Available at: https://www.fws.gov/arcata/fisheries/reports/technical/Maintenance%20Flow%20Tech%20Memo%20Final.pdf

[72] Salwasser, H., L. Norris, and J. Nicholas. 2002. Expressing Oregon Environmental Benchmarks In Ecological Terms: Recommendations to the Oregon Progress Board. Progress Report 2 from the Science Working Group and Fish Benchmarks Summit Participants (November 19, 2002). Available from https://ir.library.oregonstate.edu/downloads/3197xr806

[73] Biron, P.M., Buffin-Bélanger, T., Larocque, M., et al. 2014. Freedom space for rivers: a sustainable management approach to enhance river resilience. Environmental management, 54(5), pp.1056-1073.

[74] Kondolf, G.M., 2012. The Espace de Liberte and restoration of fluvial process: when can the river restore itself and when must we intervene. Ch 18 in: River Conservation and Management, Wiley, pp.225-242.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
			the extrapolation of migration rates calculated from historical data) + area of F_{high} (0–20 year flood return period) *See reference for method of calculation.*		migration rates calculated from historical data) + area of F_{med} (20–100 year flood return period) - L_{min} *See reference for method of calculation.*	
	% of stream and off-channel habitat length with lost floodplain connectivity (due to incision, roads, dikes, etc.)	e.g., mi channelized / mi stream length	> 50 %	10 – 50 %	< 10%	Table 10 in Nelitz et al. 2007[75](citing Smith 2005)[76], for streams <1% gradient
5.3 Promote and expand establishment of diverse riparian and wetland vegetation that contributes to complex channel and floodplain morphologies	% Site Shade Potential Realized	%	TBD	TBD	TBD	CA: Figures 5.4-5.9 in NCRWQCB 2010[77] *(could use thresholds for overall shade for these benchmarks, i.e., >50% of site shade potential fulfilled might reflect Good status).*
	Total % Shade (Canopy Cover)	% Cover	General: <75% *(Not Functioning)* Coho: ≤70%	General: 75 – 95% *(At Risk or at At High Risk)* Coho: 71-80%	General: > 95% *(Properly Functioning)* Coho: >80%	General: Tripp and Bird 2004[78] Coho: Table 4-6 in NMFS 2014[79]
	Large Woody Debris Recruitment	Pieces Pieces / mile	Key Pieces*: <2 pieces** Streams < 20ft Wide***: <54 Streams 20-30 ft Wide: <37 Streams >30ft Wide: <34	Key Pieces: 2-3 pieces Streams < 20ft Wide: 54 - 84 Streams 20-30 ft Wide: 37 - 64 Streams >30ft Wide: 34 - 60	Key Pieces: >3 pieces Streams < 20ft Wide: >85 Streams 20-30 ft Wide: > 65 Streams >30ft Wide: >60	Table 4-6 in NMFS 2014 (for coho) *Key pieces of large woody debris are pieces with a minimum diameter of 60 cm (2 ft) and a minimum length of 100 m (33 ft) (Foster et al. 2001). **Pieces of wood are defined as all wood pieces that are greater than 12 inches in diameter at 25 feet from thelarge end. ***The number of pieces of wood in streams with a

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[75] 75 Nelitz, M., K. Wieckowski and M. Porter. 2007. Refining habitat indicators for Strategy 2 of the Wild Salmon Policy: Identifying metrics and benchmarks. Final report prepared by ESSA Technologies Ltd. for Fisheries and Oceans Canada. 79 pp. Available at: https://www.psf.ca/sites/default/files/335986.pdf

[76] Smith, C.J. 2005. Salmon Habitat Limiting Factors in Washington State. Washington State Conservation Commission, Olympia, Washington.

[77] NCRWQCB. 2010. Final staff report for the Klamath River total maximum daily loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California the proposed site specific dissolved oxygen objectives for the Klamath River in California, and the Klamath River and Lost River implementation plans.

[78] Tripp, D.B., and S. Bird. 2004. Riparian effectiveness evaluation. Ministry of Forests Research Branch, Victoria, BC. Available at: www.for.gov.bc.ca/hfd/library/FIA/2004/FSP_R04-036a.pdf

[79] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*)

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
						wetted width of less than 20 feet, between 20 and 30 feet, or greater than 30 feet.

Table 14: Proposed core performance indicators (CPIs) and published suitability thresholds for WATERSHED INPUTS related objectives.

Sub-Objective	Core Performance Indicator	Units	Published Suitability Thresholds			References
			Poor	Fair	Good	
6.1 Improve instream ecological flow regimes year-round for the Klamath River mainstem and tributary streams	# cfs returned to stream *(distinguish between temporary and permanent)*	count	TBD	TBD	TBD	No guidance on thresholds found.
	Monthly flows as % of modelled historical natural flows	%	TBD	TBD	TBD	Simulated historical natural flows at Link River and Keno dams are available via the USBR (see Ch 5 Summary), and could be used to set benchmarks: https://www.usbr.gov/mp/kbao/programs/docs/undepleted-klam-fnl-rpt.pdf
6.2 Reduce anthropogenic fine sediment inputs while maintaining natural and beneficial fine sediment inputs	% embeddedness	unitless	>30	25-30	<25	Table 4-6 in NMFS 2014[80] (for coho)
	% fines (<1 mm)	unitless	> 15 (wet) > 11.1 (dry)	12-15 (wet) 8.9-11.1 (dry)	< 12 (wet) < 8.9 (dry)	Table 4-6 in NMFS 2014 (for coho)
	Total suspended sediments	ppm	>80	25-80	< 25	Table 10 in Nelitz et al. 2007 (citing EIFAC and DFO 2000)[81], see also Stalberg et al. 2009[82]
	Miles 303d listed for sediment	%	N/A	>0.1 % of streams	0% of streams	Table 4 in Fesenmeyer et al. 2013[83] *(indicator at subwatershed scale)*
	Road density	mi / mi^2	> 3	3 – 2.5	< 2.5	Table 4 in Fesenmeyer et al. 2013 *(indicator at subwatershed scale)*
	Roads in riparian zone (miles road <200 m of steam / miles of stream)	mi / mi		0.25 – 0.1	<0.1	Table 4 in Fesenmeyer et al. 2013 *(indicator at subwatershed scale)*
6.3 Reduce external nutrient and pollutant inputs that contribute to	Tailwater return flows per season	# acre-feet	0-150	150-300	>300	Appendix A, Question 2 in SVRCD 2013[84] *(scored for a "tailwater neighbourhood", defined as "a*

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[80] NMFS. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (Oncorhynchus kisutch)

[81] Nelitz, M., K. Wieckowski and M. Porter. 2007. Refining habitat indicators for Strategy 2 of the Wild Salmon Policy: Identifying metrics and benchmarks. Final report prepared by ESSA Technologies Ltd. for Fisheries and Oceans Canada. 79 pp. Available at: https://www.psf.ca/sites/default/files/335986.pdf

[82] Stalberg, H.C., Lauzier, R.B., MacIsaac, E.A., Porter, M., and Murray, C. 2009. Canada's policy for conservation of wild pacific salmon: Stream, lake, and estuarine habitat indicators. Can. Manuscr. Fish. Aquat. Sci. 2859: xiii + 135p. Available at: http://pacgis01.dfo-mpo.gc.ca/documentsforwebaccess/wildsalmonpolicydocuments/WSP_Salmon_Habitat_Indicators_Report/WSP%20Salmon%20Habitat%20Indicators%20MS%202859%20report.pdf

[83] Fesenmeyer, K. Henrery, R., and Williams, J. 2013. California Freshwater Conservation Success Index: An Assessment of Freshwater Resources in California, with focus on lands managed by the US Bureau of Land Management Version 1.0, December 2013. Trout Unlimited Science program. 45 pp. (Note: Spatial extent of indices encompass entire Klamath Basin in CA and OR; 5-point indicator scale lumped to fit into 3 categories).

[84] Shasta Valley Resource Conservation District (SVRCD). 2013. Shasta River Tailwater Reduction: Demonstration and Implementation Project Final Project Report. 97 pp. Available at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/shasta_river/

biostimulatory conditions						*geographic area or mini-basin; where several fields contribute to a single tailwater return stream".)*

4 Candidate Restoration Actions

Chapter QA remains in-progress. Not the final draft.

NOTE TO REVIEWERS: Implicit in our approach to develop the Plan is a careful effort to explicitly reference existing & in-progress/planned restoration/monitoring ----- that is relevant to our focal fish species, their stressors, objectives and CPIs.

4.1 Purpose and Approach

Making progress towards watershed restoration goals requires first identifying those restoration actions best able to address the limiting factors identified in each objective. Leveraging the significant body of knowledge on river restoration reviewed in the prior Synthesis Report (ESSA 2017), we link each objective and its associated stressors with the restoration project classes and actions recognized to alleviate those stressors. This step narrows down the types of candidate actions that should be considered in restoration planning,and helps to inform the prioritization of individual restoration projects (discussed in Chapter 6) to ensure they are contributing towards for achieving basin-wide restoration objectives.

This Chapter:

- Relates types of candidate restoration actions to objectives, species, and key stressors within each sub-region (see Chapter 2 for linkages between individual actions & stressors, see Chapter 3 for details on objectives)
- Identifies the specific types of actions that address the most objectives, species, and key stressors in a given subregion, and provides specific examples of such actions identified as having a high benefit in regional species recovery plans or in IFRMP planning workshops.
- Identifies broad critical uncertainties associated with key candidate restoration actions in each subregion
- Provides broad principles for guiding the phasing of restoration actions, which will help to inform prioritization framework discussed further in Chapter 6.

This Chapter also proceeds with the understanding that the full suite of key IFRMP candidate restoration actions should address all key stressors across all focal species functional groups (Eulachon, Lamprey, Trout, Salmon, Sturgeon, Suckers) in the Klamath Basin. As such, Chapter 4 is closely tied to the conceptual models detailed in Chapter 2 and the objectives described in Chapter 3.

4.1.1 Multiple Lines of Evidence

Arriving at an understanding of which restoration actions can deliver the broadest possible benefit across objectives, stressors, and species requires examining multiple line of evidence (Figure 6).

Here, we integrate the best available knowledge derived from document review, conceptual models, participant surveys, and workshop activities to build an Integrated Tracking Inventory that documents the interrelationships between broad types of restoration actions and the goals and objectives, key stressors, and focal species functional groups which they have been documented as benefiting. Because this plan is intended to focus on those activities of greatest potential benefit, we have constrained our analysis on candidate restoration actions to only those types of actions meeting at least one of the following criteria: (1) associated with a key stressor in any conceptual model for a given subregion; (2) ranked 4 or 5 out of 5 for its ability to address a key stressor in online participant surveys or in workshops, or (3) highlighted as a recommended action in a focal fish species recovery plan. Given that this is a basin-wide recovery plan, readers interested in the most important restoration actions for a specific species in a specific location should defer to the recovery plan for that species.

Using the Integrated Tracking Inventory, it is possible to tally the number of goals and objectives, key stressors, and focal species each type of action will benefit and produce an initial ranking of action types based on anticipated overall benefit. These ranking tables should be interpreted with care, as numerical tallies may not always completely reflect the importance or effectiveness of a specific type of action. For example, an action may address only a single stressor, but that stressor may be considered to be overwhelmingly responsible for declining fish populations in a given subbasin. Similarly, a type of action may be perceived as high benefit, but this is contingent on application of that action at a sufficient spatial and temporal scale. Although the method used for ranking is coarse, it can still help to provide evidence-based answers to the following questions:

- *What candidate actions in my subregion address the most objectives, species, and stressors? (i.e. distinguish more 'generalist' actions from. 'specialist' actions)*
- *Which actions provide the broadest benefits across stressors for a given objective or species functional group?*
- *Which objectives or species functional groups receive the least benefit from the suite of actions currently available? Could novel apporaches or collaborations be developed to address these gaps?*

To facilitate interpretation and add additional context to high-ranking action types, actions appearing within the ranking tables are assembled into packages of related actions within each functional watershed tier. These packages are then presented in a table with supporting information on potential focal areas within a subregion (sub-basins, tributaries, lakes) that might benefit most from such actions as well as specific examples of such actions that have already been proposed in existing restoration or recovery plans.

This initial ranking exerise provides a coarse filter selecting for types of restoration actions with the broadest possible benefits. Moving forward, action type rankings can be used as "breadth of benefit" weightings alongside other criteria in the subsequent application of the Prioritization Framework (see Chapter 6), which provides a fine filter for selecting specific project proposals. The prioritization step will also consider questions of *what* specific types of restoration actions should be implemented, and *where*. The resulting set of recommended projects emerging from each iterative application of the prioritization framework provides a starting point for more focused expert deliberation on the best investments in restoration for achieving basin-wide recovery.

The following sections present high-level action type rankings and supporting information for each subregion of the Klamath Basin. More detailed versions of these rankings specifying exactly which focal species and goals and objectives each action addresses are provided in **Appendix C**.

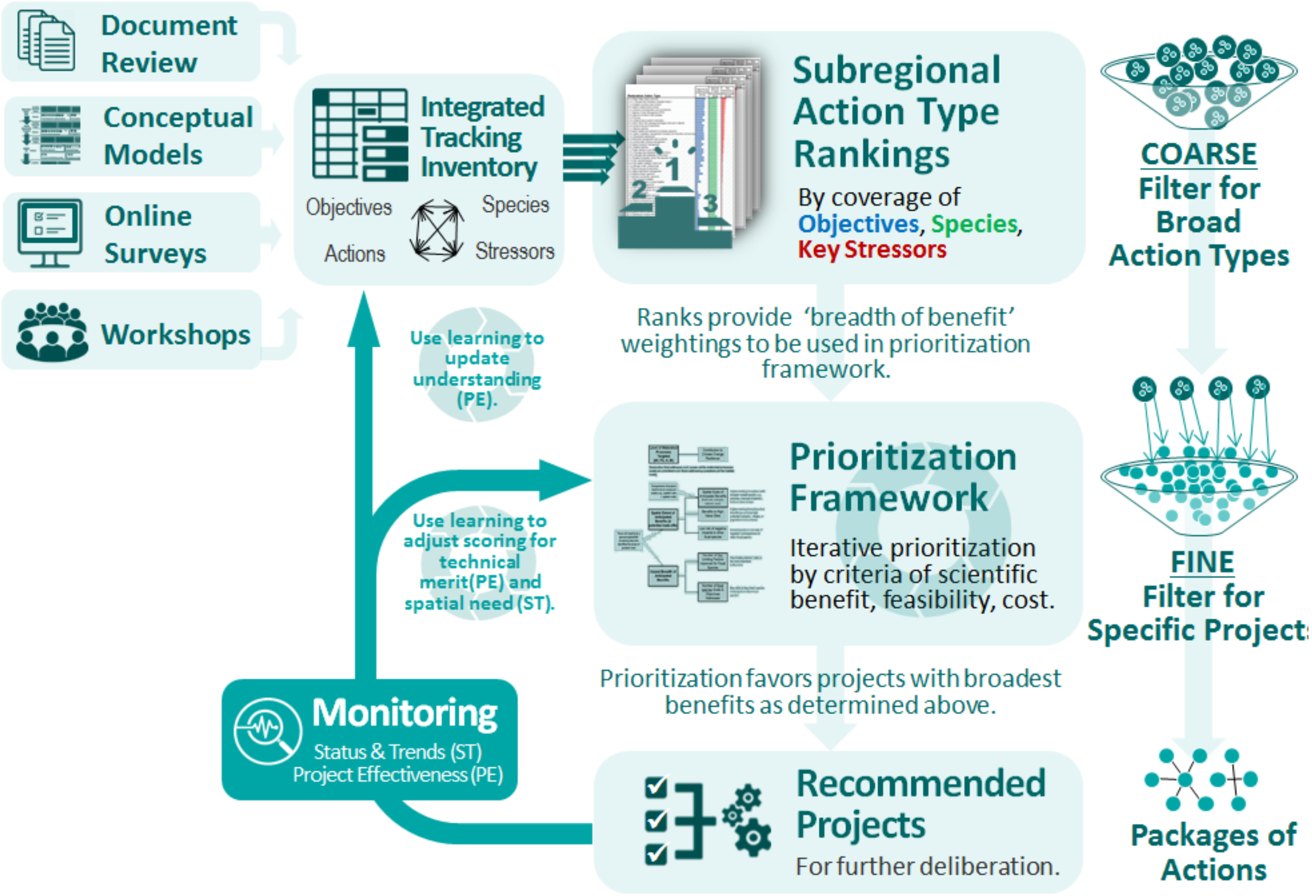


Figure 6. Flowchart of multiple lines of evidence approach used to rank broad types of actions according to the number of objectives, stressors, and species they are expected to benefit in a given subregion, and how this information flows into prioritization and the ultimate selection of specific projects. As projects are implemented, monitoring can result in new understanding that feeds back into iteratively applied ranking and prioritization schemes.

4.2 Basinwide Trends

TO DO / IN PROGRESS

NOTE TO REVIEWERS: this section is in outline form with various straw examples, comments and questions to stimulate creativity and feedback. **The figures in sections 4.2, 4.3, 4.5 and 4.5 are not final, relationships still undergoing QA/QC and will be update for the final report.**

Databases describing existing projects may have gaps, but summares of such data can still be helpful for illustrating the differences between 'generalist' and 'specialist' restoration actions. Figure 7 provides a basinwide summary of action-stressor pairings across all species groups. The stressors most commonly addressed by restoration projects included in these databases ar *water quality* (30% of unique stressor-action pairs), *channel structure/form* (20%) *water quantity* (~15%) and *injury and mortality* (~15%). Figure 7 illustrates a set of more 'generalist' actions that target a wide range of stressor categories. These actions include projects focused on fish passage improvement, instream flow, instream habitat, riparian habitat, wetland, and upland habitat/sediment. . Relative to other actions, those related to instream flow tend to address several stressors. Projects focused on water quality, fish screening, harvest management and estuarine/nearshore issues tend to be 'specialist' actions that are more targeted at individual stressor categories.

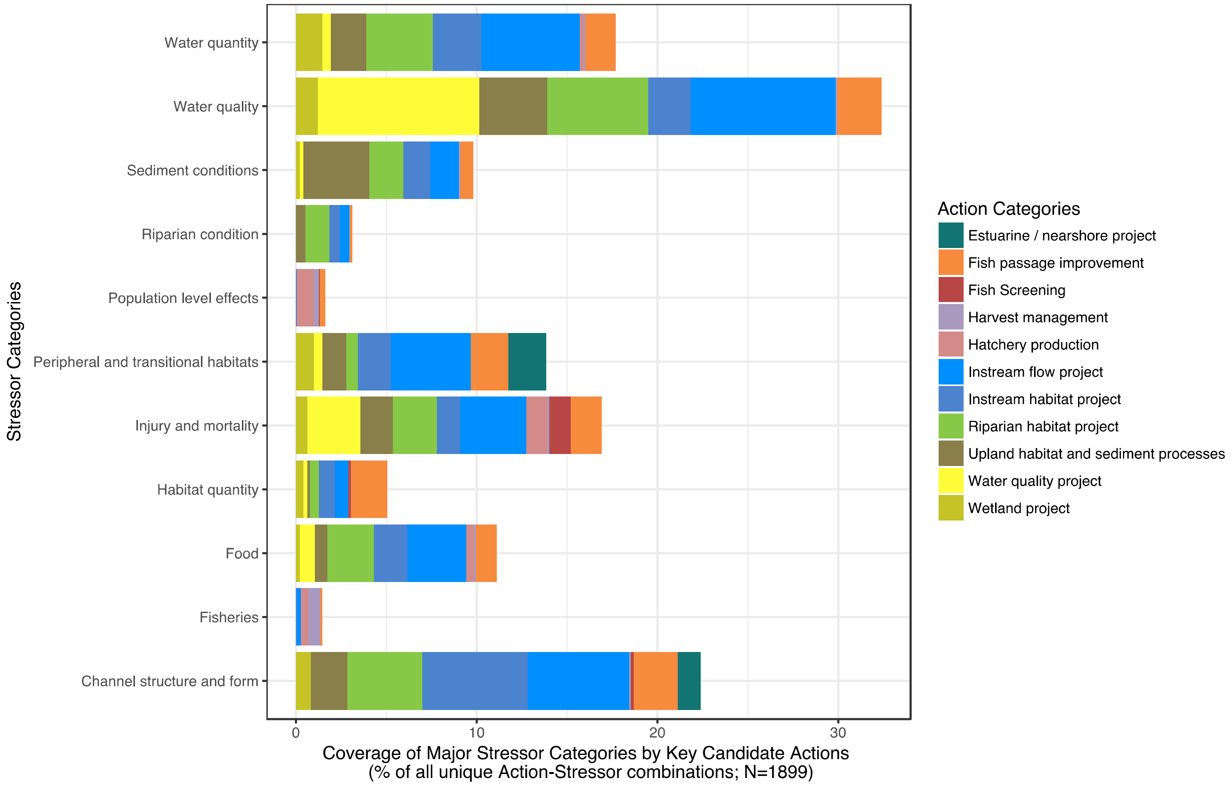


Figure 7. Basinwide Count-based Coverage of Stressors by Key Candidate Actions (Aggregated into Major Action and Stressor Categories)

Existing data bases can also serve to illustrate the alignment of restoration projects against basinwide objectives. We estimated the relative coverage of basinwide objectives by summing the number of key restoration (i.e., identified as important my at least one source in the multiple lines of evidence approach) actions that address the stressors each objective is designed to alleviate. Figure 8 shows that a total of 73 unique actions are identified as key to accomplishing the 22 objectives. This coverage is reported in aggregate over the entire Klamath Basin; tabulations at the scale of subregions showed a similar pattern.

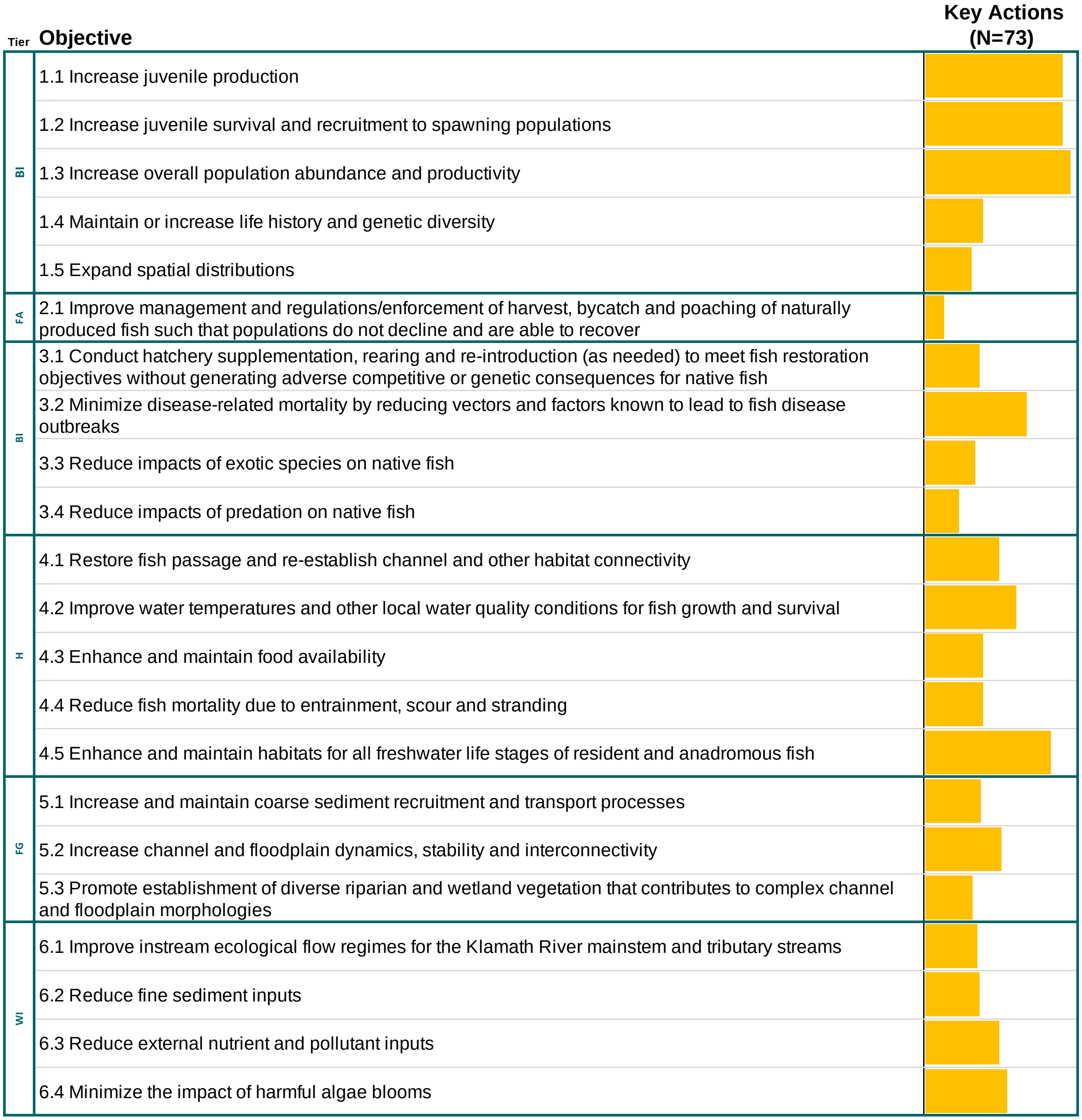


Figure 8. Count-based Coverage of Objectives by Key Candidate Actions for all Subregions & Klamath River Estuary

Figure 8 indicates that all objectives have some degree of coverage by candidate restoration actions. Those associated with the widest range and number of actions are focused at two tiers Biological Interactions and Habitat. Most candidate actions address one or more stressors.

4.3 Upper Klamath Lake Sub-region (UKL)

TO DO / IN PROGRESS

This section synthesizes the outcomes of our approach to ranking the types of restoration actions with the broadest benefits across objectives, species, and key stressors in the Upper Klamath Lake sub-region, using multiple lines of evidence.

4.3.1 Key Candidate Actions

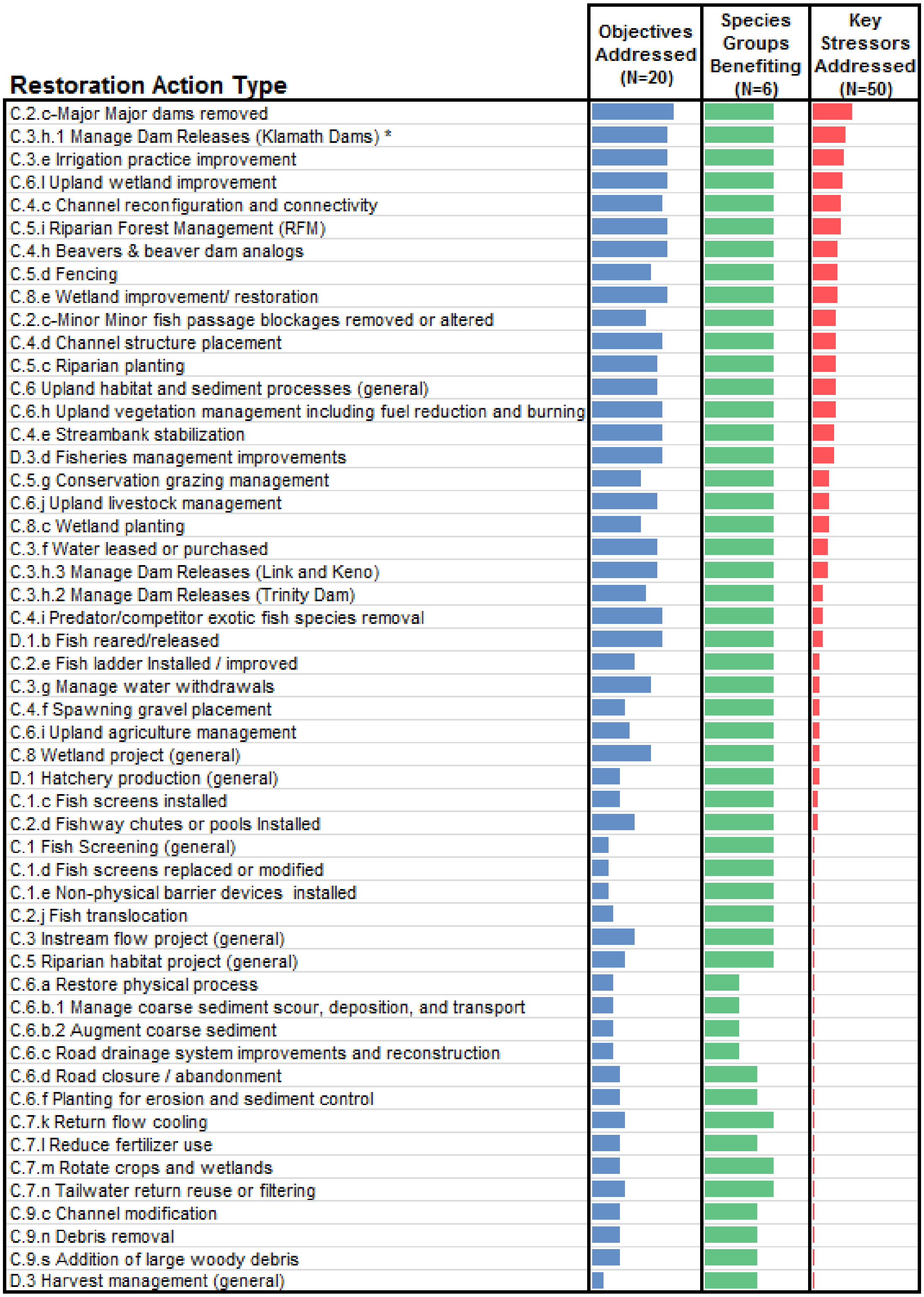
TO DO / IN PROGRESS

In total, 52 key candidate actions and 50 unique stressors are identified for UKL, and are listed in order of descending broadest benefit in Table 15 (defined in terms of the number of objectives addressed, number of species benefitting, and number of key stressors addressed). The accompanying Table 16 organizes this list into packages of similar actions and provides additional context on the areas (sub-basins, tributaries, lakes) in greatest need of these actions, based on our current understanding of the distribution of stressors, and on the specific types of projects within this category that have already been proposed by existing plans.

Once complete, the remainder of this section will include a discussion of:

- Broad patterns across the list of top-ranked projects within a sub-regional context.
- Comparison of the ranking emerging from Table 15 with the prioritization scheme in Chapter 6, noting what prioritization criteria are implicitly or explicitly included in Table 14, and which criteria are excluded
- Grouping or clustering of actions that would logically be implemented at the same time to address a stressor(s), address an objective related to an ecosystem process or component
- Candidate actions near the bottom of the list that may appear to have narrow benefit, but which local context shows are disproportionately important to address.
- Referring to the expanded tables in Appendix C, highlighting gaps in action coverage of specific species functional groups and of goals and objectives.
- Any critical uncertainties, tradeoffs, unintended consequences, or other important considerations for highly-ranked types of actions within this subregion.

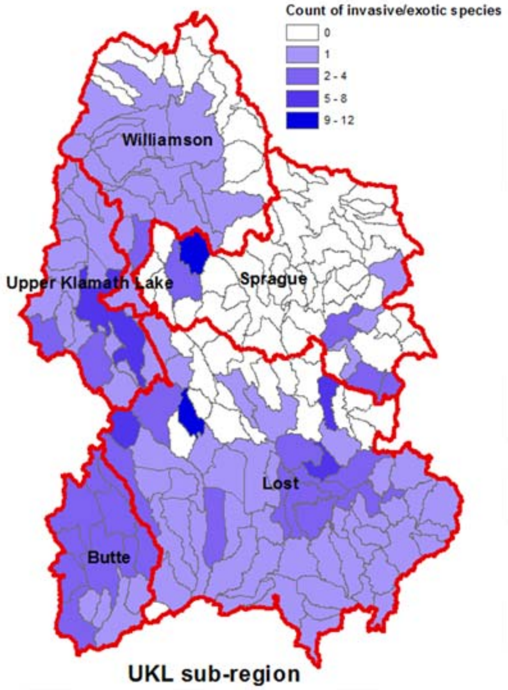
Table 15: Ranking of key candidate restoration actions ranked in descending order of those anticipated to yield the broadest benefits across objectives, species, and key stressors if implemented in the Upper Klamath Lake sub-region (here ranked first by key stressors). *(note - ranking not final, QA/QC still underway)*

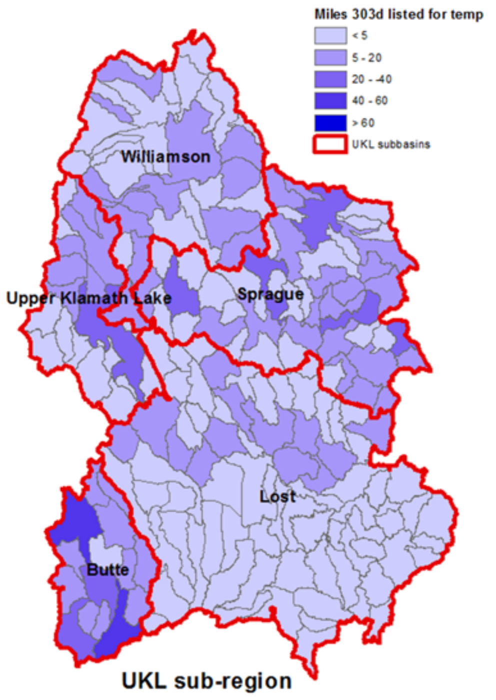
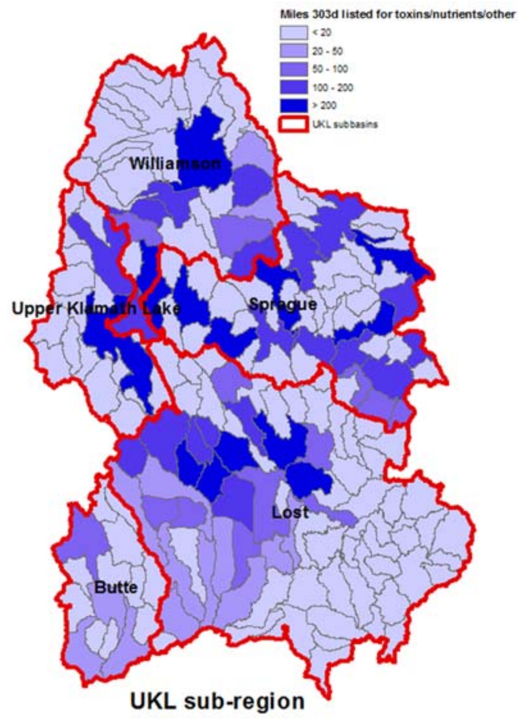


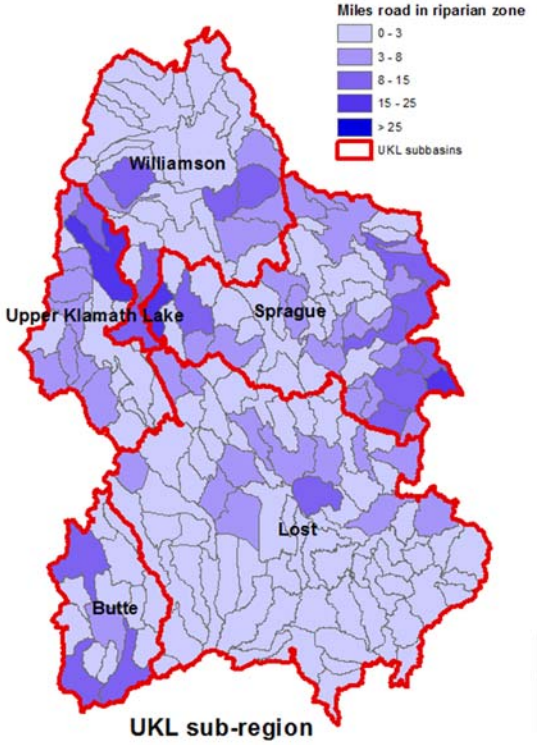
* This action would only be relevant prior to prospective dam removal.

Table 16: Table of highest-ranking restoration actions organized into packages within each functional watershed tier, with supporting contextual information on potential focal areas and similar actions that have already been proposed in existing recovery plans or through the IFRMP workshop activities. Note that within each package, actions are listed in descending order of broadest benefit based on their original sequencing in the master ranking. Codes for actions are explained in Appendix B.

Rows included are <u>draft examples only</u>, final version will extend across all top-ranked action packages.

		Broad-Based Actions *(top ranked in prior sorting exercises)*	**Potential Focal Areas** *(from participant input, plans, TU CSI)*	**Potential Candidate Projects** *(from participant input, plans)*
Fish Populations & Biological Interactions	Population Maintenance Package	- Predator/competitor removal (C.4.i)	Focus on the Upper Klamath Lake, Sprague and Williamson Subbasins, which have the worst ratings across subwatersheds within the Trout Unlimited Conservation Success Index for Introduced Species Richness, which are based on counts of introduced or exotic species present (Fesenmeyer et al. 2013). While the Lost River Subbasin also has high numbers of invasive species present, it is not as biologically significant for focal species as the other subbasins mentioned here  Counts of invasive/exotic aquatic species in each UKL sub-watershed (TU / Fesenmeyer et al. 2013)	<u>From Species Recovery Plans</u> • Remove brook trout from Upper Klamath Lake (specifically focusing on Annie Creek, Sevenmile Creek, Cherry Creek, Fort Creek, Crooked Creek, and adjacent habitats), Sycan River (in stream reaches where historic bull trout local populations were extirpated - Calahan Creek, Coyote Creek, Boulder Creek, Rifle Creek, the South Fork Sycan River, and upper Sycan River), and Upper Sprague (in stream reaches where historic bull trout local populations were extirpated - Leonard Creek, Brownsworth Creek, Boulder Creek, Dixon Creek, Camp Creek, Corral Creek, upper North Fork Sprague River, and upper South Fork Sprague River). (USFWS 2015) • Brown trout removal in Upper Sprague (in stream reaches where historic bull trout local populations were extirpated - Leonard Creek, Brownsworth Creek, Boulder Creek, Dixon Creek, Camp Creek, Corral Creek, upper North Fork Sprague River, and upper South Fork Sprague River) (USFWS 2015) • Interactions between bull trout and brown trout should be studied and control of nonnative species should take place to reduce impact on bull trout (USFWS 2015). • Determine distribution of Smallmouth Bass (introduced species) on Redband Trout in the North Fork Clearwater River (IRCT 2016) • Reduce impact of introduced salmonids on Redband populations (removal using barriers, piscicide, mechanical), prevent introduction of new invasive species, restock Redband trout (and regularly swamp gene pool with native Redband trout), and develop Redband fish management plans to reduce impacts of stocked rainbow trout. (IRCT 2016) • Clarify and reduce the effects of introduced species (eg. yellow perch, fathead minnow) on all life stages of Suckers in the Lost River (Upper Klamath Lake) by conducting and applying scientific investigations and controlled experiments (USFWS 2012).

Habitat	Improved Water Quality Package	- Irrigation practice improvement (C.3.e) - Upland wetland improvement (C.6.l) - Upland livestock management (C.6.j) - Wetland improvement/ restoration (C.8.e) - Manage dam releases (Link & Keno) (C.3.h.3) - Targeted aeration (C.7.r) - Phosphorus immobilization (C.7.s) - Dredging of lake/reservoir sediment (C.7.q) - Algae harvest (C.7.p) - Riparian planting (C.5.c)	In the UKL Sub-region focus on Upper Klamath Lake (Wood River), Sprague (Sprague River), and Williamson (Williamson River) Subbasins which have the most miles of stream 303(d) listed for temperature (Fesenmeyer et al. 2013). All three subbasins also have many miles of stream 303(d) listed for toxins/nutrients (Fesenmeyer et al. 2013). The Lost River Subbasin has many miles of stream 303(d) listed for toxins/nutrients, but it is not as biologically significant to IFRMP focal species as the other subbasins mentioned here so considered less of a priority. No IFRMP focal species are found in the Butte Subbasin.  Miles of stream in each UKL sub-watershed 303d list for water temperature impairment (TU / Fesenmeyer et al. 2013)  Miles of stream in each UKL sub-watershed 303d list for impairments from toxins and nutrients (TU / Fesenmeyer et al. 2013)	From Species Recovery Plans - USDA Forest Service Water Quality Restoration Plan for Upper Klamath Basin (IRCT 2016) - Identify areas to increase stream flows to improve habitat for Redband trout, and acquire water rights (especially at Annie Creek and Crooked Creek) (IRCT 2016) - Research the dynamics of algae cycles and algal toxin microcystin on Sucker populations at Upper Klamath Lake (USFWS 2012) From Workshop Input - Install aeration in Keno Reservoir to address anoxic barrier to fish passage - Restructure Keno Dam to reduce water residence time and improve water quality in reservoir and downstream - Develop Safe Harbour and HCPs with Upper Basin landowners that contribute largest nutrient loads to UKL, and broker agreements to reduce or eliminate inputs over the long-term - Agricultural land retirement

Fluvial Geomorphic Processes	Riparian Condition Improvement Package	- Riparian forest management (C.5.i) - Riparian planting (C.5.c) - Riparian fencing (C.5.d) - Conservation grazing management (C.5.g)	In the UKL Sub-region focus on the Sprague (Sprague River), and Williamson (Williamson River) Subbasins which have the most miles of road in riparian zones (Fesenmeyer et al. 2013).  Miles of road in riparian zones in each UKL sub-watershed (TU / Fesenmeyer et al. 2013)	From Species Recovery Plans - Restore riparian vegetation and ecological function (through fencing, native species planting, levee removal/floodplain reconnection) to support all life stages of Redband trout with focused efforts in Fishhole Creek, Fivemile Creek, Meryl Creek, North Fork Sprague River, South Fork Sprague River, and Upper Sycan watersheds (see IRCT 2016 pg. 65-77 for more details) - USDA Forest Service work to adjust livestock grazing strategies to improve riparian and stream conditions in the Upper Williamson River, North/South Fork Sprague River, and Upper Syncan River (IRCT 2016). - Restore in-stream riparian vegetation in Williamson (Annie Creek, Crooked Creek), Lower Williamson (Larkin Creek, Sunnybrook Creek), in to support all life stages of Redband trout. (IRCT 2016) - Conserve and restore riparian areas and determine the importance of in-stream rearing habitats of Suckers in the Sprague River and Willow Creek. (USFWS 2012).

4.4 Middle/Upper Klamath River Subregion (MUK)

TO DO / IN PROGRESS

This section remains to be completed using a parallel structure as presented for UKL.

4.5 Lower Klamath River (LKR) Sub-region & Klamath River Estuary (KRE)

TO DO / IN PROGRESS

This section remains to be completed using a parallel structure as presented for UKL.

4.6 Phasing of Restoration Actions

TO DO / IN PROGRESS

Because of the hierarchical nature of watershed processes, the outcomes of some types of restoration actions are dependent on adequate function of supporting processes. From this natural hierarchy follows the most overarching principle for the pursuit of restoration activities: *first treat the most underlying cause of ecosystem dysfunction before treating the symptoms arising from that underlying cause*. Carefully considering such dependencies during restoration planning can help to ensure the maximum potential benefits of restoration actions are realized.
Emphasis on underlying causes yields intuitive principles for the phasing of types of restoration actions, both across and within watershed functional tiers (i.e., watershed inputs, fluvial geomorphic processes, habitat, and biological interactions)(Roni and Beechie 2013)(Figure 9):

- **Across tiers**, restoration phasing should focus first on restoring the most fundamental watershed processes at the base of the hierarchy in Figure 9, in this case watershed inputs processed related to flow and water quality, which will yield benefits throughout successive levels that build on the foundation of well-functioning watershed inputs.[1] . Once monitoring demonstrates that performance indicators in this tier have moved past the threshold of "fair" or "good" indicator status with restoration, natural resource managers may shift their focus onto restoration of watershed processes in the next dependent tier, and so on. For example, water quality must be improved to suitable levels within a reach and at least to the levels of currently accessible habitat (Watershed Inputs tier) before passage barriers are removed (Habitat tier) or channels reconnected (Fluvial Geomorphic Processes tier) to allow fish access to that reach.

