UPPER KLAMATH BASIN WATERSHED ACTION PLAN (UKB WAP)

Draft version intended for expert review

June 14, 2019

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ACRONYMS AND ABBREVIATIONS

AARG	Adaptive aquatic restoration guide
AF	Acre-feet (volumetric unit)
DO	Dissolved oxygen (a water quality metric)
EPA	US Environmental Protection Agency
ESA	Endangered Species Act
GIS	geographic information system
KBMP	Klamath Basin Monitoring Program
KWP	Klamath Watershed Partnership
LWD	Large woody debris
NGO	Non-governmental organization
NPS pollution	Nonpoint source pollution
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish & Wildlife
OWEB	Oregon Watershed Enhancement Board
PP	Particulate phosphorus (a water quality metric)
ROA	Restoration opportunities analysis
RPF	Restoration prioritization framework
TKT	The Klamath Tribes
TMDL	Upper Klamath Lake total maximum daily load
TNC	The Nature Conservancy
TP	Total phosphorus (a water quality metric)
TSS	Total suspended solids (a water quality metric)
TU	Trout Unlimited
UKB	Upper Klamath Basin
UKB WAP	Upper Klamath Basin Watershed Action Plan
USBR	US Bureau of Reclamation
USDA	US Department of Agriculture
USFS	US Forest Service
USFWS	US Fish and Wildlife Service

EXECUTIVE SUMMARY

As endemic fish, such as the endangered Shortnose and Lost River sucker, face critical population decreases that threaten the survival of the species, water quality and restoration actions must be undertaken. Additionally, the upcoming removal of the PacifiCorp Dams on the main-stem Klamath River downstream of Upper Klamath Lake, creates an unprecedented opportunity to improve fish habitat conditions in the Upper Klamath Basin (UKB) for anadromous species including Chinook salmon and Steelhead trout. Habitat restoration initiatives will carry huge potential in re-establishing healthy fish populations in the Basin.

The Upper Klamath Basin Watershed Action Plan provides guidance for ecological restoration projects in the Upper Klamath Basin. The document is the result of a collaboration of landowners, ecology experts and government. This makes it harmonious with existing regional planning efforts and accessible to restoration partners, while also sensitive to the needs of landowners to sustain their operations and ways of life.

The Upper Klamath Basin Watershed Action Plan (UKB WAP) has three focus points:

- First it gives an overview of the ecological principles behind various types of restoration actions: the so called “Conceptual Models”.
- Next, it provides guidance in prioritizing restoration efforts, using a “Restoration Prioritization Framework”.
- Last, it gives advice on monitoring and assessment of restoration efforts by providing a “Monitoring Framework”.

Plan overview

The Upper Klamath Basin Watershed Action Plan (UKB WAP) was created through a collaboration of landowner, conservation and government organizations, with the support of two consultants. The following organizations comprise the UKB WAP Team:

- Klamath Watershed Partnership (KWP, recognized by the state of Oregon as the watershed council for the Upper Klamath Basin)
- North Coast Regional Water Quality Control Board (Regional Water Board) in California
- Oregon Department of Environmental Quality (ODEQ)
- The Klamath Tribes (TKT)
- The Nature Conservancy (TNC)
- Trout Unlimited (TU)
- The US Fish and Wildlife Service Partners for Fish and Wildlife Program (USFWS)
- Ag Innovations
- FlowWest

To ensure that the UKB WAP is inclusive of all stakeholder perspectives, stakeholder engagement played an important role in the construction of this document. Next to that, the technical accuracy of the UKB WAP was continuously evaluated by external experts.

Conceptual basis for the UKB WAP

To improve understanding of the current ecological conditions in the UKB, conceptual models are established of the key physical and biological linkages and processes in the basin. Each model consists of two parts: an existing conditions model and a restoration action model. Existing conditions models describe how processes and functions are affected by specific anthropogenic activities. Restoration action models describe how existing conditions can improve after specific restoration activities are implemented.

Conceptual models are provided for the following impairments:

- Channel incision
- Channelization
- Culvert installation
- Tailwater returns
- Water withdrawals
- Fish screens
- Construction of levees and berms
- Large woody debris
- Wetland conversion
- Fish passage barriers
- Riparian grazing
- Roads
- Spawning gravel
- Springs

Restoration Prioritization Framework

The Restoration Prioritization Framework (RPF) provides guidance in prioritizing restoration efforts and is featured in an online decision support tool. This tool enables practitioners to interactively view the above listed impairments in the geographical context of the basin. The goal of the tool is to use the best available data to describe the existing conditions in the UKB as defined by the conceptual models, and direct practitioners to where in the UKB restoration and/or further study is most needed.

The RPF tool aims to quantify impairments at the reach-scale using so-called impairment metrics. These impairment metrics used in the RPF tool are not static and can be updated when new or better data becomes available. This ensures the adaptability of the UKB WAP over time. It also gives practitioners the option to refine the metrics as new ideas and conceptual models emerge.

Currently not all impairments are featured in the RPF tool, because there is not enough data available on them. Table 0-1 gives an overview of currently available data and future data needs per impairment. Impairments marked with * have so far been adopted in the RPF tool.

The RPF tool can be found under the following link:
[INSERT LINK TO RPF TOOL]

TABLE 0-1: SUMMARY OF CONCEPTUAL MODELS AND THEIR RESPRESENTATION IN THE RPF. IMPAIRMENTS THAT ARE SO FAR ADOPTED IN THE RPF TOOL ARE MARKED WITH *.

Conceptual model	**Available data**	**Future data needs**
Channel incision	--	❖ Historical and current cross sections and bathymetry

Channelization *	❖ Channel alignment changes GIS data (FlowWest/Klamath Tribes, 2017)	❖ Sinuosity ❖ Braided index ❖ Flood control infrastructure (to evaluate constraints of any proposed channel realignment)
Tailwater returns *	❖ Sprague subbasin water quality analysis ❖ Irrigation diversions and returns (FlowWest)	❖ Additional water quality and flow monitoring throughout UKB
Water withdrawals	--	❖ Additional flow gage data throughout UKB
Fish screens *	❖ Irrigation diversions and returns (FlowWest) ❖ Wood River Valley diversions (TU)	❖ Detailed, field-verified irrigation infrastructure data
Levees and berms *	❖ Channel alignment changes (FlowWest/Klamath Tribes, 2017) ❖ Flow obstructions (FlowWest/Klamath Tribes, 2017) ❖ Critical habitat for fish species	❖ Amount of floodplain made accessible by levee removal (as in results from a hydrodynamic model discussed below on pages 15 and 16)
Large woody debris (LWD)	--	❖ Map areas with lack of LWD ❖ Habitat mapping ❖ Change in riparian zones and forested areas using historical aerial imagery
Wetland conversion	--	❖ Map historic and current lake fringe and floodplain wetlands
Fish passage barriers *	❖ Passage barriers data (TU) ❖ Irrigation diversions and returns (FlowWest) ❖ Critical habitat for fish species	❖ Detailed, field-verified irrigation infrastructure data ❖ Species life stage ❖ Seasonality of use by species ❖ Channel gradient ❖ Stream velocity and depth information
Riparian grazing *	❖ Landcover classification (FlowWest, 2018)	❖ Vegetation maps with species, wetland indicator status, soil

		stabilizer properties, diversity, age, and vigor ❖ Farmed and/or grazed lands ❖ Fencing and/or other grazing management practices locations. ❖ Assessment of riparian function ❖ Landcover data with more resolved classes (different grasses, shrubs, etc.)
Roads	❖ Road data (Klamath County) available but does not help quantify associated impairment	❖ Adding culvert attributes to road layer ❖ Road surface ❖ Road condition inventory
Spawning gravel	--	❖ Mapped areas with limited spawning gravel ❖ Habitat mapping
Springs	--	❖ Mapping of disconnected springs

Monitoring restoration projects

The UKB WAP was developed under an adaptive management framework. Monitoring is a key component to implementation of restoration projects in the UKB and brings scientific rigor to the full life stage of restoration projects from planning and design to adaptive management (see Figure 0-1). Three different categories of monitoring are discussed in this document, which are applicable to the UKB and were adapted from MacDonald et al. (1991):

1. Baseline monitoring
2. Project and Implementation monitoring
3. Trend monitoring

Baseline monitoring

Baseline monitoring refers to monitoring that assesses the impacts of multiple projects that are undertaken within a sub-watershed or basin. Example sub-watersheds in the UKB could be either the Sprague, Williamson, or Wood basins or key tributaries within each of these three watersheds. Baseline monitoring is designed to identify the current conditions within a sub-watershed or basin. Existing conditions in a sub-watershed or basin can be determined by linking the same type of monitoring actions, throughout the area of interest. As the watershed area increases the resolution and number of monitoring parameters required decreases. Often the level of effort for baseline monitoring is greater than project and implementation monitoring because project and implementation monitoring data is out of date and monitoring must be updated for a greater number of projects across a larger spatial extent.

Project implementation monitoring

Project and implementation monitoring employs monitoring methods that create fine resolution data and includes the methods described in the Monitoring Framework (Appendix A) for a specific restoration action at a specific site. Monitoring method examples include surveys of channel geometry or riparian vegetation survival at a specific site. The objectives of this type of monitoring is to ensure that the project was implemented as designed, assess the change in the site condition, and to learn from successes or failures of the project compared to the project objectives. These lessons are then used to revise conceptual models that illustrate the understanding of the physical and biological linkages operating at the site or for that type of restoration action. These monitoring efforts are often carried out for short duration that includes pre-implementation and post-implementation of the project and rarely include annual post-project monitoring. Ideally, post-implementation monitoring would be continued until the project is considered self-sustaining. Typically, post-project monitoring is considered part of the project as-built design and is built into the project implementation budget.