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[1] Note that the tiers in Figure 9 are organized from bottom to top, like Maslow's Hierarchy of Needs, while the tiers of the conceptual model are organized from top to bottom.

- **Within tiers**, restoration phasing should focus on preventing further degradation by an underlying cause before pursuing improvements. For example, restoration of riparian habitat should ensure that the underlying cause of cattle grazing is addressed through exclusion fencing before attempting habitat improvements through riparian planting.
- **Protect well-functioning areas.** In areas where conditions are naturally above the threshold of “good” for all core performance indicators in all watershed tiers, or have improved to this degree through restoration, resource managers should emphasize protection rather than ongoing restoration.

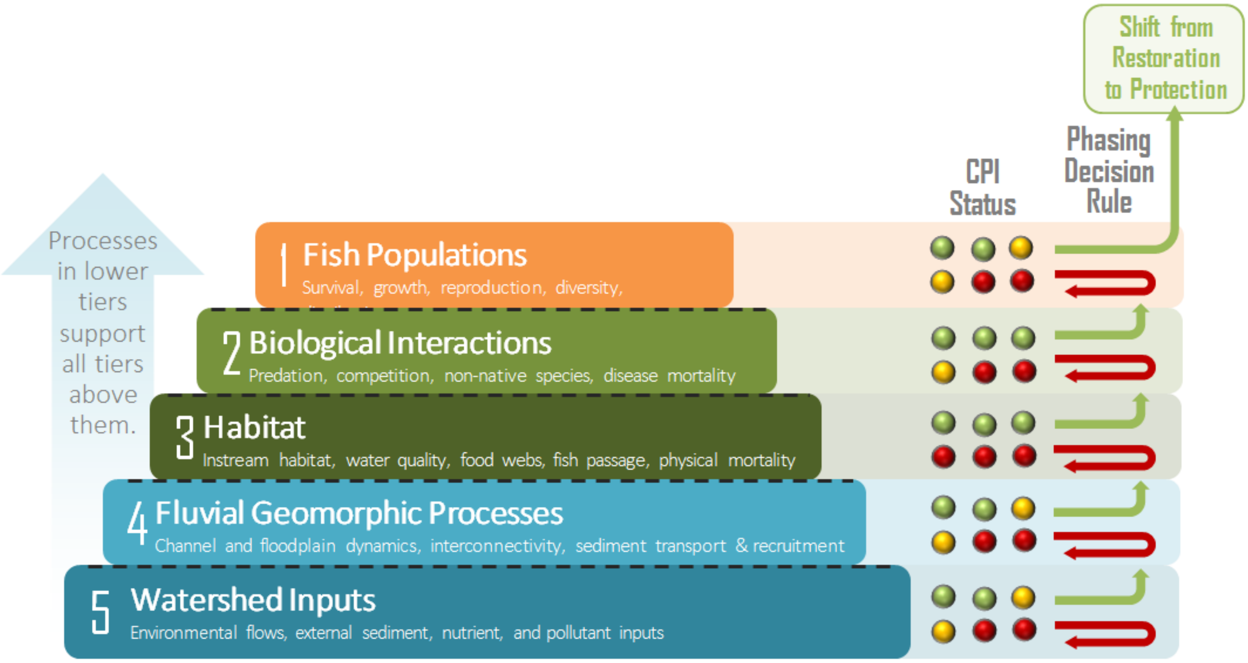


Figure 9. Schematic illustrating the concept of phasing restoration by tier of watershed processes, where restoration should focus first on addressing the most underlying causes at the base of the hierarchy before carrying out restoration in other tiers that rely on this foundation (after Roni and Beechie 2013, Harman et al. 2012).

The one exception to this rule of thumb are **emergency measures needed to prevent short-term extinction** until broader actions in foundational tiers can be completed. As an example, the emergency measure of rearing and releasing juvenile sucker has been implemented as a stop-gap measure to improve juvenile survival until the underlying causes of poor survival, among them poor water quality and habitat degradation in Upper Klamath Lake, can be addressed. Where a species is at risk of imminent extinction, emergency measures such as these should take precedence over any actions to address underlying factors.

4.7 Critical Uncertainties Associated with Key Candidate Actions

TO DO / IN PROGRESS

Discuss with Darcy where we may best consolidate a discussion of critical uncertainties; perhaps in the monitoring section re: effectivenss monitoring.

Also, we need to make it clear how critical uncertainties are handled within an adaptive management context.

This section will discuss:

- Uncertainties about the effectivenss or feasibility of some action types
- Uncertainties related to dependencies across types of actions
- Trade-offs and possible unintended consequences of actions

5 Monitoring of Key Performance Indicators

TO DO / IN PROGRESS

NOTE TO REVIEWERS: Several chapters and sections of the Initial Rough Draft IFRMP are in outline form with various straw examples, comments and questions to stimulate creativity and feedback. This in progress draft document is intended to be a repository for ideas and options – feel free to add yours as comments. Critical filtering and editing of these ideas and options is essential but will happen later. Each major section has an Introduction to provide some context, which describes the Purpose, Challenges, and Proposed Approach.

This document represents the second phase in five phase process to develop the IFRMP. From a monitoring point of view, the goal of Phase 2 is to scope the monitoring framework, setting the stage for Phase 3 where the detailed monitoring plans will be developed as part of the overall monitoring framework. Section 5.1 provides a brief overview of concepts and terminology. Section 5.2 describes high level vision for the monitoring framework. Section 5.3 describes the proposed approach to completing the monitoring framework including: gap analysis, integration, and templates for developing detailed monitoring plans. Section 5.4 provides guidance on prioritization of monitoring. Several case studies are shown for illustration purposes to demonstrate the path forward in Phase 3 (Section 5.5).

5.1 Purpose

Monitoring plays a key role in understanding how various stressors cumulatively affect the overall status and trends of fish populations and also in gauging how successful management actions are at reducing these stressors and improving fish survival. For the purposes of this document, we delineate two main categories of monitoring: (1) status and trend monitoring and (2) action effectiveness monitoring.

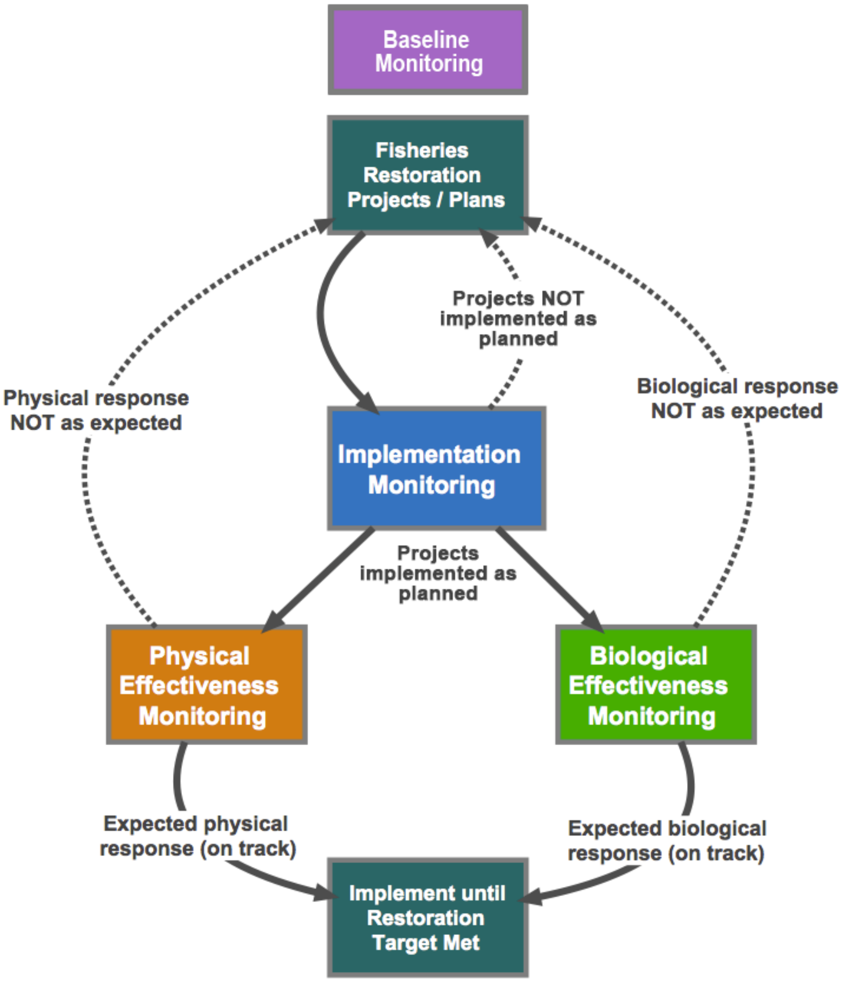


Figure 10. This figure illustrates the relationship between the different components of effectiveness monitoring.

Status and Trend (ST) monitoring provides information about changes in anthropogenic and natural stressors, habitat attributes, and fish populations, and can be divided into **Habitat Monitoring** and **Population Monitoring**. Action Effectiveness (AE) monitoring tracks how well specific classes of restoration projects are meeting their desired goals, objectives and outcomes. Action effectiveness monitoring can be further divided into five sub-types: (1) **Baseline Monitoring**; (2) **Implementation Monitoring** (which may also include associated compliance monitoring) (3) **Physical Effectiveness Monitoring**; and (4) **Biological Effectiveness Monitoring**. Figure 2 demonstrates the relationship between these four sub-types and how they are used together to assess OVERALL action effectiveness.

Both categories of monitoring may be relevant at local, sub-basin, or basin-wide spatial scales (Figure 3). For example, action effectiveness monitoring might focus on a single local scale restoration project or on the combined result of many projects at the basin scale.

Status and trend monitoring programs tend to be long-term consistent monitoring programs while action effectiveness monitoring programs often change over time depending on the phase of the restoration and speed of the response. Effectiveness monitoring is eventually phased out in favor of status and trend monitoring. **For the purpose of the IFRMP, the focus is on basin-wide status and trends and action effectiveness monitoring.** Useful guidance to high-level thinking on monitoring is presented in Figure 12 – begin by identifying key decisions and questions.

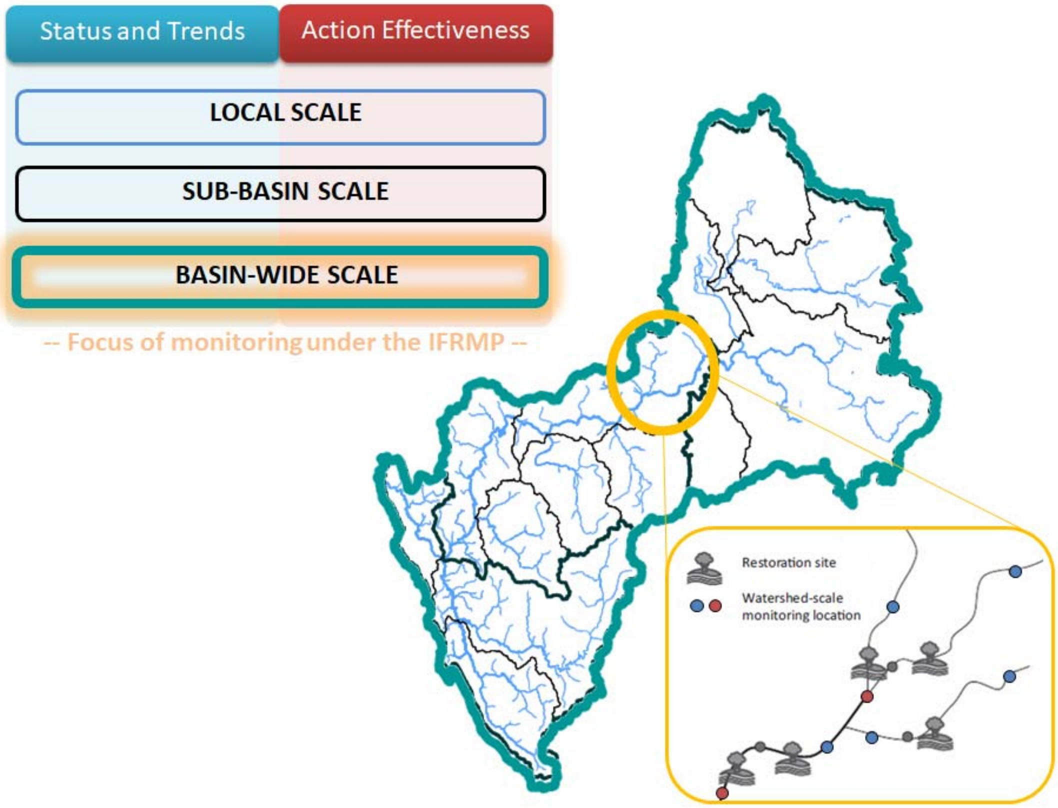


Figure 11. Both status and trends monitoring and action effectiveness monitoring may be used to answer questions at multiple spatial scales.

5.2 Monitoring Framework

The basic components of any monitoring program include:

- the decisions / questions (i.e., the **why**);
- the indicators (i.e. the **what**);
- the sampling design which describes **where** and **when** measurements are to be made, as well as the process by which those locations and times are selected; and
- the response design which describes **how** data will be collected (i.e., the field protocol) and subsequently analyzed and reported.

Designing an effective monitoring system requires thorough consideration of each of these components. While there is a natural sequence, these components are not independent of each other and it is often necessary to step back and revisit an earlier step before converging on an optimum design. The '80:20 rule' is an effective approach to ensure progress continues; start from the top and work down through the steps, but when things start to bog down, move to the next step and iterate back later rather than trying to perfect any one step in the process.

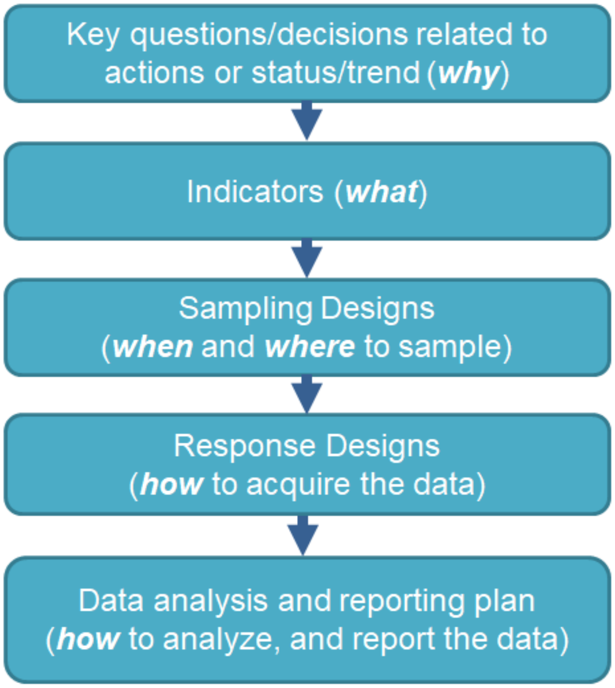


Figure 12. Components of the monitoring framework, including: why, what, when, where, and how data are collected and analyzed, adapted from Data Quality Objectives Process (EPA 2006).

Developing an effective monitoring design is relatively simple if the **problem is well defined**. Many monitoring programs fail or are inefficient (i.e., waste money) due to poor problem definition (Reynolds et al. 2016). Data are collected which don't end up being used or are inadequate to answer the questions of interest with sufficient precision in a useful timeframe at the right spatial scales. It is absolutely critical to think through how the data will be used to answer the questions of interest (Section 2) and inform management decisions at the outset. This is a fundamental concept recommended by the Environmental Protection Agency's Data Quality Objectives approach (EPA 2006).

The IFRMP Phase 1 Synthesis Report (ESSA 2017) proposed a simple organizing framework starting with Watershed Inputs and working down through the ecosystem to Biological Responses. Development of detailed conceptual models (Section 2) builds on this simple framework. Conceptual models provide a systems perspective of the linkages among physical, chemical, and biological components / processes in an ecosystem along with natural and anthropogenic stressors. These conceptual models can then be used to help identify what appropriate performance indicators best capture the pathways of effects between ecosystem stressors, potential management actions and related decisions.

Deciding **what indicators** to measure is a critical part of any monitoring framework. Careful thought at this stage ensures best use of the often limited funds available to collect and analyze data. Section 3 describes the process by which candidate performance indicators were evaluated and narrowed down to a smaller list of Core Performance Indicators (CPI) which will act as the 'vital signs' of the IFRMP. The CPI will be the focus of the long term basin-wide monitoring framework, although they do not preclude monitoring of additional indicators as needed to reduce specific uncertainties or dig deeper into concerns identified by performance of the CPIs.

Developing a **sampling design** requires an understanding of the spatial and temporal aspects of the study, both in terms of the decisions being made and the variability of the data. In general, key components include: (1) target population, (2) sample frame (the complete list of sampling units from which a sample is selected), (3) sample unit(s); (4) strata; (5) selection of sites (e.g., probabilistic sample, census, convenience sampling); (6) timing and frequency of sampling, both within a year and across years; and (7) allocation of effort across time and space. Development of the **response design** must consider the cost and feasibility. Where possible, leverage established programs and associated field protocols. However, practitioners are also encouraged to consider new and emerging methods. The level of sampling effort (number and frequency of samples) required depends on the desired precision and statistical power as well as the response design itself. A typical trade-off occurs between spatial coverage and precision, a less precise assessment (e.g., aerial photo interpretation) is possible at a broad spatial scale where more precise assessments (e.g., vegetation plots) are too costly to complete at a large number of sites. Implicit in the **data analysis and reporting** plan is the need for a data management and sharing system. While the IFRMP is not the vehicle for developing a data management system, it will serve as road map to help identify 'who' is doing what.

In general, the same considerations are applicable to both status & trends monitoring and action effectiveness monitoring. A key difference with action effectiveness studies is that there is a <u>manipulative component</u>, in other words there is some degree of control over the treatment (i.e., restoration action). This allows for the potential to involve experimental design principles such as randomization and replication. However, river restoration projects are somewhat constrained in their inherent connectivity. Before-After or Before-After Control-Impact designs are the most common experimental design approach employed in river restoration with controls typically occurring upstream of treatment sites (Roni et al. 2013a). The other typical difference with action effectiveness monitoring programs is that the <u>nature and intensity of monitoring required may change over time</u>. For example, detailed abundance surveys above the dams aren't necessary until evidence of recolonization is observed. Likewise, many physical responses may be triggered by high water events. Adaptive Management (AM) provides a systematic and rigorous approach to evaluate and reduce uncertainites (Marmorek et al. 2006). The IFRMP will apply an AM framework to effectiveness monitoring of implemented actions which have critical uncertainties. This will result in a flexible monitoring design that anticipates and directly responds to observed changes.

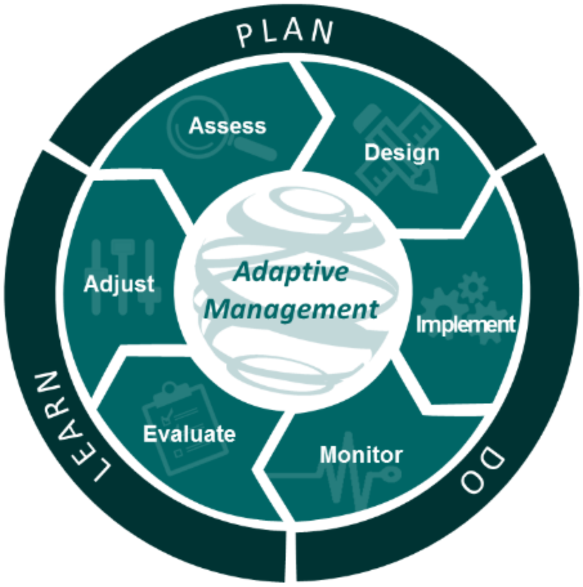


Figure 13. Schematic of the six steps of Adaptive Management which will be applied to action effectiveness monitoring to develop a flexible monitoring design that anticipates and directly responds to observed changes. (ESSA 2018).

The IFRMP monitoring framework will eventually consist of a series of detailed monitoring plans for all high priority status and trend and action effectiveness questions across sub-basins and species organized into a cohesive document. The information for each detailed monitoring plan will be contained within appendices in the final IFRMP, with simple tabular summaries provided up front to allow the reader to quickly assimilate information across sub-basins, species, and questions but still dive deeper as needed. Where existing programs already address IFRMP questions, the monitoring framework will summarize the relevant information, supplement as necessary (e.g., if new analysis is required for an existing dataset) and reference the applicable program or report (Figure 14).

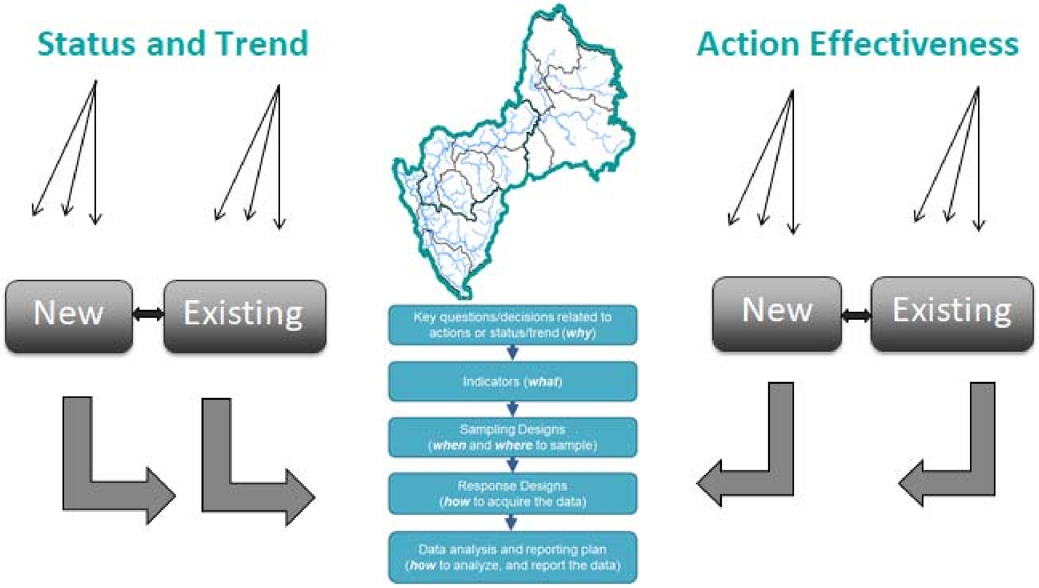
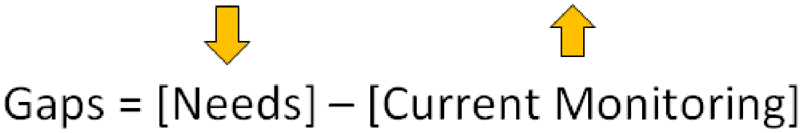


Figure 14. This figure illustrates how the detailed monitoring plans will be organized using a consistent structure and compiled to make up the IFRMP monitoring framework.

5.3 Approach

We use a combined top-down and bottom-up approach to begin developing the basin-wide monitoring framework. The IFRMP goals and objectives (Section 3) and associated monitoring questions / management actions will enable us to define the IFRMP monitoring needs. The needs can then be compared to the current monitoring initiatives across each sub-basin (Figure 15). In some cases the basin-wide monitoring needs may be adequately addressed through existing monitoring programs. In other cases gaps may be identified.



Gaps = [Needs] – [Current Monitoring]

Figure 15. Determining gaps in required monitoring.

5.3.1 Basin-Wide Questions and Management Decisions

The focus of the IFRMP is principally on **basin-wide status & trend and action effectiveness monitoring questions that address key uncertainties or management decisions at the basin scale**. While they may rely on many of the same monitoring activities and performance indicators as local or sub-basin scale monitoring programs they will differ in terms of the required spatial and temporal scales, desired precision, allocation of effort, data analysis and interpretation.

Even when limited to a single (basin-wide) scale, there can be a long list of potential monitoring questions. For example: Are the suite of restoration actions in the upper basin resulting in an improvement in water quality? Is rearing habitat for coho increasing at the basin-scale? Our experience with large monitoring programs involving multiple stakeholders is that it is usually easier to get agreement on the **high-level goals and objectives and core KPIs** than to try and agree on all possible sub-objectives and hypotheses. Section 3 provides a summary of the primary and secondary IFRMP questions.

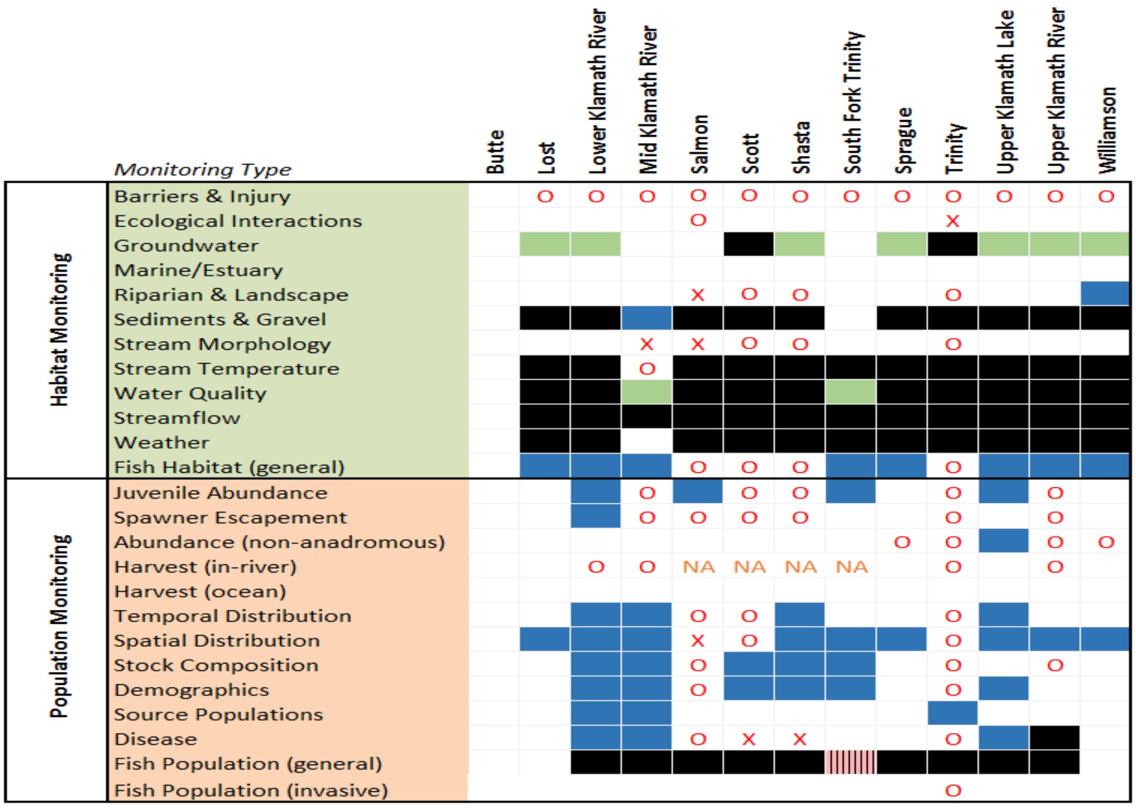
As restoration priorities are refined, it will be necessary to determine which of the actions have the greatest uncertainty and therefore require effectiveness monitoring, many may only require implementation monitoring (Section 5.4 & Figure 17).

5.3.2 Summary of Current Monitoring in the Klamath Basin

TO DO / UNDER DEVELOPMENT

The collection of data relevant to fish restoration in the Klamath Basin is a multi-organizational effort that began as early as 1904 with the first U.S. Geological Survey (USGS) flow gage placed at Keno, OR (USDI et al. 2013). While during these early years many organizations worked independently in isolated ‘silos’ this has been shifting in recent years from a fragmented collection of projects toward a more integrated approach that seeks to derive ‘benefits of scale’ by improving cooperation among all participants.

We have attempted to characterize the current state of fish restoration and monitoring in the Klamath Basin based on extensive document review, existing online databases, input received via key informant interviews, prior IFRMP workshops, and responses to information requests as part of the development of the Klamath Basin IFRMP Synthesis Report (ESSA 2017). While the level of metadata information available to our team was highly variable across different organizations we nevertheless attempted to define as best as possible the spatial and temporal aspects of past/current monitoring across Basin agencies. Figure 16 provides a high-level overview of the current monitoring data. Further detail, including species specific information, is available in a supporting Excel worksheet. This summary was further vetted during the July 2018 workshop in Klamath. Further detail will be required to confirm the usefulness of the current data to answer key questions (i.e., species relevance, spatial and temporal extent, and data quality). Given the level of effort to synthesize information at a higher resolution of detail, we will only dive deeper for those cases that are directly relevant to a key IFRMP question.



	Monitoring Type	Butte	Lost	Lower Klamath River	Mid Klamath River	Salmon	Scott	Shasta	South Fork Trinity	Sprague	Trinity	Upper Klamath Lake	Upper Klamath River	Williamson
Habitat Monitoring	Barriers & Injury		O	O	O	O	O	O	O	O	O	O	O	O
	Ecological Interactions					O					X			
	Groundwater		🟩	🟩			⬛	🟩		🟩	⬛	🟩	🟩	🟩
	Marine/Estuary													
	Riparian & Landscape					X	O	O			O			🟦
	Sediments & Gravel		⬛	⬛	🟦	⬛	⬛	⬛		⬛	⬛	⬛	⬛	⬛
	Stream Morphology				X	X	O	O			O			
	Stream Temperature		⬛	⬛	O	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	Water Quality		⬛	⬛	🟩	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛
	Streamflow		⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	Weather		⬛	⬛		⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	Fish Habitat (general)		🟦	🟦	🟦	O	O	O	🟦	🟦	O	🟦	🟦	🟦
Population Monitoring	Juvenile Abundance			🟦	O	🟦	O	O	🟦		O	🟦	O	
	Spawner Escapement			🟦	O	O	O	O			O		O	
	Abundance (non-anadromous)									O	O	🟦	O	O
	Harvest (in-river)			O	O	NA	NA	NA	NA		O		O	
	Harvest (ocean)													
	Temporal Distribution			🟦	🟦	O	O	🟦			O	🟦		
	Spatial Distribution		🟦	🟦	🟦	X	O	🟦	🟦	🟦	O	🟦	🟦	🟦
	Stock Composition			🟦	🟦	O	🟦	🟦	🟦		O		O	
	Demographics			🟦	🟦	O	🟦	🟦	🟦		O	🟦		
	Source Populations			🟦	🟦						🟦			
	Disease			🟦	🟦	O	X	X			O	🟦	⬛	
	Fish Population (general)			⬛	⬛	⬛	⬛	⬛	▥	⬛	⬛	⬛	⬛	
	Fish Population (invasive)										O			

⬛ In Internal Integrated Tracking Inventory; Currently ongoing (2015 & 2017 data)
🟩 In Internal Integrated Tracking Inventory; unknown status
🟦 Synthesis Report agency program summaries; unknown status
▥ In Internal Integrated Tracking Inventory; completed/terminated
O Ongoing Monitoring not in Internal Integrated Tracking Inventory
X Completed Monitoring not in Internal Integrated Tracking Inventory

Figure 16. Synthesis of past/current monitoring activities in the Klamath Basin across monitoring agencies. Figure rows indicate general types of information collected (for habitat and population monitoring) within each sub-basin. More detailed information on agency monitoring by monitoring type and species is available in a supporting Excel table. Our full understanding at this time of the information collected by each agency is variable (as represented in the accompanying figure legend), and this figure will be updated with information solicited through the pre-workshop survey. This summary does not provide any detail in terms of the quality of the assessments.

TO DO / UNDER DEVELOPMENT

High level Gap Analysis – summary & interpretation of survey feedback and most recent metadata summary

5.3.3 Integration and Synthesis Across the Basin

TO DO / UNDER DEVELOPMENT

This Chapter (once completed) Will:

- Discuss barriers to integration and potential solutions
- Describe alternatives for collaboration among independent monitoring programs, for example:
    - consistency in performance metric is key, consistent protocols are nice but not necessarily critical and there may be different logistical constraints or priorities in diff sub-basins that require different field protocols (i.e., response designs)
    - how to combine information from studies using different sampling designs
    - how to integrate historical data from non-random sites
    - limitations to integration
- Describe how to synthesize information from many studies to inform basin-wide questions
- Discuss how alignment with program goals and objectives influences overall effectiveness

One way that watershed restoration programs can track their overall strategic effectiveness over time is by determining how well the overall suite of restoration projects carried out in the region aligns with the original program goals and objectives (e.g., for a single basin like the Russian River as in Christian-Smith and Merenlender 2010, or an entire region like the Pacific Northwest as in Barnas et al. 2015). Mismatches between projects and restoration objectives might indicate a need for realignment of project prioritization schemes (see Chapter 6) or building capital, capacity, and local buy-in to reduce barriers preventing types of restoration that would be more effective.

5.3.4 Developing the Detailed Monitoring Plans

This section provides a short template describing the types of information that need to be fleshed out for each detailed monitoring plan within the monitoring framework. This detailed information for each monitoring question will likely be contained within appendices in the final IFRMP, with high level summaries provided up front to allow the reader to quickly assimilate information across sub-basins, species, and questions but still dive deeper as needed.

Why/what

Monitoring question	Refer to key IFRMP monitoring questions (Section 3).
Indicator(s)	Refer to core PI and section on indicator selection.
Desired Precision	Depends on the monitoring question and associated management decision. How precise does the answer need to be?

Action Effectiveness

Proposed study design (e.g., BACI)	The study or experimental design describes how treatment (i.e., restoration) sites are selected along with control sites if applicable. Ideally treatment and control sites are randomized and replicated, however there are a number of constraints in a watershed study. Given the connectivity of a watershed it is difficult to have truly independent replicates and in the case of the proposed Klamath dam removal, there is no suitable control.
Types of monitoring	Baseline; Implementation; Physical effectiveness; Biological effectiveness
Time periods of interest	What is the expected temporal response? How do the monitoring needs differ by time period? Are there particular observations which should trigger movement to the next phase of monitoring?

Sample design (where/when)

Target population	The target population is the population we would like to know about. This is where to identify the spatial boundaries of the question (e.g., tributaries vs mainstem or upstream/downstream of IGD etc.). This is also where the species of interest should be identified.
Sample frame	The sample frame is the complete list of sampling units from which a sample unit is selected. Ideally the sample frame includes all individuals or sites in the target population although in practice there are usually some mismatches (& these should be identified). The sample frame may be a list of discrete units (e.g., a list of restoration sites) or a spatial layer describing continuous features (e.g., stream network). When an area frame is used, sites are often selected by choosing a random starting point within the area.
Sample unit	The sample unit is the actual unit of measurement. Sample units may be discrete features or may be an arbitrarily defined unit from a continuous feature (e.g., a 100m reach within a stream). In many cases a multi-stage sampling design where a primary sampling unit (PSU) is selected first, and then sub-sampled using secondary sampling units (SSUs) is used. For example, we may select a random set of stream reaches (PSUs) and then sub-sample each reach with a series of vegetation plots (SSUs). The size and shape of the sample unit at each stage of the design should be selected for logistical efficiency and to minimize the variability among sample units (Darling et al. 2014, Elzinga et al. 2001).
Stratification	In a stratified monitoring design, the sampling frame is first divided into non-overlapping groups or strata, and then each of the strata are sampled. Stratification may be appropriate if: 1) there is a requirement to

	have independent estimates for different strata (e.g., sub-basin specific objectives); 2) to improve the statistical efficiency[1] of the design; or 3) in the case of rare strata which might be overlooked in a simple random sample. A stratified design is more efficient when the variability within strata is less than the variability between strata (Cochran 1977; Lohr 1999). In general, a few well-chosen strata can often greatly improve the efficiency of the design. Likewise if some strata are more important than others, a stratified design allows the user to put more effort into one stratum than the other, resulting in greater precision in the estimate of the priority stratum.
Sampling scheme	This section should describe the method for selecting sampling units from the sample frame. In general, probabilistic designs are recommended. Although, in some cases a census or systematic design may be appropriate.
Sample effort	Ultimately sample effort refers to the cost of sampling. Where cost includes capital expenditures as well as the time to measure each sample unit and the time to move between sample units. Sample effort is directly related to the number of sample units (PSUs and SSUs) selected at each stage of the design. In general, more samples = greater precision, however there are diminishing rates of return as the sample size increases. A well designed probabilistic sample can provide almost as good information as a census for substantially less cost (Cochrane 1977).
Timing	Timing and frequency of sampling are a critical component to the sampling design. Recommendations vary depending on the study objective and indicator of interest.

Response design (How)

<table>
<tr><th>Established protocols</th><th>Tradeoffs in terms of spatial coverage, feasibility, precision, cost etc.</th></tr>
<tr><td colspan="2">There are different approaches to obtaining the same estimate. Approaches often differ in spatial coverage and precision, one is usually improved at the sacrifice of the other. Feasibility may differ by subbasin depending on infrastructure, capacity, and logistics (e.g., the same methods may not work in tributaries as in the lower Klamath mainstem).</td></tr>
<tr><th>New or emerging protocols?</th><th>Tradeoffs in terms of spatial coverage, feasibility, precision, cost etc.</th></tr>
<tr><td colspan="2">What would be involved in implementing a new or emerging protocol? (e.g., capital costs, training, validation, crosswalk with past methods). What are the potential benefits?</td></tr>
</table>

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[1] An efficient design is one which results in a precise estimate for a relatively low level of effort.

Data analysis plan (How)

Data management	Where are / will the data be stored and how can it be accessed. Document metadata.
Data analysis	Proposed estimator and preliminary ideas about analytical approach. (i.e., how do you plan to use the data to answer the question?)
Reporting	Consider what figures you would need to be able to generate to communicate findings? Consider what 'key IFRMP' questions the monitoring data are supposed to inform. This will be further refined in Phase 5 as the adaptive management reporting template is developed.

5.4 Prioritization of Monitoring

TO DO / UNDER DEVELOPMENT

Optimization of monitoring is a complex decision analysis problem. **Generally, the priority management decisions/monitoring questions should drive the prioritization**. However, a single indicator or monitoring activity may often inform multiple questions. Therefore, given limited budgets it is possible to be faced with choosing between monitoring one high priority question well and monitoring multiple medium priority questions quasi-adequately.

Our approach is to first consider prioritization from several different perspectives independently and then collaboratively determine what trade-offs are preferable. For the purpose of the IFRMP three different prioritization lenses are proposed in no particular order. First the suitability of different indicators as evaluated through a set of systematic and transparent evaluation criteria described in Section 3. Second, involves considering the degree of certainty of restoration action effectiveness (as in Figure 17). The outcomes of restoration action prioritization will have some influence on monitoring activities, particularly those associated with action effectiveness monitoring. Given limited resources, it may be desirable to defer monitoring for "no-brainer" restoration actions with clear benefit and low uncertainty (e.g., restoring fish passage at a road crossing) and instead monitor effectiveness only for projects with the highest uncertainty in project effectiveness and/or magnitude of effect. For high benefit, low uncertainty projects the scope of monitoring could alternatively be limited to simply the implementation component, rather than the more expensive physical and biological effectiveness monitoring. Third, considers how many questions/objectives each monitoring activity supports. This overall approach to prioritization can be summarized in a simple monitoring activity-by-question matrix (as illustrated in the approach used for prioritizing monitoring activities within the Missouri River Recovery Program – Figure 18).

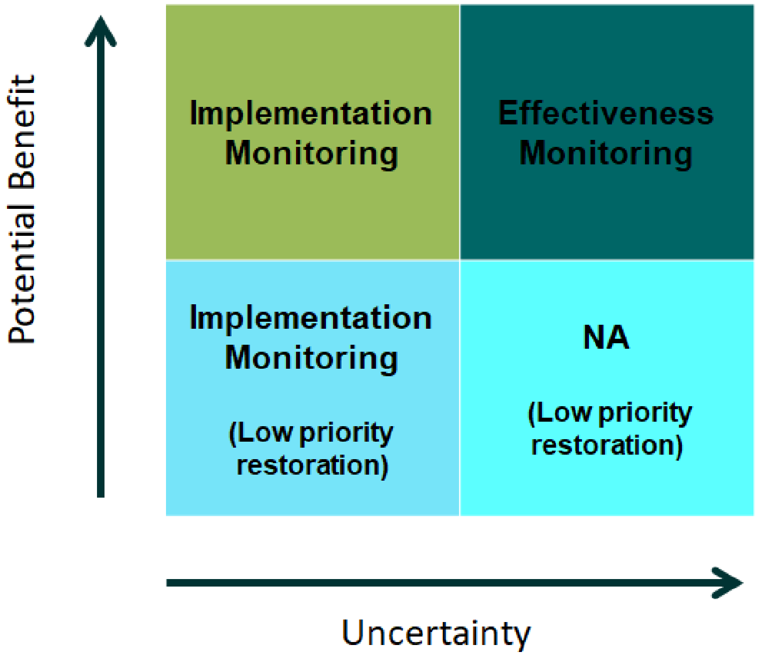
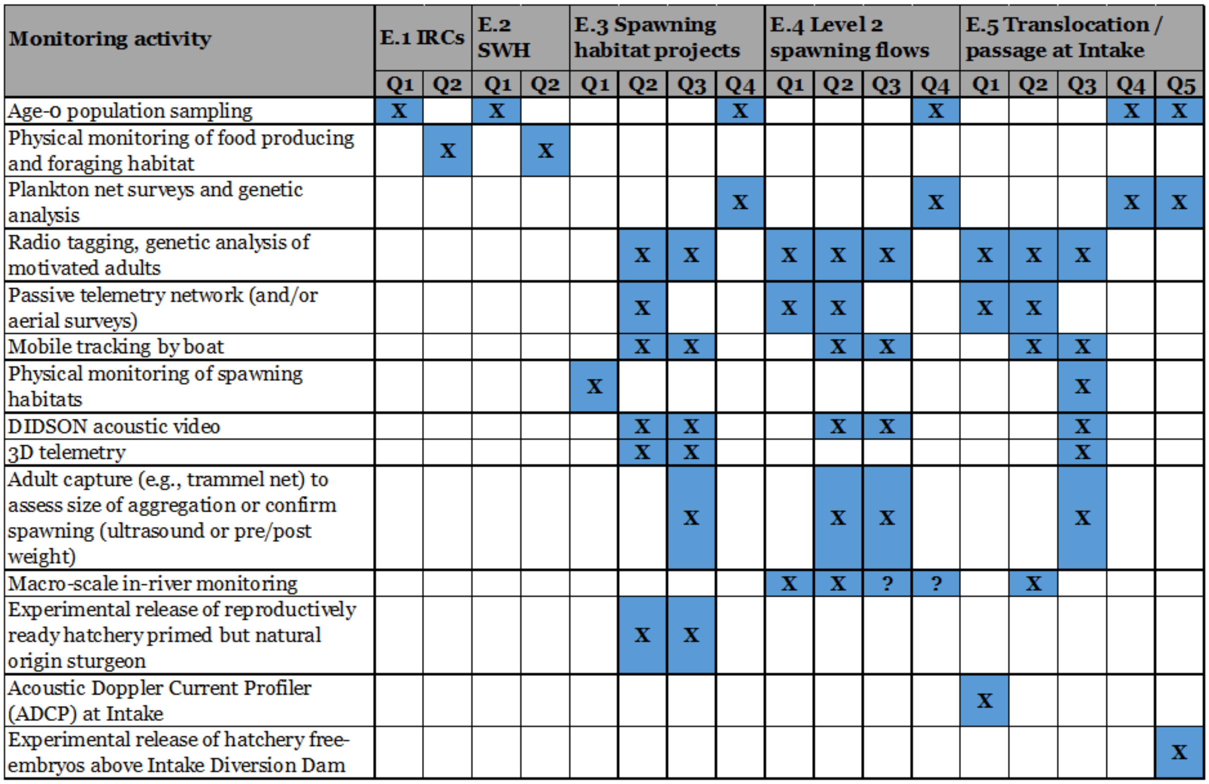


Figure 17. Effectiveness monitoring is most relevant when there is a high degree of uncertainty and high potential benefit. Implementation monitoring is sufficient when uncertainty is low (i.e., the action is proven).



Monitoring activity	E.1 IRCs		E.2 SWH		E.3 Spawning habitat projects				E.4 Level 2 spawning flows				E.5 Translocation / passage at Intake				
	Q1	Q2	Q1	Q2	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q5
Age-0 population sampling	X		X					X				X				X	X
Physical monitoring of food producing and foraging habitat		X		X													
Plankton net surveys and genetic analysis								X				X				X	X
Radio tagging, genetic analysis of motivated adults						X	X		X	X	X		X	X	X		
Passive telemetry network (and/or aerial surveys)						X			X	X			X	X			
Mobile tracking by boat						X	X			X	X			X	X		
Physical monitoring of spawning habitats					X										X		
DIDSON acoustic video						X	X			X	X				X		
3D telemetry						X	X								X		
Adult capture (e.g., trammel net) to assess size of aggregation or confirm spawning (ultrasound or pre/post weight)							X			X	X				X		
Macro-scale in-river monitoring									X	X	?	?		X			
Experimental release of reproductively ready hatchery primed but natural origin sturgeon						X	X										
Acoustic Doppler Current Profiler (ADCP) at Intake													X				
Experimental release of hatchery free-embryos above Intake Diversion Dam																	X

Figure 18. Example of a monitoring activity by monitoring question matrix as applied to the Missouri River Recovery Program. Each “x” in the matrix represents a monitoring question that can be addressed through the particular monitoring activity.

5.5 Case studies

TO DO / UNDER DEVELOPMENT

This Chapter (once completed) Will:

- Explore the monitoring considerations for a few representative examples to highlight the range of challenges or approaches which may be necessary. The case studies won't have all the details worked out but will provide a preliminary attempt at the documenting the information in the monitoring templates, provide a high level summary of key information, and will identify next steps.
- Selection of case studies does not represent priority but an attempt to demonstrate a range of considerations.
  - Status and Trends and action effectiveness questions
  - Remote sensed vs. on the ground response designs and associated sample design tradeoffs
  - Cases which are highly species dependent or not
  - Biological and physical indicators

Example with well established program vs. a data gap

5.5.1 Status and Trends

TO DO / UNDER DEVELOPMENT

5.5.2 Action Effectiveness

TO DO / UNDER DEVELOPMENT

A restoration example of particular interest is the scenario where the dams are removed. What basin-wide questions might be of interest under that state of nature and how might the monitoring requirements differ? We conjecture that assessment of dam removal impacts ("action effectiveness") will likely focus on the following major system-wide changes that would otherwise not be a focus of long-term monitoring:

1. Direct habitat effects of dam removal and elimination of existing reservoir dynamics as they impact:
   - **Dynamics of channel "redevelopment"** (including at least transport of sediments, gravels, reconfiguration of channel) from below the existing dams to whatever location below Iron Gate Dam past which no significant effects are evident (assuming such location exists); and
   - **Dynamics of changing "water quality" parameters** from the uppermost removed dam to the mouth of the Klamath including at least presence of algae/algal blooms, nutrient loads, DO, mean temperatures and spatial distribution of cool water "refugia", polychaete/disease presence.
2. Effects of dam removal on distribution and abundance of fish species, with special concern for:

- **Reintroduction of native anadromous species** including at least Coho, fall Chinook, spring Chinook, and Steelhead (possibly also Pacific Lamprey, Green sturgeon) above Iron Gate Dam; and
- **Possible unintended introductions of non-native species** populations (Large and Smallmouth Bass, Bullhead, Yellow Perch, Bluegill, new non-natives, etc.) below Iron Gate Dam and **possible establishment of viable non-native populations** in the restored mainstem channel above Iron Gate Dam.

In contrast to many of the candidate performance indicators that have been thus far proposed, many of the anticipated system-wide changes identified above **(a) focus on the mainstem Klamath River, (b) focus on species that are currently not present above Iron Gate Dam, and (c) would require long-term monitoring programs with broad rather than localized spatial coverage.** Also, as for the Elwha River restoration plan (Ward et al. 2008), it would be logical to tie certain restoration actions to achievement (or failure to achieve) clearly specified restoration targets by pre-specified dates. This requires further development of the IFRMP adaptive management framework to illustrate what would trigger certain restoration actions based on data collected in monitoring programs.

6 Initial Prioritization Framework(s)

TO DO / UNDER DEVELOPMENT

This Chapter (once completed) will:

- Describes a future process for iteratively prioritizing restoration actions
- Describe selection of criteria to be used and identify the scoring and weighting method
- Describe data collection and inventory analysis needed to assist with scoring and ranking and
- Identifies the role of discussion and synthesis of the results to form a coherent restoration strategy.

NOTE TO REVIEWERS: Several chapters and sections of the Initial Rough Draft IFRMP are in outline form with various straw examples, comments and questions to stimulate creativity and feedback. This in progress draft document is intended to be a repository for ideas and options – feel free to add yours as comments. Critical filtering and editing of these ideas and options is essential, but will happen later. Each major section has an Introduction to provide some context, which describes the Purpose, Challenges, and Proposed Approach.

This section (currently under development) will recommend an initial prioritization framework to apply to the selection of future restoration projects, to be applied in Phase 3 of Plan development, and beyond. We would not attempt to apply the initial prioritization framework to candidate restoration actions or monitoring activities in this Phase 2 of Plan development. This chapter will focus on technical considerations underlying prioritization (e.g., restoration actions that are well-justified scientifically and known to be effective would be prioritized ahead of untested or marginally successful types of restoration).

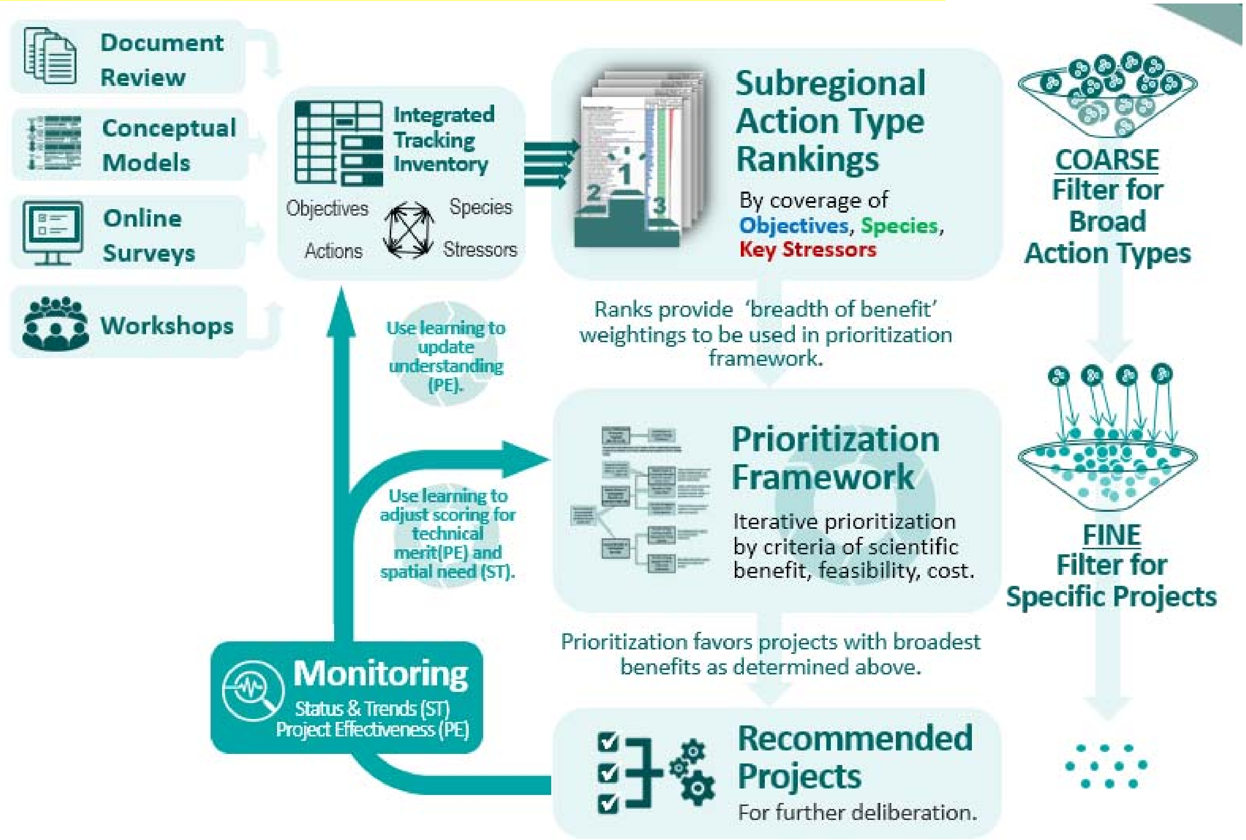
Issues related to prioritizing monitoring activities are discussed in Chapter 5.

6.1 Purpose

When developing a restoration plan encompassing an entire river basin, an organizing framework is necessary to prioritize those activities that will most effectively contribute to recovery of overall ecosystem function at the basin-wide scale, as distinct from smaller spatial scales (Beechie et al. 2008). Prioritization in this sense refers to the process of scoring or ranking potential types of restoration actions to determine the most beneficial *sequencing* to inform funding and implementation decisions, and to logically group the top-tier of priority restoration actions into a coherent restoration strategy. Prioritization can take place at the level of the basin, watershed, sub-watersheds, or reaches, or alternatively by habitat type, but prioritization at smaller scales needs to be consistent with a basin-wide restoration strategy. Initiatives at a regional scale may take a multilevel approach involving prioritization across watersheds within a basin-wide strategy, followed by prioritization of projects within watersheds (Beechie et al. 2008, Roni et al. 2013b).

Effective prioritization frameworks provide a systematic, repeatable, and transparent rationale for making restoration decisions given limited funding, capacity, and time (Beechie et al. 2008, Roni et al. 2013b). Structured frameworks help to clarify the decision-making process for funding agencies, proposal reviewers, project proponents, and other stakeholders that will be affected by these decisions and facilitate reprioritization on a regular basis (e.g., every 3-4 years) as projects are completed, new opportunities are identified, and new information becomes available.

NOTE: this section represents a finer scale filtering that would occur more frequently, every 3-4 years, supported by monitoring and adaptive mgmt. elements of the plan. Aspects of prioritization/filtering are addressed in other chapters. Key is to understand that these are happening at a coarser scale. We need to incorporate figure like this one:



To communicate the linkages/relationships. Distinguish COARSE FILTER from FINE filter (while making it clear how exceptions would be handled).

6.2 Selecting a Prioritization Approach

Many approaches to prioritization are possible depending on restoration objectives, spatial scale, and level of information available; each approach has pros and cons (Roni et al. 2013b,
Table 17). Many of the complexities of the Klamath River Basin preclude applying most of these methods (i.e., multiple species of conservation interest, varying levels of data availability across

regions, a wide range of interested participants and socioeconomic considerations). In consideration of the pros and cons of alternative methods, we recommend that the IFRMP develop a **Multi-criteria Decision Analysis (MCDA)**[2] framework. Multi-criteria scoring approaches are transparent, repeatable and highly adaptable. Multi-criteria scoring is transparent and relies on a set of criteria associated with simple scales and weighting systems (Roni et al. 2013b).

Applying multi-criteria scoring involves the following key steps:

- selection of criteria,
- identifying the scoring and weighting method,
- data collection and inventory analysis to assist with scoring,
- scoring and ranking; and
- discussion and synthesis of the results into a coherent restoration strategy.

Table 17. Common approaches for prioritizing restoration (adapted from Beechie et al. 2008, Roni et al. 2013).

Approach	Description	Pros	Cons
Logic-Based Approaches			
Project Type & Effectiveness	Ranks projects based on general understanding of effectiveness from literature review.	Helpful interim approach if no or limited data available on physical habitat conditions.	Ignores influence of local contexts on effectiveness of a given project type.
Refugia	Prioritizes protecting refugia first, and then restoration near refugia.	Useful approach for single species dependent on a specific habitat type.	Challenging to implement for multiple species with different habitat requirements. Doesn't encourage rehabilitation of process and function in highly degraded environments.
Multi-criteria Decision Analysis (MCDA)*	Also known as multi-criteria scoring. A rubric where projects or watersheds are scored on multiple criteria (e.g., effectiveness, cost, extent) to determine overall rank, and then combining projects into a coherent restoration strategy.	Widely used, transparent and easy to document, incorporates multiple information types, and adaptable to varying spatial scales and data availability.	Scales and weightings used for criteria imply some level of subjectivity in prioritization. Priorities are influenced by 'who' is asked to participate in the scoring. Scorers need to discard agency hats and be passionately neutral.
Analytical Approaches			
Scale of Effect	Ranks projects by area restored and/or projected increase in fish production	Based on habitat-abundance relationships derived from empirical data.	Data may be unavailable in all regions, challenging to predict benefit to fish populations for specific projects with much certainty.

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[2] We prefer the term "multi-criteria scoring" over MCDA.

Approach	Description	Pros	Cons
Capacity or Life-Cycle Computer Models	Estimates population benefits at each life stage to predict overall population benefit from a given project. Other types of computer models use statistical approaches to predict restoration outcomes.	Based on empirical data for specific life stages, and species, can handle complex data types.	Complex, time consuming, requires detailed habitat and fish population data by life stage, and difficult to draw conclusions at the project scale. Often many assumptions with rankings sensitive to these assumptions. One of the least transparent approaches for some stakeholders.
Cost-Benefit	A strictly cost or cost-benefit approach to ranking projects.	Provides a common currency for comparing across projects.	Many benefits are hard to translate into economic terms. Costing data difficult to obtain or compare across project types, and economic benefits of restoration challenging to estimate, omits other factors contributing to project effectiveness.

The participants at a workshop held in Klamath CA in July 2018 (Appendix D) were supportive of developing a multi-criteria scoring approach for prioritizing future IFRMP restoration actions. The key point raised by participants was that the scoring system needed to be very clear (i.e., consistent scales, higher numbers always better), use unambiguous wording and definitions, and generate comparisons of restoration benefits that were roughly comparable (e.g., system-wide dam removal not ranked against restoration of 200m of a stream channel). A repeated warning was to not apply the system blindly, but rather to use the system to inform a rational, neutral dialogue by an independent rating committee.

Multi-criteria scoring approaches are widely used in restoration programs, for example:

- by agencies setting project priorities for Species Recovery Plans (e.g., for SONCC Coho, Table 6-3 in NMFS 2014; for Pacific lamprey in Appendix B of Goodman and Reid 2015);
- by programs setting project priorities for a specific type of restoration action with multispecies benefits (e.g., prioritizing fish passage projects in Oregon, ODFW 2013); and
- by grant programs selecting among project funding proposals that best meet their program's regional restoration priorities (e.g., the Oregon Watershed Enhancement Board's Prioritization Framework, OWEB 2005).

6.3 Preliminary Criteria for Selecting Priority Restoration Actions

During the July 2018 workshop, we proposed a framework that included three broad categories:

- **Technical Merit/Scientific Benefit**
- **Feasibility & Cost**

- **Social Considerations**

6.3.1 Technical Merit / Scientific Benefit

July 2018 workshop participants rated technical merit and scientific benefit criteria much more heavily over feasibility and social considerations. Participants felt that actions should be chosen which are first and foremost scientifically defensible, and then folks can work through the feasibility and social constraints in a separate and subsequent step. They did **not** want effective actions to be vetoed based on rolling in feasibility and cost considerations into a single overall score (e.g., dam removal would never have got this far if social and economic constraints were primary or even equal to technical / scientific benefit). A single combined score was widely perceived as being too rigid and likely to inadvertently screen out worthwhile projects.

With respect to technical merit and scientific benefit criteria, most participants favoured the following criteria: *# of key limiting factors improved for focal species* (ability to address critical bottlenecks), *level*[3] *of watershed processes targeted* (some folks missed this criterion because it's at a higher level than others), *spatial scale of anticipated benefits*, *expected level of benefit*, *importance in avoiding the extinction of a species*, *reduced risk of negative impact to other species*, and *longevity of benefits*. These preferences are reflected in the updated post-workshop version of the framework in Figure 19.

Biophysical Process Level

- TO DO / UNDER DEVELOPMENT
- Frame in context of upper tiers (watershed inputs, fluvial geomorphic processes) being more beneficial (i.e., place more priority on stressors that are closer to root cause of problem – sets out sequence of priority candidate actions)

Spatial Extent of Anticipated Benefits

- TO DO / UNDER DEVELOPMENT
- Suggest a general spatial/GIS screening step that identifies the areas of greatest need;
- E.g. Green Sturgeon limited to upstream habitat @ Ishi Pishi Falls on Klamath mainstem
- Candidate locations (sub-basin scale; possibly hotspots)
- Geographic matching to the level of stressors at spatial resolution of Trout Unlimited data

Number of Key Limiting Stressors Improved

- TO DO / UNDER DEVELOPMENT

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[3] described in Chapter 2 as 'tiers' (see Figure 2)..

Number of Focal Species Goals & Objectives Addressed

- TO DO / UNDER DEVELOPMENT

6.3.2 Feasibility & Cost

- TO DO / UNDER DEVELOPMENT

Several July 2018 workshop participants were willing to drop two of the prioritization criteria: *duration to plan and implement*; and *whether the restoration technique had been successfully applied elsewhere* (excluded from the post-workshop framework in Figure 19). With respect to the latter criterion, people were concerned that you could box yourself in by only applying restoration techniques that had already been applied. For example, 10 years ago, nobody was using Beaver Dam Analogs (BDA) but now they are very common. In general, most people felt that since the problem was complex, it would require complex, large, time-consuming projects which were not easy to implement; hence feasibility should receive a lower weight. Participants did not want effective actions to be vetoed from the get go based on feasibility / economic constraints.

Additional criteria mentioned were *risk of failure* and *ease of monitoring effectiveness* (easier to move forward with implementation) and the *value of taking advantage of ephemeral funding opportunities* that could be lost if not pursued.

Ability to Monitor to Demonstrate Effectiveness

- TO DO / UNDER DEVELOPMENT

Legal/Administrative Permitting Effort

- TO DO / UNDER DEVELOPMENT

Ongoing Annual Costs

- TO DO / UNDER DEVELOPMENT
- Coarse, fairly subjective cost framing (e.g., $$$, $$ assignment to each action assuming project scale held constant)

Cost Sharing Opportunities

- TO DO / UNDER DEVELOPMENT

6.3.3 Social Considerations

There were differing views on the criterion *Level of Landowner Cooperation Required*. Some felt that this could easily change as land ownership changed, and therefore was not a permanent constraint, whereas others felt that willing landowners (and willing partners in general, not just landowners) were an essential asset to a restoration project. Where the inability to access land could kill a project it is clearly worth evaluating early in the process. If access is impossible, it may not be worth evaluating all of the other criteria.

These preferences are reflected in the updated post-workshop version of the framework in Figure 19.

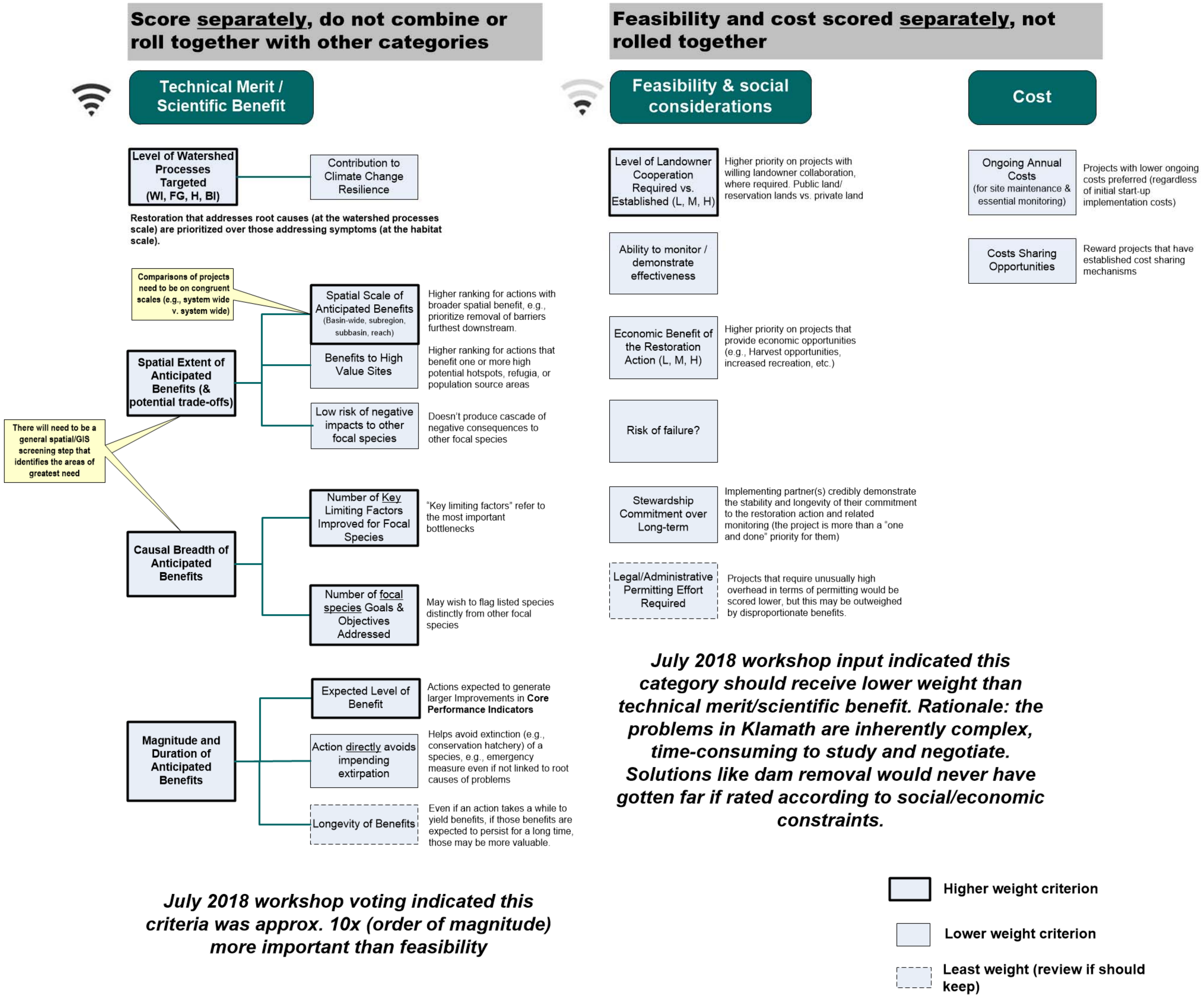


Figure 19: {FIGURE NEEDS TOTAL OVERHAUL FOR READABILITY} Post July 2018 multi-criteria scoring framework for the Klamath River Basin IFRMP. {Note: Intentionally displayed on 11x17 page}.

Level of Landowner Cooperation Required

- TO DO / UNDER DEVELOPMENT

Economic Benefits of the Restoration Action

- TO DO / UNDER DEVELOPMENT

Stewardship Commitment over Long-term

- TO DO / UNDER DEVELOPMENT

6.4 Application

6.4.1 Independent Rating Committee

- TO DO / UNDER DEVELOPMENT

6.4.2 Sequencing and Pre-requisite Actions

- TO DO / UNDER DEVELOPMENT
- Being clear on the sequence in which criteria should be calculated/estimated (e.g., if answers on some criteria were "no", there may be no need to proceed with scoring);

-Pre-requisite actions: main pre-requisite is dam removal, but there is also removal of small dams/barriers; riparian restoration actions (e.g., fencing needed before planting to make sure cows don't eat riparian vegetation); no point in removing invasive species unless first find a way to prevent recolonization; no point in implementing hatchery production/rearing if habitat is bad, etc.).
-Inter-regional & Intra-regional dependencies
-May be important to target which life stage would benefit from an action (eg Juvenile coho rearing vs. upstream migration)

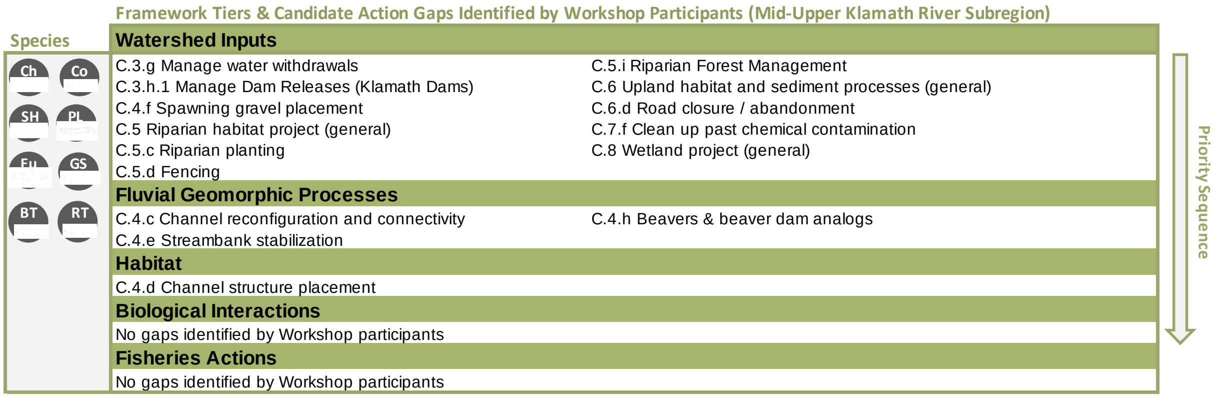
This section is under development. We can currently identify several subregional dependencies from database but need to categorize in terms of broad principles for pre-requisites & complete the identification of pre-requisites.

6.4.3 Maintain Inventory & Perform Periodic Gap Assessment

- TO DO / UNDER DEVELOPMENT
- Incorporate categories of actions that were identified as gaps during the March 2018 workshop in Ashland (example in Figure 20)
- Propose data collection and analysis to assist with scoring
- Appropriate frequency of scoring exercises

- Testing of scoring methods as part of effectiveness monitoring (i.e., were judgements made in the scoring system confirmed during and after project implementation?)
- Refinement of the scoring system based on testing results (e.g., adding, dropping, rephrasing, rescaling, reweighting criteria)

TO DO -- Cedar can provide tables like the one shown below from database (both gaps and priority actions were identified – only gaps shown here) – possibly of use for June workshop as a conversation starter:


Framework Tiers & Candidate Action Gaps Identified by Workshop Participants (Mid-Upper Klamath River Subregion)

Species: Ch, Co, SH, PL, Eu, GS, BT, RT

Species	Framework Tiers	
Ch Co SH PL Eu GS BT RT	**Watershed Inputs**	
	C.3.g Manage water withdrawals C.3.h.1 Manage Dam Releases (Klamath Dams) C.4.f Spawning gravel placement C.5 Riparian habitat project (general) C.5.c Riparian planting C.5.d Fencing	C.5.i Riparian Forest Management C.6 Upland habitat and sediment processes (general) C.6.d Road closure / abandonment C.7.f Clean up past chemical contamination C.8 Wetland project (general)
	Fluvial Geomorphic Processes	
	C.4.c Channel reconfiguration and connectivity C.4.e Streambank stabilization	C.4.h Beavers & beaver dam analogs
	Habitat	
	C.4.d Channel structure placement	
	Biological Interactions	
	No gaps identified by Workshop participants	
	Fisheries Actions	
	No gaps identified by Workshop participants	

Figure 20. Example Gap Prioritization by Framework Tier (Mid-Upper Klamath River Subregion).

6.4.4 Example Application

- TO DO / UNDER DEVELOPMENT

6.5 Tradeoffs Interpreting Prioritization Outcomes

- TO DO / UNDER DEVELOPMENT

It is important to understand that a low prioritization rank for a project does not necessarily mean it should never be implemented. For example, some projects may have greater benefit if implemented later in the restoration sequence after other tasks have already been completed, and other projects scoring high on potential benefit but low on proven effectiveness may be candidates for research or pilot studies coupled with effectiveness monitoring before they are widely implemented. Finally, we should always remember that prioritization frameworks provide guidance, but groups of people will ultimately make the final decisions on which projects provide the most logical and coherent package during a given phase of restoration. In practice, some lower ranking projects may be implemented anyway because they are either easy to implement, less expensive or take advantage of ephermeral funding opportunties.

7 Major Tasks Remaining to Complete Plan

TO DO / IN PROGRESS

NOTE TO REVIEWERS: Several chapters and sections of the Initial Rough Draft IFRMP are in outline form with various straw examples, comments and questions to stimulate creativity and feedback. This in progress draft document is intended to be a repository for ideas and options – feel free to add yours as comments. Critical filtering and editing of these ideas and options is essential, but will happen later. Each major section has an Introduction to provide some context, which describes the Purpose, Challenges, and Proposed Approach.

Essentially a "Next Steps" chapter. This section provides an outline of the recommended tasks to complete the Integrated Fisheries Restoration and Monitoring Plan for the Klamath River Basin.

This would be the basis for Phase 3 IFRMP work plan. As presented here, this would not include specific sub-task details, time-lines estimates or cost information, but focus on narrative.

7.1 Priorities for Phase 3 IFRMP Development

TO DO / IN PROGRESS

7.2 Next Step 1

TO DO / IN PROGRESS

7.3 Next Step 2

TO DO / IN PROGRESS

7.4 Next Step 3

TO DO / IN PROGRESS

7.5 Improve Communication

TO DO / IN PROGRESS

A key step in dealing with uncertainty is understanding how and why it exists. Many uncertainties associated with fish restoration in the Klamath Basin are multi-disciplinary in nature. This characteristic means that understanding the sources of uncertainty is better served by expanding participation beyond disciplinary and agency silos. Bringing together scientists, policy and decision makers and public interest groups has multiple benefits in terms of increasing knowledge about the sources of uncertainty, enhancing education and communication, and increasing opportunities for consensus building across interest groups (Lemons and Victor 2008). In addition to these benefits, improved communication and outreach can help motivate participation in implementation strategies. For example, cattle fencing is a restoration action with known effectiveness, but there is uncertainty around the level of rancher participation. Improved communication and outreach can help motivate that participation.

Other benefits of improved communication include an enhanced ability to collaborate in the identification and resolution of uncertainties arising from information and data gaps. For example, several mid Klamath partners including the NOAA Restoration Center the Mid Klamath Watershed Council, the Karuk Tribe and the Yurok Tribe recognized a significant data gap in California off-channel projects and worked together to develop case studies sharing what was learned over the past few years. These case studies include a lessons learned section that can help guide future off channel restoration projects. Many examples of this type of cross-agency collaboration already exist in the Klamath basin and the IFRMP process is part of that lineage.

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TO DO: include prompt for readers to go to IFRMP web library, where many of these reports can be obtained.

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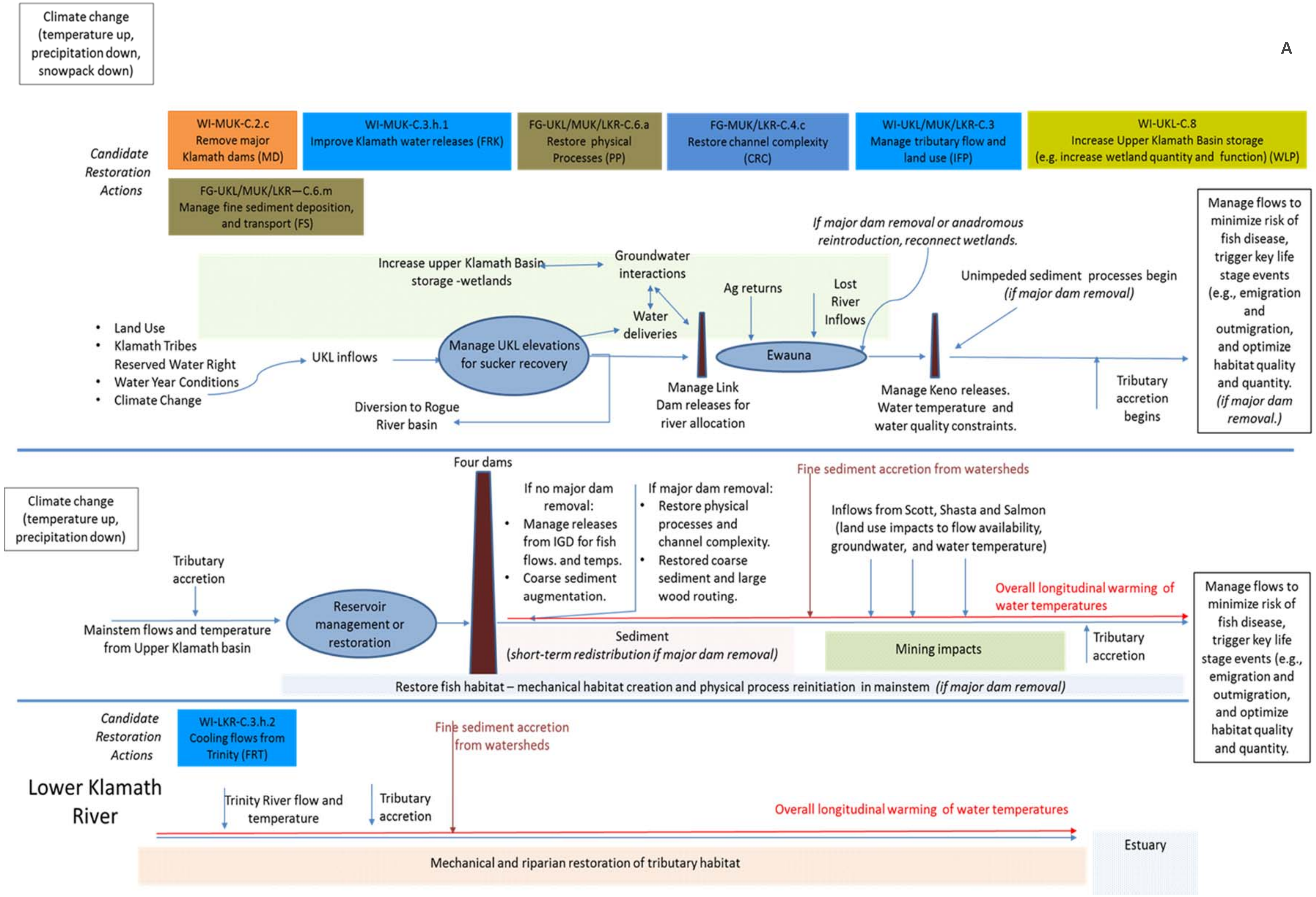
Appendix A: Klamath IFRMP Conceptual Models



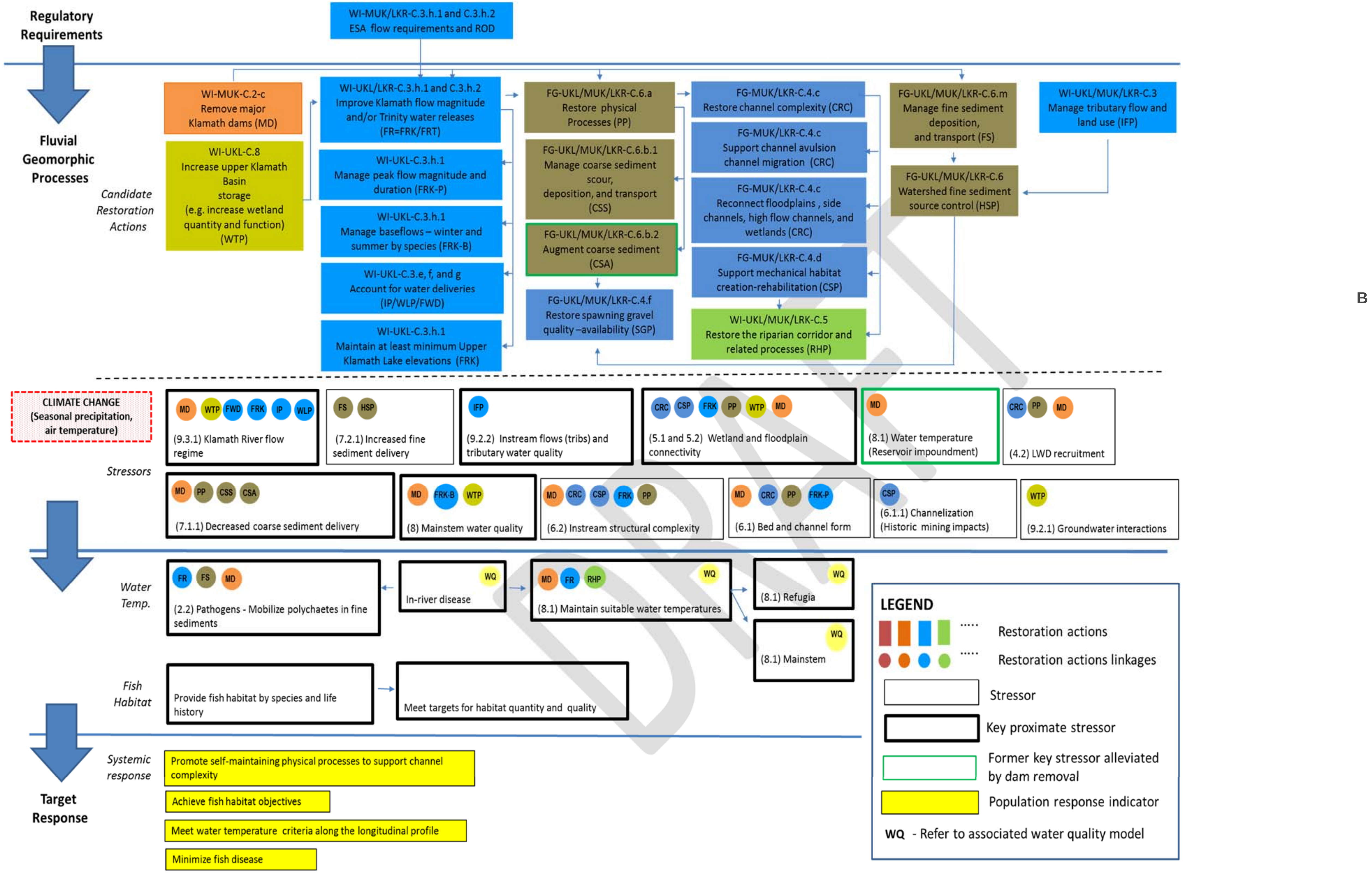


Figure A1. Conceptual diagrams of fluvial geomorphic processes in the Klamath Basin and effects of current and potential future candidate restoration actions on key related stressors. (A) provides a dynamic representation of geomorphic process interactions while (B) shows greater detail as to the linkages between specific geomorphic process-related stressors and the actions that could minimize or mitigate their impacts.

Table A1. Links between fluvial geomorphology-related stressors for fish across Klamath Basin sub-regions, candidate restoration actions and hypothesized effects of restoration actions on fish habitat, in support of the detailed linkages illustrated in Figure A1.