Trend monitoring

Lastly, trend monitoring typically requires a separate monitoring program and sampling design compared to implementation and project and baseline monitoring programs. Often when looking at comparisons between watersheds there is a discrepancy in the amount and quality of data between watersheds. A common set of parameters is needed to assess trends and the cumulative benefits of restoration actions between watersheds or for the entire basin that may be inconsistent between watersheds. This requires the development of a monitoring network than can be compared across the basin, often where no existing monitoring network exists. The level of effort increases as the area of analysis increases. For large and remote areas, travel time can be a significant component of the monitoring program. The duration of the trend monitoring covers longer periods of time with rich data sets requiring decades to cultivate. Often biological and physical processes take a range of conditions to be able to access success or failure. Fish population dynamics typical take numerous generations for a trend to established and physical processes are often tied to hydrologic conditions that may occur infrequently, such as large floods.

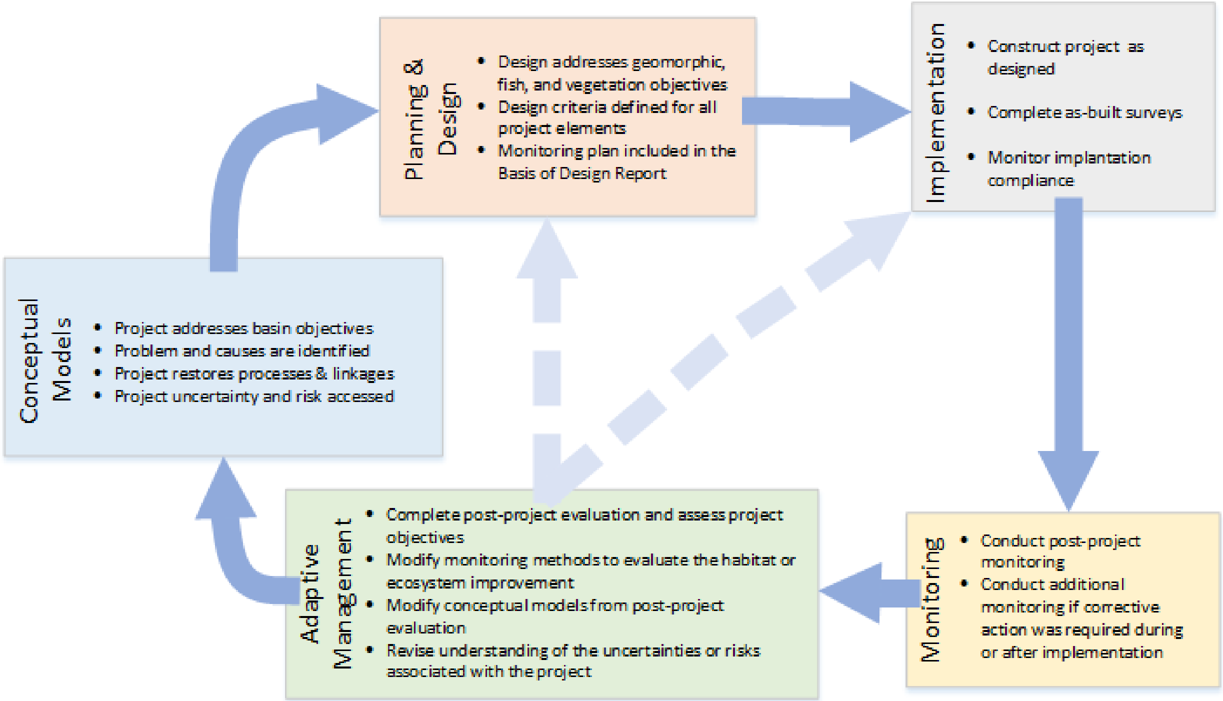


FIGURE 0-1: RESTORATION PROJECT LIFE-CYCLE SHOWING THE CRITICAL ROLE OF POST-PROJECT MONITORING

Next steps

Data and knowledge gaps

The development of the Restoration Prioritization Framework (RPF) tool identified several key data and knowledge gaps essential for making well-informed prioritization of restoration activities at the UKB-scale. Limited data is available for riparian, roads, and tailwater returns conceptual models. Additionally, there is currently no available data for the following conceptual models in terms of quantifying impairment and the costs/benefits of restoration actions:

- Channel incision
- Large Woody Debris (LWD)
- Spawning Gravel
- Wetland Conversion
- Water Withdrawals
- Springs

The UKB WAP Team identified many future data and/or study needs to enhance and expand the RPF tool. Future data sources and studies that would aid in building the RPF are listed in Chapter 6.

Impairment summary by watersheds

To compare impairment metrics between and within watersheds, the watershed impairment scores are shown in Figure 0-2. Based on the level of impairment, restoration practitioners and watershed managers can prioritize further study or restoration actions between metrics and watersheds. The scores were derived by summing the number of reaches with metric scores that fall within the 75th percentile (indicating higher impairment), and then normalizing that total by the sum of reaches in the watershed with data for the impairment metric. This score was not calculated for the Water Quality metric as the data used was different for each watershed (see Chapter 4).

Continuation of the UKB WAP

Although there is no direct path forward or additional funding at this time, the UKB WAP Team is committed to identifying additional funding sources to continue development of the UKB WAP. The UKB WAP Team welcomes the participation by other interested parties for development of future phases of the UKB WAP and interested parties are encouraged to contact any of the UKB WAP Team members to provide input and recommendations for future iterations of the UKB WAP.

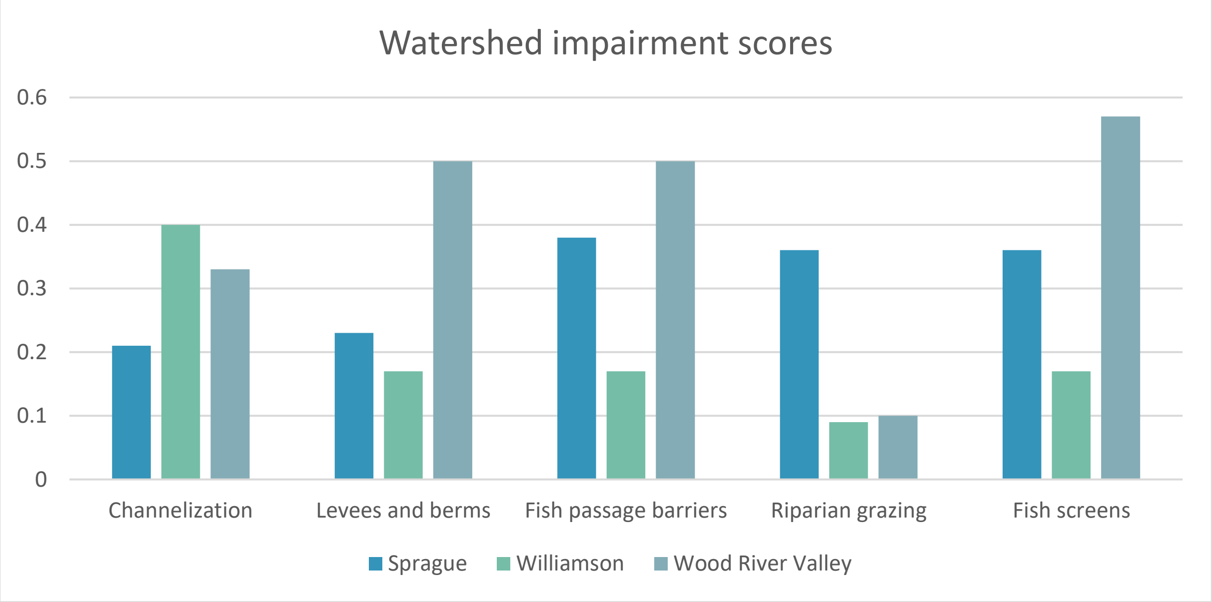


FIGURE 0-2: COMPARISON OF WATERSHED IMPAIRMENT SCORES

Chapter 1 PLAN OVERVIEW

INTRODUCTION

Plan need

The Upper Klamath Basin Watershed Action Plan (UKB WAP) aids in developing a strategic approach to restoration in the Upper Klamath Basin (UKB), in order to achieve water quality improvements and habitat improvements for endangered fish species (Shortnose and Lost River sucker). Through the use of the best available data and science, and an adaptive management framework, the UKB WAP will guide practitioners on a path to habitat improvements through the restoration of ecosystem process and function.

The upcoming removal of the PacifiCorp Dams on the main-stem Klamath River downstream of Upper Klamath Lake, creates an unprecedented opportunity to improve fish habitat conditions in the UKB. As endemic fish return to their historic ranges upstream of the dams, habitat restoration initiatives will carry huge potential in re-establishing healthy fish populations in the UKB. The UKB WAP is needed to review the available data and science related to strategic planning of restoration in the UKB, synthesize these findings, and provide findings to restoration practitioners in a usable, scalable, and adaptive format.

Concept

The Upper Klamath Basin Watershed Action Plan (UKB WAP) is an accessible and adaptive planning and mapping tool that guides and prioritizes future restoration projects in the Upper Klamath Basin (UKB). The UKB WAP has full buy-in from all organizations in the UKB WAP Team, is harmonious with other regional planning efforts, and is accessible to partners while also sensitive to the needs of landowners to sustain their operations and ways of life. The UKB WAP aims to identify where the most important restoration opportunities exist through a Restoration Prioritization Framework (RPF), with the long-term goal of working with willing landowners to implement restoration actions. The plan is not regulatory in nature as such. The UKB WAP is aligned with the Upper Klamath Lake Drainage Total Maximum Daily Loads (TMDL), the Lost River and Shortnose Sucker Recovery Plan, and the Bull Trout Recovery Plan.