Row	Framework tier	Stressor for fish	Sub-region(s) affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
1	Watershed Inputs	Klamath River flow regime	UKL, MUK, LRK	Remove major dams	C.2.c-Major (MD)	Increases quantity of water available for fish needs
2	Watershed Inputs	See stressor in Row 1	UKL, MUK, LKR	Increase upper Klamath basin storage	C.8 (WTP)	See effect in Row 1
3	Watershed Inputs	See stressor in Row 1	UKL, MUK, LRK	ESA flow requirements and ROD	C.3.h.1 and C.3.h.2 (FRK/FRT)	See effect in Row 1
4	Watershed Inputs	See stressor in Row 1	UKL, MUK, LKR	Account for water deliveries	C.3.e, f, and g (IP/WLP/FWD)	See effect in Row 1
5	Watershed Inputs	Increased fine sediment delivery	UKL, MUK, LKR	Watershed fine sediment source control	C.6 (HSP)	Reduces excess fine sediment inputs that could impair fish habitats
6	Watershed Inputs	Instream flows (tribes) and tributary water quality	UKL, MUK, LKR	Manage tributary flow and land use	C.3 (IFP)	Increases quantity of water available for fish needs
7	Habitat	Wetland and floodplain connectivity	MUK, LKR	Restore channel complexity	C.4.c (CRC)	Increases extent and diversity of fish habitats
8	Habitat	See stressor in Row 7	MUK, LKR	Support channel avulsion and channel migration	C.4.c (CRC)	See effect in Row 7
9	Habitat	See stressor in Row 7	UKL, MUK, LKR	Reconnect floodplains, side channels, high flow channels, and wetlands	C.4.c (CRC)	See effect in Row 7
10	Habitat	See stressor in Row 7	UKL, MUK, LKR	Support mechanical habitat creation-rehabilitation	C.4.d (RHP)	See effect in Row 7
11	Habitat	See stressor in Row 7	UKL, MUK, LKR	ESA flow requirements and ROD	C.3.h.1 and C.3.h.2 (FRK/FRT)	See effect in Row 7
12	Habitat	See stressor in Row 7	UKL, MUK, LKR	Manage baseflows—winter and summer by species	C.3.h.1 (FRK)	See effect in Row 7
13	Habitat/Fluvial Geomorphic	See stressor in Row 7	UKL, MUK, LKR	Restore physical processes	C.6.a (PP)	See effect in Row 7
14	Habitat	See stressor in Row 7	UKL	Increase upper Klamath Basin storage	C.8 (WTP)	See effect in Row 7
15	Habitat	Water temperature	MUK	Remove major Klamath	C.2.c-Major (MD)	Reduces water temperatures in the

Row	Framework tier	Stressor for fish	Sub-region(s) affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
		(reservoir impoundment)		dams		mainstem
16	Habitat/Fluvial Geomorphic	Large wood debris (LWD) recruitment	UKL, MUK, LKR	Restore channel complexity	C.4.c (CRC)	Provides large woody debris and coarse sediment for habitat complexity and fish spawning needs downstream.
17	Habitat/Fluvial Geomorphic	See stressor in Row 16	UKL, MUK, LKR	Restore physical processes	C.6.a (PP)	See effect in Row 16
18	Habitat/Fluvial Geomorphic	See stressor in Row 16	UKL, MUK, LKR	Remove major dams	C.2c-Major (MD)	See effect in Row 16
19	Fluvial Geomorphic	Decreased coarse sediment delivery	MUK	Remove major dams	C.2c-Major (MD)	Provides additional quantities and distribution of coarse sediments for fish spawning habitats
20	Fluvial Geomorphic	See stressor in Row 19	UKL, MUK, LKR	Restore physical processes	C.6.a (PP)	See effect in Row 19
21	Fluvial Geomorphic	See stressor in Row 19	UKL, MUK, LKR	Manage coarse sediment scour, deposition, and transport	C.6.b.1 (CSS)	See effect in Row 19
22	Fluvial Geomorphic	See stressor in Row 19	MUK	Augment coarse sediment	C.6.b.2 (CSA)	See effect in Row 19
23	Watershed Inputs	Mainstem water quality	MUK	Remove major Klamath dams	C.2.c-Major (MD)	Improves water quality conditions for fish growth and survival
24	Watershed Inputs	See stressor in Row 23	UKL, MUK, LKR	ESA flow requirements and ROD	C.3.h.1 and C.3.h.2 (FRK/FRT)	See effect in Row 23
25	Watershed Inputs	See stressor in Row 23	MUK, LKR	Manage baseflows—winter and summer by species	C.3.h.1 (FRK)	See effect in Row 23
26	Watershed Inputs	See stressor in Row 23	UKL,	Increase upper Klamath Basin storage	C.8 (WTP)	See effect in Row 23
27	Habitat	Instream structural complexity	UKL, MUK, LKR	Remove major Klamath dams	C.2.c-Major (MD)	Increases extent and diversity of fish habitats
28	Habitat	See stressor in Row 27	UKL, MUK, LKR	Restore channel complexity	C.4.c (CRC)	See effect in Row 27
29	Habitat	See stressor in Row 27	MUK, LKR	Support channel avulsion and channel migration	C.4.c (CRC)	See effect in Row 27
30	Habitat	See stressor in Row 27	UKL, MUK, LKR	Reconnect floodplains, side channels, high flow channels, and wetlands	C.4.c (CRC)	See effect in Row 27

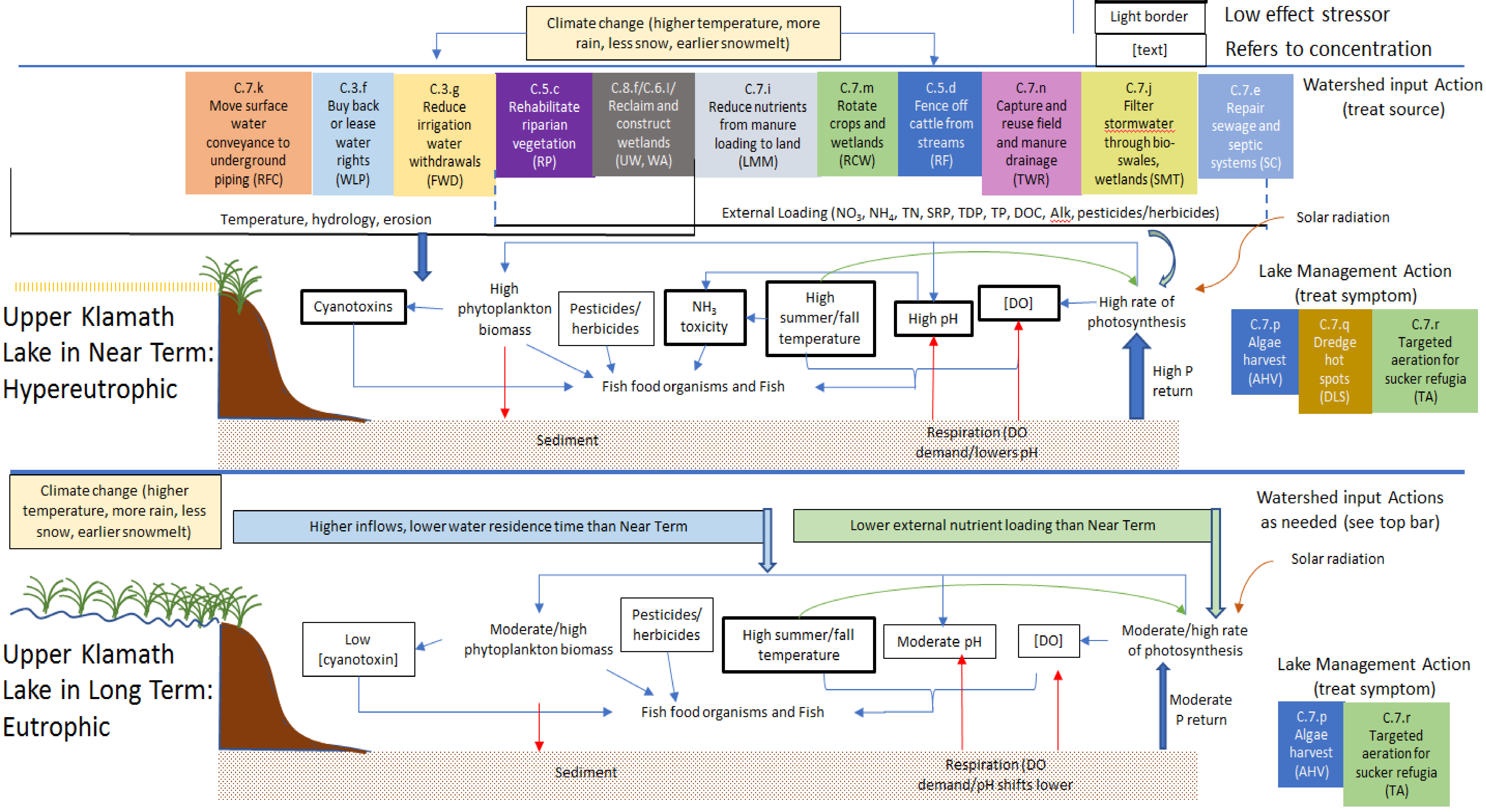
Row	Framework tier	Stressor for fish	Sub-region(s) affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
31	Habitat	See stressor in Row 27	UKL, MUK, LKR	Support mechanical habitat creation-rehabilitation	C.4.d (CSA)	See effect in Row 27
32	Habitat	See stressor in Row 27	MUK, LKR	Manage baseflows—winter and summer by species	C.3.h.1 (FRK)	See effect in Row 27
33	Habitat	See stressor in Row 27	MUK, LKR	Manage peak flow magnitude and duration	C.3.h.1 (FRK)	See effect in Row 27
34	Habitat	See stressor in Row 27	UKL, MUK, LKR	Restore physical processes	C.6.a (PP)	See effect in Row 27
35	Fluvial Geomorphic	Bed and channel form	UKL, MUK	Remove major Klamath dams	C.2.c-Major (MD)	Promotes processes that create increased extent and diversity of fish habitats
36	Fluvial Geomorphic	See stressor in Row 35	MUK	Support channel avulsion and channel migration	C.4.c (CRC)	See effect in Row 35
37	Fluvial Geomorphic	See stressor in Row 35	UKL, MUK, LKR	Reconnect floodplains, side channels, high flow channels, and wetlands	C.4.c (CRC)	See effect in Row 35
38	Fluvial Geomorphic	See stressor in Row 35	UKL, MUK, LKR	Restore channel complexity	C.4.c (CRC)	See effect in Row 35
39	Fluvial Geomorphic	See stressor in Row 35	MUK, LKR	Manage peak flow magnitude and duration	C.3.h.1 (FRK)	See effect in Row 35
40	Fluvial Geomorphic	See stressor in Row 35	UKL, MUK, LKR	Restore physical processes	C.6.a (PP)	See effect in Row 35
41	Fluvial Geomorphic	Channelization (historic mining impacts)	MUK	Mechanical habitat creation-rehabilitation	C.4.d (CSP)	Creates increased extent and diversity of fish habitats
42	Watershed Inputs	Groundwater interactions	UKL,	Increase upper Klamath Basin storage	C.8 (WTP)	Promotes processes that create increased extent and diversity of fish habitats

Upper Klamath Lake sub-region (Upper Klamath Lake)

A

Legend

Coloured box	Action
Bold border	Extreme stressor
Light border	Low effect stressor
[text]	Refers to concentration



Climate change (higher temperature, more rain, less snow, earlier snowmelt)

Watershed input Action (treat source)

- C.7.k Move surface water conveyance to underground piping (RFC)
- C.3.f Buy back or lease water rights (WLP)
- C.3.g Reduce irrigation water withdrawals (FWD)
- C.5.c Rehabilitate riparian vegetation (RP)
- C.8.f/C.6.l/ Reclaim and construct wetlands (UW, WA)
- C.7.i Reduce nutrients from manure loading to land (LMM)
- C.7.m Rotate crops and wetlands (RCW)
- C.5.d Fence off cattle from streams (RF)
- C.7.n Capture and reuse field and manure drainage (TWR)
- C.7.j Filter stormwater through bio-swales, wetlands (SMT)
- C.7.e Repair sewage and septic systems (SC)

Temperature, hydrology, erosion

External Loading (NO_3, NH_4, TN, SRP, TDP, TP, DOC, Alk, pesticides/herbicides)

Solar radiation

Upper Klamath Lake in Near Term: Hypereutrophic

Cyanotoxins

High phytoplankton biomass

Pesticides/ herbicides

NH_3 toxicity

High summer/fall temperature

High pH

[DO]

High rate of photosynthesis

Fish food organisms and Fish

High P return

Sediment

Respiration (DO demand/lowers pH

Lake Management Action (treat symptom)

- C.7.p Algae harvest (AHV)
- C.7.q Dredge hot spots (DLS)
- C.7.r Targeted aeration for sucker refugia (TA)

Climate change (higher temperature, more rain, less snow, earlier snowmelt)

Higher inflows, lower water residence time than Near Term

Lower external nutrient loading than Near Term

Watershed input Actions as needed (see top bar)

Solar radiation

Upper Klamath Lake in Long Term: Eutrophic

Low [cyanotoxin]

Moderate/high phytoplankton biomass

Pesticides/ herbicides

High summer/fall temperature

Moderate pH

[DO]

Moderate/high rate of photosynthesis

Moderate P return

Fish food organisms and Fish

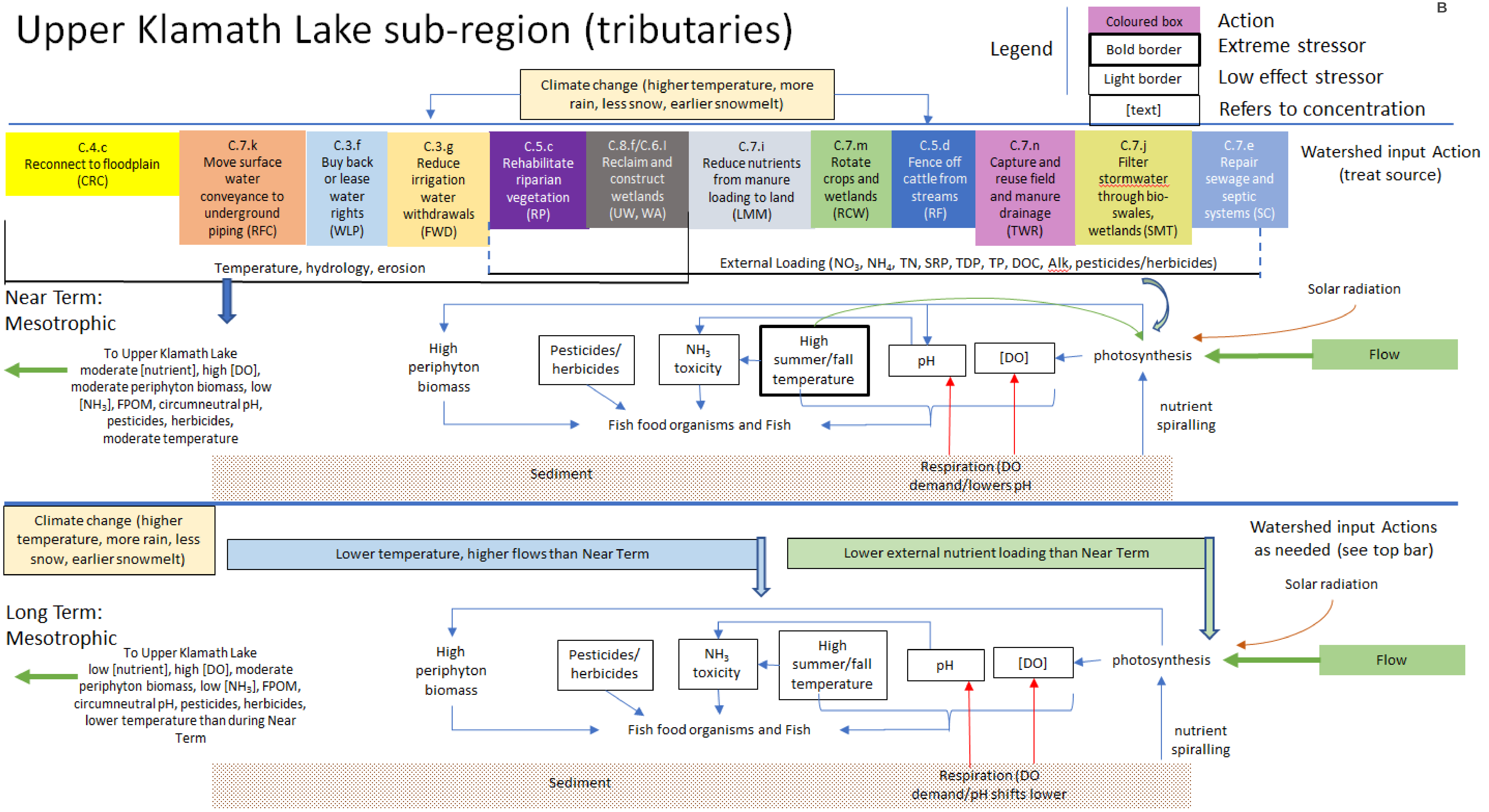
Sediment

Respiration (DO demand/pH shifts lower

Lake Management Action (treat symptom)

- C.7.p Algae harvest (AHV)
- C.7.r Targeted aeration for sucker refugia (TA)

Upper Klamath Lake sub-region (tributaries)



B

Legend

Coloured box	Action
Bold border	Extreme stressor
Light border	Low effect stressor
[text]	Refers to concentration

Climate change (higher temperature, more rain, less snow, earlier snowmelt)

C.4.c Reconnect to floodplain (CRC)

C.7.k Move surface water conveyance to underground piping (RFC)

C.3.f Buy back or lease water rights (WLP)

C.3.g Reduce irrigation water withdrawals (FWD)

C.5.c Rehabilitate riparian vegetation (RP)

C.8.f/C.6.l Reclaim and construct wetlands (UW, WA)

C.7.i Reduce nutrients from manure loading to land (LMM)

C.7.m Rotate crops and wetlands (RCW)

C.5.d Fence off cattle from streams (RF)

C.7.n Capture and reuse field and manure drainage (TWR)

C.7.j Filter stormwater through bio-swales, wetlands (SMT)

C.7.e Repair sewage and septic systems (SC)

Watershed input Action (treat source)

Temperature, hydrology, erosion

External Loading (NO_3, NH_4, TN, SRP, TDP, TP, DOC, Alk, pesticides/herbicides)

Near Term: Mesotrophic

To Upper Klamath Lake moderate [nutrient], high [DO], moderate periphyton biomass, low [NH_3], FPOM, circumneutral pH, pesticides, herbicides, moderate temperature

Climate change (higher temperature, more rain, less snow, earlier snowmelt)

Lower temperature, higher flows than Near Term

Lower external nutrient loading than Near Term

Watershed input Actions as needed (see top bar)

Long Term: Mesotrophic

To Upper Klamath Lake low [nutrient], high [DO], moderate periphyton biomass, low [NH_3], FPOM, circumneutral pH, pesticides, herbicides, lower temperature than during Near Term

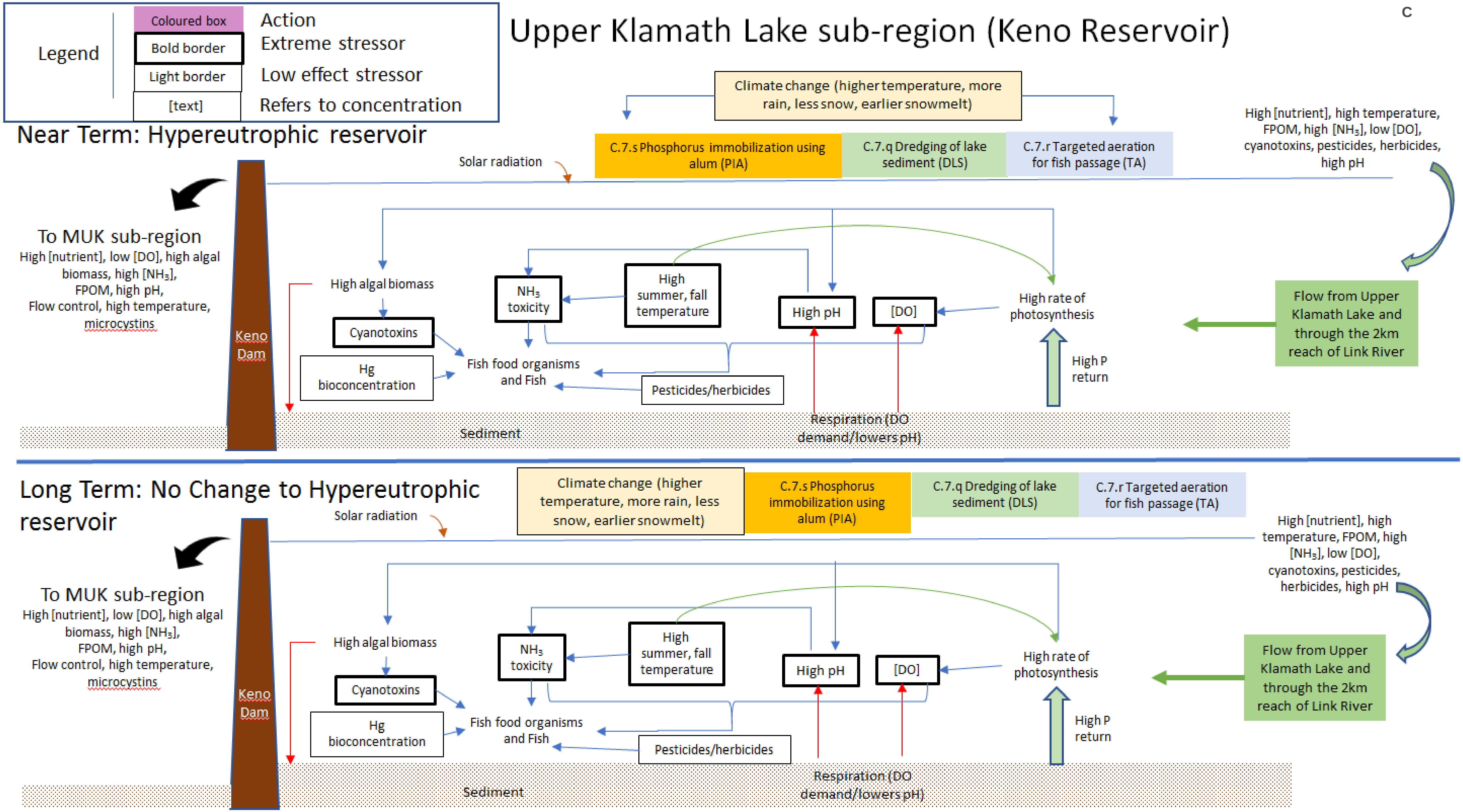


Figure A2. Conceptual model of water quality issues in the Upper Klamath Lake (UKL) sub-region (A) within Upper Klamath Lake, (B) within upper basin tributaries, and (C) within Keno reservoirs, both currently (near term in figure) and following restoration actions (long term in figure). Boxes with bold borders are considered extreme stressors, and those with light borders are considered low effect stressors.

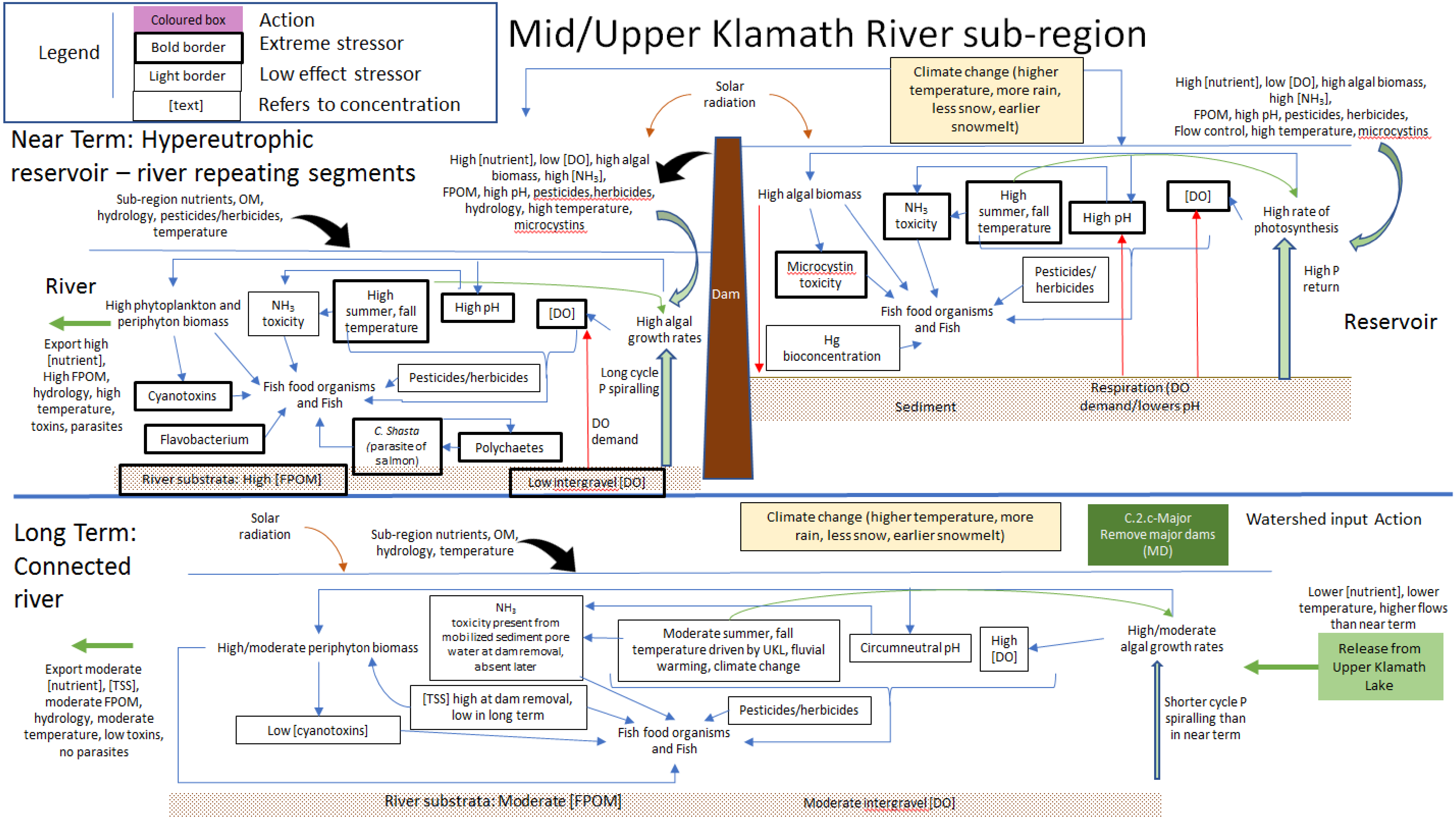


Figure A3. Conceptual model of water quality issues in the Mid/Upper Klamath River sub-region (MUK) both currently (near term in figure) and following restoration actions (long term in figure). Boxes with bold borders are considered extreme stressors, and those with light borders are considered low effect stressors.

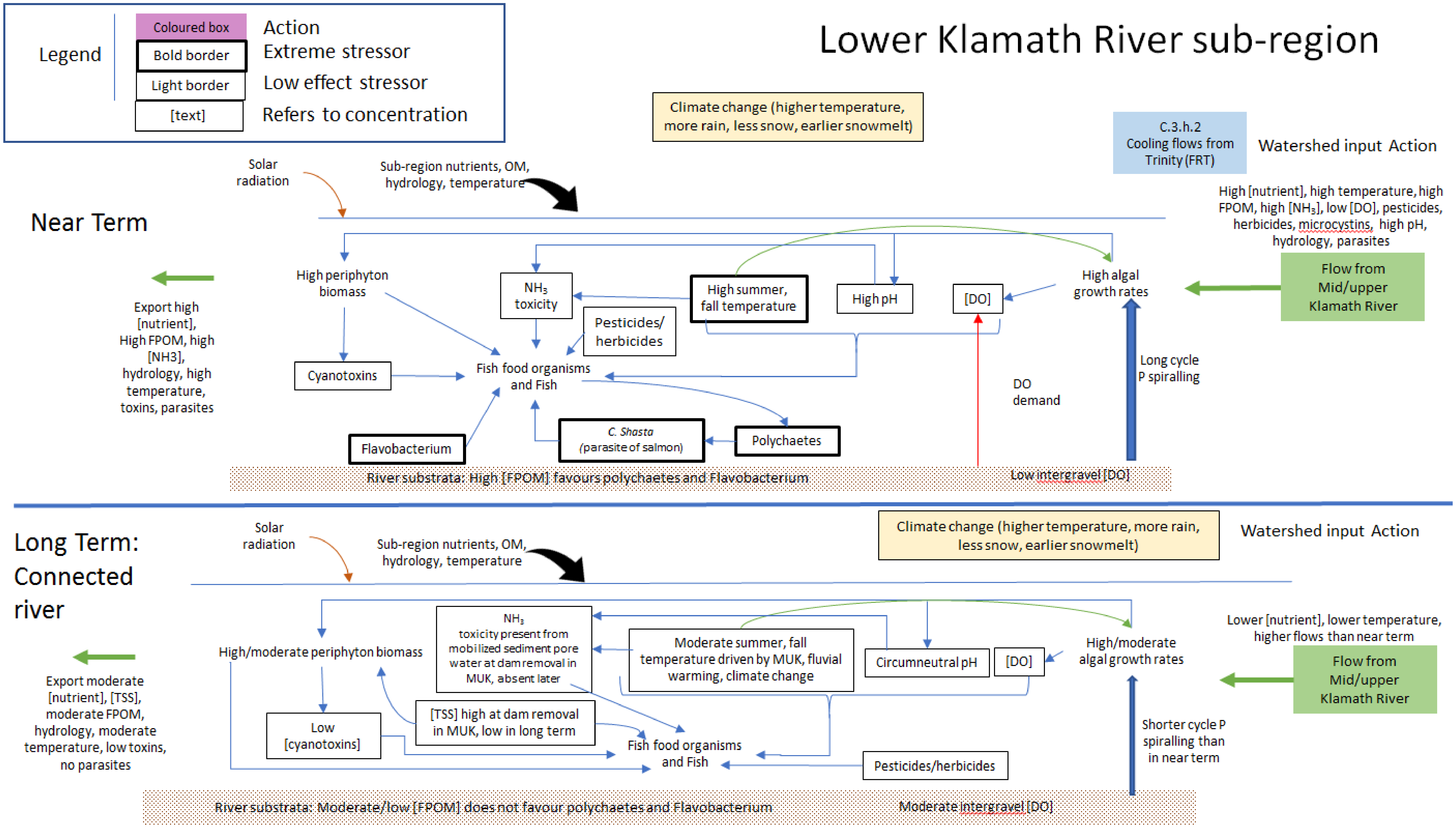


Figure A4. Conceptual model of water quality issues in the Lower Klamath River sub-region (LKR) both currently (near term in figure) and following restoration actions (long term in figure). Boxes with bold borders are considered extreme stressors, and those with light borders are considered low effect stressors.

Table A2. Links between water quality-related stressors for fish across Klamath Basin sub-regions, candidate restoration actions, and hypothesized effects of restoration actions on habitat and fish populations in support of the Klamath Basin Water Quality subregional models.

Row	Framework tier	Stressor **for fish**	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
1	Watershed Inputs	High water temperature in summer and early fall that is lethal to fish • Climate change increases water temperature • Agriculture (alfalfa, hay, grains, potatoes, onions, and livestock (among others)) has replaced wetland, reduced water storage in wetlands, reduced cooling of surface waters by wetlands. • Water withdrawal for agriculture lowers flows and raises water temperature. • Reservoirs in MUK cause cumulative warming of water	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Keno Reservoir • Reservoirs and river in MUK	Move surface water conveyance to underground piping	C.7.k (RFC)	Temperature attenuation
2	Watershed Inputs	See stressor in Row 1	UKL	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake	Buy back or lease water rights from land owners for conversion to wetlands	C.3.f (WLP)	See effect in Row 1
3	Watershed Inputs	See stressor in Row 1	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK	Reduce irrigation water withdrawals	C.3.g (FWD)	See effect in Row 1
4	Watershed Inputs	See stressor in Row 1	UKL, MUK, LKR	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK • River in LKR	Rehabilitate riparian vegetation	C.5.c (RP)	See effect in Row 1
5	Watershed Inputs	See stressor in Row 1	UKL	• Streams upstream of Upper Klamath Lake	Reclaim and construct wetlands on non-	C.8.f (WA)	See effect in Row 1

Row	Framework tier	Stressor **for fish**	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
				• Upper Klamath Lake	private lands		
6	Habitat	See stressor in Row 1	MUK	• Reservoirs and river in MUK • River in LKR	Remove major Klamath dams (eliminates warming in surface layer of reservoirs)	C.2.c-Major (MD)	See effect in Row 1
7	Watershed Inputs	See stressor in Row 1	LKR	• River in LKR	Use flows from Trinity River to cool Lower Klamath River	C.3.h.2 (FRT)	See effect in Row 1
8	Watershed Inputs	Episodic high pH that is toxic to fish • High rates of photosynthesis in Upper Klamath Lake and reservoirs produces episodic high pH that exceeds tolerance range for fish	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Buy back or lease water rights from land owners for conversion to wetlands	C.3.f (WLP)	Lowers the rate of photosynthesis by reducing nutrient loading • Photosynthesis is driven by light (not managed), temperature (managed in rows 1-7), nutrient load and concentrations (managed in rows 8-17)
9	Watershed Inputs	See stressor in Row 8	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Rehabilitate riparian vegetation	C.5.c (RP)	See effect in Row 8
10	Watershed Inputs	See stressor in Row 8	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Reclaim and construct wetlands on non-private lands	C.6.l (UW)	See effect in Row 8
11	Watershed Inputs	See stressor in Row 8	MUK	• Reservoirs and river in MUK	Reduce fertilizer use on agricultural lands	C.7.l (RFT)	See effect in Row 8
12	Watershed Inputs	See stressor in Row 8	UKL, MUK		Rotate crops and wetlands	C.7.m (RCW)	See effect in Row 8
13	Watershed	See stressor in Row 8	UKL, MUK	• Upper Klamath Lake	Fence off cattle from	C.5.d (RF)	See effect in Row 8

Row	Framework tier	Stressor for fish	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
	Inputs			• Reservoirs and river in MUK	streams		
14	Watershed Inputs	See stressor in Row 8	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Capture and reuse field and manure drainage	C.7.n (TWR)	See effect in Row 8
15	Watershed Inputs	See stressor in Row 8	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Filter storm-water through bio-swales and wetlands	C.7.j (SMT)	See effect in Row 8
16	Watershed Inputs	See stressor in Row 8	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Repair sewage and septic systems	C.7.e (SC) (SC)	See effect in Row 8
17	Habitat	See stressor in Row 8	MUK	Reservoirs and river in MUK	Remove Klamath dams (eliminates a source of high pH)	C.2.c-Major (MD)	See effect in Row 8
18	Habitat	See stressor in Row 8	UKL	Upper Klamath Lake	Harvest algae	C.7.p (AHV)	See effect in Row 8
19	Habitat	See stressor in Row 8	MUK	Keno Reservoir	Alum treatment	C.7.s (PIA)	See effect in Row 8
20	Habitat	See stressor in Row 8	UKL	Streams upstream of Upper Klamath Lake	Reconnect floodplain	C.4.c (CRC)	See effect in Row 8
21	Watershed Inputs	Episodic low [DO] that is lethal to fish • Occurs inversely to rates of photosynthesis in Upper Klamath Lake. When photosynthetic rate drops, respiratory demand for DO in sediments increases and causes a drop in water column [DO] that is below the tolerance range for fish	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Buy back or lease water rights from land owners for conversion to wetlands	C.3.f (WLP)	Lowers the rate of respiration in sediments by reducing nutrient loading • Nutrient loading drives the production of organic matter in Upper Klamath Lake, streams, and Klamath River
22	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Rehabilitate riparian vegetation	C.5.c (RP)	See effect in Row 21

Row	Framework tier	Stressor **for fish**	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
23	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Reclaim and construct wetlands on non-private lands	C.6.l (UW)	See effect in Row 21
24	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Reservoirs and river in MUK	Reduce fertilizer use on agricultural lands	C.7.l (RFT)	See effect in Row 21
25	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Rotate crops and wetlands	C.7.m (RCW)	See effect in Row 21
26	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Fence off cattle from streams	C.5.d (RF)	See effect in Row 21
27	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Capture and reuse field and manure drainage	C.7.n (TWR)	See effect in Row 21
28	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Filter storm-water through bio-swales and wetlands	C.7.n (TWR)	See effect in Row 21
29	Watershed Inputs	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Repair sewage and septic systems	C.7.e (SC)	See effect in Row 21
30	Habitat	See stressor in Row 21	MUK	• Reservoirs and river in MUK	Remove Klamath dams (eliminates a source of low [DO])	C.2.c-Major (MD)	See effect in Row 21
31	Habitat	See stressor in Row 21	UKL	• Upper Klamath Lake	Harvest algae	C.7.p (AHV)	See effect in Row 21
32	Habitat	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake, Keno Reservoir	Dredge “hot spots”	C.7.q (DLS)	See effect in Row 21
33	Habitat	See stressor in Row 21	UKL, MUK	• Upper Klamath Lake, Keno Reservoir	Targeted aeration for sucker refugia	C.7.r (TA)	See effect in Row 21
34	Habitat	See stressor in Row 21	MUK	• Keno Reservoir	Alum treatment	C.7.s (PIA)	See effect in Row 21
35	Habitat	See stressor in Row 21	UKL	• Streams upstream of Upper Klamath Lake	Reconnect floodplain	C.4.c (CRC)	See effect in Row 21
36	Watershed Inputs	**NH3 toxicity** (loss of equilibrium, hyperexcitability, increased respiratory activity and oxygen uptake, and	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake	Buy back or lease water rights from land owners for conversion	C.3.f (WLP)	Lowers the rate of nitrogen loading from watersheds

Row	Framework tier	Stressor for fish	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
		increased heart rate. At extreme ammonia levels, fish may experience convulsions, coma, and death) • NH3 is the un-ionized form of ammonia. The ionized form is NH_4. • NH3 is favoured at high pH (rows 8-17) according to the equilibria $NH_3 + H_2O \leftrightarrow NH_4+ + OH^-$ If pH rises the equilibria shifts to the left and produces more NH3. • NH3 formation is also favoured at high temperature (rows 1-7)		• Reservoirs and river in MUK	to wetlands •		• This N loading directly contributes to total ammonia in water bodies. High pH and high temperature in those water bodies drive formation of un-ionized ammonia (NH3) • Lower the rates of photosynthesis that shifts pH up (rows 8-17) by reducing nutrient loading
37	Watershed Inputs	See stressor in Row 36	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK	Rehabilitate riparian vegetation	C.5.c (RP)	See effect in Row 36
38	Watershed Inputs	See stressor in Row 36	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK	Reclaim and construct wetlands on non-private lands	C.6.I (UW)	See effect in Row 36
39	Watershed Inputs	See stressor in Row 36	MUK	• Reservoirs and river in MUK	Reduce fertilizer use on agricultural lands	C.7.k (RFC)	See effect in Row 36
40	Watershed Inputs	See stressor in Row 36	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK	Rotate crops and wetlands	C.7.m (RCW)	See effect in Row 36
41	Watershed Inputs	See stressor in Row 36	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake	Fence off cattle from streams	C.5.d (RF)	See effect in Row 36

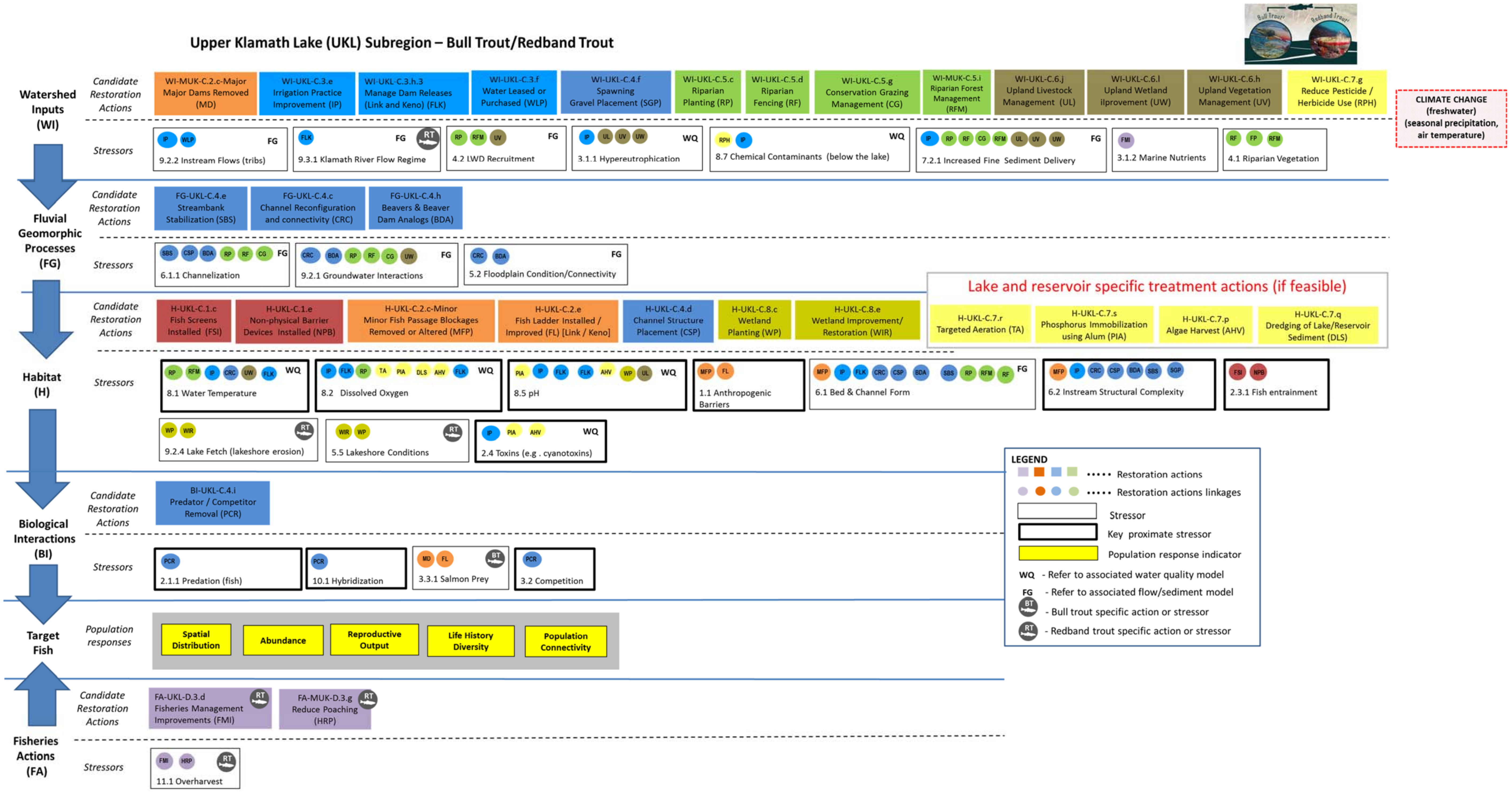
Row	Framework tier	Stressor **for fish**	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
				• Reservoirs and river in MUK			
42	Watershed Inputs	See stressor in Row 36	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK	Capture and reuse field and manure drainage	C.7.n (TWR)	See effect in Row 36
43	Watershed Inputs	See stressor in Row 36	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK	Filter storm-water through bio-swales and wetlands	C.7.j (SMT)	See effect in Row 36
44	Watershed Inputs	See stressor in Row 36	UKL, MUK	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Reservoirs and river in MUK	Repair sewage and septic systems	C.7.e (SC)	See effect in Row 36
45	Habitat	See stressor in Row 36	MUK	• Reservoirs and river in MUK	Remove Klamath dams (eliminates a source of total ammonia from reducing conditions at the sediment-water interface in reservoirs)	C.2.c-Major (MD)	See effect in Row 36
46	Habitat	See stressor in Row 36	UKL	• Streams upstream of Upper Klamath Lake	Reconnect floodplain	C.4.c (CRC)	See effect in Row 36
47	Watershed Inputs	Microcystin toxicity from cyanobacteria that are favoured at high [bio-available P]	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Buy back or lease water rights from land owners for conversion to wetlands	C.3.f (WLP)	Lower production of cyanobacteria that produce microcystins
48	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Rehabilitate riparian vegetation	C.5.c (RP)	See effect in Row 47

Row	Framework tier	Stressor for fish	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
49	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Reclaim and construct wetlands on non-private lands	C.6.l (UW)	See effect in Row 47
50	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Reservoirs and river in MUK	Reduce fertilizer use on agricultural lands	C.7.l (RFT)	See effect in Row 47
51	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Rotate crops and wetlands	C.7.m (RCW)	See effect in Row 47
52	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Fence off cattle from streams	C.5.d (RF)	See effect in Row 47
53	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Capture and reuse field and manure drainage	C.7.n (TWR)	See effect in Row 47
54	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Filter storm-water through bio-swales and wetlands	C.7.j (SMT)	See effect in Row 47
55	Watershed Inputs	See stressor in Row 47	UKL, MUK	• Upper Klamath Lake • Reservoirs and river in MUK	Repair sewage and septic systems	C.7.e (SC)	See effect in Row 47
56	Habitat	See stressor in Row 47	MUK	• Reservoirs and river in MUK	Remove Klamath dams (eliminates a source of total ammonia from reducing conditions at the sediment-water interface in reservoirs)	C.2.c-Major (MD)	See effect in Row 47
57	Habitat	See stressor in Row 47	UKL	• Upper Klamath Lake	Harvest algae	C.7.p (AHV)	See effect in Row 47
58	Habitat	See stressor in Row 47	MUK	• Keno Reservoir	Alum treatment	C.7.s (PIA)	See effect in Row 47
59	Habitat	See stressor in Row 47	UKL	• Streams upstream of Upper Klamath Lake	Reconnect floodplain	C.4.c (CRC)	See effect in Row 47
60	Biological interactions	Pathogens • *C.Shasta* parasite causes	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Buy back or lease water rights from land owners for conversion	C.3.f (WLP)	Lower parasitism and disease in salmonids by removing conditions that

Row	Framework tier	Stressor **for fish**	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
		hemorrhaging and necrosis of the intestine of salmon and trout resulting in mortality, especially at high water temperatures. Mature myxospores released from fish infect a freshwater polychaete worm and develop into actinospores for the parasite to be able to infect another fish and continue its lifecycle. *C. shasta* is not transmissible to humans • Also, *flavobacterium* infections of fish that cause septicemic diseases in salmonids			to wetlands		are favoured by C. Shasta and flavobacteria (POM is driven by nutrient supply and primary production)
61	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Rehabilitate riparian vegetation	C.5.c (RP)	See effect in Row 61
62	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Reclaim and construct wetlands on non-private lands	C.6.l (UW)	See effect in Row 61
63	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Reduce fertilizer use on agricultural lands	C.7.l (RFT)	See effect in Row 61
64	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Rotate crops and wetlands	C.7.m (RCW)	See effect in Row 61
65	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Fence off cattle from streams	C.5.d (RF)	See effect in Row 61
66	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Capture and reuse field and manure drainage	C.7.n (TWR)	See effect in Row 61
67	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK	Filter storm-water through bio-swales	C.7.j (SMT)	See effect in Row 61

Row	Framework tier	Stressor for fish	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
				• River in LKR	and wetlands		
68	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Repair sewage and septic systems	C.7.e (SC)	See effect in Row 61
69	Biological interactions	See stressor in Row 61	MUK, LKR	• Reservoirs and river in MUK • River in LKR	Remove Klamath dams (eliminates a source of nutrients from sediments under reducing conditions that drives production of organic matter that favours polychaetes and bacteria)	C.2.c-Major (MD)	See effect in Row 61
70	Watershed Inputs	Pesticides and herbicides used in agricultural practices that can be harmful to fish	UKL, MUK, LKR	• Below Upper Klamath Lake • Keno Reservoir • Reservoirs and river in MUK • River in LKR	Implementation of best agricultural management practices such as low or no till agriculture, conservation land management; or, upland irrigation water management for water conservation.	C.6.i (UA)	Lower the impacts of toxic pesticides and herbicides used in agricultural practices
71	Watershed inputs	See stressor in Row 70	UKL, MUK, LKR	• Streams upstream of Upper Klamath Lake • Upper Klamath Lake • Keno Reservoir • Reservoirs and river in MUK • River in LKR	Reduce usage of herbicides, pesticides, or other chemical products.	C.7.g (RHP)	See effect in Row 71
72	Habitat	Hg bioconcentration in fish	MUK	• All reservoirs	Remove Klamath dams. This action will eliminate a source of Hg and reducing	C.2.c-Major (MD)	Eliminate conditions favouring methylation of Hg (low [DO])