Purpose

Using the best available science, the UKB WAP's purpose is to achieve ecological outcomes by increasing the pace and scale of voluntary habitat restoration and water quality improvement projects in the region. The plan is intended to guide how restoration dollars (federal, state, other) will be directed and allocated in the future, including funds associated with fish recovery following dam removal. Given the unprecedented opportunity for fish recovery in the Upper Klamath Basin, it is critical that the best available information be analyzed and compiled in a single report that can be used by local organizations to prioritize where work should occur, and by granting organizations to identify where their restoration funds should be directed.

UKB WAP LAYOUT

The UKB WAP is presented in the following chapters of this document. Chapter 2 provides an overview of the history of ecology and land use in the UKB as well as some geographical and hydrological context of the study area. Chapter 3 outlines the conceptual models for the Restoration Prioritization Framework (RPF), which describe the current understanding of the critical processes and linkages responsible for existing ecosystem conditions and potential restored conditions. Chapter 4 presents the

RPF and how it can be used to guide and inform restoration actions in the UKB. Chapter 4 focuses on the methods and results of quantifying existing conditions conceptual models for which there was available data, and the RPF decision support tool that was built out of those metrics. Chapter 4 concludes with a section documenting data gaps and scientific study needed to quantify additional conceptual models and further build the RPF. Chapter 5 summarizes best practices for restoration project monitoring techniques, as well as recommendations for additional monitoring. The final chapter, Chapter 6, summarizes the needs to further inform prioritization of restoration activities in support of the UKB WAP.

UKB WAP TEAM

The Upper Klamath Basin Watershed Action Plan Team (UKB WAP Team) is a collaborative entity formed to create the UKB WAP, and to gather input from key community and agency partners in order to harmonize this work with other efforts and understand stakeholder concerns within the larger community. The following organizations comprise the UKB WAP Team:

- Klamath Watershed Partnership (KWP, recognized by the state of Oregon as the watershed council for the Upper Klamath Basin)
- North Coast Regional Water Quality Control Board (Regional Water Board) in California
- Oregon Department of Environmental Quality (ODEQ)
- The Klamath Tribes (TKT)
- The Nature Conservancy (TNC)
- Trout Unlimited (TU)
- US Fish and Wildlife Service Partners for Fish and Wildlife Program (USFWS)

The UKB WAP Team also includes two consultant teams: FlowWest and Ag Innovations. FlowWest was responsible for writing the Watershed Action Plan, for providing the information and data to the UKB WAP team that would enable them to make informed decisions about the scope and approach of the plan; and for overseeing coordination of all plan components as the UKB WAP project manager. Ag Innovations was responsible for meeting design and facilitation, stakeholder engagement process design and facilitation, coordination among UKB WAP team entities, supplying communications tools for public and agency outreach, and handling meeting logistics.

The working structure of the UKB WAP Team

From the UKB WAP team as a whole, several smaller groups were formed, with different functions:

1. The UKB WAP Team as a whole was involved in all decision making, gathering external expert input, and stakeholder engagement.
2. The UKB WAP Working Group worked most closely and consistently with the facilitation team of FlowWest and Ag Innovations and operated as an advisory council to the larger group.
3. Technical subgroups provided edits, technical research, and proposals to whole group, according to their areas of expertise.
4. The Stakeholder Engagement subgroup was involved in planning the stakeholder engagement process, including outreach to policy makers, community members, and colleagues about the plan, and building buy-in.

Process of the UKB WAP Team

1. The **stakeholder engagement process** was employed to identify and engage with stakeholder groups, including local residents and entities, organizational partners, subject matter experts, and policymakers.
2. The **external expert input process** involved team members self-selecting into small groups according to their areas of expertise and was adopted in order to gather feedback from external experts on different technical aspects of the UKB WAP. The process was designed and implemented for the purpose of acquiring the most accurate and complete information possible, and in order to identify any blind spots on the part of the plan design team. The external scientific experts reviewed initial metrics that were the basis of the UKB WAP data set, as well as the UKB WAP plan draft and accompanying new metrics and data.
3. The **conceptual model process** used a subgroup of the UKB WAP team with the appropriate technical expertise to update existing conceptual models for the UKB WAP.
4. The **RPF metric subgroup process** involved smaller groups of UKB WAP members reviewing available data per metric, drafting the metric, and presenting recommendations to the UKB WAP Team, and iterating until there was buy-in from the entire UKB WAP Team on the metric.

OUTREACH AND SYNERGIES

Stakeholder outreach

As the Upper Klamath Basin has a contentious history around water allocation, use and stewardship, the UKB WAP facilitation team identified the need to develop stakeholder buy-in among community members, organizational partners, and local entities and experts as key to the success of the plan. Based on input from UKB WAP team members, Ag Innovations developed a stakeholder engagement framework to support five identified groups with interests, concerns, and valuable input on the UKB WAP in the engagement process. Technical experts, landowners (particularly those who own property in the plan's focus area), policy makers, potential funders, and other organizational partners were identified, with accompanying strategies and materials developed for each group.

A stakeholder engagement subgroup was formed and provided with a framework to gather, organize, incorporate, and address stakeholder feedback. Main stakeholder groups were identified and key messages were developed to help stakeholders understand:

1. the voluntary (rather than regulatory) nature of the plan,
2. the science-based nature of the plan, and
3. the adaptability of the plan over time.

As was revealed in interviews with UKB WAP team members, a common framing of the tensions related to water use in the Upper Klamath Basin is the polarizing of landowners and agricultural producers against environmental/resource conservationists in the allocation of scarce water resources. The UKB WAP attempts to acknowledge and address potential landowner concerns about the plan by framing it in the following ways:

- Emphasis on the voluntary, non-regulatory nature of the plan
- Articulation that the UKB WAP is inspired by the need for productive and unifying community engagement as a guiding value of the UKB WAP Team
- Noting that restoration practitioners on the UKB WAP team working with landowners are translating landowner concerns based on their on-the-ground experience, which will be integrated into the tone and content of the UKB WAP as appropriate

- Impairments and restoration actions related to agriculture are identified in the tool and RPF as opportunity areas for future development; several of these impairments (i.e. irrigation diversions) need more data to be represented in the tool
- Landowner representatives will review the UKB WAP draft for input after completion of the initial draft
- Parcels and land ownership are not denoted in UKB mapping tool (Chapter 4) in order to respect landowner's privacy

Watershed stewardship approach

The organizations working together to develop the Upper Klamath Basin Watershed Action Plan have been working for decades within the upper basin implementing watershed stewardship projects. The UKB WAP is a voluntary initiative to create a framework to better coordinate the efforts of many into a cohesive watershed stewardship program.

The UKB WAP Team is a growing partnership which currently includes: Klamath Watershed Partnership (KWP) - recognized by the state of Oregon as the watershed council for the Upper Klamath Basin, The Klamath Tribes (TKT), Trout Unlimited (TU), The Nature Conservancy (TNC), US Fish and Wildlife Service Partners for Fish and Wildlife Program (USFWS), Oregon Department of Environmental Quality (ODEQ), and California North Coast Regional Water Quality Control Board (Regional Water Board).

Staff from these organizations have been contributing their services to serve as the leads to develop the voluntary UKB WAP and coordinate the activities of participants. These partners will continue to reach out to individual landowners and other organizations to encourage their voluntary participation. The following section provides some introductory background information on the watershed stewardship approach, which is the general process used to build the voluntary water quality improvement coordination framework to implement the UKB WAP.

Stewardship process, purpose and audience

The stewardship approach is intended to provide interactive feedback from local stakeholders regarding water quality conditions and stewardship actions in the Upper Klamath Basin. Unlike the Upper Klamath Lake Drainage Total Maximum Daily Loads (TMDL), the stewardship approach addresses surface water status for both 303(d) listings and other surface-water-related concerns, such as restoration actions and upland conditions. Additionally, the watershed stewardship approach holistically evaluates the ecological status of the Upper Klamath Basin, working to improve the status of endangered species, and the resiliency of the working landscape.

The Upper Klamath Basin Action Plan is based on a voluntary adaptive management process and includes a series of steps intended to build more effective partnerships. The UKB WAP includes a process for identifying restoration priorities that provide multiple benefits to partners. The UKB WAP Team will rely on an existing coordinated status and trends monitoring framework within the Upper Klamath Basin that will provide the information necessary to sustain an adaptive management strategy for the watershed stewardship framework.

UKB WAP adaptive management

The UKB WAP outlines the future stewardship actions prompted by the water quality status identified by the assessment of current conditions. The UKB WAP includes partner program monitoring and restoration organizations' efforts toward ecosystem rehabilitation in the Upper Klamath Basin. The

Upper Klamath Basin Watershed Action Plan will employ adaptive management principles; therefore, refinements will be continuous (Figure 1-1).

The adaptive management framework is a six-step process:

1. Build Partnerships and Define Goals – Several monitoring organizations collect water quality data in the Upper Klamath Basin. Partnerships are key to generating a collaborative monitoring framework guided by a common set of monitoring goals and objectives.
2. Characterize River Watershed – Through the collaborative monitoring framework, a holistic understanding of water quality conditions in Upper Klamath Basin can be generated.
3. Identify Problems and Develop Solutions – Sources of water quality impairment can be identified based on the status and trend results from the collaborative monitoring framework. Funds from participating organizations can be leveraged to common priorities.
4. Implement Solutions – Non-regulatory and direct actions may be taken to address the sources of impairment.
5. Measure and Evaluate Progress – Metrics for measuring progress are described within Chapter 5 of the Upper Klamath Basin Watershed Action Plan.
6. Make Adjustments – Following the progress assessment and the direct actions, the various approaches may be evaluated and refined to better address the sources of water quality impairment. Steps 3 through 6 will be repeated until there is forward progress toward ecosystem rehabilitation.