Row	Framework tier	Stressor **for fish**	Sub-region(s) affected	Water bodies affected	Candidate restoration action	Restoration action identifier	Hypothesized effect of restoration action
					conditions that favour the formation of methyl Hg at the sediment-water interface in reservoirs		



Upper Klamath Lake (UKL) Subregion – Bull Trout/Redband Trout

Watershed Inputs (WI)

Candidate Restoration Actions

- WI-MUK-C.2.c-Major Major Dams Removed (MD)
- WI-UKL-C.3.e Irrigation Practice Improvement (IP)
- WI-UKL-C.3.h.3 Manage Dam Releases (Link and Keno) (FLK)
- WI-UKL-C.3.f Water Leased or Purchased (WLP)
- WI-UKL-C.4.f Spawning Gravel Placement (SGP)
- WI-UKL-C.5.c Riparian Planting (RP)
- WI-UKL-C.5.d Riparian Fencing (RF)
- WI-UKL-C.5.g Conservation Grazing Management (CG)
- WI-MUK-C.5.i Riparian Forest Management (RFM)
- WI-UKL-C.6.j Upland Livestock Management (UL)
- WI-UKL-C.6.l Upland Wetland iIprovement (UW)
- WI-UKL-C.6.h Upland Vegetation Management (UV)
- WI-UKL-C.7.g Reduce Pesticide / Herbicide Use (RPH)

CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)

Stressors

- IP WLP FG 9.2.2 Instream Flows (tribs)
- FLK FG RT 9.3.1 Klamath River Flow Regime
- RP RFM UV FG 4.2 LWD Recruitment
- IP UL UV UW WQ 3.1.1 Hypereutrophication
- RPH IP WQ 8.7 Chemical Contaminants (below the lake)
- IP RP RF CG RFM UL UV UW FG 7.2.1 Increased Fine Sediment Delivery
- FMI 3.1.2 Marine Nutrients
- RF FP RFM 4.1 Riparian Vegetation

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

- FG-UKL-C.4.e Streambank Stabilization (SBS)
- FG-UKL-C.4.c Channel Reconfiguration and connectivity (CRC)
- FG-UKL-C.4.h Beavers & Beaver Dam Analogs (BDA)

Stressors

- SBS CSP BDA RP RF CG FG 6.1.1 Channelization
- CRC BDA RP RF CG UW FG 9.2.1 Groundwater Interactions
- CRC BDA FG 5.2 Floodplain Condition/Connectivity

Habitat (H)

Candidate Restoration Actions

- H-UKL-C.1.c Fish Screens Installed (FSI)
- H-UKL-C.1.e Non-physical Barrier Devices Installed (NPB)
- H-UKL-C.2.c-Minor Minor Fish Passage Blockages Removed or Altered (MFP)
- H-UKL-C.2.e Fish Ladder Installed / Improved (FL) [Link / Keno]
- H-UKL-C.4.d Channel Structure Placement (CSP)
- H-UKL-C.8.c Wetland Planting (WP)
- H-UKL-C.8.e Wetland Improvement/ Restoration (WIR)

Lake and reservoir specific treatment actions (if feasible)

- H-UKL-C.7.r Targeted Aeration (TA)
- H-UKL-C.7.s Phosphorus Immobilization using Alum (PIA)
- H-UKL-C.7.p Algae Harvest (AHV)
- H-UKL-C.7.q Dredging of Lake/Reservoir Sediment (DLS)

Stressors

- RP RFM IP CRC UW FLK WQ 8.1 Water Temperature
- IP FLK RP TA PIA DLS AHV FLK WQ 8.2 Dissolved Oxygen
- PIA IP FLK FLK AHV WP UL WQ 8.5 pH
- MFP FL 1.1 Anthropogenic Barriers
- MFP IP FLK CRC CSP BDA SBS RP RFM RF FG 6.1 Bed & Channel Form
- MFP IP CRC CSP BDA SBS SGP 6.2 Instream Structural Complexity
- FSI NPB 2.3.1 Fish entrainment
- WP WIR RT 9.2.4 Lake Fetch (lakeshore erosion)
- WIR WP RT 5.5 Lakeshore Conditions
- IP PIA AHV WQ 2.4 Toxins (e.g . cyanotoxins)

Biological Interactions (BI)

Candidate Restoration Actions

- BI-UKL-C.4.i Predator / Competitor Removal (PCR)

Stressors

- PCR 2.1.1 Predation (fish)
- PCR 10.1 Hybridization
- MD FL BT 3.3.1 Salmon Prey
- PCR 3.2 Competition

Target Fish

Population responses

- Spatial Distribution
- Abundance
- Reproductive Output
- Life History Diversity
- Population Connectivity

Fisheries Actions (FA)

Candidate Restoration Actions

- FA-UKL-D.3.d Fisheries Management Improvements (FMI) RT
- FA-MUK-D.3.g Reduce Poaching (HRP) RT

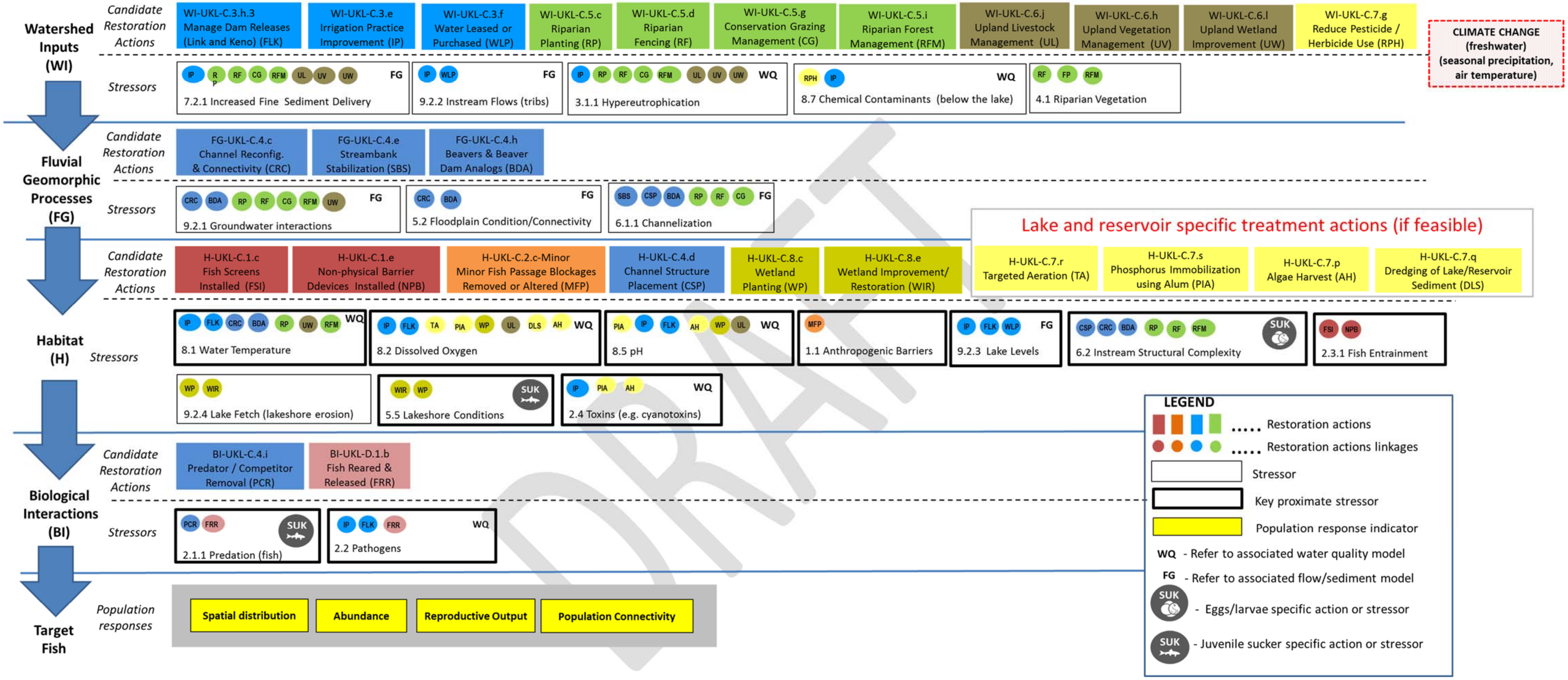
Stressors

- FMI HRP RT 11.1 Overharvest

LEGEND

- ■ ■ ■ ■ ••••• Restoration actions
- ● ● ● ● ••••• Restoration actions linkages
- ☐ Stressor
- ☐ Key proximate stressor
- 🟨 Population response indicator
- WQ - Refer to associated water quality model
- FG - Refer to associated flow/sediment model
- BT - Bull trout specific action or stressor
- RT - Redband trout specific action or stressor

Upper Klamath Lake (UKL) Subregion – Endangered Suckers (Lost River Sucker and Shortnose Sucker)



Watershed Inputs (WI)

Candidate Restoration Actions

- WI-UKL-C.3.h.3 Manage Dam Releases (Link and Keno) (FLK)
- WI-UKL-C.3.e Irrigation Practice Improvement (IP)
- WI-UKL-C.3.f Water Leased or Purchased (WLP)
- WI-UKL-C.5.c Riparian Planting (RP)
- WI-UKL-C.5.d Riparian Fencing (RF)
- WI-UKL-C.5.g Conservation Grazing Management (CG)
- WI-UKL-C.5.i Riparian Forest Management (RFM)
- WI-UKL-C.6.j Upland Livestock Management (UL)
- WI-UKL-C.6.h Upland Vegetation Management (UV)
- WI-UKL-C.6.l Upland Wetland Improvement (UW)
- WI-UKL-C.7.g Reduce Pesticide / Herbicide Use (RPH)

CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)

Stressors

- 7.2.1 Increased Fine Sediment Delivery — IP, RP, RF, CG, RFM, UL, UV, UW — FG
- 9.2.2 Instream Flows (tribs) — IP, WLP — FG
- 3.1.1 Hypereutrophication — IP, RP, RF, CG, RFM, UL, UV, UW — WQ
- 8.7 Chemical Contaminants (below the lake) — RPH, IP — WQ
- 4.1 Riparian Vegetation — RF, FP, RFM

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

- FG-UKL-C.4.c Channel Reconfig. & Connectivity (CRC)
- FG-UKL-C.4.e Streambank Stabilization (SBS)
- FG-UKL-C.4.h Beavers & Beaver Dam Analogs (BDA)

Stressors

- 9.2.1 Groundwater interactions — CRC, BDA, RP, RF, CG, RFM, UW — FG
- 5.2 Floodplain Condition/Connectivity — CRC, BDA — FG
- 6.1.1 Channelization — SBS, CSP, BDA, RP, RF, CG — FG

Habitat (H)

Candidate Restoration Actions

- H-UKL-C.1.c Fish Screens Installed (FSI)
- H-UKL-C.1.e Non-physical Barrier Ddevices Installed (NPB)
- H-UKL-C.2.c-Minor Minor Fish Passage Blockages Removed or Altered (MFP)
- H-UKL-C.4.d Channel Structure Placement (CSP)
- H-UKL-C.8.c Wetland Planting (WP)
- H-UKL-C.8.e Wetland Improvement/ Restoration (WIR)

Lake and reservoir specific treatment actions (if feasible)

- H-UKL-C.7.r Targeted Aeration (TA)
- H-UKL-C.7.s Phosphorus Immobilization using Alum (PIA)
- H-UKL-C.7.p Algae Harvest (AH)
- H-UKL-C.7.q Dredging of Lake/Reservoir Sediment (DLS)

Stressors

- 8.1 Water Temperature — IP, FLK, CRC, BDA, RP, UW, RFM — WQ
- 8.2 Dissolved Oxygen — IP, FLK, TA, PIA, WP, UL, DLS, AH — WQ
- 8.5 pH — PIA, IP, FLK, AH, WP, UL — WQ
- 1.1 Anthropogenic Barriers — MFP
- 9.2.3 Lake Levels — IP, FLK, WLP — FG
- 6.2 Instream Structural Complexity — CSP, CRC, BDA, RP, RF, RFM — SUK
- 2.3.1 Fish Entrainment — FSI, NPB
- 9.2.4 Lake Fetch (lakeshore erosion) — WP, WIR
- 5.5 Lakeshore Conditions — WIR, WP — SUK
- 2.4 Toxins (e.g. cyanotoxins) — IP, PIA, AH — WQ

Biological Interactions (BI)

Candidate Restoration Actions

- BI-UKL-C.4.i Predator / Competitor Removal (PCR)
- BI-UKL-D.1.b Fish Reared & Released (FRR)

Stressors

- 2.1.1 Predation (fish) — PCR, FRR — SUK
- 2.2 Pathogens — IP, FLK, FRR — WQ

Target Fish

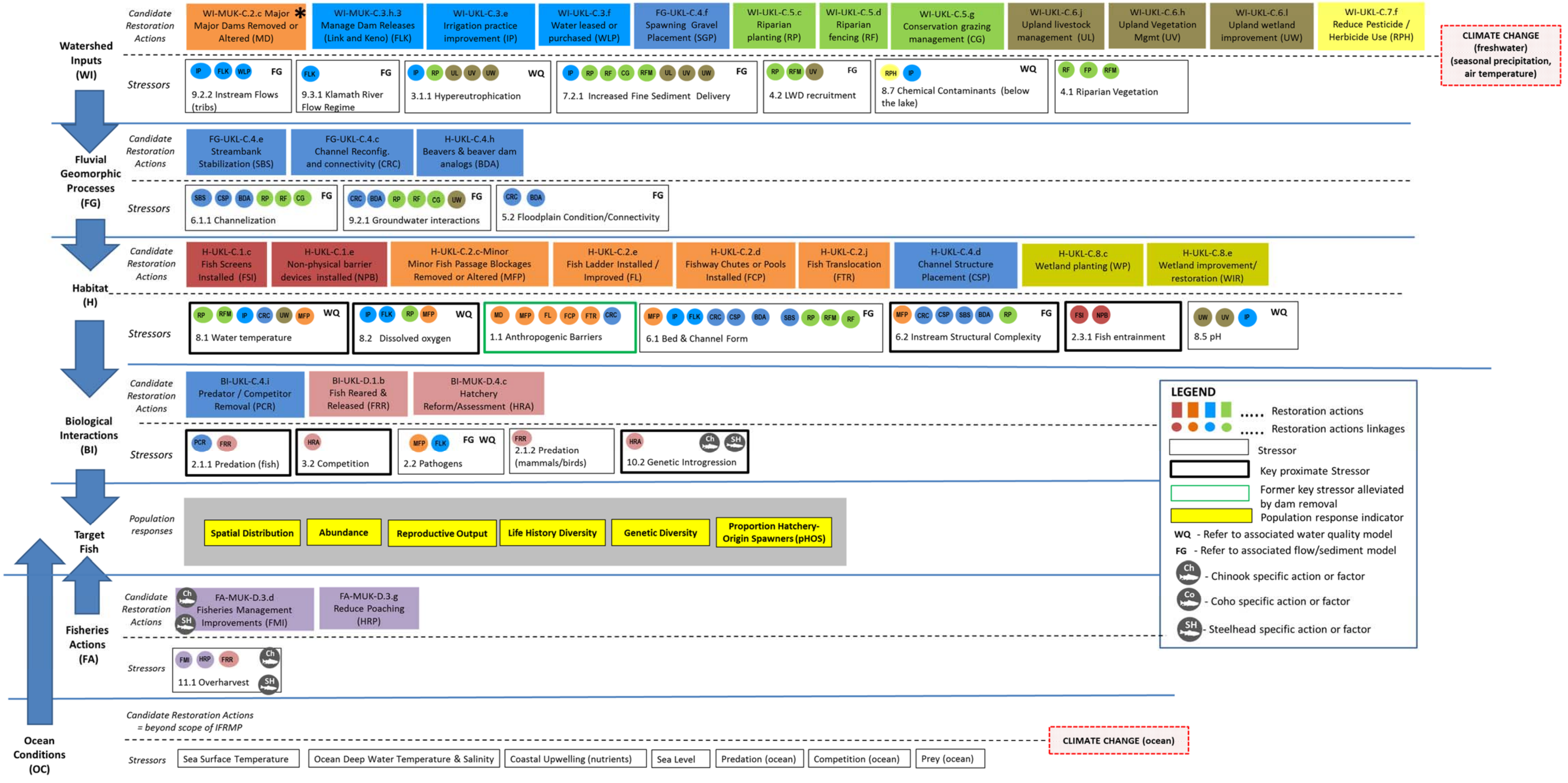
Population responses

- Spatial distribution
- Abundance
- Reproductive Output
- Population Connectivity

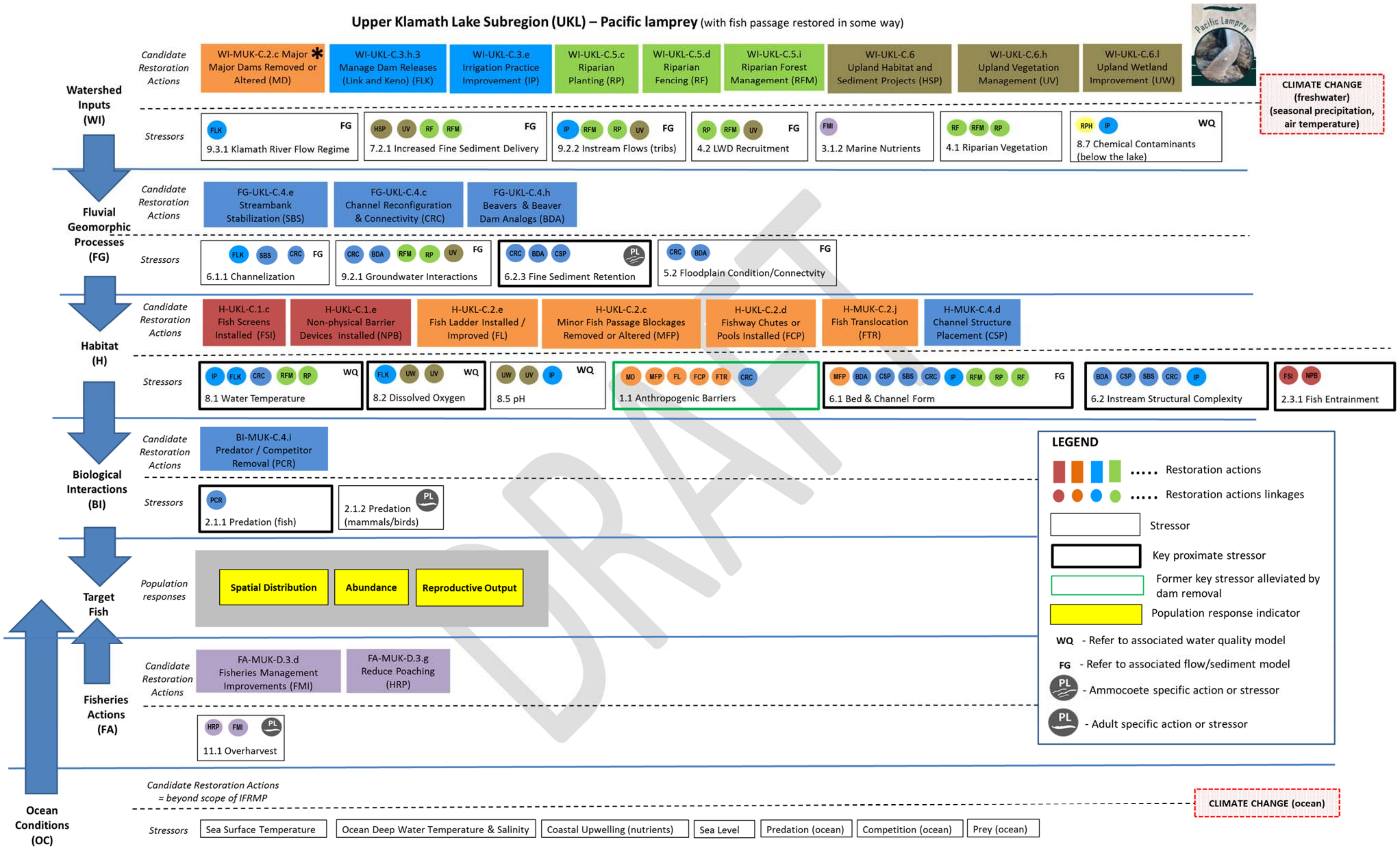
LEGEND

- 🟥 🟧 🟦 🟩 ..... Restoration actions
- ● ● ● ● ..... Restoration actions linkages
- ☐ Stressor
- ▭ Key proximate stressor
- 🟨 Population response indicator
- WQ - Refer to associated water quality model
- FG - Refer to associated flow/sediment model
- SUK - Eggs/larvae specific action or stressor
- SUK - Juvenile sucker specific action or stressor

Upper Klamath Lake Subregion (UKL) - Salmon (Chinook/Coho/Steelhead) (with fish passage restored in some way)



All actions of this conceptual model could still be beneficial to restored salmon in the UKL subregion regardless of whether or not mainstem dams are removed.



***All actions of this conceptual model could still be beneficial to restored Pacific Lamprey in the UKL subregion regardless of whether or not mainstem dams are removed.**

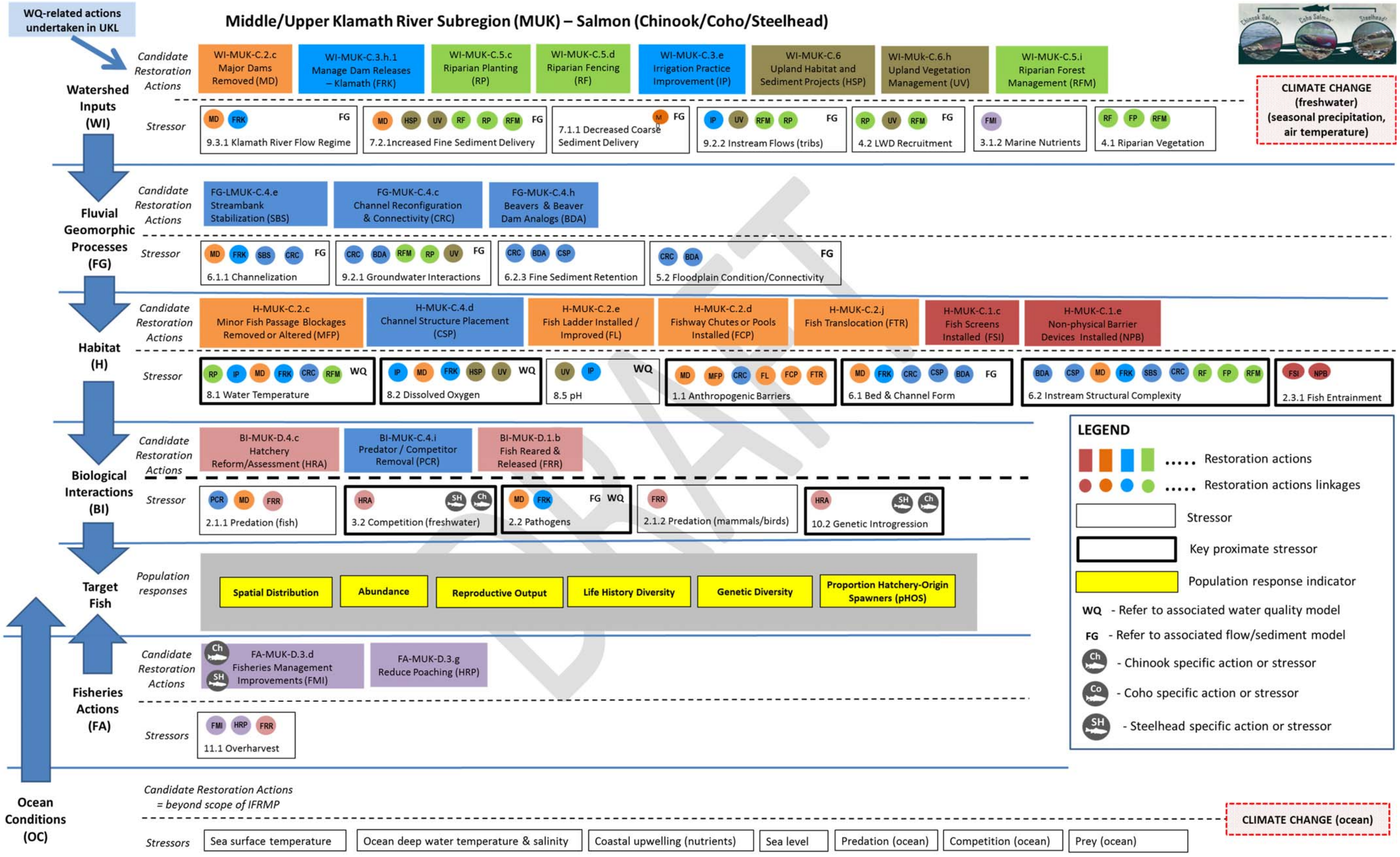
Figure A5. Conceptual diagrams and supporting table for stressors and potential restoration actions across model framework tiers for focal fish species in the Upper Klamath Lake (UKL) sub-region: Bull Trout & Redband Trout, Endangered Suckers (Lost River Sucker, and Shortnose Sucker); and potential future species in the UKL - Chinook, Coho, & Steelhead, and Pacific Lamprey. See Figure 2 for explanation of abbreviations.

Table A3. Stressors affecting the focal fish species/functional groups in the Upper Klamath Lake (UKL) sub-region and the candidate restoration actions that could help alleviate/mitigate each stressor (codes in table match with those for stressors and restoration actions in UKL species conceptual diagrams. Critical uncertainties around each restoration action are described in the Klamath IFRMP Master Restoration Actions Dictionary (Appendix B).

Upper Klamath Lake Focal Species Models Summary (Stressors and Candidate Restoration Actions)			
Tier	Stressors	Candidate Restoration Actions to Alleviate Stressor	Restoration Action Code
Watershed Inputs	7.2.1 Increased fine sediment input/delivery	Upland livestock management (UL)	FG-UKL-C.6.j
		Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.g
		Riparian forest management (RFM)	WI-UKL-C.5.i
		Upland wetland improvement (UW)	WI-UKL-C.6.l
		Upland livestock management (UL)	WI-UKL-C.6.j
		Upland vegetation management (UV)	WI-UKL-C.6.h
	9.2.2 Instream flow (tribs)	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Water leased or purchased (WLP)	WI-UKL-C.3.f
	3.1.1 Hypereutrophication	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.j
		Riparian forest management (RFM)	WI-UKL-C.5.j
		Upland livestock management (UL)	WI-UKL-C.6.j
		Upland vegetation management (UV)	WI-UKL-C.6.h
		Upland wetland improvement (UW)	WI-UKL-C.6.l
		Wetland improvement/ restoration (WIR)	WI-UKL-C.8.e
	8.7 Chemical contaminants (below the lake)	Reduce pesticide/herbicide use (RPH)	WI-UKL-C.7.g
		Irrigation practice improvement (IP)	WI-UKL-C.3.e
	4.1 Riparian vegetation	Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Riparian forest management (RFM)	WI-UKL-C.5.i
Fluvial	9.2.1 Groundwater interactions	Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c

Geomorphic Processes		Beavers and beaver dam analogues (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.g
		Riparian forest management (RFM)	WI-UKL-C.5.i
		Upland wetland improvement (UW)	WI-UKL-C.6.l
	5.2 Floodplain condition/connectivity	Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c
		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
	9.2.3 Channelization	Streambank stabilization (SBS)	FG-UKL-C.4.e
		Channel structure placement (CSP)	H-UKL-C.4.d
		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Conservation grazing management (CG)	WI-UKL-C.5.g
Habitat	8.1 Water temperature	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3
		Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c
		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Upland wetland improvement (UW)	WI-UKL-C.6.l
		Riparian forest management (RFM)	WI-UKL-C.5.i
	8.2 Dissolved oxygen	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3
		Targeted aeration (TA)	H-UKL-C.7.r
		Phosphorus immobilization using alum (PIA)	HI-UKL-C.7.s
		Wetland planting (WP)	H-UKL-C.8.c
		Upland livestock management (UL)	WI-UKL-C.6.j
		Dredging of lake/reservoir sediment (DLS)	H-UKL-C.7.q
		Algae harvest (AH)	H-UKL-C.7.p
	8.5 pH	Phosphorus immobilization using alum (PIA)	H-UKL-C.7.s
		Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3

		Algae harvest (AH)	H-UKL-C.7.p
		Wetland planting (WP)	H_UKL-C.8.c
		Upland livestock management (UL)	WI-UKL-C.6.j
	1.1 Anthropogenic barriers	Minor fish passage blockages removed or altered (MFP)	H-UKL-C.2.c-Minor
	9.2.3 Lake levels	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage dam releases (Link and Keno) (FLK)	WI-UKL-C.3.h.3
		Water leased or purchased (WLP)	WI-UKL-C.3.f
	6.2 Instream structural complexity	Channel structure placement (CSP)	H-UKL-C.4.d
		Channel reconfiguration and connectivity (CRC)	FG-UKL-C.4.c
		Beavers & beaver dam analogs (BDA)	FG-UKL-C.4.h
		Riparian planting (RP)	WI-UKL-C.5.c
		Riparian fencing (RF)	WI-UKL-C.5.d
		Riparian forest management (RFM)	WI-UKL-C.5.i
	2.3.1 Fish entrainment	Fish Screens Installed (FSI)	H-UKL-C.1.c
		Non-physical barrier devices installed (NPB)	H-UKL-C.1.e
	9.2.4 Lake fetch	Wetland planting (WP)	H_UKL-C.8.c
		Wetland improvement (WIR)	H-UKL-C.8.e
	5.5 Lakeshore conditions	Wetland planting (WP)	H_UKL-C.8.c
		Wetland improvement (WIR)	H-UKL-C.8.e
	2.4 Toxins (e.g., cyanotoxins)	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Phosphorus immobilization using alum (PIA)	H-UKL-C.7.s
		Algae harvest (AH)	H-UKL-C.7.p
Biological Interactions	2.1.1 Predation (fish)	Predator / Competitor Removal (PCR)	BI-UKL-C.4.i
	2.1.1 Competition	Fish Reared & Released (FRR)	BI-UKL-D.1.b
	2.2 Pathogens	Irrigation practice improvement (IP)	WI-UKL-C.3.e
		Manage Dam Releases (Link and Keno) (FLK)	WI-UKL-C.3.h.1
		Fish Reared & Released (FRR)	BI-UKL-D.1.b



Middle/Upper Klamath River Subregion (MUK) – Salmon (Chinook/Coho/Steelhead)

WQ-related actions undertaken in UKL

CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)

Watershed Inputs (WI)

Candidate Restoration Actions

- WI-MUK-C.2.c Major Dams Removed (MD)
- WI-MUK-C.3.h.1 Manage Dam Releases – Klamath (FRK)
- WI-MUK-C.5.c Riparian Planting (RP)
- WI-MUK-C.5.d Riparian Fencing (RF)
- WI-MUK-C.3.e Irrigation Practice Improvement (IP)
- WI-MUK-C.6 Upland Habitat and Sediment Projects (HSP)
- WI-MUk-C.6.h Upland Vegetation Management (UV)
- WI-MUK-C.5.i Riparian Forest Management (RFM)

Stressor

- MD FRK FG 9.3.1 Klamath River Flow Regime
- MD HSP UV RF RP RFM FG 7.2.1ncreased Fine Sediment Delivery
- M FG 7.1.1 Decreased Coarse Sediment Delivery
- IP UV RFM RP FG 9.2.2 Instream Flows (tribs)
- RP UV RFM FG 4.2 LWD Recruitment
- FMI 3.1.2 Marine Nutrients
- RF FP RFM 4.1 Riparian Vegetation

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

- FG-LMUK-C.4.e Streambank Stabilization (SBS)
- FG-MUK-C.4.c Channel Reconfiguration & Connectivity (CRC)
- FG-MUK-C.4.h Beavers & Beaver Dam Analogs (BDA)

Stressor

- MD FRK SBS CRC FG 6.1.1 Channelization
- CRC BDA RFM RP UV FG 9.2.1 Groundwater Interactions
- CRC BDA CSP 6.2.3 Fine Sediment Retention
- CRC BDA FG 5.2 Floodplain Condition/Connectivity

Habitat (H)

Candidate Restoration Actions

- H-MUK-C.2.c Minor Fish Passage Blockages Removed or Altered (MFP)
- H-MUK-C.4.d Channel Structure Placement (CSP)
- H-MUK-C.2.e Fish Ladder Installed / Improved (FL)
- H-MUK-C.2.d Fishway Chutes or Pools Installed (FCP)
- H-MUK-C.2.j Fish Translocation (FTR)
- H-MUK-C.1.c Fish Screens Installed (FSI)
- H-MUK-C.1.e Non-physical Barrier Devices Installed (NPB)

Stressor

- RP IP MD FRK CRC RFM WQ 8.1 Water Temperature
- IP MD FRK HSP UV WQ 8.2 Dissolved Oxygen
- UV IP WQ 8.5 pH
- MD MFP CRC FL FCP FTR 1.1 Anthropogenic Barriers
- MD FRK CRC CSP BDA FG 6.1 Bed & Channel Form
- BDA CSP MD FRK SBS CRC RF FP RFM 6.2 Instream Structural Complexity
- FSI NPB 2.3.1 Fish Entrainment

Biological Interactions (BI)

Candidate Restoration Actions

- BI-MUK-D.4.c Hatchery Reform/Assessment (HRA)
- BI-MUK-C.4.i Predator / Competitor Removal (PCR)
- BI-MUK-D.1.b Fish Reared & Released (FRR)

Stressor

- PCR MD FRR 2.1.1 Predation (fish)
- HRA SH Ch 3.2 Competition (freshwater)
- MD FRK FG WQ 2.2 Pathogens
- FRR 2.1.2 Predation (mammals/birds)
- HRA SH Ch 10.2 Genetic Introgression

Target Fish

Population responses

- Spatial Distribution
- Abundance
- Reproductive Output
- Life History Diversity
- Genetic Diversity
- Proportion Hatchery-Origin Spawners (pHOS)

Fisheries Actions (FA)

Candidate Restoration Actions

- Ch SH FA-MUK-D.3.d Fisheries Management Improvements (FMI)
- FA-MUK-D.3.g Reduce Poaching (HRP)

Stressors

- FMI HRP FRR 11.1 Overharvest

Ocean Conditions (OC)

Candidate Restoration Actions = beyond scope of IFRMP

CLIMATE CHANGE (ocean)

Stressors

- Sea surface temperature
- Ocean deep water temperature & salinity
- Coastal upwelling (nutrients)
- Sea level
- Predation (ocean)
- Competition (ocean)
- Prey (ocean)

LEGEND

🟥 🟧 🟦 🟩 ..... Restoration actions

● ● ● ● ..... Restoration actions linkages

☐ Stressor

☐ Key proximate stressor

🟨 Population response indicator

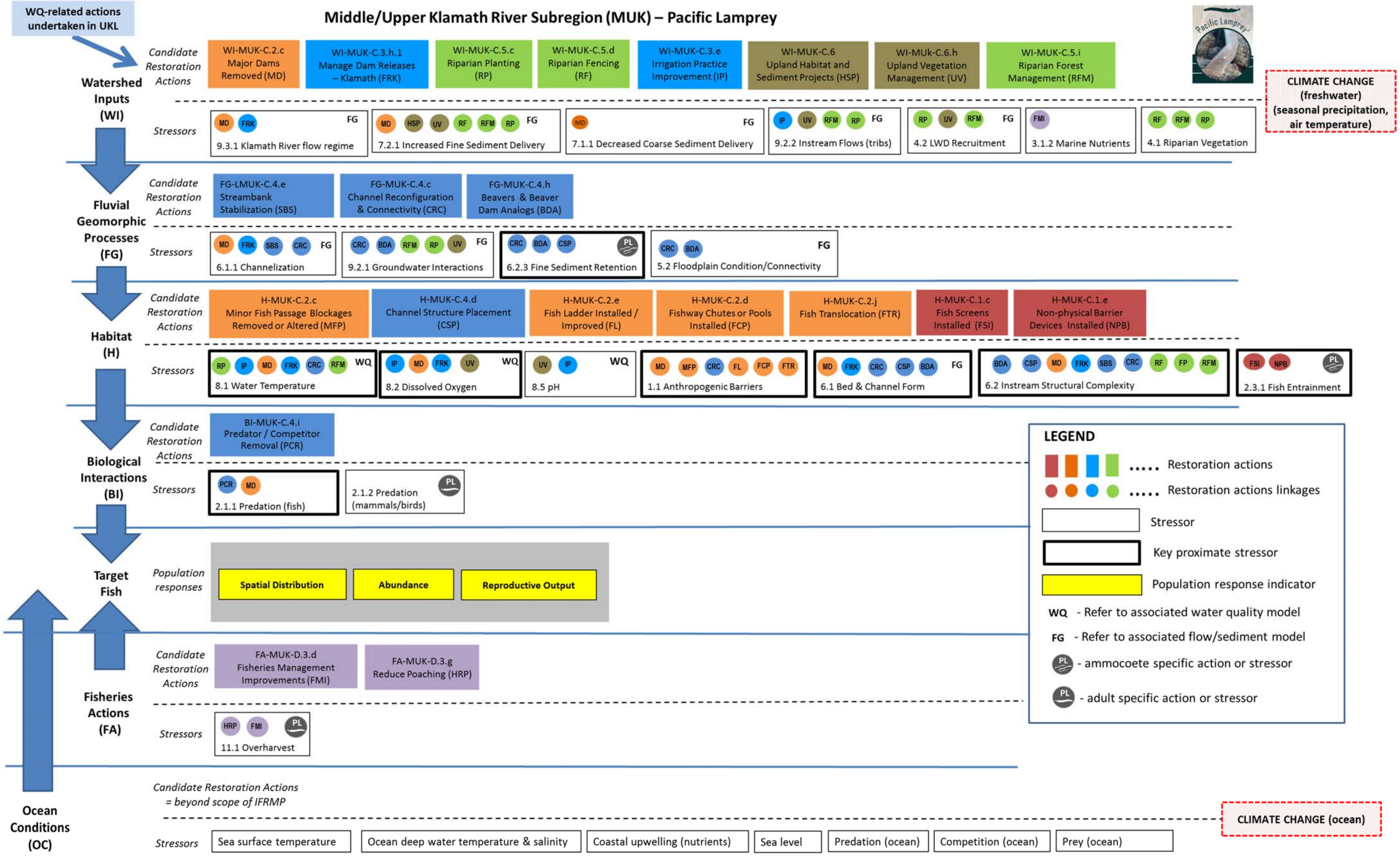
WQ - Refer to associated water quality model

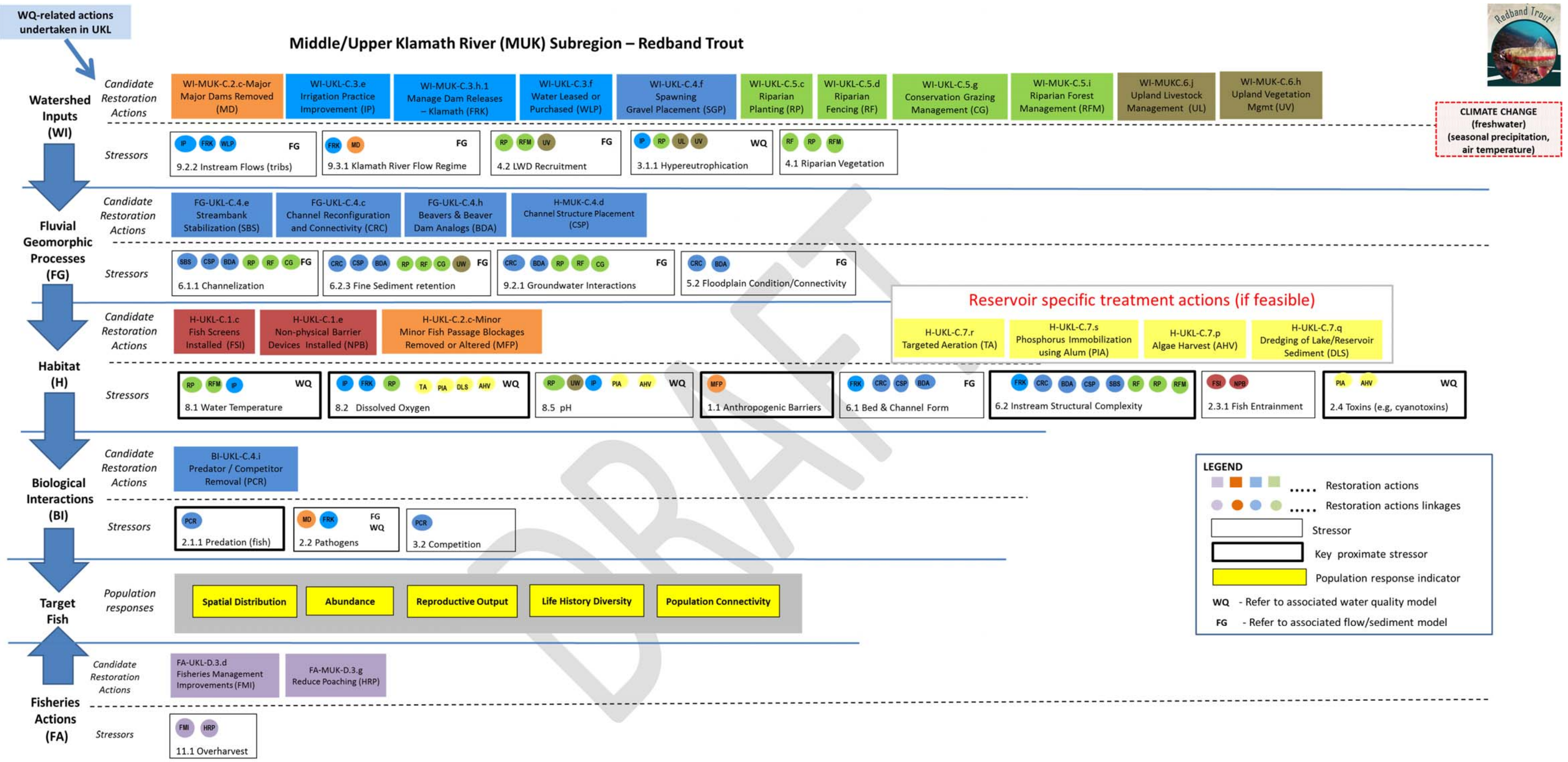
FG - Refer to associated flow/sediment model

Ch - Chinook specific action or stressor

Co - Coho specific action or stressor

SH - Steelhead specific action or stressor


Middle/Upper Klamath River Subregion (MUK) – Pacific Lamprey
WQ-related actions undertaken in UKL
Pacific Lamprey
CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)
Watershed Inputs (WI)
Candidate Restoration Actions
WI-MUK-C.2.c Major Dams Removed (MD)
WI-MUK-C.3.h.1 Manage Dam Releases – Klamath (FRK)
WI-MUK-C.5.c Riparian Planting (RP)
WI-MUK-C.5.d Riparian Fencing (RF)
WI-MUK-C.3.e Irrigation Practice Improvement (IP)
WI-MUK-C.6 Upland Habitat and Sediment Projects (HSP)
WI-MUk-C.6.h Upland Vegetation Management (UV)
WI-MUK-C.5.i Riparian Forest Management (RFM)
Stressors
MD FRK FG 9.3.1 Klamath River flow regime
MD HSP UV RF RFM RP FG 7.2.1 Increased Fine Sediment Delivery
MD FG 7.1.1 Decreased Coarse Sediment Delivery
IP UV RFM RP FG 9.2.2 Instream Flows (tribs)
RP UV RFM FG 4.2 LWD Recruitment
FMI 3.1.2 Marine Nutrients
RF RFM RP 4.1 Riparian Vegetation
Fluvial Geomorphic Processes (FG)
Candidate Restoration Actions
FG-LMUK-C.4.e Streambank Stabilization (SBS)
FG-MUK-C.4.c Channel Reconfiguration & Connectivity (CRC)
FG-MUK-C.4.h Beavers & Beaver Dam Analogs (BDA)
Stressors
MD FRK SBS CRC FG 6.1.1 Channelization
CRC BDA RFM RP UV FG 9.2.1 Groundwater Interactions
CRC BDA CSP PL 6.2.3 Fine Sediment Retention
CRC BDA FG 5.2 Floodplain Condition/Connectivity
Habitat (H)
Candidate Restoration Actions
H-MUK-C.2.c Minor Fish Passage Blockages Removed or Altered (MFP)
H-MUK-C.4.d Channel Structure Placement (CSP)
H-MUK-C.2.e Fish Ladder Installed / Improved (FL)
H-MUK-C.2.d Fishway Chutes or Pools Installed (FCP)
H-MUK-C.2.j Fish Translocation (FTR)
H-MUK-C.1.c Fish Screens Installed (FSI)
H-MUK-C.1.e Non-physical Barrier Devices Installed (NPB)
Stressors
RP IP MD FRK CRC RFM WQ 8.1 Water Temperature
IP MD FRK UV WQ 8.2 Dissolved Oxygen
UV IP WQ 8.5 pH
MD MFP CRC FL FCP FTR 1.1 Anthropogenic Barriers
MD FRK CRC CSP BDA FG 6.1 Bed & Channel Form
BDA CSP MD FRK SBS CRC RF FP RFM 6.2 Instream Structural Complexity
FSI NPB PL 2.3.1 Fish Entrainment
Biological Interactions (BI)
Candidate Restoration Actions
BI-MUK-C.4.i Predator / Competitor Removal (PCR)
Stressors
PCR MD 2.1.1 Predation (fish)
PL 2.1.2 Predation (mammals/birds)
Target Fish
Population responses
Spatial Distribution
Abundance
Reproductive Output
Fisheries Actions (FA)
Candidate Restoration Actions
FA-MUK-D.3.d Fisheries Management Improvements (FMI)
FA-MUK-D.3.g Reduce Poaching (HRP)
Stressors
HRP FMI PL 11.1 Overharvest
Ocean Conditions (OC)
Candidate Restoration Actions = beyond scope of IFRMP
CLIMATE CHANGE (ocean)
Stressors
Sea surface temperature
Ocean deep water temperature & salinity
Coastal upwelling (nutrients)
Sea level
Predation (ocean)
Competition (ocean)
Prey (ocean)
LEGEND
..... Restoration actions
..... Restoration actions linkages
Stressor
Key proximate stressor
Population response indicator
WQ - Refer to associated water quality model
FG - Refer to associated flow/sediment model
PL - ammocoete specific action or stressor
PL - adult specific action or stressor



Middle/Upper Klamath River (MUK) Subregion – Redband Trout

WQ-related actions undertaken in UKL

CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)

Watershed Inputs (WI)

Candidate Restoration Actions
- WI-MUK-C.2.c-Major Major Dams Removed (MD)
- WI-UKL-C.3.e Irrigation Practice Improvement (IP)
- WI-MUK-C.3.h.1 Manage Dam Releases – Klamath (FRK)
- WI-UKL-C.3.f Water Leased or Purchased (WLP)
- WI-UKL-C.4.f Spawning Gravel Placement (SGP)
- WI-UKL-C.5.c Riparian Planting (RP)
- WI-UKL-C.5.d Riparian Fencing (RF)
- WI-UKL-C.5.g Conservation Grazing Management (CG)
- WI-MUK-C.5.i Riparian Forest Management (RFM)
- WI-MUKC.6.j Upland Livestock Management (UL)
- WI-MUK-C.6.h Upland Vegetation Mgmt (UV)

Stressors
- 9.2.2 Instream Flows (tribs) — IP, FRK, WLP — FG
- 9.3.1 Klamath River Flow Regime — FRK, MD — FG
- 4.2 LWD Recruitment — RP, RFM, UV — FG
- 3.1.1 Hypereutrophication — IP, RP, UL, UV — WQ
- 4.1 Riparian Vegetation — RF, RP, RFM

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions
- FG-UKL-C.4.e Streambank Stabilization (SBS)
- FG-UKL-C.4.c Channel Reconfiguration and Connectivity (CRC)
- FG-UKL-C.4.h Beavers & Beaver Dam Analogs (BDA)
- H-MUK-C.4.d Channel Structure Placement (CSP)

Stressors
- 6.1.1 Channelization — SBS, CSP, BDA, RP, RF, CG — FG
- 6.2.3 Fine Sediment retention — CRC, CSP, BDA, RP, RF, CG, UW — FG
- 9.2.1 Groundwater Interactions — CRC, BDA, RP, RF, CG — FG
- 5.2 Floodplain Condition/Connectivity — CRC, BDA — FG

Habitat (H)

Candidate Restoration Actions
- H-UKL-C.1.c Fish Screens Installed (FSI)
- H-UKL-C.1.e Non-physical Barrier Devices Installed (NPB)
- H-UKL-C.2.c-Minor Minor Fish Passage Blockages Removed or Altered (MFP)

Reservoir specific treatment actions (if feasible)
- H-UKL-C.7.r Targeted Aeration (TA)
- H-UKL-C.7.s Phosphorus Immobilization using Alum (PIA)
- H-UKL-C.7.p Algae Harvest (AHV)
- H-UKL-C.7.q Dredging of Lake/Reservoir Sediment (DLS)

Stressors
- 8.1 Water Temperature — RP, RFM, IP — WQ
- 8.2 Dissolved Oxygen — IP, FRK, RP, TA, PIA, DLS, AHV — WQ
- 8.5 pH — RP, UW, IP, PIA, AHV — WQ
- 1.1 Anthropogenic Barriers — MFP
- 6.1 Bed & Channel Form — FRK, CRC, CSP, BDA — FG
- 6.2 Instream Structural Complexity — FRK, CRC, BDA, CSP, SBS, RF, RP, RFM
- 2.3.1 Fish Entrainment — FSI, NPB
- 2.4 Toxins (e.g, cyanotoxins) — PIA, AHV — WQ

Biological Interactions (BI)

Candidate Restoration Actions
- BI-UKL-C.4.i Predator / Competitor Removal (PCR)

Stressors
- 2.1.1 Predation (fish) — PCR
- 2.2 Pathogens — MD, FRK — FG WQ
- 3.2 Competition — PCR

Target Fish

Population responses
- Spatial Distribution
- Abundance
- Reproductive Output
- Life History Diversity
- Population Connectivity

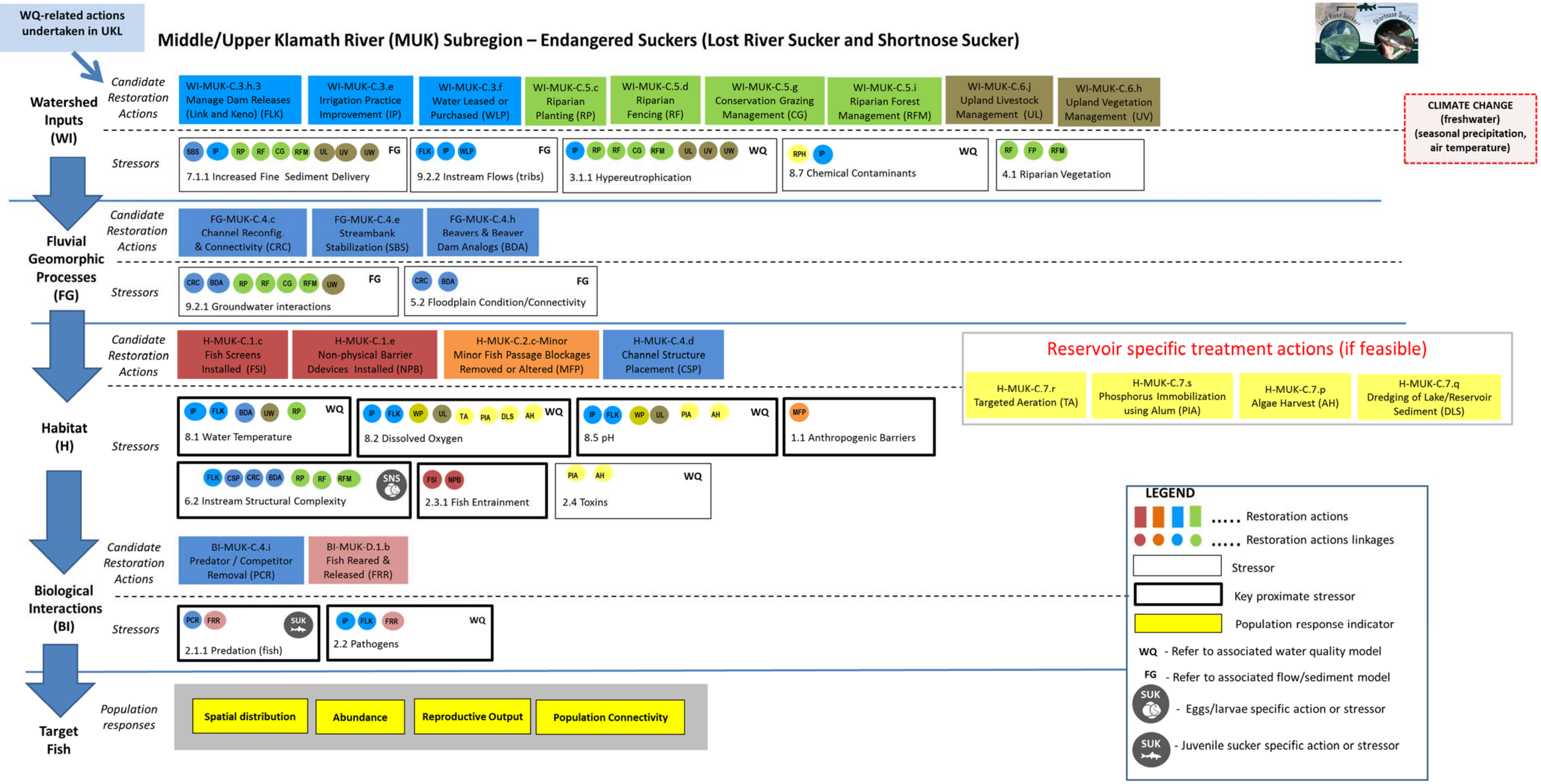
Fisheries Actions (FA)

Candidate Restoration Actions
- FA-UKL-D.3.d Fisheries Management Improvements (FMI)
- FA-MUK-D.3.g Reduce Poaching (HRP)

Stressors
- 11.1 Overharvest — FMI, HRP

LEGEND
- ■ ■ ■ ■ ..... Restoration actions
- ● ● ● ● ..... Restoration actions linkages
- ☐ Stressor
- ▭ Key proximate stressor
- 🟨 Population response indicator
- WQ - Refer to associated water quality model
- FG - Refer to associated flow/sediment model

Middle/Upper Klamath River (MUK) Subregion – Endangered Suckers (Lost River Sucker and Shortnose Sucker)



WQ-related actions undertaken in UKL

Watershed Inputs (WI)

Candidate Restoration Actions

- WI-MUK-C.3.h.3 Manage Dam Releases (Link and Keno) (FLK)
- WI-MUK-C.3.e Irrigation Practice Improvement (IP)
- WI-MUK-C.3.f Water Leased or Purchased (WLP)
- WI-MUK-C.5.c Riparian Planting (RP)
- WI-MUK-C.5.d Riparian Fencing (RF)
- WI-MUK-C.5.g Conservation Grazing Management (CG)
- WI-MUK-C.5.i Riparian Forest Management (RFM)
- WI-MUK-C.6.j Upland Livestock Management (UL)
- WI-MUK-C.6.h Upland Vegetation Management (UV)

Stressors

- 7.1.1 Increased Fine Sediment Delivery — SBS, IP, RP, RF, CG, RFM, UL, UV, UW — FG
- 9.2.2 Instream Flows (tribs) — FLK, IP, WLP — FG
- 3.1.1 Hypereutrophication — IP, RP, RF, CG, RFM, UL, UV, UW — WQ
- 8.7 Chemical Contaminants — RPH, IP — WQ
- 4.1 Riparian Vegetation — RF, FP, RFM

CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

- FG-MUK-C.4.c Channel Reconfig. & Connectivity (CRC)
- FG-MUK-C.4.e Streambank Stabilization (SBS)
- FG-MUK-C.4.h Beavers & Beaver Dam Analogs (BDA)

Stressors

- 9.2.1 Groundwater interactions — CRC, BDA, RP, RF, CG, RFM, UW — FG
- 5.2 Floodplain Condition/Connectivity — CRC, BDA — FG

Habitat (H)

Candidate Restoration Actions

- H-MUK-C.1.c Fish Screens Installed (FSI)
- H-MUK-C.1.e Non-physical Barrier Ddevices Installed (NPB)
- H-MUK-C.2.c-Minor Minor Fish Passage Blockages Removed or Altered (MFP)
- H-MUK-C.4.d Channel Structure Placement (CSP)

Reservoir specific treatment actions (if feasible)

- H-MUK-C.7.r Targeted Aeration (TA)
- H-MUK-C.7.s Phosphorus Immobilization using Alum (PIA)
- H-MUK-C.7.p Algae Harvest (AH)
- H-MUK-C.7.q Dredging of Lake/Reservoir Sediment (DLS)

Stressors

- 8.1 Water Temperature — IP, FLK, BDA, UW, RP — WQ
- 8.2 Dissolved Oxygen — IP, FLK, WP, UL, TA, PIA, DLS, AH — WQ
- 8.5 pH — IP, FLK, WP, UL, PIA, AH — WQ
- 1.1 Anthropogenic Barriers — MFP
- 6.2 Instream Structural Complexity — FLK, CSP, CRC, BDA, RP, RF, RFM — SNS
- 2.3.1 Fish Entrainment — FSI, NPB
- 2.4 Toxins — PIA, AH — WQ

Biological Interactions (BI)

Candidate Restoration Actions

- BI-MUK-C.4.i Predator / Competitor Removal (PCR)
- BI-MUK-D.1.b Fish Reared & Released (FRR)

Stressors

- 2.1.1 Predation (fish) — PCR, FRR — SUK
- 2.2 Pathogens — IP, FLK, FRR — WQ

Target Fish

Population responses

- **Spatial distribution**
- **Abundance**
- **Reproductive Output**
- **Population Connectivity**

LEGEND

🟥 🟧 🟦 🟩 ….. Restoration actions

● ● ● ● ….. Restoration actions linkages

☐ Stressor

☐ Key proximate stressor

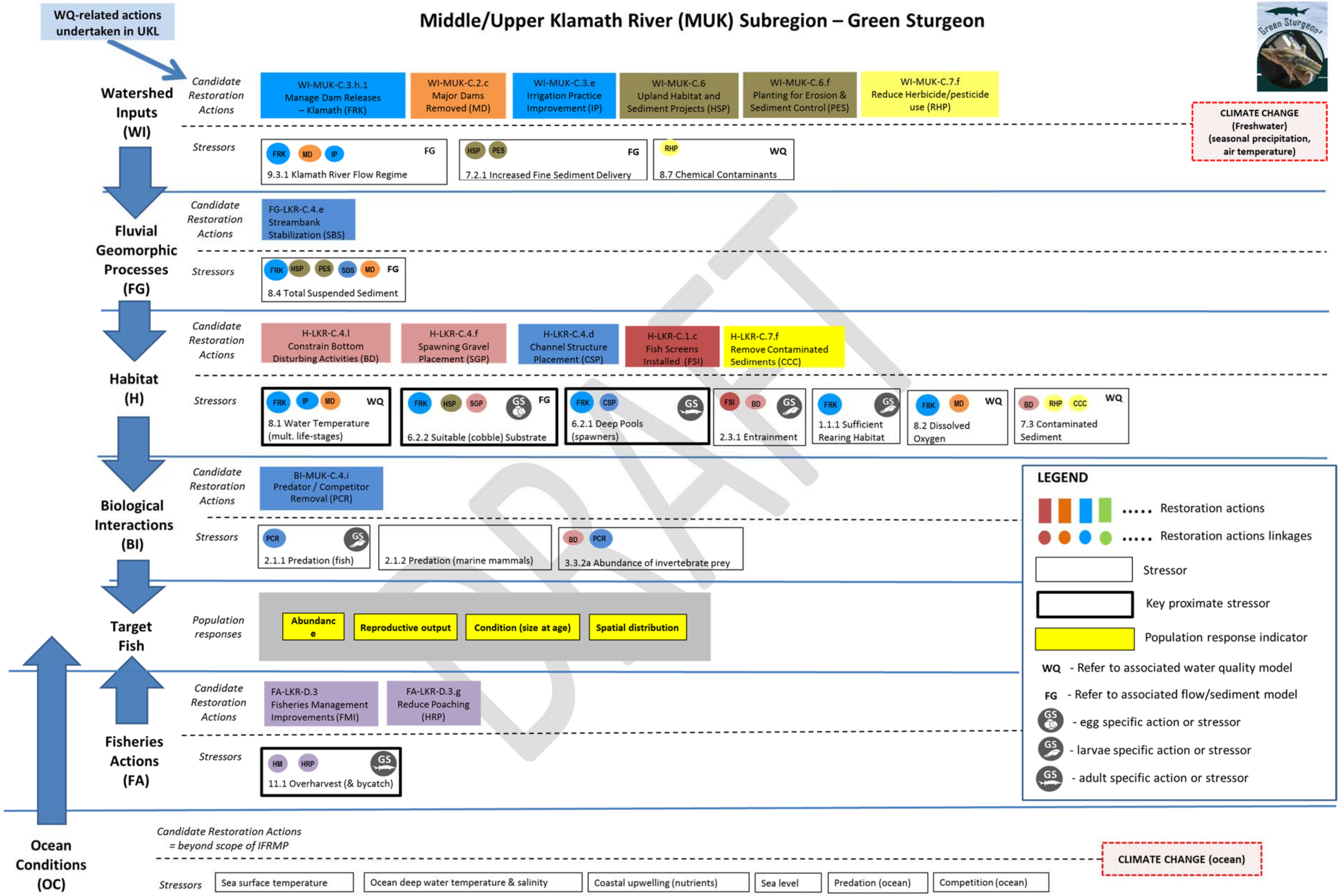
🟨 Population response indicator

WQ - Refer to associated water quality model

FG - Refer to associated flow/sediment model

SUK - Eggs/larvae specific action or stressor

SUK - Juvenile sucker specific action or stressor



WQ-related actions undertaken in UKL

Middle/Upper Klamath River (MUK) Subregion – Green Sturgeon

Watershed Inputs (WI)

Candidate Restoration Actions

WI-MUK-C.3.h.1 Manage Dam Releases – Klamath (FRK)

WI-MUK-C.2.c Major Dams Removed (MD)

WI-MUK-C.3.e Irrigation Practice Improvement (IP)

WI-MUK-C.6 Upland Habitat and Sediment Projects (HSP)

WI-MUK-C.6.f Planting for Erosion & Sediment Control (PES)

WI-MUK-C.7.f Reduce Herbicide/pesticide use (RHP)

Stressors

FRK MD IP FG 9.3.1 Klamath River Flow Regime

HSP PES FG 7.2.1 Increased Fine Sediment Delivery

RHP WQ 8.7 Chemical Contaminants

CLIMATE CHANGE (Freshwater) (seasonal precipitation, air temperature)

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

FG-LKR-C.4.e Streambank Stabilization (SBS)

Stressors

FRK HSP PES SBS MD FG 8.4 Total Suspended Sediment

Habitat (H)

Candidate Restoration Actions

H-LKR-C.4.l Constrain Bottom Disturbing Activities (BD)

H-LKR-C.4.f Spawning Gravel Placement (SGP)

H-LKR-C.4.d Channel Structure Placement (CSP)

H-LKR-C.1.c Fish Screens Installed (FSI)

H-LKR-C.7.f Remove Contaminated Sediments (CCC)

Stressors

FRK IP MD WQ 8.1 Water Temperature (mult. life-stages)

FRK HSP SGP GS FG 6.2.2 Suitable (cobble) Substrate

FRK CSP GS 6.2.1 Deep Pools (spawners)

FSI BD GS 2.3.1 Entrainment

FRK GS 1.1.1 Sufficient Rearing Habitat

FRK MD WQ 8.2 Dissolved Oxygen

BD RHP CCC WQ 7.3 Contaminated Sediment

Biological Interactions (BI)

Candidate Restoration Actions

BI-MUK-C.4.i Predator / Competitor Removal (PCR)

Stressors

PCR GS 2.1.1 Predation (fish)

2.1.2 Predation (marine mammals)

BD PCR 3.3.2a Abundance of invertebrate prey

Target Fish

Population responses

Abundance

Reproductive output

Condition (size at age)

Spatial distribution

Fisheries Actions (FA)

Candidate Restoration Actions

FA-LKR-D.3 Fisheries Management Improvements (FMI)

FA-LKR-D.3.g Reduce Poaching (HRP)

Stressors

HM HRP GS 11.1 Overharvest (& bycatch)

Ocean Conditions (OC)

Candidate Restoration Actions = beyond scope of IFRMP

CLIMATE CHANGE (ocean)

Stressors

Sea surface temperature

Ocean deep water temperature & salinity

Coastal upwelling (nutrients)

Sea level

Predation (ocean)

Competition (ocean)

LEGEND

🟥🟧🟦🟩	Restoration actions
●●●●	Restoration actions linkages
☐	Stressor
▭	Key proximate stressor
🟨	Population response indicator
WQ	- Refer to associated water quality model
FG	- Refer to associated flow/sediment model
GS	- egg specific action or stressor
GS	- larvae specific action or stressor
GS	- adult specific action or stressor

Figure A6. Conceptual diagrams for stressors and potential restoration actions across model framework tiers for focal species in the Mid/Upper Klamath River (MUK) sub-region: Chinook, Coho, & Steelhead, Pacific Lamprey, Redband Trout, Endangered Suckers (Lost River Sucker and Shortnose Sucker), and Green Sturgeon. See Figure 2 for explanation of abbreviations.

Table A4. Stressors affecting the focal fish species/functional groups in the Mid/Upper Klamath River (MUK) sub-region and the candidate restoration actions that could help alleviate/mitigate each stressor (codes in table match with those for stressors and restoration actions in MUK focal species conceptual diagrams. Critical uncertainties around each restoration action are described in the Klamath IFRMP Master Restoration Actions Dictionary (Appendix B).

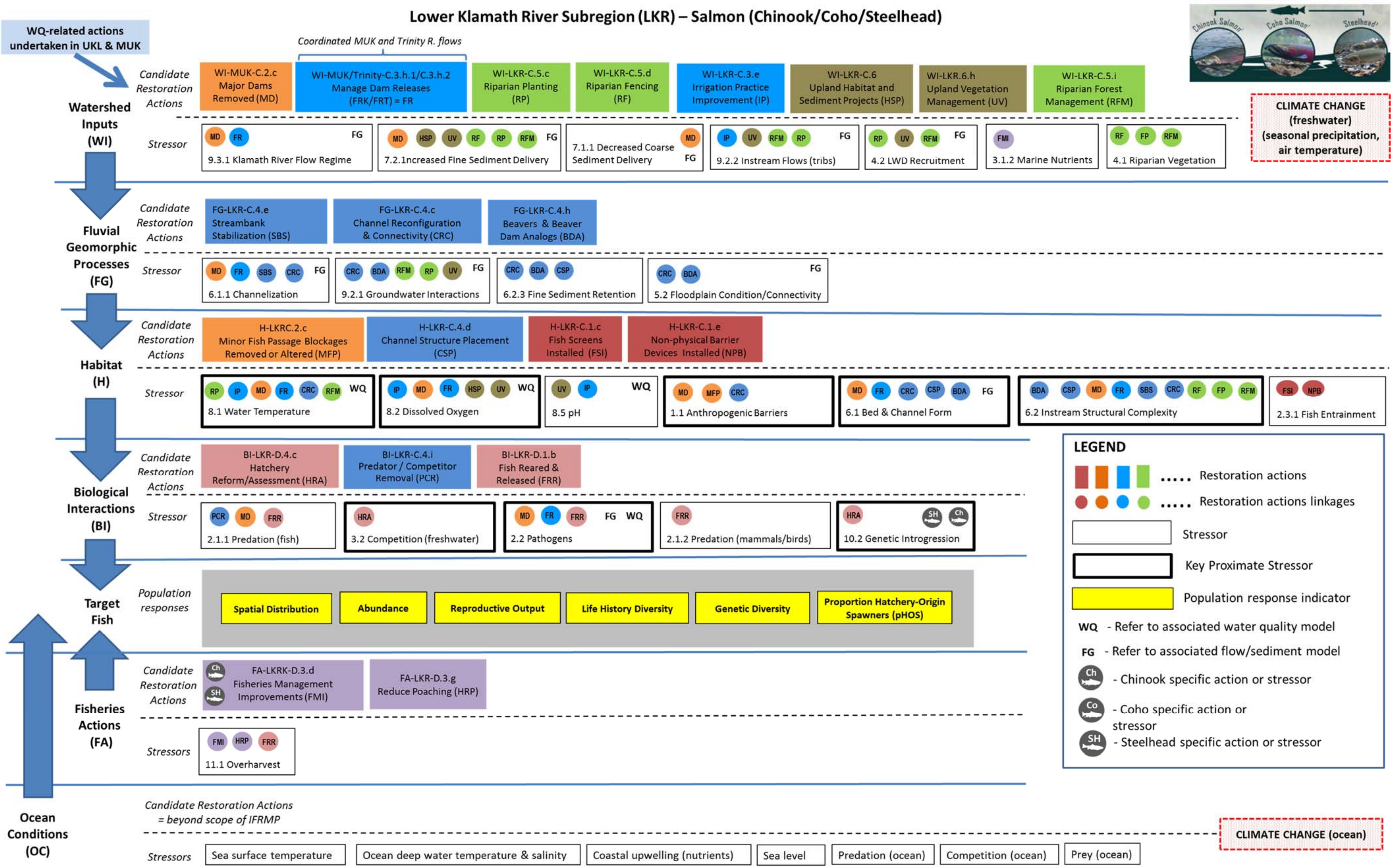
(table below to be updated for MUK)

Tier	Stressor	Candidate Restoration Actions to Alleviate Limiting Factor	Restoration Action Code
Watershed Inputs	9.3.1 Klamath River flow regime	Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
	7.2.1 Fine sediment delivery	Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Upland Habitat and Sediments Projects (HSP)	WI-MUK-C.6
		Riparian Forest Management (RFM)	WI-MUK-C.5.i
		Riparian Fencing (RF)	WI-MUK-C.5.d
		Riparian planting (RP)	WI-MUK-C.5.c
		Upland Vegetation Mgmt (UV)	WI-MUK-C.6.h
	7.1.1. Coarse Sediment Delivery	Major Dams Removed (MD)	WI-MUK-C.2.c-Major
	9.2.2 Instream flow (tribs)	Irrigation Practice Improvement (IP)	WI-MUK-C.3.e
		Riparian Planting (RP)	WI-MUK-C.5.d
		Riparian Forest Management (RFM)	WI-MUK-C.5.i
		Upland Vegetation Mgmt (UV)	WI-MUK-C.6.h
	4.2 Large woody debris	Riparian planting (RP)	WI-MUK-C.5.c
		Riparian Forest Management (RFM)	WI-MUK-C.5.i
		Upland Vegetation Mgmt (UV)	WI-MUK-C.6.h
	3.1.2 Marine nutrients	Fisheries Management Improvement	WI-MUK-D.3.d
Fluvial Geomorphic Processes	6.1.1 Channelization	Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1

		Streambank Stabilization (SBS)	FG-MUK-C.4.e
		Channel Reconfiguration and Connectivity (CRC)	FG-MUK-C.4.c
	9.2.1 Groundwater interactions	Channel Reconfiguration and Connectivity (CRC)	FG-MUK-C.4.c
		Riparian planting (RP)	WI-MUK-C.5.c
		Riparian fencing (RF)	WI-MUK-C.5.d
		Upland Vegetation Mgmt (UV)	WI-MUK-C.6.h
		Beaver and beaver dam analogs (BDA)	H--MUK-C.4.h
	6.2.3 Fine sediment retention	Channel Reconfiguration and Connectivity (CRC)	FG-MUK-C.4.c
		Beaver and beaver dam analogs (BDA)	H--MUK-C.4.h
		Channel Structure Placement (CSP)	H-MUK-C.4.d
Habitat	8.1 Water temperature	Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Riparian Forest Management (RFM)	WI-MUK-C.5.i
		Channel Reconfiguration and Connectivity (CRC)	FG-MUK-C.4.c
		Irrigation Practice Improvement (IP)	WI-MUK-C.3.e
		Riparian Planting (RP)	WI-MUK-C.5.c
	8.2 Dissolved oxygen	Irrigation Practice Improvement (IP)	WI-MUK-C.3.e
		Upland Habitat and Sediments Projects (HSP)	WI-MUK-C.6
		Upland Vegetation Mgmt (UV)	WI-MUK-C.6.h
		Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1

	8.5 pH	Upland Habitat and Sediments Projects (HSP)	WI-MUK-C.6
		Upland Vegetation Mgmt (UV)	WI-MUK-C.6.h
		Irrigation Practice Improvement (IP)	WI-MUK-C.3.e
	1.1.1 Access to spawning & rearing habitat	Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Minor Fish Passage Blockages Removed or Altered (MFP)	H-MUK-C.2.c-Minor
		Channel Reconfiguration and Connectivity (CRC)	FG-MUK-C.4.c
		Fish ladder installed/improved (FL)	H-MUK-C.2.e
		Fishway chutes or pools installed (FCP)	H-MUK-C.2.d
		Fish translocation (FTR)	H-MUK-C.2.j
	6.2 Habitat complexity (mesohabitats)	Minor Fish Passage Blockages Removed or Altered (MFP)	H-MUK-C.2.c-Minor
		Riparian Planting (RP)	WI-MUK-C.5.c
		Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Beaver and beaver dam analogs (BDA)	H--MUK-C.4.h
		Irrigation practice improvement (IP)	WI-MUK-C.3.e
		Riparian Forest Management (RFM)	WI-MUK-C.5.i
		Streambank Stabilization (SBS)	FG-MUK-C.4.e
		Channel Reconfiguration and Connectivity (CRC)	FG-MUK-C.4.c
		Channel Structure Placement (CSP)	H-MUK-C.4.d
	6.2.3 Habitat Suitability (microhabitats)	Beaver and beaver dam analogs (BDA)	H--MUK-C.4.h
		Channel Structure Placement (CSP)	H-MUK-C.4.d

		Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Irrigation Practice Improvement (IP)	WI-MUK-C.3.e
		Streambank Stabilization (SBS)	FG-MUK-C.4.e
		Channel Reconfiguration and Connectivity (CRC)	FG-MUK-C.4.c
Biological Interactions	2.1.1 Predation (fish)	Predator / Competitor Removal (PCR)	BI-MUK-C.4.i
		Major Dams Removed (MD)	WI-MUK-C.2.c-Major
	11.2 Overharvest	Fisheries Management Improvement (FMI)	BI-MUK-D.3.d
		Reduce Poaching (HRP)	BI-MUK-D.3.g
	2.2 Disease	Major Dams Removed (MD)	WI-MUK-C.2.c-Major
		Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
	2.1.1 Predation (mammals/birds)	no actions identified	no actions identified
	3.2 Competition	Hatchery Production (HPP)	BI-MUK-D.1.b



Lower Klamath River Subregion (LKR) – Salmon (Chinook/Coho/Steelhead)

WQ-related actions undertaken in UKL & MUK

Coordinated MUK and Trinity R. flows

Watershed Inputs (WI)

Candidate Restoration Actions

- WI-MUK-C.2.c Major Dams Removed (MD)
- WI-MUK/Trinity-C.3.h.1/C.3.h.2 Manage Dam Releases (FRK/FRT) = FR
- WI-LKR-C.5.c Riparian Planting (RP)
- WI-LKR-C.5.d Riparian Fencing (RF)
- WI-LKR-C.3.e Irrigation Practice Improvement (IP)
- WI-LKR-C.6 Upland Habitat and Sediment Projects (HSP)
- WI-LKR.6.h Upland Vegetation Management (UV)
- WI-LKR-C.5.i Riparian Forest Management (RFM)

Stressor

- MD FR FG 9.3.1 Klamath River Flow Regime
- MD HSP UV RF RP RFM FG 7.2.1ncreased Fine Sediment Delivery
- MD FG 7.1.1 Decreased Coarse Sediment Delivery
- IP UV RFM RP FG 9.2.2 Instream Flows (tribs)
- RP UV RFM FG 4.2 LWD Recruitment
- FMI 3.1.2 Marine Nutrients
- RF FP RFM 4.1 Riparian Vegetation

CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

- FG-LKR-C.4.e Streambank Stabilization (SBS)
- FG-LKR-C.4.c Channel Reconfiguration & Connectivity (CRC)
- FG-LKR-C.4.h Beavers & Beaver Dam Analogs (BDA)

Stressor

- MD FR SBS CRC FG 6.1.1 Channelization
- CRC BDA RFM RP UV FG 9.2.1 Groundwater Interactions
- CRC BDA CSP 6.2.3 Fine Sediment Retention
- CRC BDA FG 5.2 Floodplain Condition/Connectivity

Habitat (H)

Candidate Restoration Actions

- H-LKRC.2.c Minor Fish Passage Blockages Removed or Altered (MFP)
- H-LKR-C.4.d Channel Structure Placement (CSP)
- H-LKR-C.1.c Fish Screens Installed (FSI)
- H-LKR-C.1.e Non-physical Barrier Devices Installed (NPB)

Stressor

- RP IP MD FR CRC RFM WQ 8.1 Water Temperature
- IP MD FR HSP UV WQ 8.2 Dissolved Oxygen
- UV IP WQ 8.5 pH
- MD MFP CRC 1.1 Anthropogenic Barriers
- MD FR CRC CSP BDA FG 6.1 Bed & Channel Form
- BDA CSP MD FR SBS CRC RF FP RFM 6.2 Instream Structural Complexity
- FSI NPB 2.3.1 Fish Entrainment

Biological Interactions (BI)

Candidate Restoration Actions

- BI-LKR-D.4.c Hatchery Reform/Assessment (HRA)
- BI-LKR-C.4.i Predator / Competitor Removal (PCR)
- BI-LKR-D.1.b Fish Reared & Released (FRR)

Stressor

- PCR MD FRR 2.1.1 Predation (fish)
- HRA 3.2 Competition (freshwater)
- MD FR FRR FG WQ 2.2 Pathogens
- FRR 2.1.2 Predation (mammals/birds)
- HRA SH Ch 10.2 Genetic Introgression

Target Fish

Population responses

- **Spatial Distribution**
- **Abundance**
- **Reproductive Output**
- **Life History Diversity**
- **Genetic Diversity**
- **Proportion Hatchery-Origin Spawners (pHOS)**

Fisheries Actions (FA)

Candidate Restoration Actions

- Ch SH FA-LKRK-D.3.d Fisheries Management Improvements (FMI)
- FA-LKR-D.3.g Reduce Poaching (HRP)

Stressors

- FMI HRP FRR 11.1 Overharvest

Ocean Conditions (OC)

Candidate Restoration Actions = beyond scope of IFRMP

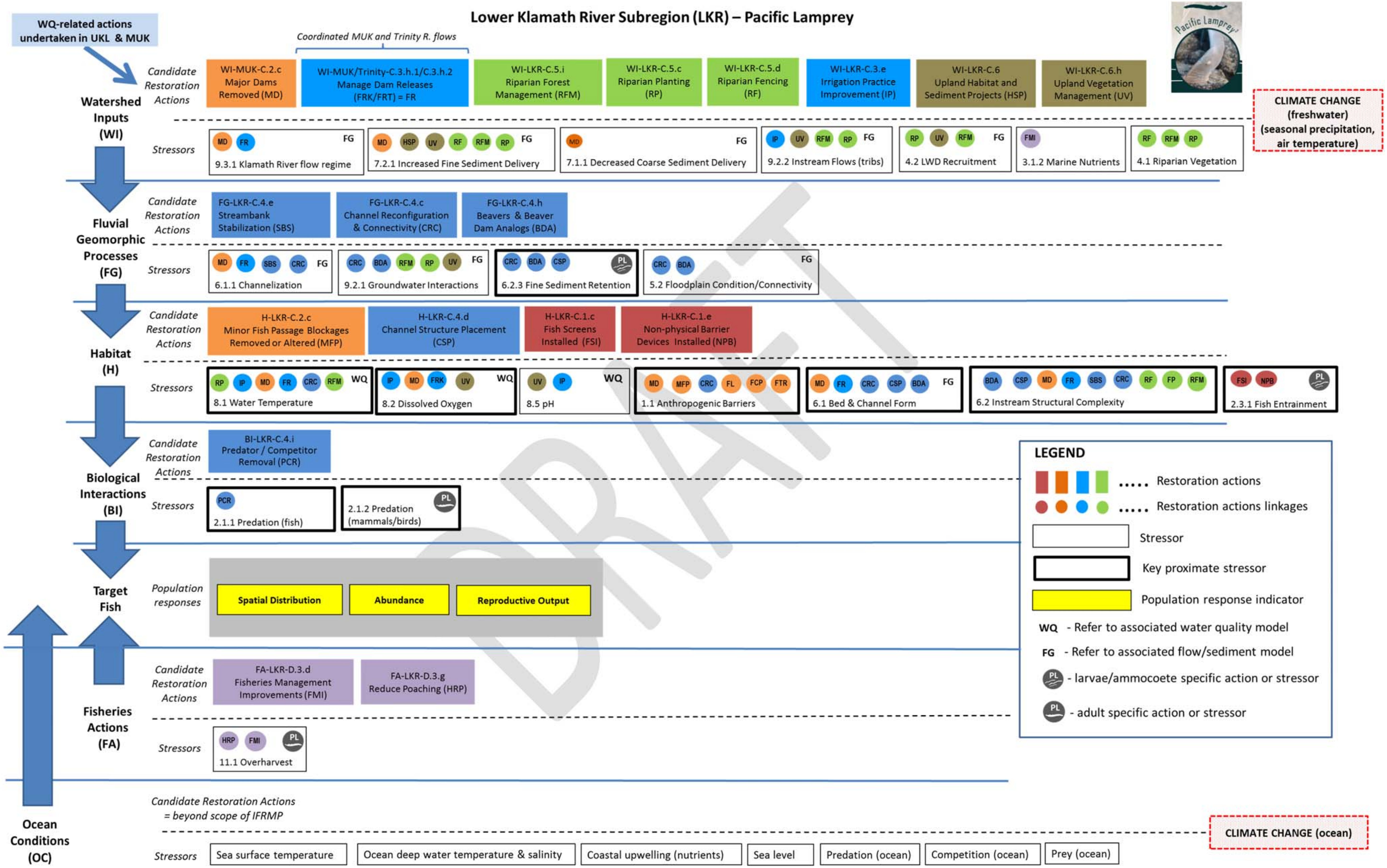
CLIMATE CHANGE (ocean)

Stressors

- Sea surface temperature
- Ocean deep water temperature & salinity
- Coastal upwelling (nutrients)
- Sea level
- Predation (ocean)
- Competition (ocean)
- Prey (ocean)

LEGEND

- 🟥🟧🟦🟩 ..... Restoration actions
- ●●●● ..... Restoration actions linkages
- ☐ Stressor
- ☐ Key Proximate Stressor
- 🟨 Population response indicator
- **WQ** - Refer to associated water quality model
- **FG** - Refer to associated flow/sediment model
- Ch - Chinook specific action or stressor
- Co - Coho specific action or stressor
- SH - Steelhead specific action or stressor



Lower Klamath River Subregion (LKR) – Pacific Lamprey

WQ-related actions undertaken in UKL & MUK

Coordinated MUK and Trinity R. flows

Watershed Inputs (WI)

Candidate Restoration Actions

- WI-MUK-C.2.c Major Dams Removed (MD)
- WI-MUK/Trinity-C.3.h.1/C.3.h.2 Manage Dam Releases (FRK/FRT) = FR
- WI-LKR-C.5.i Riparian Forest Management (RFM)
- WI-LKR-C.5.c Riparian Planting (RP)
- WI-LKR-C.5.d Riparian Fencing (RF)
- WI-LKR-C.3.e Irrigation Practice Improvement (IP)
- WI-LKR-C.6 Upland Habitat and Sediment Projects (HSP)
- WI-LKR-C.6.h Upland Vegetation Management (UV)

Stressors

- 9.3.1 Klamath River flow regime — MD, FR — FG
- 7.2.1 Increased Fine Sediment Delivery — MD, HSP, UV, RF, RFM, RP — FG
- 7.1.1 Decreased Coarse Sediment Delivery — MD — FG
- 9.2.2 Instream Flows (tribs) — IP, UV, RFM, RP — FG
- 4.2 LWD Recruitment — RP, UV, RFM — FG
- 3.1.2 Marine Nutrients — FMI
- 4.1 Riparian Vegetation — RF, RFM, RP

CLIMATE CHANGE (freshwater) (seasonal precipitation, air temperature)

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

- FG-LKR-C.4.e Streambank Stabilization (SBS)
- FG-LKR-C.4.c Channel Reconfiguration & Connectivity (CRC)
- FG-LKR-C.4.h Beavers & Beaver Dam Analogs (BDA)

Stressors

- 6.1.1 Channelization — MD, FR, SBS, CRC — FG
- 9.2.1 Groundwater Interactions — CRC, BDA, RFM, RP, UV — FG
- 6.2.3 Fine Sediment Retention — CRC, BDA, CSP — PL
- 5.2 Floodplain Condition/Connectivity — CRC, BDA — FG

Habitat (H)

Candidate Restoration Actions

- H-LKR-C.2.c Minor Fish Passage Blockages Removed or Altered (MFP)
- H-LKR-C.4.d Channel Structure Placement (CSP)
- H-LKR-C.1.c Fish Screens Installed (FSI)
- H-LKR-C.1.e Non-physical Barrier Devices Installed (NPB)

Stressors

- 8.1 Water Temperature — RP, IP, MD, FR, CRC, RFM — WQ
- 8.2 Dissolved Oxygen — IP, MD, FRK, UV — WQ
- 8.5 pH — UV, IP — WQ
- 1.1 Anthropogenic Barriers — MD, MFP, CRC, FL, FCP, FTR
- 6.1 Bed & Channel Form — MD, FR, CRC, CSP, BDA — FG
- 6.2 Instream Structural Complexity — BDA, CSP, MD, FR, SBS, CRC, RF, FP, RFM
- 2.3.1 Fish Entrainment — FSI, NPB — PL

Biological Interactions (BI)

Candidate Restoration Actions

- BI-LKR-C.4.i Predator / Competitor Removal (PCR)

Stressors

- 2.1.1 Predation (fish) — PCR
- 2.1.2 Predation (mammals/birds) — PL

Target Fish

Population responses

- Spatial Distribution
- Abundance
- Reproductive Output

Fisheries Actions (FA)

Candidate Restoration Actions

- FA-LKR-D.3.d Fisheries Management Improvements (FMI)
- FA-LKR-D.3.g Reduce Poaching (HRP)

Stressors

- 11.1 Overharvest — HRP, FMI — PL

Ocean Conditions (OC)