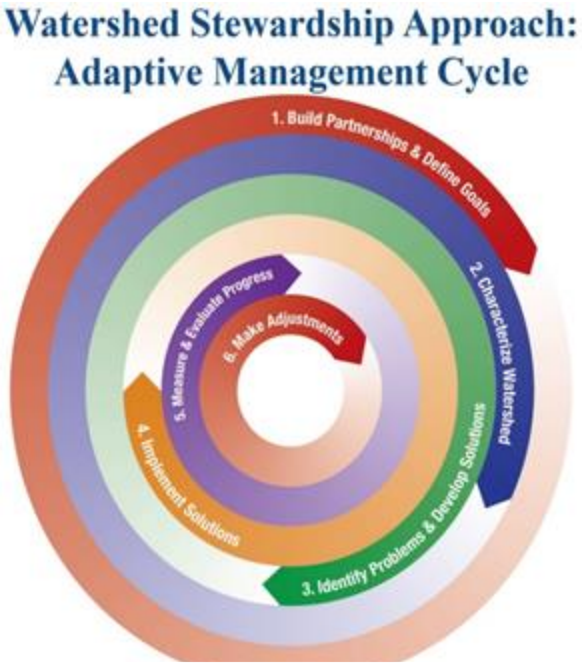


FIGURE 1-1: VISUALIZATION OF THE ADAPTIVE MANAGEMENT FRAMEWORK

The adaptive management cycle is maintained through the collaborative effort of program partner organizations. If desired progress update reports developed collaboratively by the UKB WAP Team can be published to the Klamath Basin Monitoring Program (KBMP) Stewardship website for greater public access. Established in 2007, KBMP includes over forty organizations who voluntarily coordinate and implement water quality monitoring for the stewardship, protection, and restoration of all beneficial uses within the Klamath River Basin.

The Upper Klamath Basin Watershed Action Plan is not the final product of this stewardship approach process. Rather, the document will be updated and amended over time with further input and communication from Upper Klamath Basin stakeholders. The UKB WAP is the first version based on available information and the plan will be formally updated as appropriate.

Chapter 2 UPPER KLAMATH BASIN HISTORICAL AND GEOGRAPHICAL CONTEXT

LOCATION

The Upper Klamath Basin (UKB) as defined for the Watershed Action Plan is comprised of the Sprague River, Williamson River and Wood River Valley watersheds, as shown in Figure 2-1.

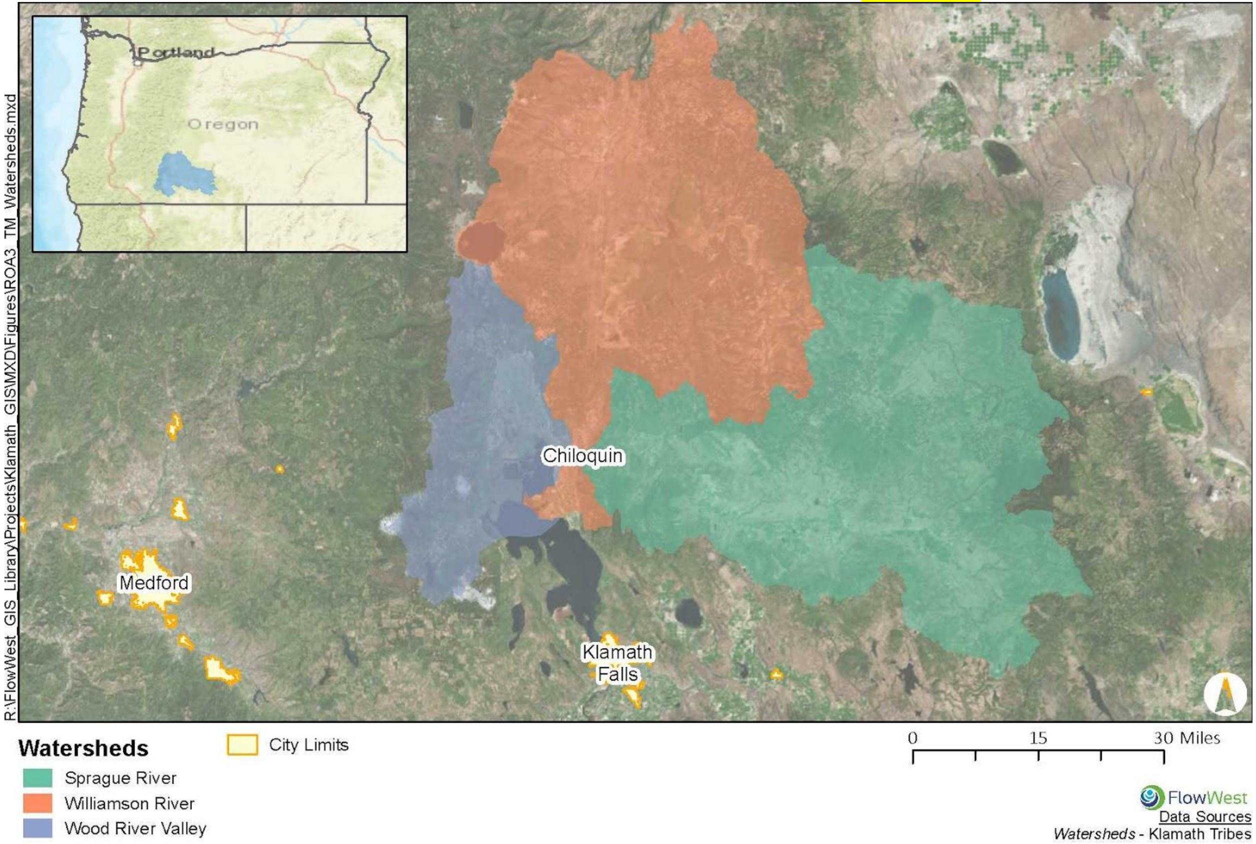


FIGURE 2-1: THE UPPER KLAMATH BASIN STUDY AREA

ECOLOGICAL HISTORY

Climate

Upper Klamath Basin has a Mediterranean climate with warm, dry summers where most precipitation falls as rain and snow in the winter months (Kottek et al., 2006). Annual precipitation varies largely over the area from 8 to 36 inches a year (PRISM Climate Group, 2015). Mountainous areas around Crater Lake, Mount Thielsen, Yamsay Mountain and Gearhart Mountain have a continental climate, with winter snow and dry, mostly warm summers (Kottek et al., 2006).

Hydrology

The Upper Klamath Basin is a semiarid region and consists of three watersheds: the Williamson River, Sprague River, and Wood River (see Figure 2-1). The Williamson River receives its water from the Modoc Plateau (USBR, 2011). Flows generally peak in April, with yearly average flow around 1,014 cubic feet per second (cfs) (see Figure 2-2). Near the town of Chiloquin, OR, the Williamson is met by its largest tributary, the Sprague River. The Sprague is mostly fed by springtime snowmelt and summer rainstorms (Connelly & Lyons, 2007). Just like the Williamson river, it usually peaks in April and it has a yearly average flow of 569 cfs (see Figure 2-3). The Wood River is the smallest of the three rivers. It is fed by spring water, precipitation runoff and agricultural runoff (USBR, 2011). The Wood flows out into Agency Lake, which is connected to Upper Klamath Lake in the south. It has a yearly average discharge of 377 cfs and the flow is fairly constant throughout the year because the river is mostly groundwater fed (see Figure 2-4) (Gannett, Lite, La Marche, Fisher, & Polette, 2007).

The US Geological Survey prepared an extensive report about the groundwater hydrology of Upper Klamath (Gannett et al., 2007): The geology of Upper Klamath is dominated by Late Tertiary and Quaternary volcanic rocks, sedimentary rocks and deposits. These vary in permeability, creating aquifers (mostly volcanic rocks and air-fall deposits) and aquitards (mostly sedimentary rocks and other deposits). Groundwater recharge takes place from precipitation in the Cascade Range and along the eastern edge of the basin. Discharge takes place through large natural springs that flow into Wood River and into Williamson River near Yamsay Mountain and the confluence with Sprague River. The groundwater table fluctuates 0 to 10 feet due to a decadal climate cycle and is further influenced by pumpage for irrigation, especially in the last years due to drought and changes in surface water management.

Agriculture and water management substantially influence the hydrology of the Upper Klamath Basin. The Upper Klamath Basin originally contained a substantial amount of floodplain areas. Nowadays these areas have been largely reduced for agricultural use and by flood protection infrastructure, but there are still floodplains surrounding Upper Klamath Lake and Agency Lake (Snyder & Morace, 1997). The dynamics of floodplain inundation are complex and can influence the hydrology of the watershed (Yamazaki et al., 2011). Next to this, surface water extraction takes place, which can also have an influence on the hydrology depending on the volume that is being extracted.

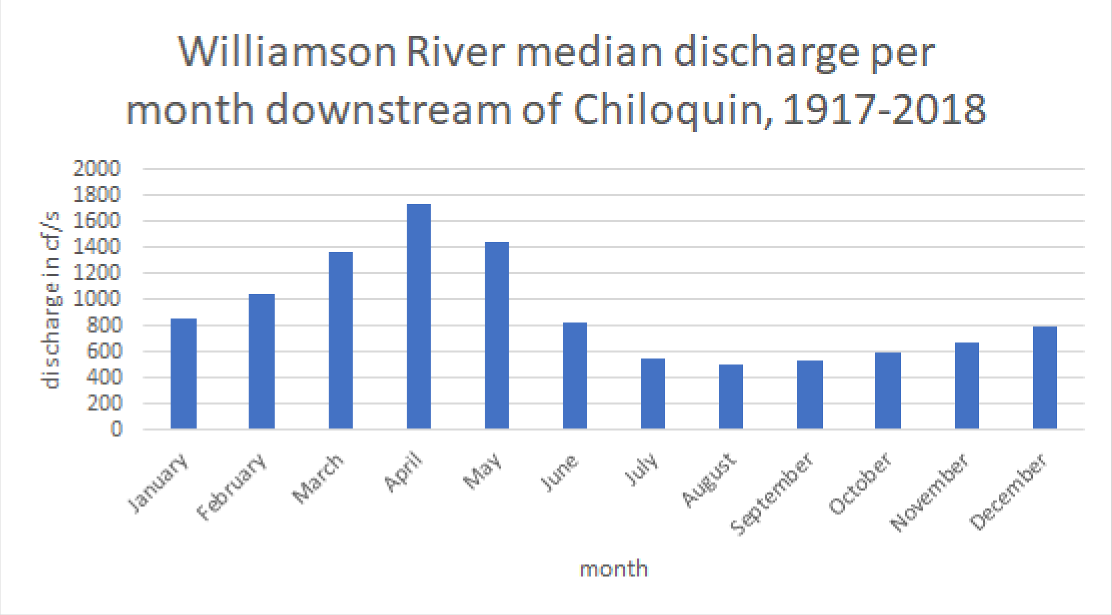


FIGURE 2-2: MEDIAN DISCHARGE OF THE WILLIAMSON RIVER. BASED ON USGS (2019).

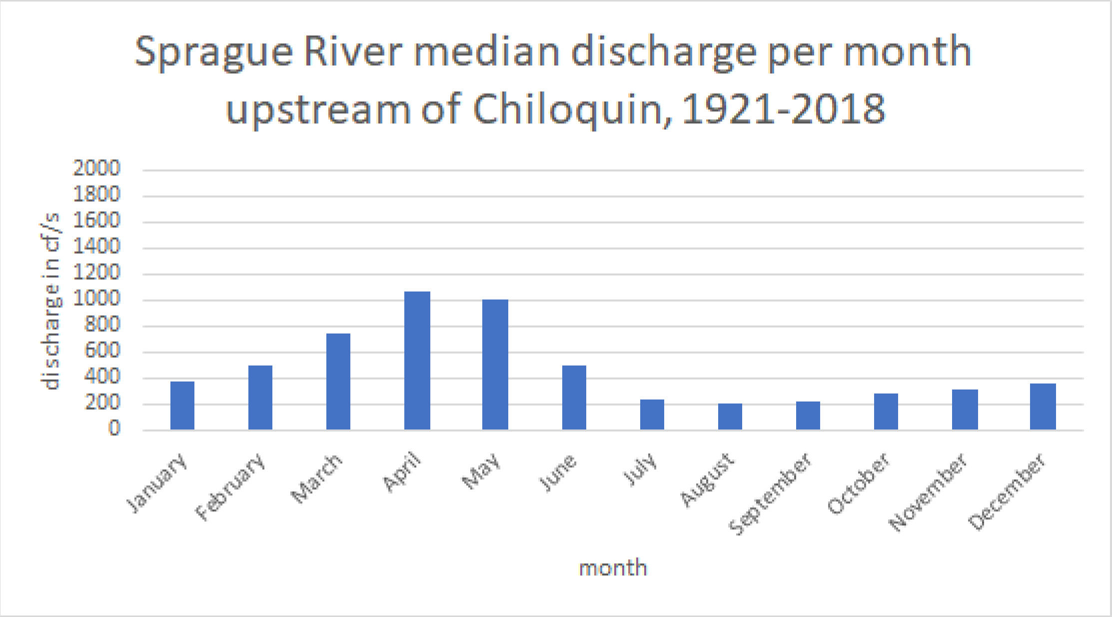


FIGURE 2-3: MEDIAN DISCHARGE OF THE SPRAGUE RIVER. BASED ON USGS (2019).

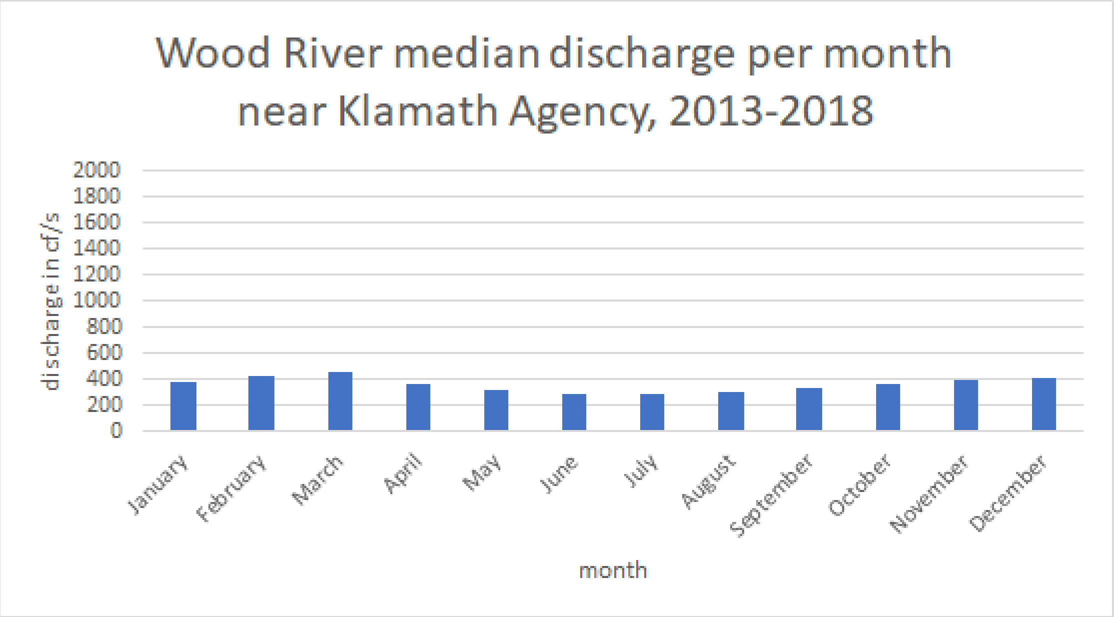


FIGURE 2-4: FIGURE 2.4: MEDIAN DISCHARGE OF THE WOOD RIVER. BASED ON USGS (2019).

Geomorphology

Williamson River Basin

The Williamson River Basin lies in a wide, lowland area bordered in the east and the west by large volcanic peaks, as described by Conaway (2000). The Williamson River itself originates from several groundwater springs in the east of the basin and then flows into Klamath Marsh, a 150,000-acre wetland. The elevation of this wetland used to be higher, but it subsided when the Kirk Sill barrier was broken (presumably around 1900) and the marshland drained (Conaway, 2000). The marsh is neighbored in the south by a 5-mile canyon, approximately 300 feet deep, which was likely formed during the Pleistocene, when flows were greater (Conaway, 2000). The Basin flows out through Williamson River Delta and into Upper Klamath Lake. The river delta, originally a marshland area, was drained for agricultural uses in the first half of the 20th century but has since been largely restored (Crandall et al., 2008).

Sprague River Basin

In the headwater regions of the Sprague River Basin, the landscape features confined valleys with steep slopes and low sinuosity, whereas the valleys of the basin are characterized by braided channels with higher sinuosity and lower gradients (NewFields River Basin Services & Kondolf, 2012). The multiform channels in the Sprague River Basin valleys avulse and reoccupy former channel pathways at longer-term, geomorphic scales, rather than being primarily influenced by larger flood events (NewFields River Basin Services & Kondolf, 2012). Despite anthropogenic modifications to the system, geomorphic processes that impact channel and floodplain form continue to operate at the basin-scale, and therefore historical channel and floodplain conditions are appropriate to use as a reference for restoration project evaluation (O'Connor et al., 2015).

Wood River Basin

The Wood River flows through a broad flat valley (Wood River valley). Historically, the river was surrounded by marshland; 79% of which is now converted to agricultural land (ONRCS, 2010). The Wood River Basin is characterized by a low gradient and many connections between streams and marshland areas (ONRCS, 2010). Riparian vegetation is crucial to maintain the morphology of the soft riverbanks and the river as a whole. Historically, livestock grazing removed vegetation on the riverbanks, leading to erosion and channel-widening, and filling the channel up with sediment. However, recent successful restoration initiatives have been undertaken in collaboration with farmers to improve channel morphology in the basin (ONRCS, 2010).

Water quality

Upper Klamath Lake is located in a valley adjacent to the eastern slopes of the Cascade Range in south-central Oregon. The shallow lake has a mean summer depth of about 8 feet and a maximum depth of about 58 feet (U.S. Army Corp of Engineers, 1979, 1982 cited in ODEQ 2002). A massive eruption from Mount Mazama at the northern end of Upper Klamath Lake occurred about 6,900 years ago. During the eruption, Mount Mazama collapsed forming Crater Lake and generated pumice and ash deposits over much of the Upper Klamath Lake Drainage (ODEQ 2002) that are naturally rich in phosphorus. Link River Dam, which was constructed in 1919, regulates the water surface elevation of Upper Klamath Lake.

Upper Klamath Lake is hypereutrophic, with low dissolved oxygen and pH water quality violations that led to the 1998 303(d) listing. Low dissolved oxygen and high pH levels have been linked to high algal productivity in Upper Klamath Lake (Kann and Walker, 2001 and Walker 2001 cited in ODEQ 2002). High algal productivity also occurs when Oregon's water quality standards for pH, dissolved oxygen and free ammonia are exceeded. Upper Klamath Lake has been designated as water quality limited for resident fish and aquatic life (ODEQ 303(d) List 1998) based on monitored levels of dissolved oxygen, pH and chlorophyll-a (ODEQ 2002).