Candidate Restoration Actions = beyond scope of IFRMP

Stressors

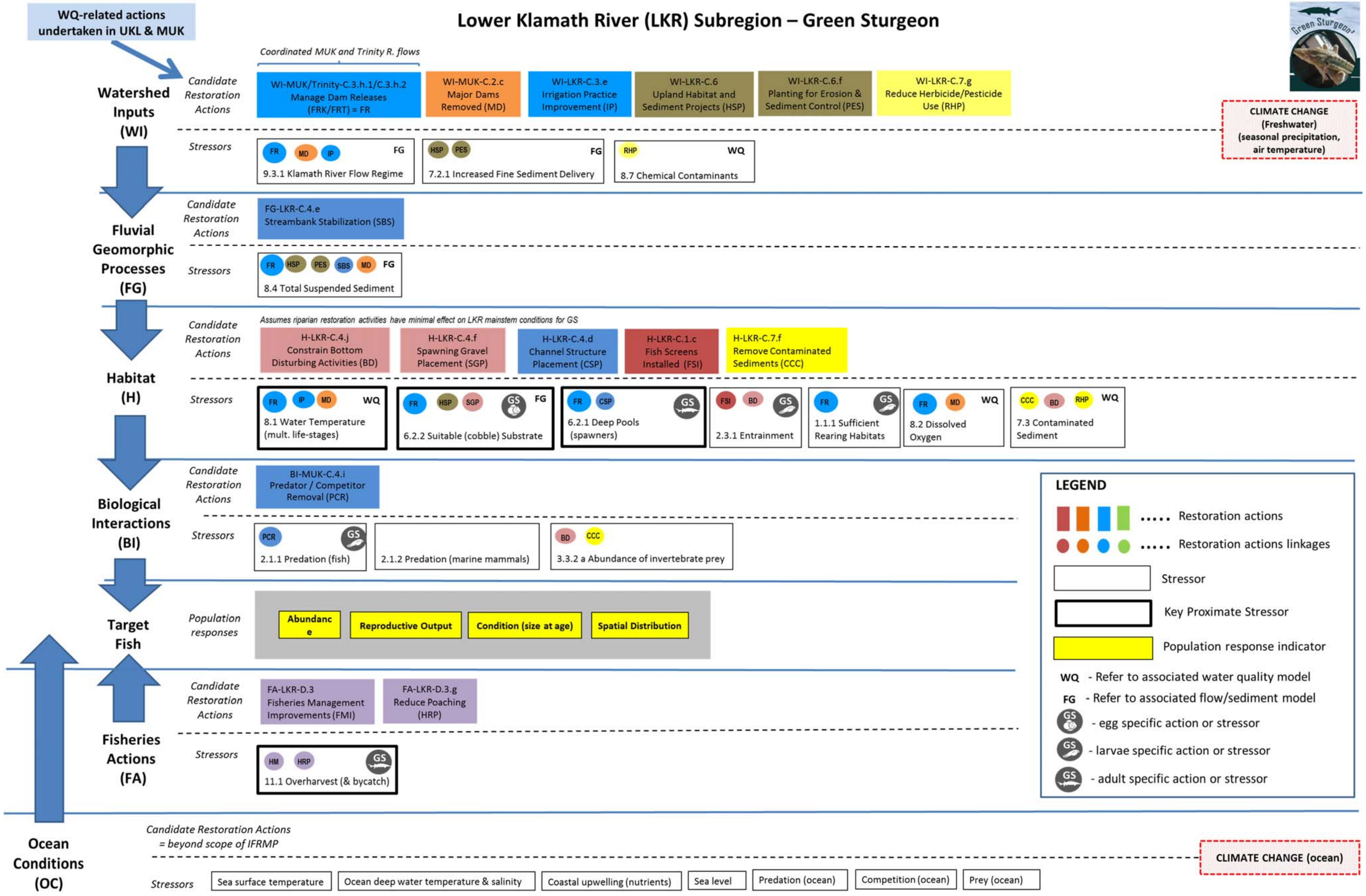
- Sea surface temperature
- Ocean deep water temperature & salinity
- Coastal upwelling (nutrients)
- Sea level
- Predation (ocean)
- Competition (ocean)
- Prey (ocean)

CLIMATE CHANGE (ocean)

LEGEND

- 🟥🟧🟦🟩 ….. Restoration actions
- ●●●● ….. Restoration actions linkages
- ☐ Stressor
- ☐ Key proximate stressor
- 🟨 Population response indicator
- **WQ** - Refer to associated water quality model
- **FG** - Refer to associated flow/sediment model
- PL - larvae/ammocoete specific action or stressor
- PL - adult specific action or stressor

Lower Klamath River (LKR) Subregion – Green Sturgeon



WQ-related actions undertaken in UKL & MUK

Watershed Inputs (WI)

Candidate Restoration Actions

Coordinated MUK and Trinity R. flows

- WI-MUK/Trinity-C.3.h.1/C.3.h.2 Manage Dam Releases (FRK/FRT) = FR
- WI-MUK-C.2.c Major Dams Removed (MD)
- WI-LKR-C.3.e Irrigation Practice Improvement (IP)
- WI-LKR-C.6 Upland Habitat and Sediment Projects (HSP)
- WI-LKR-C.6.f Planting for Erosion & Sediment Control (PES)
- WI-LKR-C.7.g Reduce Herbicide/Pesticide Use (RHP)

Stressors

- FR MD IP FG 9.3.1 Klamath River Flow Regime
- HSP PES FG 7.2.1 Increased Fine Sediment Delivery
- RHP WQ 8.7 Chemical Contaminants

CLIMATE CHANGE (Freshwater) (seasonal precipitation, air temperature)

Fluvial Geomorphic Processes (FG)

Candidate Restoration Actions

- FG-LKR-C.4.e Streambank Stabilization (SBS)

Stressors

- FR HSP PES SBS MD FG 8.4 Total Suspended Sediment

Habitat (H)

Candidate Restoration Actions

Assumes riparian restoration activities have minimal effect on LKR mainstem conditions for GS

- H-LKR-C.4.j Constrain Bottom Disturbing Activities (BD)
- H-LKR-C.4.f Spawning Gravel Placement (SGP)
- H-LKR-C.4.d Channel Structure Placement (CSP)
- H-LKR-C.1.c Fish Screens Installed (FSI)
- H-LKR-C.7.f Remove Contaminated Sediments (CCC)

Stressors

- FR IP MD WQ 8.1 Water Temperature (mult. life-stages)
- FR HSP SGP GS FG 6.2.2 Suitable (cobble) Substrate
- FR CSP GS 6.2.1 Deep Pools (spawners)
- FSI BD GS 2.3.1 Entrainment
- FR GS 1.1.1 Sufficient Rearing Habitats
- FR MD WQ 8.2 Dissolved Oxygen
- CCC BD RHP WQ 7.3 Contaminated Sediment

Biological Interactions (BI)

Candidate Restoration Actions

- BI-MUK-C.4.i Predator / Competitor Removal (PCR)

Stressors

- PCR GS 2.1.1 Predation (fish)
- 2.1.2 Predation (marine mammals)
- BD CCC 3.3.2 a Abundance of invertebrate prey

Target Fish

Population responses

- **Abundance**
- **Reproductive Output**
- **Condition (size at age)**
- **Spatial Distribution**

Fisheries Actions (FA)

Candidate Restoration Actions

- FA-LKR-D.3 Fisheries Management Improvements (FMI)
- FA-LKR-D.3.g Reduce Poaching (HRP)

Stressors

- HM HRP GS 11.1 Overharvest (& bycatch)

Ocean Conditions (OC)

Candidate Restoration Actions = beyond scope of IFRMP

CLIMATE CHANGE (ocean)

Stressors

- Sea surface temperature
- Ocean deep water temperature & salinity
- Coastal upwelling (nutrients)
- Sea level
- Predation (ocean)
- Competition (ocean)
- Prey (ocean)

LEGEND

🟥🟧🟦🟩 …..	Restoration actions
●●●● …..	Restoration actions linkages
☐	Stressor
☐	Key Proximate Stressor
🟨	Population response indicator
WQ	- Refer to associated water quality model
FG	- Refer to associated flow/sediment model
GS	- egg specific action or stressor
GS	- larvae specific action or stressor
GS	- adult specific action or stressor

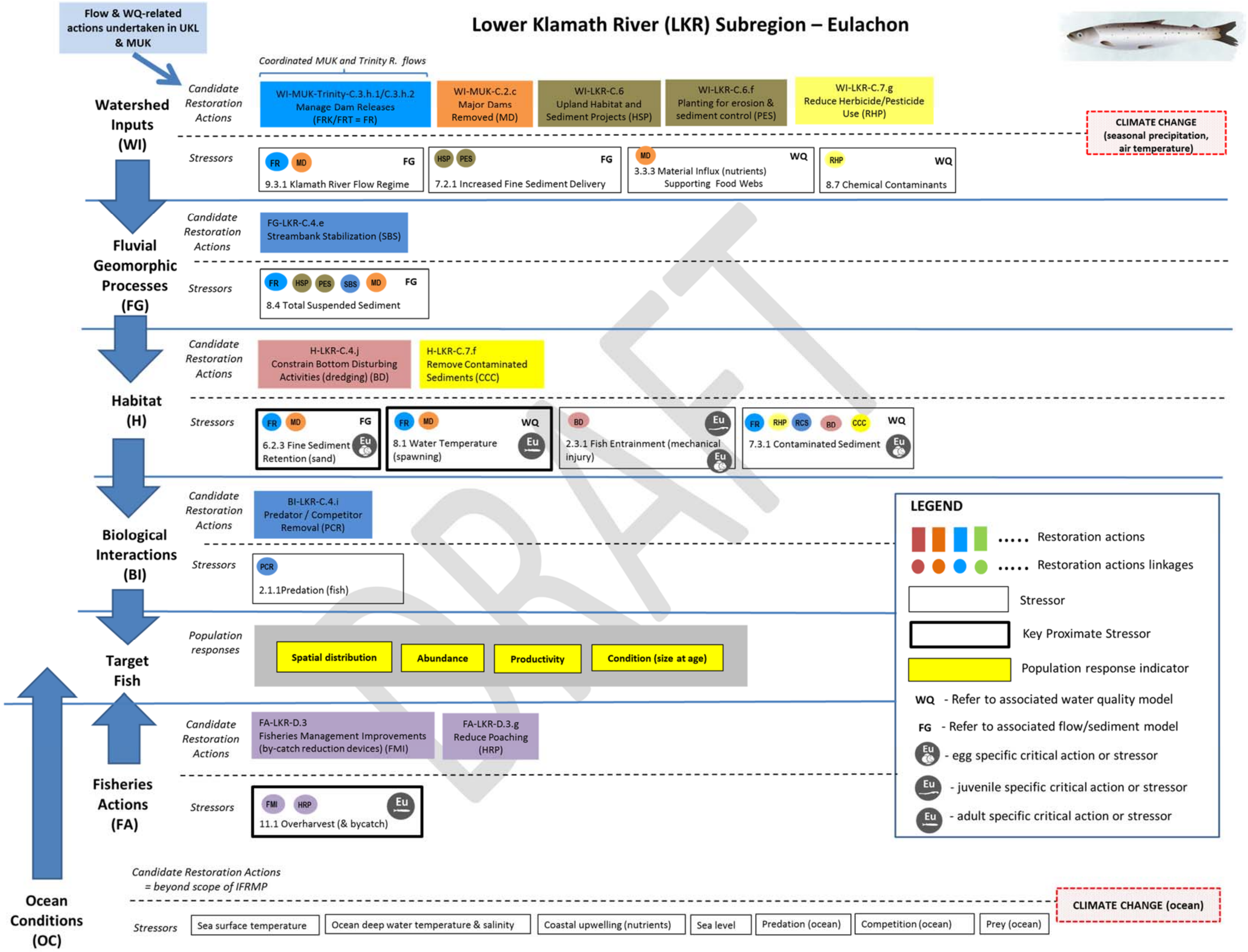


Figure A7. Conceptual diagrams for stressors and potential restoration actions across model framework tiers for focal species in the Lower Klamath River (LKR) sub-region: Chinook, Steelhead, Coho, Pacific Lamprey, Green Sturgeon, and Eulachon. See Figure 2 for explanation of abbreviations.

Table A5. Stressors affecting the focal fish species/functional groups in the Lower Klamath River (LKR) sub-region and the candidate restoration actions that could help alleviate/mitigate each stressor (codes in table match with those for stressors and restoration actions in LKR focal species conceptual diagrams. Critical uncertainties around each restoration action are described in the Klamath IFRMP Master Restoration Actions Dictionary (Appendix B).

(table below to be updated for LKR)

Tier	Stressors	Candidate Restoration Actions to Alleviate Limiting Factor	Restoration Action Code
Watershed Inputs	(9.3.1) Klamath River flow regime	Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Major Dams removed (MD)	WI-MUK-C.2.c
	(7.2.1) Fine sediment delivery	Upland Habitat and Sediment Projects (HSP)	WI-LKR-C.6
		Planting for Erosion & Sediment Control (PES)	WI-LKR-C.6.f
	(3.3.3) Material influx (nutrients) support. food webs	Major Dams removed (MD)	WI-MUK-C.2.c
	(8.7) Toxic contaminants (esp. metals)	Reduce Toxin Inputs (RTI)	WI-LKR-C.7.f
Fluvial Geomorphic Processes	(8.4) Total suspended sediment	Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Streambank Stabilization (SBS)	FG-LKR-C.4.e
		Upland Habitat and Sediment Projects (HSP)	WI-LKR-C.6
		Planting for Erosion & Sediment Control (PES)	WI-LKR-C.6.f
		Major Dams removed (MD)	WI-MUK-C.2.c
Habitat	(5.3) Estuary conditions	Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Major Dams removed (MD)	WI-MUK-C.2.c
	(5.4) Nearshore conditions (incld. anthropogenic barriers/construction)	Shoreline Armor Removal of Modification (EAR)	H-ES-C.9.k
	(6.2.3) Suitable (fine grain) substrate	Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Major Dams removed (MD)	WI-MUK-C.2.c
	(8.1) Water temperature (spawning)	Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Major Dams removed (MD)	WI-MUK-C.2.c
	(2.3.1) Entrainment of larvae/juveniles	Constrain bottom disturbing activities (dredging) (BDA)	H-LKR-C.4.l

	(7.3.1) Contaminated sediment	Manage Dam Releases - Klamath (FRK)	WI-MUK-C.3.h.1
		Reduce Toxin Inputs (RTI)	WI-LKR-C.7.f
		Remove Contaminated Sediments (RCS)	H-LKR-C.4.k
Biological Interactions	(11.2) Overharvest (& bycatch)	Harvest Management (HM)	BI-LKR-D.3
	(2.1.1) Predation	Predator / Competitor Removal (PCR)	BI-LKR-C.4.i

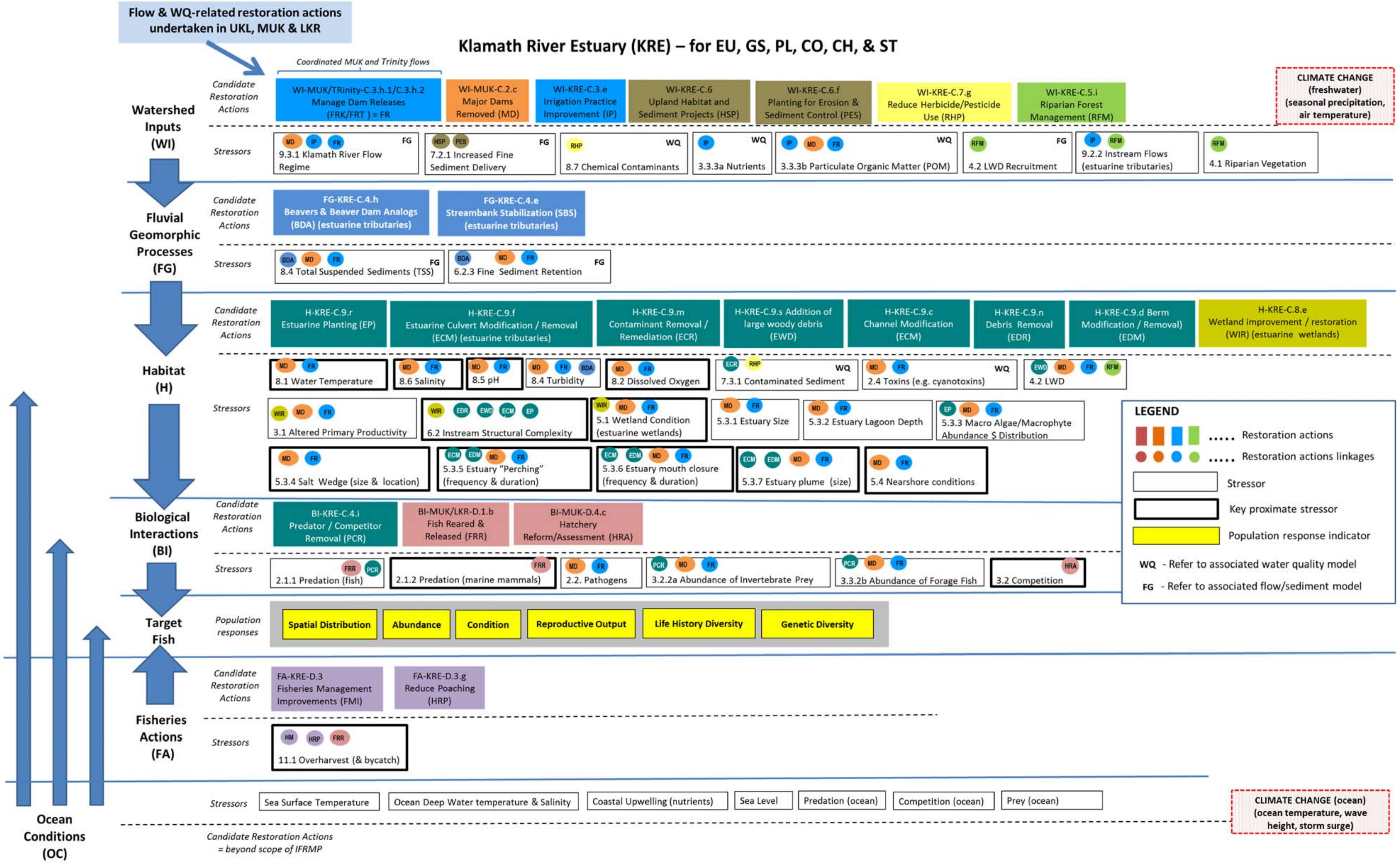


Figure A8. Conceptual diagrams for stressors and potential restoration actions across model framework tiers for focal species in the Klamath River Estuary (KRE) sub-region: Eulachon, Green Sturgeon, Pacific Lamprey Chinook, Coho, & Steelhead. See Figure 2 for explanation of abbreviations.

Table A6. Stressors affecting the focal fish species/functional groups in the Klamath River Estuary (KRE) sub-region and the candidate restoration actions that could help alleviate/mitigate each stressor (codes in table match with those for stressors and restoration actions in KRE focal species conceptual diagrams. Critical uncertainties around each restoration action are described in the Klamath IFRMP Master Restoration Actions Dictionary (Appendix B).

(table below to be populated for LKR)

Tier	Stressors	Candidate Restoration Actions to Alleviate Limiting Factor	Restoration Action Code
Watershed Inputs			
Fluvial Geomorphic Processes			
Habitat			

Biological Interactions			

Appendix B: Klamath IFRMP – Candidate Restoration Actions Dictionary

This document provides a generic (or default) set of restoration action categories, sub-types and associated definitions/descriptions in relation to issues in the Klamath Basin. It is based on the Pacific Coastal Salmon Recovery Fund (PCSRF) Data Dictionary and has been updated by ESSA to include additional Klamath-specific restoration actions, more types of water quality and fluvial geomorphic processes actions, and additional columns for the Hypothesized Mechanisms of the actions and associated Critical Uncertainties. Hypothesized mechanisms are populated with information derived from the Klamath IFRMP Synthesis Report and other sources. Note that lettered sections other than C and D in the original dictionary have been excluded here because they refer to administrative or research activities outside the direct scope of this plan. References cited in the table below are the same as in the Klamath IFRMP Synthesis Report, available for download on the IFRMP website (http://kbifrm.psmfc.org/).

Data Field ID	Sub-Category Name	Work Type or Attribute Name	Work Type Abbrev.	Definition	Hypothesized Mechanism	Critical Uncertainties
C.	*SECTION C: Salmonid Habitat Restoration and Acquisition Category*					
C.1	*Fish Screening*		FSP	*Projects that result in the installation, improvement or maintenance of screening systems that prevent fish from passing into areas that do not support fish survival; for example, into irrigation diversion channels.*		
C.1.c		Fish screens installed	FSI	New fish screens installed where no screen had existed previously.	Fish screens are physical barriers designed to prevent fish entrainment and stranding in diversions while allowing water to pass for its intended purpose. Often installed after the removal of a barrier to prevent fish entering previously inaccessible diversions.	Most fish screens are designed to protect salmonids, and there is growing recognition that Pacific Lamprey which are comparatively poor swimmers may not be adequately protected by all fish screens, thus new screen designs might be necessary and are currently being tested (ODFW 2013).
C.1.d		Fish screens replaced or modified	FSM	Pre-existing fish screens that are replaced, repaired or modified.	A fish screen is often added to a diversion to prevent fish from accessing diversions where they may become stranded. Often installed after the removal of a barrier to prevent fish entering previously inaccessible diversions. Older screens may no longer effectively prevent fish passage, or may not have equal effectiveness for all species, and may need to be modified or replaced.	Older screens designed to less stringent past criteria may not prevent entrainment of juvenile fish as well as newer screens (PSMFC 2000, NMFS 2011). Most fish screens are designed to protect salmonids, and there is growing recognition that Pacific Lamprey which are comparatively poor swimmers may not be adequately protected by all fish screens, thus new screen designs might be necessary and are currently being tested (ODFW 2013).
C.1.e		Non-physical barrier devices installed	NPB	Includes non-physical fish-protection devices, such as louvres or sensory deterrents.	Includes non-physical fish-protection devices, such as louvres or sensory deterrents (e.g., electrical, visual, acoustic, chemical, and hydrological), which can behaviorally deter fish from approaching or being entrained into water diversions. Studies have shown that the addition of a trash-rack box, louvre box, or perforated cylinder on the pipe inlet can all significantly reduce the proportion of fish that are entrained through the pipe (Poletto et al. 2015). Such methods have been successfully tested on several species, including green sturgeon and Chinook (Poletto et al. 2015, Perry et al. 2014). BOR's Denver office has tested various forms of NPBs for use with sucker species (approx. 10 years ago).	Success greatly depends on the site and context, and no single deterrent is "one size fits all" for all species, such that streams with a larger diversity of fish may benefit more from physical fish deterrents (Noatch and Suski 2012).

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C.2	*Fish Passage Improvement*		FPI	*Projects that improve or provide anadromous fish (and potentially other native aquatic organisms) migration up and down stream including fish passage at road crossings (bridges or culverts), barriers (dams or log jams), fishways (ladders, chutes or pools), and weirs (log or rock).*		
C.2.c-Major		Major dams removed	MD	Removal of major dams to allow fish passage and to help restore natural flow regimes.	Removal of barriers opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat. Removing dams may also improve water quality in previously dammed reaches due to the elimination of impoundments that can act as heat sinks, and the improvement of flow, water mixing, and sediment scour which can also potentially reduce the incidence of disease (Perry et al. 2011, USFWS 2016, Bartholomew et al. 2017, USDI et al. 2012, USDI 2016). In addition, the removal of barriers can help restore hydrologic regimes and provide large woody debris and coarse sediment for habitat complexity and spawning needs downstream.	There is uncertainty surrounding the scale and downstream impacts of the stored sediment mobilized from reservoirs after dam removal as well as surrounding the long-term changes in the structure and function of downstream river reaches and of the river estuary (Hart et al. 2002, Shaffer et al. 2017). For UKL there are uncertainties on survivability of migrating fish through the lake, overlap and competition with suckers, etc. once dams have been removed. Following barrier removal, upstream tributaries may not only be recolonized by native species, but also by invasive species and pathogens (Hart et al. 2002, Stanley and Doyle 2003, Hurst et al. 2012, McLaughlin et al. 2013, Pess et al. 2014). These impacts have been observed following the removal of small dams as well as large dams (Doyle et al. 2005).
C.2.c-Minor		Minor fish passage blockages removed or altered	MFP	Removal or alteration of blockages, impediments or barriers to allow or improve fish passage (other than road crossings reported in C.2.f to C.2.i).	Removal of barriers opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat. Removing dams may also improve water quality in previously dammed reaches due to the elimination of impoundments that can act as heat sinks, and the improvement of flow, water mixing, and sediment scour which can also potentially reduce the incidence of disease (Perry et al. 2011, USFWS 2016, Bartholomew et al. 2017, USDI et al. 2012, USDI 2016). In addition, the removal of barriers can help restore hydrologic regimes and provide large woody debris and course sediment for habitat complexity and spawning needs downstream.	There is uncertainty surrounding natural recolonization success across species after barrier removal due to variation in life history characteristics - some species have a greater tendency towards expanding into habitat within existing streams but a low tendency of colonizing new streams (e.g., lamprey, coho salmon) whereas others are just as likely to expand in existing streams as colonize new streams (e.g., steelhead, Chinook salmon) (Pess et al. 2014). Following barrier removal, upstream tributaries may not only be recolonized by native species, but also by invasive species and pathogens (Hart et al. 2002, Stanley and Doyle 2003, Hurst et al. 2012, McLaughlin et al. 2013, Pess et al. 2014). These impacts have been observed following the removal of small dams as well as large dams (Doyle et al. 2005).
C.2.d		Fishway chutes or pools Installed	FCP	Placement of an engineered bypass (other than fish ladder) for fish to pass more safely around or over a barrier. This includes bedrock chutes, weirs, rock boulder step pools, chutes constructed/roughened in bed rock, and engineered channel structures.	Addition of passage structures to assist fish in moving over or around a barrier opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat. Individual species and life stage needs such as juvenile fish, lamprey, and sucker need to be accounted for.	Fishways and fish ladders require maintenance and repair after flow events to ensure passage conditions for the target species are maintained to design conditions. The maintenance often involves removing organic debris and sediment that have filled or damaged the fishway structure. Suckers have more limited jumping ability compared to salmon – ODFW should have criteria for flows and heights for sucker passageways.
C.2.e		Fish ladder	FL	Installation or modification (upgrade/improvement) of a fish ladder.	Addition of passage structures to assist fish in moving over or	Fishways and fish ladders require maintenance and repair after flow events

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		Installed / improved			around a barrier opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat.	to ensure passage conditions for the target species are maintained to design conditions. The maintenance often involves removing organic debris and sediment that have filled or damaged the fishway structure.
C.2.f.		Culvert installed or Improved at road stream crossing	CU	Installation or improvement/upgrade (including replacement) of a culvert to a standard that provides juvenile and adult fish passage.	Addition of passage structures to assist fish in moving over or around a barrier opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat.	There is uncertainty surrounding the effectiveness of some culvert designs compared to others for providing fish passage.
C.2.g		Bridge installed or improved at road stream crossing	BR	Installation, improvement/upgrade or replacement of a bridge over a stream to provide/improve fish passage under a road. The bridge could be replacing a culvert.	Addition of passage structures to assist fish in moving over or around a barrier opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat.	Bridges may require maintenance and repair after major flow events to ensure passage conditions for the target species are maintained to design conditions.
C.2.h		Rocked ford - road stream crossing	RFR	Placement of a crushed gravel reinforced track through a stream that still allows unimpeded stream flow. This could replace a dysfunctional culvert.	Addition of passage structures to assist fish in moving over or around a barrier opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat. Vented fords, if properly sited, designed and constructed, can provide passage for fish while not jeopardizing a geomorphically stable channel.	Fords frequently create barriers to fish and other aquatic organisms and interrupt transport of sediment and debris. Additionally, they often require frequent maintenance and repair that cause repeated disturbance to the adjacent stream channel. For passage and maintenance, they are very sensitive to any changes of elevation in the natural streambed, especially un-vented fords. (CDFW Restoration Manual: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=12512).
C.2.i		Road stream crossing removal	RSC	Removal of stream road crossing and the affiliated road structures so that the stream flows unimpeded. Stream crossing removal involves excavating crossing fill, culverts, logs, bridge structures, abutments, and other debris from stream channels.	Addition of passage structures to assist fish in moving over or around a barrier opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat.	Stream crossing removal projects involve a complex set of procedures to accomplish full topographic rehabilitation. Stream crossings pose the highest risk of post-treatment failure if something is not done right. Regular monitoring should occur to document changes in the slopes or stream channel following stream crossing removal. https://viardsol.wordpress.com/2016/10/27/road-stream-crossing-removal/
C.2.j		Fish translocation	FTR	Translocation of fish past barriers using trap and haul or other methods.	Directly assisting fish in moving over or around a barrier through translocation opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat.	There is uncertainty surrounding the survival, reproductive success, and ability for further natural range expansion of fish translocated to areas above barriers (Pess et al. 2014).
C.3	*Instream Flow Project*		IFP	*Projects that maintain and/or increase the flow of water to provide needed fish habitat conditions. This can include water rights purchases/leases, or irrigation practice improvements (reduced flow into fields) including water conservation projects to reduce stream diversions or extractions.*		
C.3.d		Water flow gauges	FG	Water gauges installed to measure and regulate water use.	Water flow gages facilitate overall flow management and provide hydrologic data necessary to design restoration projects.	Flow gages need to be maintained and rated several times per year which can be expensive and long-term funding can be difficult to obtain for maintenance. OWRD started requiring gauges on the largest diverters in the UKL area a few years ago, but they do not have a reporting requirement or way to report the data, and often the gauges are manual, not electronic, and nobody reads them. It's hard to measure flow in screw gates/flap gates and open ditches, and probably <1% of all diversions are gauged. Many

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						landowners might not be willing to install if there's no guarantee of water deliveries.
C.3.e		Irrigation practice improvement	IP	Improvement of irrigation practices (where water is removed from a stream) to protect fish. This includes: installing a headgate with water gauge to control water flow into irrigation canals and ditches; regulating flow on previously unregulated diversions; installing a well or storage holding tanks to eliminate a diversion; or, replacing open canals with pipes to reduce water loss to evaporation and dedicating the saved water to aquatic resources.	Reducing overall water usage irrigators to decrease, seasonally restrict, or eliminate the amount of water withdrawn from the stream, including activities to improve the efficient use of smaller amounts of water withdrawn. In addition, water conservation projects can include water exchanges where the diverters change points of diversion to warmer water sources in exchange for leaving colder spring or tributary water in the stream for aquatic resources. There is a need for saved water to be dedicated to instream use otherwise it might just get used by the next person in line.	Effects of climate change could undermine advances; economic incentives to farmers uncertain. Also the finding that irrigation improvement may mean the same water used and more acres irrigated. Water savings not certain unless a water right is transferred instream. Water laws in CA and OR can be complicated and often require a significant amount of planning and studies prior to being able to implement these types of projects.
C.3.f		Water leased or purchased	WLP	Water that is leased or purchased, and thus not withdrawn from the stream. This includes the purchase of water rights.	Reducing overall water withdrawals by leasing or purchasing water rights which are then not used and so remain in the stream.	Effects of climate change could undermine advances; economic incentives to farmers uncertain. Transactions work well in wet and normal years, but tend to be difficult to secure in dry years when the fish need the water most.
C.3.g		Manage water withdrawals	FWD	Preventing or reducing water withdrawals from stream.	Reducing overall water usage by irrigators to decrease, seasonally restrict or eliminate the amount of water withdrawn from the stream, including activities to improve the efficient use of smaller amounts of water withdrawn.	Effects of climate change could undermine advances; economic incentives to farmers uncertain.
C.3.h.1		Manage Dam Releases (Klamath Dams)	FRK	This action is specific to the Klamath River where Klamath flows may be regulated to some extent to provide cooling and improved flows in the mainstem Klamath River	Managing dam releases to maintain adequate flows in downstream reaches to meet fish needs.	Effects of climate change could undermine advances; trade-offs with needs for irrigation. New BiOp for Klamath Project.
C.3.h.2		Manage Dam Releases (Trinity Dam)	FRT	This action is specific to the Klamath River where Trinity flows may be regulated to some extent to provide cooling and improved flows in the mainstem Klamath River downstream of the Trinity confluence.	Managing dam releases to maintain adequate flows in downstream reaches to meet fish needs.	Effects of climate change could undermine advances; trade-offs with needs for irrigation.
C.3.h.3		Manage Dam Releases (Link and Keno)	FLK	This action is specific to the Klamath River where Link RIver flows may be regulated to some extent to provide cooling and improved flows in the mainstem Klamath River downstream of the Keno and Link River dams.	Managing dam releases to maintain adequate flows in downstream reaches to meet fish needs.	Effects of climate change could undermine advances; trade-offs with needs for irrigation.
C.4	*Instream Habitat Project*		IHP	*Projects that increase or improve the physical conditions within the stream environment (below the ordinary high water mark of the stream) to support increased fish population.*		

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C.4.c		Channel reconfiguration and connectivity	CRC	Changes in channel morphology, sinuosity or connectivity to off-channel habitat, wetlands or floodplains. This includes instream pools added/created; removal of instream sediment; meanders added; former channel bed restored; removal or alteration of levees or berms (including setback levees) to connect floodplain; and, creation of off-channel habitat consisting of side channels, backwater areas, alcoves, oxbows, ponds, or side-pools.	Channel reconfiguration and connectivity activities promote natural channel migration, restores biological connectivity, allows more natural transport of sediment and nutrients, and tends to decrease stream grade and thus reduce fast flows and resulting erosion. In the case of reconnecting springs, restoring cool groundwater inputs into the main river can help to expand thermal refugia for fish (Roni et al. 2008, Newfields and Kondolf 2012).	Some potential issues with off channel habitat projects may include fish stranding, low DOs, higher temperatures and channel avulsion if these elements have not been considered during the design phase. Although off channel habitat restoration projects have been implemented in the Pacific Northwest since the late 1980s, it is a relatively new technique in California. Several mid Klamath partners including the NOAA Restoration Center the Mid Klamath Watershed Council, the Karuk Tribe and the Yurok Tribe recognized the significant data gap in California off channel projects, and worked to develop case studies in order to share what was learned over the past few years. These case studies include a lessons learned section that can help guide future off channel restoration projects. http://www.westcoast.fisheries.noaa.gov/habitat/off_channel_case_studies.html Non-native fish will also colonize new floodplain habitat which could be problematic for larval suckers for example. The benefit to natives probably outweighs the costs though. Economic incentives are uncertain.
C.4.d		Channel structure placement	CSP	Placement of large woody debris or rocks/boulders (including deflectors, barbs, weirs) to collect and retain gravel for spawning habitat; deepen existing resting/jumping pools; create new pools above and/or below the structure; trap sediment; aerate the water; channel roughening; or, promote deposition of organic debris. This includes floodplain roughening or fencing.	In-channel structures are installed primarily to alter flow and scour patterns, increasing habitat diversity. Instream structures also provide shade, increase habitat complexity, recruit woody debris, and provide cover from predation (Whiteway et al. 2010). The addition of channel structures, including large woody debris, may also provide benefits to tributaries that did not historically have significant natural inputs of channel structure.	Effectiveness depends on optimal selection of materials and placement for a given reach. These structures may not achieve their full benefits if the limiting factors on fish populations are not habitat complexity but, for example, upstream stressors such as watershed inputs that have not yet been resolved.
C.4.e		Streambank stabilization	SBS	Stabilization of the streambank through resloping and/or placement of rocks, logs, or other material on streambank.	Streambank stabilization reduces bank erosion during fast flows which can result in further loss of channel structure and fish habitat and also result in increased sediment inputs to the stream. More direct stabilization methods are used when streambanks are eroding too quickly for planted vegetation to establish (SRCD 1996). Bioengineering with willow and cottonwood on slopes 1:3 and greater is the preferred method to prevent bank erosion that will also allow for riparian forest restoration and channel migration.	Success of these methods depends on correcting the factors contributing to erosion in the first place, such as unsustainable riparian grazing pressure. This might come after a grazing management and fencing strategy, but without those, success is limited. Streambank stabilization projects may also have negative impacts to the stream resulting in stream channelization, including lost floodplain connectivity, impaired riparian function, and degraded foraging and cover habitat along the streambank. (NMFS issued jeopardy biological opinions for FEMA's NFIP in both Puget Sound (2008) and the state of Oregon (2016)).
C.4.f		Spawning gravel placement	SGP	Addition of spawning gravel to the stream, either in locations where high flows in the near future will entrain and distribute gravel downstream as bars or riffles or instead placed directly at spawning sites.	Supplementing appropriate reaches with gravel expands the amount of suitable spawning substrate and also benefits later life stages by providing habitat for macroinvertebrate food sources (Wheaton et al. 2004).	Success is contingent on hydrodynamic conditions at proposed restoration sites that are suitable for gravel distribution or retention (Wheaton et al. 2004). It is important to plan gravel placement projects in areas that will not result in an "ecological trap", where redds could be dewatered and fry rearing habitat is limited.
C.4.g		Plant	PC	Removal or control of aquatic non-native plants, invasive species or	Invasive plants can outcompete native stream plants without	Non-native species removal programs are labor intensive and there is

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		removal/control		noxious weeds growing in the stream channel and riparian. Removal of aquatic vegetation in wetlands to provide habitat mosaic.	necessarily providing the same food or shelter benefits, and may overgrow and choke streams. Some wetlands become overly decadent and do not provide fish habitat because of the density of vegetation.	uncertainty surrounding the degree of effort required to achieve an ongoing ecological benefit.
C.4.h		Beavers & beaver dam analogs	BDA	Introduction or management of beavers to add natural stream complexity (beaver dams, ponds, etc.). Restoration of aquatic habitat to support beaver populations through the usage of deciduous shrub and trees, beaver dam analogs (BDA) or post-assisted woody structures (PAWS).	Promotes increased frequency of flooding and produces deeper, low velocity, cooler pools, restored connections with floodplain swales and relict channels, and promotes the development of riparian vegetation (DeVries et al. 2012). Slowing flows also contributes to elevation of the water table and increased groundwater recharge (Pollock et al. 2015). Finally, beaver dams and analogs enhance groundwater-surface water connectivity, buffer against large diel temperature ranges, and create thermal diversity (Weber et al. 2017).	In some cases, natural beaver dams may grow to a size where they completely inhibit fish passage. Beaver reintroduction may not be practical or feasible in all locations, such that beaver dam analogs which require regular maintenance and replacement must be used instead. (DeVries et al. 2012, Pollock et al. 2012, 2017).
C.4.i		Predator/competitor or exotic fish species removal	PCR	Control or removal of invasive, non-native/alien fish species fish predators or competitors (e.g., northern pike minnow, non-native fish, invasive animals) from the instream habitat, including construction of barriers to limit the expansion of non-native fish into uninvaded reaches.	Non-native fish such as brook trout and brown trout are known to compete, prey on, and often displace native fish species. Their removal or control (via barriers) can help to reduce competition for food and space and increase the success of native salmonids (USFSW 2012b).	The effects of many of the other invasive species in the basin are uncertain, as little quantitative information exists to evaluate their possible impacts (USFSW 2012b). See Mount and Moyle 2003 Non-native species removal programs are labor intensive and there is uncertainty surrounding the degree of effort required to achieve an ongoing ecological benefit.
C.4.j		Constrain bottom disturbing activities	BD	Restriction of activities that could disturb benthic communities or release contaminants stored in river/lake/stream sediments	Physical disruption of river or lake bottom sediments through dredging or other activities could cause release of toxic compounds into the water column where the pollutants become more active in terms of affecting biota. Bottom disturbance could also affect benthic organisms directly by crushing them or displacing them.	The level of impact from bottom disturbing activities would depend on the benthic communities affected and the concentrations of toxic compounds that could be released from disturbed sediments.
C.5	*Riparian Habitat Project*		RHP	*Projects that change areas (above the ordinary high water mark of the stream and within the flood plain of streams) in order to improve the environmental conditions necessary to sustain fish throughout their life cycle. This includes lakeshores of connected lakes.*		
C.5.c		Riparian planting	RP	Riparian planting or native plant establishment.	Riparian planting helps to more rapidly re-establish native vegetation in previously degraded habitat, where such vegetation helps to stabilize streambanks and prevent future erosion, provide food and habitat, regulate stream temperature through shading, improve oxygenation through photosynthesis when considering emergent vegetation and, in the long-term, will both deliver and recruit more large woody debris to the system (Flosi et al. 2010, Opperman and Merenlender 2004, Lennox et al. 2011).	Successful regeneration of riparian vegetation can require intensive efforts to protect (e.g., through caging and watering) seedlings until plants are beyond stages vulnerable to drought and grazing. Planted areas may require riparian thinning of non-native species to improve the survival of new plantings (Anderson and Graziano 2002, Flosi et al. 2010).
C.5.d		Fencing	RF	Creation of livestock exclusion or other riparian fencing. Open	Because overgrazing is a common cause of riparian habitat loss,	Depends on cooperation with ranchers for restoration on private lands.

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				watercourses are assumed to provide open access to cattle.	many projects involve the construction of livestock exclusion fencing to prevent future overgrazing of riparian areas (Anderson and Graziano 2002, Flosi et al. 2010).	There seems to be a lack of understanding of what a “good” riparian area looks like in more meadow dominated reaches.
C.5.e		Riparian exclusion	RE	Preventing or removing access to riparian areas by means other than fencing.	Because overgrazing is a common cause of riparian habitat loss, any method of excluding grazing/browsing livestock from riparian areas is beneficial.	One option to deter cattle use on streams is to install water troughs in shade away from the stream. That might be considered a deterrent rather than “exclusion”. The effectiveness of such potential alternative approaches for riparian exclusion is unclear.
C.5.f		Water gap development	WG	Installation of a fenced livestock stream crossing or livestock bridge.	Crossings and bridges, when paired with riparian fencing, channel livestock across crossings and prevent them from crossing directly through streams where they may trample riparian vegetation and instream habitat, increase sediment transport and turbidity, and introduce nutrients through manure (Anderson and Graziano 2002, Flosi et al. 2010).	Depends on cooperation with ranchers for restoration on private lands, and most effective when the rest of the streambank is fenced to prevent direct crossings.
C.5.g		Conservation grazing management	CG	Alteration of agricultural land use practices to reduce grazing pressure for conservation (e.g., rotate livestock grazing to minimize impact on riparian areas).	Reducing grazing pressure on riparian areas contributes to conservation and can reduce the need for future restoration.	Depends on cooperation with ranchers for restoration on private lands, and also requires sufficient grazing lands available to allow for rotation. The upper basin also lacks a grazing management expert currently to provide advice on such plans.
C.5.h		Riparian plant removal / control	RR	Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the riparian zone or water table.	Removal of invasive plants can help to reduce known impacts including their tendency to outcompete native stream plants without necessarily providing the same food or shelter benefits. Invasives often consume large amounts of water affecting the water table, and may overgrow and choke streams (Anderson and Graziano 2002, Flosi et al. 2010).	Non-native species removal programs are labor intensive and there is uncertainty surrounding the degree of effort required to achieve an ongoing ecological benefit.
C.5.i		Riparian Forest Management (RFM)	RFM	Treating or managing trees and undergrowth in riparian area including fuel reduction treatments, prescribed burnings, stand thinning, girdling, stand conversions, and silviculture.	Where unsustainable forestry practices are the cause of riparian decline, restoration may involve changes to forest management such as implementing buffer areas to prevent harvesting directly alongside streams (Flosi et al. 2010). In addition, in riparian areas where there are monocultures of early successional species such as alder and cottonwood, some thinning might be necessary to allow optimal conditions to allow for conifer growth.	Riparian forest management activities could result in increased stream temperatures due to canopy reduction and/or invasive species colonization due to increased light on the riparian forest floor.
C.5.j		Debris/structures removal	DR	Removal of debris (e.g., tires, appliances) or structures (e.g., old cabins) from the riparian area to allow growth of riparian vegetation.	Clearing debris from riparian areas allows room for further riparian growth.	Feasibility may depend on the size and type of structure. State Historic Preservation Office (SHPO) considerations may be a concern for removal of old structures. Landowner willingness is a consideration as well for historic structures.
C.6	*Upland Habitat and Sediment Project*		HSP	*Landscape level projects implemented above the elevation of the riparian zone (above the floodplain) that are intended to benefit fish habitat (for example, reducing/eliminating sediment flow from upland areas into streams).*		

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C.6.a		Restore physical process	PP	Streamflows, mechanical restoration, and sediments combine to restore key physical processes to support a self-maintaining dynamic channel, including bed scour, sediment transport, riparian initiation and establishment, and floodplain development and connectivity, among others.	Managing the relationships between flow, sediment, and mechanical restoration to jumpstart physical processes to create dynamic fish habitat for target fish species across all life stages.	Feasibility hinges on water supply availability for peak releases of sufficient magnitude and duration to mobilize D_{84} bed surface. Necessary flow magnitudes will vary based on location along the longitudinal profile.
C.6.b.1		Manage coarse sediment scour, deposition, and transport	CSS	Develop targets of scour, deposition, and transport by reach necessary to restore physical processes and promote channel complexity across a range of flows. Manage flows and sediment budgets to meet those targets.	Managing coarse sediment will result in improved habitat availability and quality. Coarse sediment targets will vary by river reach.	The timeframe, quantities, and grainsize associated with eventual routing of coarse sediments stored behind the four major dams are not fully known. Coarse sediment is believed to naturally balanced 18 miles downstream of Iron Gate Dam, near Cottonwood Creek.
C.6.b.2		Augment coarse sediment	CSA	Add coarse sediment downstream of Iron Gate Dam to mitigate deficit caused by the dam.	The reach downstream of Iron Gate Dam has been starved of coarse sediment, which has fossilized bars and reduced floodplain connectivity, scour, and other key physical processes.	Coarse sediment augmentation will not be necessary if the four major dams are removed. The augmentation sites, volume, and grain size of coarse sediment necessary for augmentation remains to be determined.
C.6.c		Road drainage system improvements and reconstruction	RDS	Road projects that reduce or eliminate sediment transport into streams. This includes placement of structures or rolling dips to contain/ control run-off from roads, road reconstruction or reinforcement, surface, inboard ditch, culvert and peak-flow drainage improvements, and roadside vegetation. These roads may extend into or are in the riparian zone.	Reduces the deposition of high concentrations of fine sediments into gravels and pools, simplifying instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008).	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.d		Road closure / abandonment	RCA	Closure (abandonment), relocation, decommissioning or obliteration of existing roads (including pavement such as parking areas) to diminish sediment transport into stream and/or improve riparian habitat. These roads/pavement may extend into or are in the riparian zone.	Reduces the deposition of high concentrations of fine sediments into gravels and pools, simplifying instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008).	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.e		Erosion control structures installed	ECS	Construction/placement of sediment basins, sediment collection ponds, sediment traps, or water bars (other than road projects (see C.6.c) or upland agriculture (see C.6.i)).	Reduces the deposition of high concentrations of fine sediments into gravels and pools, simplifying instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008).	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.f		Planting for erosion and sediment control	PES	Upland projects that control erosion through planting and revegetation or grassed waterways.	Reduces the deposition of high concentrations of fine sediments into gravels and pools, simplifying instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008).	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.g		Slope stabilization	SS	Implementation of slope/hillside stabilization, bioengineering or slope erosion control methods including landslide reparation and non-ag terracing.	Reduces the deposition of high concentrations of fine sediments into gravels and pools, simplifying instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008).	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.h		Upland	UV	Upland vegetation treatment or removal projects for water	Reduces the deposition of high concentrations of fine sediments,	Sediment reduction actions are preventative in nature and the benefits to

Data Field ID	Sub-Category Name	Work Type or Attribute Name	Work Type Abbrev.	Definition	Hypothesized Mechanism	Critical Uncertainties
		vegetation management including fuel reduction and burning		conservation or sediment control including plant removal (e.g., juniper removal or noxious weeds), selective tree thinning, undergrowth removal, fuel reduction treatments, prescribed burnings, stand conversions, and silviculture.	particularly those associated with forest fires, into gravels and pools, simplifying instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008).	species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.i		Upland agriculture management	UA	Implementation of best agricultural management practices such as low or no till agriculture, conservation land management; or, upland irrigation water management for water conservation.	Reduces the deposition of high concentrations of fine sediments into gravels and pools, which can simplify instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008). Also reduces nutrient inputs from manure and fertilizers, and the toxin inputs from pesticides or herbicides..	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.j		Upland livestock management	UL	Upland livestock management action designed to control sediment flow into a stream or riparian area. This includes livestock watering schedules; grazing management plans; upland exclusion and fencing; and, livestock water development (also called off-channel watering or livestock water supply) including installation of upland ditches, wells, and ponds.	Reduces the deposition of high concentrations of fine sediments into gravels and pools, which can simplify instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008). Also reduces nutrient inputs from manure.	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.k		Trail or campground improvement	TC	Improvements to trails or campgrounds that are designed to control sediment flow into a fish bearing stream. These trails/campgrounds may extend into or are in the riparian zone.	Reduces the deposition of high concentrations of fine sediments into gravels and pools, simplifying instream habitats used by fish and disrupting normal fish development, emergence, and behavior (Berg and Northcote 1985; Chapman 1988, NRC 2008).	Sediment reduction actions are preventative in nature and the benefits to species are difficult to quantify. There are tradeoffs in sediment reduction objectives - some species are disadvantaged by fine sediment (salmonids) while others will require fine sediments (lampreys) (Stanley and Doyle 2003, Streif 2008).
C.6.l		Upland wetland improvement	UW	Projects designed to protect, create or improve upland wetlands (wetlands that are not connected to a stream, and are instead charged by groundwater or precipitation).	Restoration of upland wetlands can trap sediment moving over the landscape, but at high elevations can also improve the ability of the landscape to absorb and slow the release of cold water into downstream reaches which can help to mitigate against climate warming. Slowing the flow in this way can also help to recharge groundwater aquifers (Williams et al. 2015).	Protection of groundwater dependent ecosystems (GDEs): http://www.groundwatercalifornia.org/ https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/oregon/freshwater/Documents/GW_Aldous%20and%20Bach_2011_NWN.pdf
C.6.m		Manage fine sediment deposition and transport	FS	Develop targets for fine sediment deposition and transport by reach to minimize negative impacts to some fisheries (e.g. salmon redds) and maximize other benefits to others (e.g. lamprey rearing habitats, riparian establishment).Mobilization of fine sediments is also necessary for fish disease management and prevention purpose.	Flows will mobilize and flush fine sediments from channel bed and deposit fine sediments on target upland surfaces for beneficial wildlife and riparian recruitment purposes. Flows will mobilize fine sediments and disrupt fish disease parasites, reducing disease risk.	Field measurements may be needed in the reaches upstream of the four major dams to evaluate fine sediment availability. Fine sediments stored behind the four major dams have been predicted to flush from the system within one year after dam removal. The potential longer-term signature of fine sediment routing is ultimately unknown.
C.7	*Water Quality Project*		WQP	*Projects that improve instream water quality conditions for fish or reduce impacts of instream point/non-point pollution. This includes improved water quality treatment; nutrient enhancement through carcass placement; return flow cooling; removal or prevention of toxins, sewage or refuse; or, the reduction or treatment of sewage outfall and/or stormwater.*		

Data Field ID	Sub-Category Name	Work Type or Attribute Name	Work Type Abbrev.	Definition	Hypothesized Mechanism	Critical Uncertainties
C.7.d		Refuse/debris removal	DR	Removal of garbage/trash from stream, wetland or other inland body of water used by fish. This would include removal of derelict fishing gear or ghost nets from rivers and lakes.	Reduces pollutants and entrapment	Labor intensive
C.7.e (SC)		Clean up sewage	SC	Reduction or clean-up of sewage outfall including failed septic systems.	Reduces pollutants	One significant emerging issue is the input of pharmaceuticals, endocrine disruptors, and personal care products to the watershed, products that are not effectively removed in standard treatment processes (Sumpter and Johnson 2005).
C.7.f		Clean up past chemical contamination	CCC	Clean-up or prevention of mine or dredge tailings or toxic sediments.	Remedial actions remove or isolate toxic contaminants from the environment. Remediation at mine sites can involve the in-place treatment or physical removal of mine waste and mill tailings from a stream, its associated flood plain, and the surrounding landscape. Remediation can also involve the reduction or elimination of metal and acid loading from draining mines.	Variable effectiveness of remediation depending on methods utilized. Cleanup can be very costly. The actual cleanup activities can result in ecological injury and should be addressed early in the planning process, because some remedial actions may interfere with successful ecological restoration. https://pubs.usgs.gov/pp/1651/downloads/Vol2_combinedChapters/vol2_chapF.pdf
C.7.g		Reduce herbicide / pesticide use	RHP	Reduce usage of herbicides, pesticides, or other chemical products.	Pesticides, herbicides, fertilizers, gasoline, and other petroleum products contaminate drainage waters and harm juvenile coho salmon and their aquatic invertebrate prey (Crisp et al. 1998, Flaherty and Dodson 2005). Reducing the use of herbicides, pesticides, and other chemical products can minimize the negative effects on fish.	This is not a very big consideration for UKL as row crops are not a large component of the agricultural community.
C.7.h		Carcass or nutrient placement	CN	Placement of fish carcasses, fish meal bricks, or other fertilizer in or along the stream for nutrient enrichment.	Historically, large numbers of salmonid carcasses provided entire watersheds with abundant nutrients and organic matter derived from the ocean. Salmon carcasses play a key role in maintaining the productivity of salmonid systems and benefiting the aquatic and terrestrial ecosystem as a whole. Rearing juveniles also consume salmon eggs, feed directly on spawned-out carcasses, and benefit from increased abundance of invertebrates and algal growth.. http://www.pac.dfo-mpo.gc.ca/publications/pdfs/carcass-carcasse-guide-eng.pdf	Numerous factors can influence the benefits of carcass (and analogous nutrient block) placement in streams. These include ambient nutrient content in treatment streams, abundance of native salmon spawners, presence of fish disease agents in carcasses, retention and distribution of carcasses in waterways, water temperatures, flow levels, light penetration, and predator / scavenger activity on carcasses by insects, fish, birds and mammals. http://www.pac.dfo-mpo.gc.ca/publications/pdfs/carcass-carcasse-guide-eng.pdf
C.7.i		Livestock manure management	LMM	Relocation or modification of livestock manure holding structures and/or manure piles to reduce or eliminate drainage into streams.	If not managed properly, manure will accumulate very quickly and pose the potential for polluting the environment through contamination of surface water and groundwater.	Manure storage management requires a strategic approach to manure application taking crop needs and weather into account. Extra storage depth must be provided for manure holding structures to allow for precipitation and mandatory freeboard. http://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/442/442-307/442-307_pdf.pdf

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C.7.j		Stormwater / wastewater modification or treatment	SMT	Modifications to stormwater/wastewater and drainage into stream to improve water quality.	As it travels to storm sewers, stormwater picks up pollution along the way. Stormwater can contain motor oil, gasoline, dog waste, garbage, fertilizer and other contaminants. These materials go directly into the nearest body of water, where they can be harmful to fish and other biota.	Heavy rains can put unusually high volumes of stormwater into streams and creeks in a short period of time and overwhelm treatment and conveyance systems.
C.7.k		Return flow cooling	RFC	Return flow cooling projects where extracted water that has heated during use is cooled before it is returned to the stream. This can occur in power plants, large industry, and smaller applications which generally consist of replacing old open return ditches with underground PVC pipe.	Eliminates thermal loading by routing or filtering flows underground where they can cool before discharge into streams.	Prior to constructing return flow piping, efforts should be focused on irrigation efficiencies to reduce water use.
C.7.l		Reduce fertilizer use	RFT	Reduction of fertilizer applications on agricultural or other lands.	Lowers external nutrient loads from anthropogenic sources to local watercourses (progressive as action advances)	Fertilizer is not often used in the upper basin
C.7.m		Rotate crops and wetlands	RCW	Crop rotation program allowing flooding of fields and return to wetland between planting years, providing intermittent habitat and water quality benefits.	Increase in wetland area:agriculture area ratio reduces nutrient loading to downstream water bodies	Depends on landowner willingness to engage in this practice. Uncertain as to the science around the nutrient loading impacts once the flooded fields are drained before farming again. P and N loads may be high.
C.7.n		Tailwater return reuse or filtering	TWR	Capturing drainage from fields and using it on fields or directing it to wetlands and/or bioswales for treatment before discharge to subsurface piping leading to streams.	Increased water storage and increased cooling of water by wetlands lowers water temperature in streams draining agricultural lands	Prior to constructing tailwater collection ponds, efforts should be focused on irrigation efficiencies to reduce tailwater inputs. Tailwater capture projects should be located far enough away from streams to avoid fish stranding and potential channel avulsion. There is no real tangible benefit for landowners to do this; it has therefore been slow to implement. If land needed, unclear what landowner incentives could be developed.
C.7.o		Stormwater filtering	SWF	Capture and filtering of stormwater through bio-swales, rain gardens or wetlands before discharge in streams.	Interception of storm water by bio-swales along roads, rain gardens and by wetlands results in lower external nutrient loads. The traditional approach to stormwater management was to drain stormwater as quickly as possible into the nearest waterway. Modern approaches try to mimic natural processes and allow stormwater to soak into the ground or be released more slowly into local waters. http://www.metrovancouver.org/services/liquid-waste/drainage/stormwater-management/about-stormwater/Pages/default.aspx	Heavy rains can put unusually high volumes of stormwater into streams and creeks in a short period of time and overwhelm treatment and conveyance systems.
C.7.p		Algae harvest	AH	Mechanical harvesting of lake algae	Physical removal of algae biomass could reduce buildup of algal toxins.	Not likely to be very effective. Would need to be very large scale to make an impact. See Stillwater report.
C.7.q		Dredging of lake or reservoir sediment	DLS	Dredging of lake sediments. Sediment to be disposed of on land (e.g., landfill or as in-fill in landscaping or agriculture projects).	Removal of sediment nutrients and toxins which could otherwise re-enter the ecosystem through mixing or bioturbation.	Highly labor intensive, may never be approved because of presence in lake and reservoirs of ESA-listed sucker. Impacts to endangered lake suckers, their food sources. Probably could not be done on a large enough scale to have any impact. Problem of nutrient loading to the lake would not be solved. Too much disturbance to profundal zone.

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C.7.r		Targeted aeration for fish refugia	TA	Oxygen injection via compressed air diffuser or direct oxygen injection by mechanical means in part or all of an enclosed water body (e.g., lake, impoundment, etc.). In the context of the Klamath Basin, this applies to Upper Klamath Lake.	Provides improved dissolved oxygen conditions in key areas of the lake utilized during key fish life stages	Difficult to undertake on big lakes. Upper Klamath Lake is so large, targeting specific areas would be hard. Could be effective in Keno reach. Would need to alert boaters somehow.
C.7.s		Phosphorus immobilization using alum	PIA	Alum is a chemical compound containing aluminum and sulfate that when added to water forms a semisolid matrix commonly referred to as “floc”.	Alum floc is made up of aluminum hydroxide, which is heavier than water and sinks through the water column, collecting phosphorus as it settles. The settled phosphorus remains bound over time, and benthic organisms live amongst the floc particles as they would other sediments.	Difficult to undertake on big lakes. Impacts to endangered suckers and benthic organisms.
C.7.u		Reduction of impacts related to illegal marijuana grow clean-ups	RMJ	Clean-up of illegal marijuana grow ops that have been cleared by law enforcement and pose risk to aquatic ecosystems. Actions included in this activity would be accomplished by hand or through the utilization of heavy equipment when existing road access permits.	Restoration activities may include reestablishing stream channels and/or removing illegal dams from headwater streams, removing waste such as tarps, pipes, garbage, chemicals or other products, and vegetating disturbed sites using native plants.	Uncertainties as to the range of actions that would be required for full mitigation of potential impacts and the effectiveness of these actions; will be situational dependent. Likely labor intensive.
C.8	*Wetland Project*		WTP	*Projects designed to improve connected wetland, meadow or floodplain areas (wetlands that are connected to the stream/riparian area) that are known to support fish production.*		
C.8.c		Wetland planting	WP	Planting of native wetland species in wetland areas.	Planting may be required to accelerate wetland restoration after flooding of drained former wetland sites, creating new habitat for fish that depend on wetlands for spawning, rearing, and feeding and contributing to water quality improvement (Steere 2000). In addition, planting of macrophytes (emergent and submergent) can reduce or mitigate the impacts of water body fetch on nutrient issues, where larger fetch is associated with more upwelling and distribution of nutrients in sediments (Laenen and LeTourneau 1996).	The effectiveness of wetland planting for reducing particular stressors is contingent on the type of plant and the area in which it is planted. For example, tall emergent wetlands may provide more sequestration benefits in slow/slack water areas rather than being implemented in areas with relatively high flow; short emergent sedges might provide more seasonal benefits where overland flow or lateral ground water movement is occurring; Nuphar may be beneficial in systems with less consolidated substrates; submergents may provide benefits in more open water areas.
C.8.d		Wetland plant removal / control	WC	Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the wetland area or water table.	Removal of invasive plants can help to reduce known impacts including their tendency to outcompete native stream plants without necessarily providing the same food or shelter benefits, often consume large amounts of water affecting the water table, and may overgrow and choke streams (Anderson and Graziano 2002, Flosi et al. 2010). Goal in emergent wetlands is to keep the emergent vegetation from becoming a monoculture (maintain diversity) and ensure its patchy distribution to maximize the volume of edge habitat available for fish. Once the emergent vegetation becomes overly decadent and edge habitat is reduced, mowing, disking, or burning in the wetlands might be necessary to maintain open spaces and channels through the dense beds of vegetation.	Non-native species removal programs are labor intensive and there is uncertainty surrounding the degree of effort required to achieve an ongoing ecological benefit. While there are a few invasive species present, not considered a big concern in UKL.

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C.8.e		Wetland improvement/ restoration	WIR	Improvement, reconnection, or restoration of existing or historic wetland (other than vegetation planting or removal (C.8.c and C.8.d)).	Expansion and reconnection of existing wetlands through restoration increases available habitat for fish that depend on wetlands for spawning, rearing, and feeding (especially endangered suckers) and contributing to water quality improvement (Steere 2000). The effectiveness of wetland restoration projects is fairly unequivocal – fish species like sucker that depend on wetland recruit to restored sites and have been shown to be more abundant in larger restored wetlands than in lakeshore fringe wetlands that have not undergone restoration (Erdman et al. 2011).	Wetland restoration may be more challenging due to the subsidence of some former wetlands after decades of diking. These areas would no longer be shallow wetlands upon re-flooding, but deeper water habitat that may require extensive construction or importation of fill or dredge material to restore elevation in order to achieve a functioning wetland that would yield ecological benefits for sucker and water quality (Erdman and Hendrixson 2012). In addition, some reconnected wetlands formerly used for agricultural purposes may release large amounts of phosphorous stored in soils immediately after flooding, and although these levels are expected to eventually level off there is uncertainty surrounding the trajectory of stabilization (TNC 2013). This is one of the most important pieces of UKL restoration. Many problems with achieving it: many landowners may want over the appraised value of these pieces. Land trusts are bound to Land Trust Alliance standards to not pay more than appraised value for properties. Funders will often not pay over the appraised value.
C.8.f		Artificial wetland created	WA	New (artificial) wetland created in an area not formerly a wetland. This is wetland area created where it did not previously exist.	Constructed treatment wetlands (also known as diffuse source treatment wetlands (DSTWs) can be purpose-built in locations between the source of agricultural runoff and the natural watercourses it will return to, in order to filter water to reduce sediments and nutrients before it returns to streams (CH2M 2012, Stillwater Sciences et al. 2013).	In some cases there may be a drive to create new wetlands in areas where they did not exist before. In such cases, the soils, geology, and hydrology of the site must be carefully considered to determine whether it will hold water, which is generally a given for the sites of historic wetlands (Bonsignore and Liske 2000).
C.9	*Estuarine / Nearshore Project*		ENP	*Projects that result in improvement of or increase in the availability of estuarine or nearshore marine habitat (tidally influenced areas) such as tidal channel restoration, tidal floodplain connectivity, tide gate fish passage or diked land conversion.*		
C.9.c		Channel modification	ECM	Deepening or widening an existing tidal channel or adding structures to improve fish habitat. This includes creation of new channels that provide or improve intertidal flow to existing estuarine habitat.	Channel modification can allow for more natural flow movement through an estuary and provides the potential for off-channel habitat usage.	Uncertain if such engineering will persist if natural river flows that would maintain channel structure continue to be impaired.
C.9.d		Dike or berm modification / removal	EDM	Removal, breaching, reconfiguration or other action affecting the physical presence of barriers or structures that prevent tidal or riverine access to the estuary. This involves lateral structures only, and does not include dams or other perpendicular obstructions to flow.	Modification/removal of dikes/berms allows for a natural flow/flood regime in an estuary and the potential for off-channel habitat usage.	The influx of marine water from berm breaching can change an estuary's physicochemical regime by altering salinity, temperature, nutrients, current and habitat availability.
C.9.e		Tide gate alteration / removal	ETA	Changes to tide gates that allow water to flow freely when the tide goes out, but prevent water from flowing in the other direction. Changes are generally made to allow fish passage at low and high tide.	Tide gates serve to drain tidelands (areas that incoming tides regularly cover) for agricultural or other uses. First a dike is built to isolate the area to be drained. A large pipe or culvert passes through the dike. On tidewater side of the pipe there is a hinged door which opens outwards towards the bay or estuary. When water levels are higher on the side of the pipe towards the drained	Poorly designed tide gates can create situations where fish that enter drained land through the tide gates may be injured or trapped on the drained side. http://www.westcoast.fisheries.noaa.gov/fish_passage/solutions/tide_gates.html

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					area, the weight of the water holds the door open, allowing water to flow out into the bay or estuary. When the tide rises, the level of water on the tidewater side becomes higher than on the drained area side, holding the door closed so water does not flow back into the drained area. http://www.westcoast.fisheries.noaa.gov/fish_passage/solutions/tide_gates.html	
C.9.f		Estuarine culvert modification / removal	ECM	Modification or removal of culvert to improve fish passage between estuarine and off-channel areas.	Addition of passage structures to assist fish in moving over or around a barrier opens up fish passage and restores access to previously unavailable habitat, which may be of higher quality than previously accessible habitat.	There is uncertainty surrounding the effectiveness of some culvert designs compared to others for providing fish passage.
C.9.g		Removal of existing fill material	ERF	Removal of fill that isn't associated with a dike (e.g., removal of tideflat fill)	Reconnects the estuary to adjacent streams or wetlands.	Duration/permanency of reconnection can be uncertain.
C.9.h		Fill placement	EFP	Placement of fill to raise elevations to allow for proper terrestrial function.	Could be used to overcome effects of past excavations, to raise portions of a site above tide level for germination of upland vegetation.	May require maintenance to ensure germination of desired native upland plants on new fill and restrict invasives.
C.9.i		Regrading of slope	ERS	Shaping of terrestrial or aquatic slopes to achieve proper function. Usually done with land based equipment.	Could be used to reshape portions of a site above tide level for germination of upland vegetation or to lower portions of a site for development of aquatic plants/communities.	Duration/permanency of new landscaping can be uncertain depending on flow regime and natural channel reconfiguration processes.
C.9.j		Estuarine plant removal / control	EPR	Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the estuarine area.	Invasive plants can outcompete native plants without necessarily providing the same food or shelter benefits, and may overgrow and choke estuary areas.	Non-native species removal programs are labour intensive and there is uncertainty surrounding the degree of effort required to achieve an ongoing ecological benefit.
C.9.k		Shoreline armor removal or modification	EAR	Removal or modification of shoreline armoring structures (e.g. seawalls, breakwaters, riprap) or bulkheads.	Removal of armoring can allow for more natural flow and sediment movements through an estuary or nearshore and provides the potential for off-channel habitat usage.	Benefits of removing armouring will vary as subsequent rates of erosion and shoreline evolution will be influenced both by human activities and by natural factors such as sediment supply, changes in sea level, and the effects of waves, currents, tides, and wind. https://oceanservice.noaa.gov/facts/shoreline-armoring.html.
C.9.l		Beach nourishment (aka Beach Filling)	EBN	Physical placement of natural (but not necessarily local) beach substrates to a beach, stretch of shoreline or other location to combat erosion and increase beach width. Also includes actions where native materials are allowed to naturally (passive) or through human intervention (active) enter the drift cell.	Beneficial where historic supplies of beach substrates have either been eliminated or are insufficient to overcome existing degradations.	Sudden inputs of sand through beach nourishment could kill animals living on the beach while new sand may not be the same grain size or chemical makeup of the natural sand, changing the habitat for beach animals. The time needed for a beach ecosystem to recover from a single beach filling episode is uncertain. Duration/permanency of benefits may be uncertain given potential climate-change associated sea level rise and increasing storms that threaten to erode sandy beaches. http://explorebeaches.msi.ucsb.edu/beach-health/beach-nourishment.
C.9.m		Contaminant	ECR	Physical removal (through chemical remediation or biological	Remedial actions remove or isolate toxic contaminants from the	Variable effectiveness of remediation depending on methods utilized. Cleanup

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		removal / remediation		treatment, if possible) of chemical contamination/hazardous wastes found in the nearshore environment, or prevention of contaminant sources (stormwater modification).	environment. Work can benefit fish intertidal, sub-tidal and supra-tidal habitat conditions.	can be very costly. The actual cleanup activities can result in ecological injury and should be addressed early in the planning process, because some remedial actions may interfere with successful ecological restoration. https://pubs.usgs.gov/pp/1651/downloads/Vol2_combinedChapters/vol2_chapF.pdf
C.9.n		Debris removal	EDR	Removal of solid waste, derelict and otherwise abandoned items in the nearshore and estuarine areas including bays. Common examples include derelict fishing gear, sunken refuse (vessels, cars), pilings, or other discrete items that adversely affect fish habitat. Does not include removal of fill or contaminated sediments.	Reduces pollutants and entrapment	Labor intensive
C.9.o		Overwater structure removal / modification	EOR	Modification or removal of overwater structures such as piers, floating decks and docks.	Improperly constructed overwater structures can affect light penetration and growth of eelgrass, or provide habitat to predators. Large overwater structures may also affect fish behavior.	Effects of overwater structures on fish behavior and habitat use may be variable by species and by type of overwater structure.
C.9.p		Exclusion devices	EED	Deployment of physical exclusion devices to prevent unwanted disturbance of a restoration feature. Commonly includes fencing to keep public/animals away from delicate or newly planted vegetation, installation of mooring buoys, boardwalks/trails, etc.	Any method that prevents or minimizes disturbance of habitat restoration sites by people or animals is beneficial.	The effectiveness of such exclusion efforts may be variable.
C.9.q		Creation of new estuarine area	ENA	Creation of an estuarine area where one did not exist previously using methods not including tide gates or dikes.	Creation of new estuarine areas increases available habitat for fish that use the estuary for spawning, rearing, and feeding and may contribute to water quality improvement.	In some cases there may be a drive to create new areas of estuarine habitat in areas where it did not exist before. In such cases, the soils, geology, and hydrology of the site must be carefully considered to determine whether it will be successful.
C.9.r		Estuarine planting	EP	Estuarine planting or native plant establishment.	Restoration/improvement of estuarine areas increases available habitat for fish that use the estuary for spawning, rearing, and feeding and may contribute to water quality improvement.	The effectiveness of estuarine planting is contingent on the type of plants and the area in which they are planted.
C.9.s		Addition of large woody debris	EWD	Adding large woody debris (LWD) to help recruit natural sediment and restore natural beaches at the mouths of estuaries.	LWD is installed primarily to alter flow and scour patterns, and can provide shade, increase habitat complexity, and provide cover from predation (Whiteway et al. 2010).	Effectiveness of LWD placement depends on placement in the estuary. These structures may not achieve their full benefits if the limiting factors on fish populations are not habitat complexity.
D.	SECTION D: Fish Hatcheries and Harvest Management Category					
D.1	*Hatchery Production*		HPP	*Operations that collect and spawn adult fish incubate eggs; rear and maintain fry/smolt in a hatchery facility or pond; or, outplant fry/smolt.*	*INCLUDED FOR COMPLETENESS, BUT UNDERSTOOD TO BE UNDER JURISDICTION OF STATE AND FEDERAL AGENCIES (other than localized sucker rearing pilot projects)*	
D.1.b		Fish reared/released	FRR	Fish fry/smolt that are produced in a hatchery or other facility and released to re-establish fish to an area or to supplement a wild population. Encompasses hatchery operations that collect and spawn adult fish for the purpose of rearing and out-planting fry or	The historical focus of the hatcheries has been simply to provide a greater abundance of fish available for recreational, tribal and commercial fisheries, however in recent years more emphasis has been placed on the role conservation hatcheries can have in	Although stocking has increased the overall abundance of many populations, numerous studies have reported the potential for deleterious effects of stocking on wild populations (Araki and Schmid 2010), which are described in more detail in Section 3.5.2. These potential effects are most

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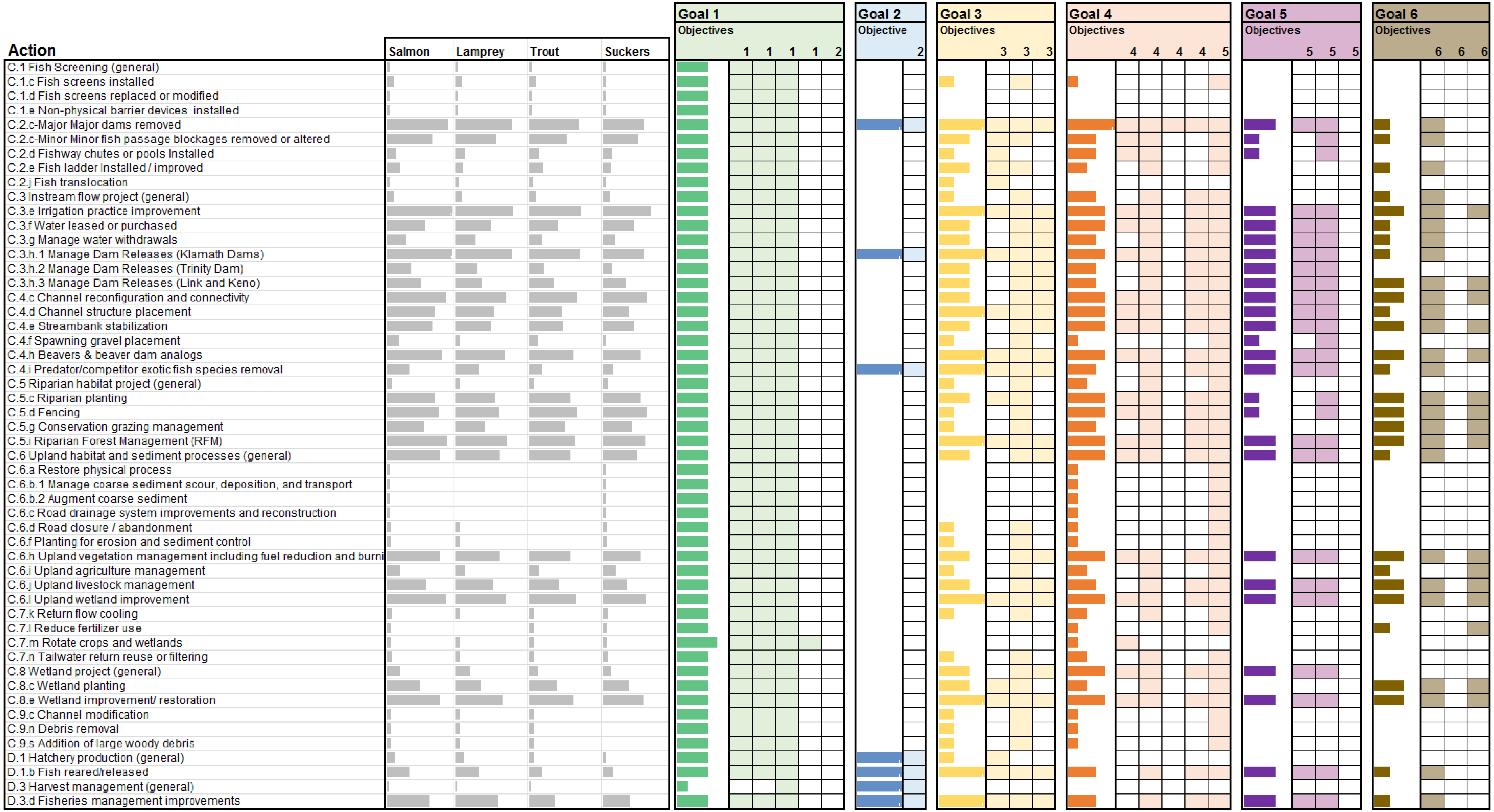
				smolt, as well as small-scale rearing programs that rear artificially spawned or wild-caught fry in streamside rearing ponds to improve survival prior to release.	species recovery through support to reintroduction programs.	pronounced in the absence of strict genetic management protocols include increased competition with wild stocks, potentially increasing harvesting pressure on wild stocks, reduced fitness of hatchery-raised fish, loss of genetic diversity in the overall population, and the potential of hatchery fish to spread disease to wild stocks (Araki and Schmid 2010, Maynard and Trial 2014, Miller et al. 2014)
D.3	*Harvest Manage-ment*		HM			
D.3.d		Fisheries management improvements	FMI	Development and implementation of regulations or management actions that benefit ESA-listed or wild fish.	Management of fish populations through allocations of harvestable fish for commercial, tribal or recreational fisheries across regulatory agencies to achieve targets for conservation and harvest. Fish closures as needed etc. to prevent overfishing as supported by specific quantitative goals for size limits, harvest, escapement, and other parameters for individual stocks.	Fisheries rules, regulations and enforcement measures may not always be adequate to protect stocks; fishing capacity and efforts are not always sufficiently limited or controlled. Complex dynamics of harvested populations may not be sufficiently understood.
D.3.e		Reduce poaching	HRP	Policing (enforcement and compliance monitoring) to prevent illegal harvest of vulnerable wild fish species/stocks	Reduces the (illegal) harvest of fish from streams, rivers or lakes.	Effectiveness of enforcement may be uncertain; responsibilities across agencies for policing poaching sometimes unclear.
D.4	Hatchery Reform	Hatchery reform development / implementation	HR	Hatchery reform projects that assess or evaluate hatchery production levels and strategies for maximizing harvest levels while minimizing ESA and wild salmonid impacts, and/or minimizing hatchery/wild interactions.	*INCLUDED FOR COMPLETENESS, BUT UNDERSTOOD TO BE UNDER JURISDICTION OF STATE AND FEDERAL AGENCIES*	
D.4.c		Hatchery reform assessment/ implementation	HRA	Development and implementation of hatchery reform actions. This includes development of HGMPs (Hatchery Genetic Management Plans) for facilities.	Hatchery and genetic management plans that can reduce the potential ecological and genetic impacts of fish produced and released in the Klamath Basin by the Trinity River Hatchery and Iron Gate Hatchery. Such plans attempt to minimize the ecological and genetic impacts of hatchery operation on wild stocks through a variety of supporting objectives such as maintaining a low proportion of hatchery-origin adults on the spawning ground (pHOS), using local broodstock, and restricting the introduction of disease agents.	Few studies show a positive effect of hatchery rearing on fitness after release or provided direct evidence for enhanced wild stock after release (Naish et al. 2007, Rand et al. 2012, Araki and Schmid 2010, Blount et al. 2017). Overall, most experts conclude that while they may increase overall abundance, it cannot be assumed that hatchery programs will necessarily help wild stocks (Rand et al. 2012, Araki and Schmid 2010).

Appendix C: Expanded Restoration Action Benefit Tables

Table C 1: Expanded restoration action benefit tables for the Upper Klamath Lake subregion, organized by action type bot not in ranking order due to the multidimensionality of this information. *(Final document will include tables for all regions)*



Action
C.1 Fish Screening (general)
C.1.c Fish screens installed
C.1.d Fish screens replaced or modified
C.1.e Non-physical barrier devices installed
C.2.c-Major Major dams removed
C.2.c-Minor Minor fish passage blockages removed or altered
C.2.d Fishway chutes or pools Installed
C.2.e Fish ladder Installed / improved
C.2.j Fish translocation
C.3 Instream flow project (general)
C.3.e Irrigation practice improvement
C.3.f Water leased or purchased
C.3.g Manage water withdrawals
C.3.h.1 Manage Dam Releases (Klamath Dams)
C.3.h.2 Manage Dam Releases (Trinity Dam)
C.3.h.3 Manage Dam Releases (Link and Keno)
C.4.c Channel reconfiguration and connectivity
C.4.d Channel structure placement
C.4.e Streambank stabilization
C.4.f Spawning gravel placement
C.4.h Beavers & beaver dam analogs
C.4.i Predator/competitor exotic fish species removal
C.5 Riparian habitat project (general)
C.5.c Riparian planting
C.5.d Fencing
C.5.g Conservation grazing management
C.5.i Riparian Forest Management (RFM)
C.6 Upland habitat and sediment processes (general)
C.6.a Restore physical process
C.6.b.1 Manage coarse sediment scour, deposition, and transport
C.6.b.2 Augment coarse sediment
C.6.c Road drainage system improvements and reconstruction
C.6.d Road closure / abandonment
C.6.f Planting for erosion and sediment control
C.6.h Upland vegetation management including fuel reduction and burni
C.6.i Upland agriculture management
C.6.j Upland livestock management
C.6.l Upland wetland improvement
C.7.k Return flow cooling
C.7.l Reduce fertilizer use
C.7.m Rotate crops and wetlands
C.7.n Tailwater return reuse or filtering
C.8 Wetland project (general)
C.8.c Wetland planting
C.8.e Wetland improvement/ restoration
C.9.c Channel modification
C.9.n Debris removal
C.9.s Addition of large woody debris
D.1 Hatchery production (general)
D.1.b Fish reared/released
D.3 Harvest management (general)
D.3.d Fisheries management improvements

Appendix D: Klamath IFRMP – 2018 Workshop Participants

March 2018 - IFRMP Conceptual Models, Most Promising Restoration Actions & Potential Performance Indicators Workshop (Participants)

Participants	Affiliation
Barry McCovey	Yurok Tribe
Andrew Braugh	California Trout
Ben Ramirez	Oregon Department of Fish & Wildlife (ODFW)
Betsy Stapleton	Scott River Watershed Council (SRWC)
Bill Chesney	California Department of Fish & Wildlife (CDFW)
Bill Pinnix	US Fish & Wildlife Service (USFWS)
Bob Pagliuco	National Oceanic & Atmospheric Administration (NOAA)
Caitlin Bean	California Department of Fish & Wildlife (CDFW)
Charles Wickman	Mid Klamath Watershed Council (MKWC)
Chris Wheaton	Pacific States Marine Fisheries Commission (PSMFC)
Christie Nichols	US Fish & Wildlife Service (USFWS) - Klamath Falls
Chrysten Lambert	Trout Unlimited
Clayton Creager	North Coast Regional Water Quality Control Board
Crystal Robinson	Quartz Valley Indian Reservation (QVIR)
Cynthia Le Doux-Bloom	Hoopa Valley Tribe - Fisheries Dept.
Damon Goodman	US Fish & Wildlife Service (USFWS)
Elizabeth Nielsen	Siskiyou County Natural Resources (SCNR)
Eric Janney	United States Geological Survey (USGS)
Erich Yokel	Scott River Watershed Council (SRWC)
Elizabeth Nielsen	Siskiyou County Natural Resources (SCNR)
Elizabeth Nielsen	Siskiyou County Natural Resources (SCNR)
Greg Schrott	US Fish & Wildlife Service (USFWS)
Heather Hendrixson	The Nature Conservancy
Jacob Kann	Aquatic Ecosystem Sciences LLC
Jeff Abrams	National Oceanic & Atmospheric Administration (NOAA)
Jim Simondet	NOAA - National Marine Fisheries Service (NMFS)
Karuna Greenberg	Salmon River Restoration Council (SRRC)
LeRoy Cyr	US Forest Service (USFS) - Six Rivers National Forest
Liam Schenk	United States Geological Survey (USGS)
Mark Buettner	The Klamath Tribes
Mark Hereford	Oregon Department of Fish & Wildlife (ODFW)
Mark Johnson	Klamath Water Users Association (KWUA)
Matt Baun	US Fish & Wildlife Service (USFWS)

Matt Parker	Siskiyou County Natural Resources (SCNR)
Michael Pollock	National Oceanic & Atmospheric Administration (NOAA)-NWFSC
Mike Hiatt	Oregon Department of Environmental Quality (ODEQ)
Morgan Knechtle	California Department of Fish & Wildlife (CDFW)
Nell Scott	Trout Unlimited
Randy Turner	Klamath Basin Monitoring Program (KBMP)/SFEI
Robert Franklin	Hoopa Valley Tribe
Ryan Fogerty	US Fish & Wildlife Service (USFWS)
Sarah Rockwell	Klamath Bird Observatory
Shari Witmore	National Oceanic & Atmospheric Administration (NOAA)
Susan Fricke	Karuk Tribe
Ted Wise	Oregon Department of Fish and Wildlife (ODFW)
Tommy Williams	National Oceanic & Atmospheric Administration (NOAA)
Toz Soto	Karuk Tribe
Wade Sinnen	California Department of Fish & Wildlife (CDFW)
ESSA Team	
Clint Alexander	ESSA
David Marmorek	ESSA
Marc Porter	ESSA
Natascia Tamburello	ESSA
Andrea Hilton	McBain Associates
Chris Perrin	Limnotek
David Hankin	Humboldt State University

July 2018 - IFRMP Objectives Hierarchy, Key Performance Indicators & Monitoring Framework Workshop (Participants)

Last Name	First Name	Group	Organization
Abrams	Jeff	LKR	NOAA - lead rep from NOAA
Baun	Matt	FCG / TWG	USFWS
Carpenter	Winne	Intern	Hoopa Tribal Fisheries Department
Creager	Clayton	UKL	North Coast Regional Water Quality Control Board
Edwards	Mike	LKR	USFWS
Fingerle	Amy	MUK	Salmon River Restoration Council
Fogerty	Ryan	FCG/ TWG/ MUK	USFWS
Franklin	Robert	MUK	Hoopa Tribe
Greenberg	Karuna	MUK	Salmon River Restoration Council
Hereford	Mark	MUK	Oregon Department of Fish & Wildlife
Hetrick	Nicholas	FCG / TWG	USFWS

Hiatt	Mike	TWG / UKL	ODEQ
Knechtle	Morgan	MUK	California State Wildlife Agency
McCovey	Barry	LKR	Yurok Tribe
Nichols	Christie	UKL	Klamath Falls Fish and Wildlife Office
Pinnix	Bill	LKR	USFWS
Scott	Eli	MUK	North Coast Regional Water Quality Control Board
Scott	Nell	UKL	Trout Unlimited
Simondet	Jim	FCG/ TWG	NMFS
Stanton	Ed	MUK	Shasta Valley RCD and KBMP fellow KBMP presenter
Stapleton	Betsy	MUK	Scott River Watershed Council
Turner	Randy	UKL	Klamath Basin Monitoring Program - Coordinator
Wheaton	Chris	FCG	PSMFC
Williams	Thomas (Tommy)	FCG	NOAA Fisheries Southwest Fisheries Science Centre
Wise	Ted	TWG/ MUK & UKL	Oregon Department of Fish & Wildlife
Witmore	Shari	FCG / UKL	NOAA Fisheries
Yokel	Erich	MUK	Scott River Watershed Council