Water quality conditions in Upper Klamath Lake have changed over the past 100 years when Upper Klamath Lake was considered eutrophic. Land use changes that contributed to the degradation of the water quality in the lake include the loss of wetlands, increases in upland water yields, extensive diking and draining of seasonal wetland/marsh areas, water diversions from tributaries entering the lake, diversion of water out of the lake, and construction of the Link River Dam in 1921. 35,000 acres of wetlands adjacent to Upper Klamath Lake have been converted to pasture and agriculture (Gearheart et al. 1995; Risley and Laenen 1999 cited in ODEQ 2002). These land use changes have resulted in alteration of the timing and quantity of the lake flushing flows and nutrient retention dynamics. Additionally, Upper Klamath Lake surface elevation and volume are seasonally reduced below historic levels (ODEQ 2002).

The Upper Klamath Lake TMDL uses total phosphorus as a controlling parameter for adverse pH and dissolved oxygen levels in Upper Klamath Lake. Sources of phosphorus are generated within Upper Klamath Lake (internal) and from the Upper Klamath Lake watershed (external). Phosphorus from the lake sediments produces roughly two thirds of the yearly average total phosphorus load. External sources account for the remaining one third of the phosphorus load in Upper Klamath Lake. Sources of external phosphorus include near lake reclaimed wetlands, upland erosion, increased water yields, riparian/wetland disturbance and springs (ODEQ 2002). Monitoring of pastures during first-flush irrigation events and storm events has shown the potential to export large quantities of phosphorus from irrigated grazing land in the UKB (Ciotti et al., 2010 cited in Walker et al. 2012). Excessive algal production is typically associated with water quality standard violations and extensive blooms of the cyanobacterium Aphanizomenon flos-aquae (AFA) results in water quality deterioration from photosynthetically elevated pH (Kann and Smith1993 cited in ODEQ 2002) and supersaturated and low dissolved oxygen (DO) concentrations (Kann 1993a,1993b cited in ODEQ 2002). These water quality impacts reduce native fish survival and viability during periods of both high pH and low DO.

Historic salmon and sucker populations

The prominence of salmon migration in the Klamath Tribes culture and oral traditions indicate the species historical presence in the basin. According to historical accounts from European-Americans in the mid-19th century, anecdotal estimates of salmon runs vary from the thousands to millions (Hamilton et al., 2016). Historical observations of salmon runs in the UKB prior to 1912 (when upstream migration was prevented through the installation of Copco 1 Dam) were seasonally diverse and reported salmon at different life stages (Hamilton et al., 2016). The abundance of salmon in the UKB was adequate to support tribal community needs as well as recreational fishing and commercial fisheries until fish passage was blocked by dams (Hamilton et al., 2016).

Lost River and shortnose suckers are also a significant species for the Klamath Tribes, both culturally and as a food source, and historical accounts estimate tribal harvests of these species in the tens of thousands (NCRWQCB, 2008). As discussed in the “Water quality” section above, these species may have been impacted by many factors in the UKB including: degraded water quality conditions, reduced spawning habitat, competition with introduced fish species, reduction in wetland habitat, changes in lake levels from historical conditions, and fish disease. Current factors attributed to limiting sucker recovery include high mortality of larvae and juveniles due to reduced rearing habitat, entrainment in water management structures, poor water quality and negative interactions with introduced species (USFWS 2012) Severe declines in these species, more than 50% for Lost River suckers and more than 75% for shortnose suckers between 2001 and 2016 (Hewitt et al. 2017), also stem from loss of historic habitat range, which is estimated to be approximately 75% (USFWS, 2012).

LAND USE AND IMPACTS

The people of the Klamath Tribes: the Klamaths, the Modocs and the Yahooskin, have lived in the UKB for thousands of years, and relied on fishing primarily for sustenance (Hamilton et al., 2016). Fur traders began accessing tribal lands in 1826, and through the middle of the 19th century European-American immigration grew (Klamath Tribes, 2019). Hydraulic mining was prevalent starting in 1850 until it was outlawed in 1884, which severely impacted anadromous fish habitat (Hamilton et al., 2016). Livestock-raising was one of the earliest and most widespread industries in the UKB, and overgrazing was an issue in the basin as early as 1907 (KBEF & KBREC, 2007). Once the first railroad was built in 1909, the logging industry boomed (KBEF & KBREC, 2007). The landscape was altered significantly in the latter part of the 19th and early 20th century as transportation, flood protection, and irrigation infrastructure was implemented throughout the basin. One of the most significant impacts on the ecosystem, as well as on the traditional tribal harvest of native fish species, was the installation of several dams on the Klamath River downstream from the UKB in California: Copco 1 Dam (1912), Copco 2 Dam (1925) and Iron Gate Dam (1962), which prevented salmonid migration upstream (Hamilton et al., 2016).

Loss of fringe wetlands

Prior to 1889, Upper Klamath Lake was bordered by wetland marshes, which served important ecological functions. The marshes acted as a buffer to activities further upstream in the tributaries and trapped and filtered incoming water and sediment moving into the lake. As of 2004, 64% of lake-fringe wetlands had been drained (Bradbury et al., 2004). Wetlands were drained to support agricultural activities in the UKB (Snyder & Morace, 1997). The loss of wetlands buffering the lake in conjunction with channelization in upstream tributaries, resulted in more direct pathways for nutrients and sediment to reach the Lake, thereby greatly impacting lake water quality. The Upper Klamath Lake has become increasingly eutrophic, as discussed in the previous Water Quality section. Impaired water quality in the lake has led to fish-kills, including of endemic and federally endangered species Lost River and shortnose suckers (Perkins et al., 2000). These species are culturally significant and a traditional food source for the Klamath Tribes.

External nutrient loading

Nutrient loading in the UKB impacts water quality in the river ecosystems, Upper Klamath Lake, as well as further downstream via the Klamath River. The reduction of nutrient loading to the lake was identified as a priority for improving water quality and habitability for endemic fish species--in particular phosphorus reduction is of critical importance because it promotes Aphanizomenon and microcystin algal blooms. Phosphorus sources to the lake include external contributions (39%), as well as internal sources from lake sediments (61%) (ODEQ, 2002). External loading sources include nutrients delivered via tributaries (7-mile Canal, Wood River, and the Williamson River), precipitation, agricultural pumping, springs, and ungauged tributaries (Kann & Walker, 2001). The Upper Klamath Lake total maximum daily load (TMDL) calls for a 40% reduction in external phosphorus loading to achieve water quality targets for the lake (Boyd et al., 2002).

CURRENT SETTING

European-American development in the UKB, supported by state and federal governments, led to water availability constraints for various users and ecosystem requirements. The Klamath Project, initiated in the 1905 by the United States Bureau of Reclamation, drew farmers and ranchers to the region with the promise of irrigation for agricultural production (Gosnell & Clover Kelly, 2010). European-American immigrants claimed water rights in the UKB under the state prior appropriation doctrine, however the Klamath Tribes’ water rights are senior to all appropriative rights. Tribal instream rights include claims for physical and riparian habitat flows (OWRD 2013). In addition to water rights, the Klamath Tribes maintain several treaty rights within the former reservation boundary, including fishing, hunting, gathering, and trapping.

Conflict over water supply for endangered species, agriculture, commercial fishing, tribal uses, local communities, and hydroelectric power generation has persisted in the UKB throughout the 20th century and into the 21st.Recent federal efforts to address water supply challenges include support for water conservation infrastructure (the 2002 Farm Bill), incentivizing crop-idling (2002, 2004), promoting groundwater supplementation, and other financial assistance for farmers and commercial fisheries (Gosnell & Clover Kelly, 2010). Climate change impacts further stress water availability in the UKB, as warmer winter temperatures and snowpack reductions alter the timing of snowmelt runoff flows and reduce groundwater recharge (Mayer & Naman, 2011). The plan to decommission four hydroelectric dams: J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate, is intended to restore fish passage in the Klamath River, create a free-flowing river through the reach, and improve access to cold, spring-fed water in upstream reaches for species (ESSA, 2017; KRRC, 2018). This action will provide opportunity for improved riverine conditions and fish recovery, and hopefully reduce pressures on competing water supply interests.

The removal of four dams on the Klamath River in the Lower Klamath Basin is a major and promising restoration action, which could benefit fish populations in the Upper Klamath Basin as well. Restoration activities have been on-going in the Klamath Basin for many years; fisheries restoration efforts date back to the early 1900s and included hatcheries, water quality, and flow monitoring (Leitritz, 1970; Royer & Stubblefield, 2016). Early restoration efforts were often more site-specific and limited by developing understandings of ecosystem functions and interdependence. Restoration activity types in more recent years include: fish passage improvement, fish screening, hatchery and rearing reintroduction, instream flow restoration, instream habitat restoration, riparian habitat restoration, upland habitat and sediment management, water quality restoration, and wetland restoration (ESSA, 2017). Monitoring of restoration activities is essential for evaluating action impacts, tracking anticipated benefits, refining the science of restoration planning and implementation, and building support and buy-in for additional restoration activities. Monitoring typically consists of status and trends monitoring to track changes in habitat, stressors, species population, etc., and project effectiveness monitoring, which evaluates how well projects meet the anticipated goals (ESSA, 2017). Trends in restoration activities show peaks associated responses to ecological crises, important scientific findings in the basin, and significant infrastructure agreements, such as listings under the Endangered Species Act (ESA), biological opinions, fish kills, and milestones in infrastructural planning efforts (e.g. PacifiCorp Dams, Klamath Project) (ESSA, 2017). Restoration projects have been implemented by a broad range of entities, including public agencies, the Klamath Tribes, non-governmental organizations (NGOs), academic institutions, and private landowners (ESSA, 2017). There is a need for a more integrated approach to restoration planning and implementation across the UKB, given the diversity of entities and types of efforts that are required.

REFERENCES

Boyd, M., Kirk, S., Wiltsey, M., & Kasper, B. (2002). *Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP)*. Retrieved from State of Oregon Department of Environmental Quality website: https://www.oregon.gov/deq/FilterDocs/UKtmdlwqmp.pdf

Bradbury, J.P., Colman, S.M., & Reynolds, R.L. (2004). The history of recent limnological changes and human impact on Upper Klamath Lake, Oregon. *Journal of Paleolimnology 31*: 151–165.

Ciotti, D., & Griffith, S. M. (2010). Nutrient and Sediment Transport on Flood-Irrigated Pasture in the Klamath Basin, Oregon. *Rangeland Ecology & Management*, *63*(3), 308–316. https://doi.org/10.2111/08-127.1

Committee on Hydrology, Ecology and Fishes of the Klamath River, National Research Council. (2008). *Hydrology, ecology, and fishes of the Klamath River Basin*. Washington, DC: The National Academies Press.

Conaway, J. S. (2000). *Hydrogeology and paleohydrology in the Williamson River Basin, Klamath county, Oregon* (Master of Science thesis, Portland State University). Retrieved from http://web.pdx.edu/~i1kc/geolinq/thesis/texts/142-Conaway-1999.pdf

Connelly, M., & Lyons, L. (2007). *Upper Sprague Watershed Assessment*. Retrieved from Klamath Basin Ecosystem Foundation website: https://nrimp.dfw.state.or.us/web%20stores/data%20libraries/files/OWEB/OWEB_916_2_Upper%20Sprague%20WS%20Assessment.pdf

Crandall, J. D., Bach, L. B., Rudd, N., Stern, M., & Barry, M. (2008). Response of larval Lost River and Shortnose Suckers to wetland restoration at the Williamson River Delta, Oregon. *Transactions of the American Fisheries Society*, *137*(2), 402–416. https://doi.org/10.1577/T06-196.1

Eilers J.M., Kann, J., Cornett J., Moser K., & St. Amand, A. (2004). Paleolimnological evidence of change in a shallow, hypereutrophic lake: Upper Klamath Lake, Oregon, USA. *Hydrobiologia 520*: 7–18.

ESSA, (2017). *Klamath Basin integrated fisheries restoration and monitoring (IFRM) synthesis report*. 416 pp + Appendices. Retrieved from http://kbifrm.psmfc.org/wp-content/uploads/2017/05/Klamath_Synthesis_Report_20170814_FINAL.pdf

Gannett, M. W., Lite, K. E. J., La Marche, J. L., Fisher, B. J., & Polette, D. J. (2007). *Ground-water hydrology of the Upper Klamath Basin, Oregon and California* (No. 2007–5050; p. 98). Reston, Virginia: US Geological Survey with Oregon Water Resources Department.

Gosnell, H., & Clover Kelly, E. (2010). Peace on the river? social-ecological restoration and large dam removal in the Klamath Basin, USA. *Water Alternatives 3(2):* 361-383. Retrieved from http://www.water-alternatives.org/index.php/allabs/98-a3-2-21/file

Hamilton, J.B., Rondorf, D.W., Tinniswood, W.R., Leary, R.J., Mayer, T., Gavette, C., & Casal, L.A. (2016). The persistence and characteristics of Chinook salmon migrations to the upper Klamath river prior to exclusion by dams. *Oregon Historical Quarterly, 117 (3)*, pp. 326-377. Retrieved from:

https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=3443&context=wild_facpub

Hewitt, D.A., Janney, E.C., Hayes, B.S., & Harris, A.C. (2015). *Status and trends of adult Lost River (Deltistes luxatus) and shortnose (Chasmistes brevirostris) sucker populations in Upper Klamath Lake, Oregon, 2017: U.S. Geological Survey Open-File Report 2018–1064*, 40. Retrieved from https://pubs.usgs.gov/of/2018/1064/ofr20181064.pdf

Kann, J. & Walker, W (2001). Nutrient and hydrologic loading to Upper Klamath Lake, Oregon 1991-1998. Prepared for the Bureau of Reclamation, Klamath Falls, Oregon

KBEF (Klamath Basin Ecosystem Foundation), & KBREC (Oregon State University Klamath Basin Research and Extension Center) (2007). *Upper Sprague Watershed Assessment*. Retrieved from https://nrimp.dfw.state.or.us/web%20stores/data%20libraries/files/OWEB/OWEB_916_2_Upper%20Sprague%20WS%20Assessment.pdf

KRRC (Klamath River Renewal Corporation) (June 2018). *Definite plan for the Lower Klamath Project*. Retrieved from http://www.klamathrenewal.org/wp-content/uploads/2018/06/LKP-FERC-Definite-Plan.pdf

Klamath Tribes (2019). *Klamath Tribes history.* Retrieved from http://klamathtribes.org/history/.

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift*, *15*(3), 259–263. https://doi.org/10.1127/0941-2948/2006/0130

Leitritz, E. (1970). *A history of California's fish hatcheries: 1870 – 1960. California Department of Fish and Wildlife, Inland Fisheries Branch. Fish Bulletin 150*. 82 pp. Retrieved from http://www.oac.cdlib.org/view?docId=kt5k4004bd&brand=oac4&doc.view=entire_text

Mayer, T.D., & Naman, S.W. (2011). Streamflow response to climate as influenced by geology and elevation. Journal of the American Water Resources Association (JAWRA) 1-15. DOI: 10.1111/j.1752-1688.

NewFields River Basin Services, Kondolf, G.M. (2012). Evaluating Stream Restoration Projects in the Sprague River Basin. Prepared for: Klamath Watershed Partnership, in conjunction with the Klamath Tribes, U.S. Fish and Wildlife Service, Klamath Basin Rangeland Trust, Sustainable Northwest, and The Nature Conservancy. Retrieved from: https://docs.wixstatic.com/ugd/2f25ac_86db6dc9ea7c4bdc88d0d4fa00ba1fc9.pdf

NCRWQCB (North Coast Region Water Quality Control Board) (2008). *Appendix 5: Fish and fishery resources of the Klamath River Basin. In 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*. State of California, North Coast Regional Water Quality Control Board. Santa Rosa, California. Retrieved from https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/100927/staff_report/17_Appendix5_FishandFishery_Resources.pdf

O'Connor, J.E., McDowell, P.F., Lind, Pollyanna, Rasmussen, C.G., & Keith, M.K. (2015). *Geomorphology and floodplain vegetation of the Sprague and lower Sycan Rivers, Klamath Basin, Oregon (U.S. Geological Survey Scientific Investigations Report 2014–5223)*. DOI: http://dx.doi.org/10.3133/sir20145223.

ODEQ (Oregon Department of Environmental Quality) (2002). *Upper Klamath Lake drainage total maximum daily load (TMDL) and water quality management plan (WQMP)*. Retrieved from https://www.oregon.gov/deq/FilterDocs/UKtmdlwqmp.pdf

ONRCS (Oregon Natural Resources Conservation Service) (2010, April). Wood River, Upper Klamath Basin, Oregon conservation effects assessment project - special emphasis watershed - final report. Retrieved April 8, 2019, from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd334614.pdf

OWRD (Oregon Water Resources Department) (2013, March). Adjudicator's Findings of Fact and Final Order of Determination. Klamath County Circuit Court. March 7, 2013. https://www.courts.oregon.gov/courts/klamath/resources/Pages/KlamathBasinAdjudication.aspx

Perkins, D., Kann, J., & Scoppettone, G.G. (2000). *The role of poor water quality and fish kills in the decline of endangered Lost River and shortnose suckers in Upper Klamath Lake*. U.S. Geological Survey Biological Resources Division Report Submitted to U.S. Bureau of Reclamation, Klamath Falls Project Office, Klamath Falls, OR, 97603 -- Contract 4-AA-29-12160. Retrieved from https://www.researchgate.net/profile/Jacob_Kann/publication/253727176_The_Role_of_Poor_Water_Quality_and_Fish_Kills_in_the_Decline_of_Endangered_Lost_River_and_Shortnose_Suckers_in_Upper_Klamath_Lake/links/5604157e08aeb5718feedc27/The-Role-of-Poor-Water-Quality-and-Fish-Kills-in-the-Decline-of-Endangered-Lost-River-and-Shortnose-Suckers-in-Upper-Klamath-Lake.pdf

PRISM Climate Group, Oregon State University (2015). *30-yr normal precipitation: Annual - Period: 1981-2010*. Retrieved from http://www.prism.oregonstate.edu/normals/

Royer, C. F., & Stubblefield, A. P. (2016). *Klamath Basin water quality monitoring plan. Klamath Basin Monitoring Program*. pp.1–207. Retrieved from http://www.kbmp.net/images/stories/pdf/KBMP_Monitoring_Plan_2016_Update.pdf

Synder, D.T., & Morace, J.L. (1997). *Nitrogen and phosphorus loading from drained wetlands adjacent to Upper Klamath and Agency lakes, Oregon. Water-Resources Investigations Report 97-4059*. Prepared in cooperation with the Bureau of Reclamation. Retrieved from https://pubs.er.usgs.gov/publication/wri974059

USBR (US Bureau of Reclamation) (2011). *Hydrology, Hydraulics, and Sediment Transport Studies for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration* (No. SRH-2011-02; p. 762). U.S. Department of the Interior, Bureau of Reclamation.

USBR (US Bureau of Reclamation) (2018). *2018 Annual Operations Plan - Klamath Project, Oregon-California, Mid-Pacific Region* (p. 9). Retrieved from U.S. Department of the interior, Bureau of Reclamation, Mid-Pacific Region website: https://www.usbr.gov/mp/kbao/programs/docs/2018-klamath-project-ops-plan.pdf

USGS (US Geological Survey) (2019). USGS Surface Water data for USA: USGS Surface-Water Monthly Statistics. Retrieved April 3, 2019, from USGS Surface-Water Monthly Statistics for the Nation website: https://waterdata.usgs.gov/nwis/monthly?referred_module=sw

USFWS (U.S. Fish and Wildlife Service) (2012). Revised recovery plan for the Lost River sucker (Deltistes luxatus) and shortnose sucker (Chasmistes brevirostris). U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, California. xviii + 122 pp

Walker, J. D., Kann, J., & Walker, W. W. (2015). Spatial and temporal nutrient loading dynamics in the Sprague River Basin, Oregon. Prepared by Aquatic Ecosystem Sciences, J. D. Walker, and W. W. Walker for the Klamath Tribes Natural Resources Department. 73p. + appendices. Retrieved from https://s3.amazonaws.com/walkerenvres.com/reports/klamath/2015-sprague-nutrient-dynamics/Sprague_River_Nutrient_Dynamics_20151229_final.pdf

Walker, W.W., Walker, J.D., Kann, J. (2012). *Evaluation of Water and Nutrient Balances for the Upper Klamath Lake Basin in Water Years 1992-2010.* Technical Report to the Klamath Tribes Natural Resources Department, Chiloquin, OR.

Chapter 3 CONCEPTUAL BASIS FOR THE UKB WAP

INTRODUCTION

The initial conceptual models used to guide the Upper Klamath Basin Watershed Action Plan (UKB WAP) were originally developed in the Adaptive Aquatic Restoration Guide (AARG), a guide for stream restoration planning, design, monitoring, and adaptive management for restoration practitioners in the Upper Klamath Basin (UKB) (FlowWest, 2017). The conceptual models reflect the best available information on physical and biological processes and linkages in the basin and provide an adaptive basis from which to plan, design, and monitor restoration projects in the basin. The conceptual models provided the guiding logic for the Restoration Opportunities Analysis (ROA)—also completed by FlowWest for the Klamath Tribes; the ROA study resulted in several datasets used in the UKB WAP Restoration Prioritization Framework (RPF). The UKB WAP Team revised and significantly enhanced the initial AARG versions of the conceptual models during the UKB WAP development process. The UKB WAP Team developed additional conceptual models to increase the understanding of the physical and biological linkages and processes in the UKB.

The conceptual models are intended to improve understanding of the critical processes and linkages responsible for current ecosystem conditions and potential restored conditions. Existing conditions models depict how processes/functions are affected by specific anthropogenic activities or impairments resulting from multiple anthropogenic activities. Modified condition models depict how processes/functions change from existing conditions models after specific restoration activities are implemented. The UKB WAP Team developed the following conceptual models for the UKB:

- Channel incision
- Channelization
- Tailwater returns
- Water Withdrawals
- Fish Screens
- Construction of levees and berms
- Large Woody Debris
- Wetland Conversion
- Fish Passage barriers
- Riparian grazing
- Roads
- Spawning gravel
- Springs

The following sections provide an overview of the critical physical and biological processes and linkages in the UKB. The first paragraph of each section gives a general description of these processes and linkages with references to relevant literature. The second paragraph gives a summary of the conceptual model of existing conditions, which is the UKB WAP Team's understanding of the physical and biological processes and linkages under the current conditions. The third paragraph summarizes the conceptual model of restoration actions, which is the UKB WAP Team's understanding of the physical and biological processes and linkages under a restored condition. For a more thorough understanding of each conceptual model, see the conceptual model diagrams in the accompanying figures. The models are intended to be read from left to right, starting with the anthropogenic activity that causes change in the ecosystem, followed by the direct and indirect results, the ecological responses to the activity, and finally the linkages to the UKB goals and UKB WAP objectives.

CHANNEL INCISION

Understanding of UKB processes

Channel incision is streambed lowering that leads to an imbalance in flow energy and sediment load in a stream. After incision, the stream can convey larger flows via the deepened channel and energy is not released as water spills out of the channel over the floodplain; this increase in stream power can convey more sediment downstream and results in the channel continuing to incise (Simon & Rinaldi, 2006). There are several causes of channel incision in the UKB. Channelization, or channel straightening, leads to channel incision. Unmanaged livestock access to stream channels can destabilize the channel bed through hoof compaction, direct shearing, or trampling of vegetation (FlowWest 2017). Levees block overflow onto the floodplain, which raises the stream stage and thereby increases shear stress along the bed of the channel. The increase in shear stress along the channel bed leads to incision.

Conceptual model of existing conditions

The direct results of channel incision are a decreased connection between floodplain and river and decreased periods or complete lack of floodplain inundation. The channel incision impacts to the floodplain and river-floodplain connection impair the watershed indirectly in terms of floodplain condition and process, riverine process and function, native fish needs, and algal and bacterial response. For instance, indirect results of channel incision include decreased groundwater elevation, recharge, and contribution to baseflow, increased algal productivity, and changes in the plant community. The ecosystem responds to channel incision impairments through changes in hydrology and geomorphology, poor water quality, and decreased native fish habitat quality and quantity.

Conceptual model of restoration actions

Actions that address channel incision include beaver reintroduction, beaver dam analogs, and/or other actions that will aggrade the channel. Restored conditions anticipated from the implementation of these practices are rooted in the increased floodplain-river connection, in which the duration and frequency of floodplain inundation is increased. Other activities that can address incision are levee removal and channel re-meandering, which are both discussed in following sections.

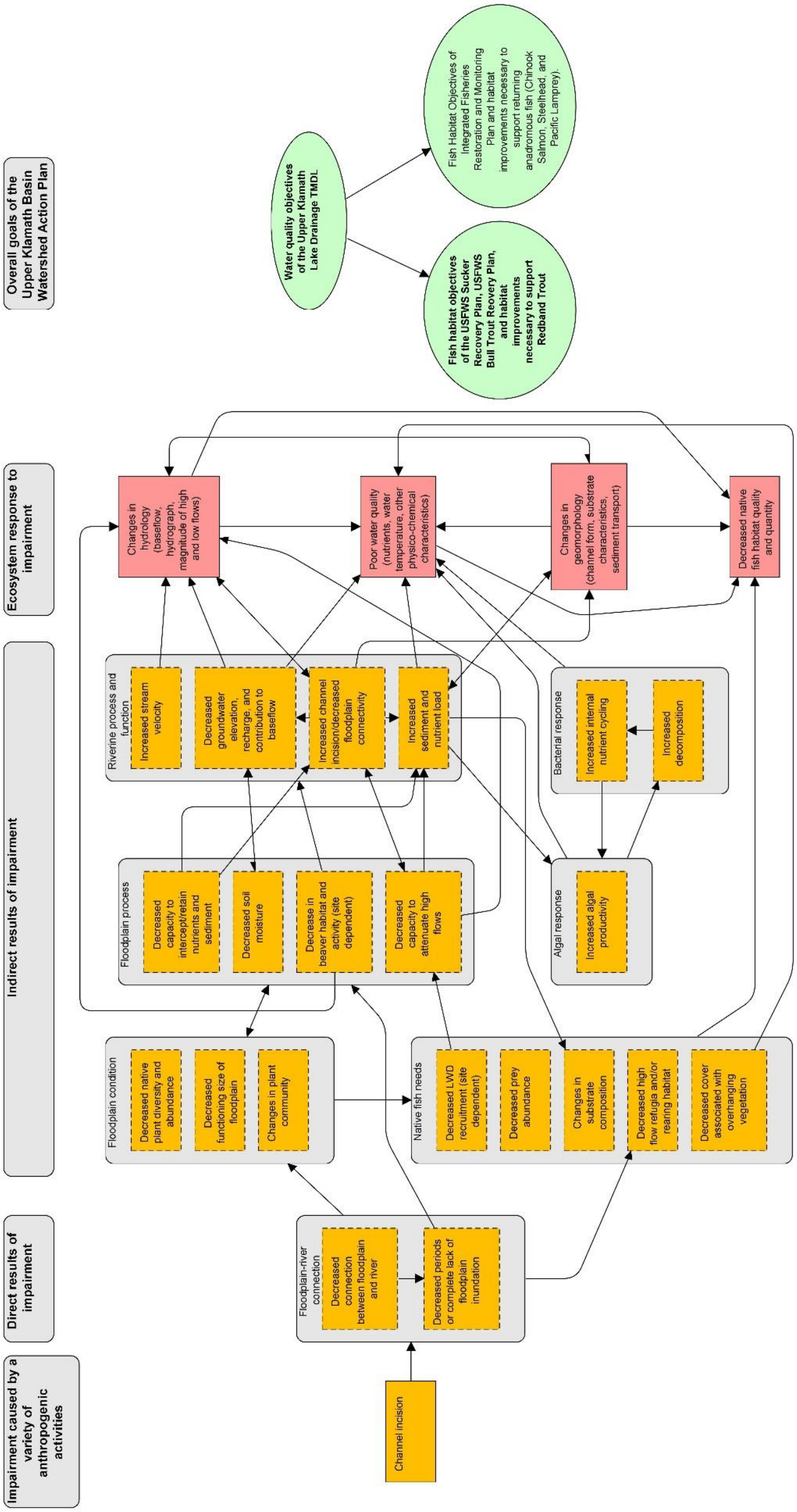


FIGURE 3-1: CHANNEL INCISION CONCEPTUAL MODEL OF EXISTING CONDITIONS

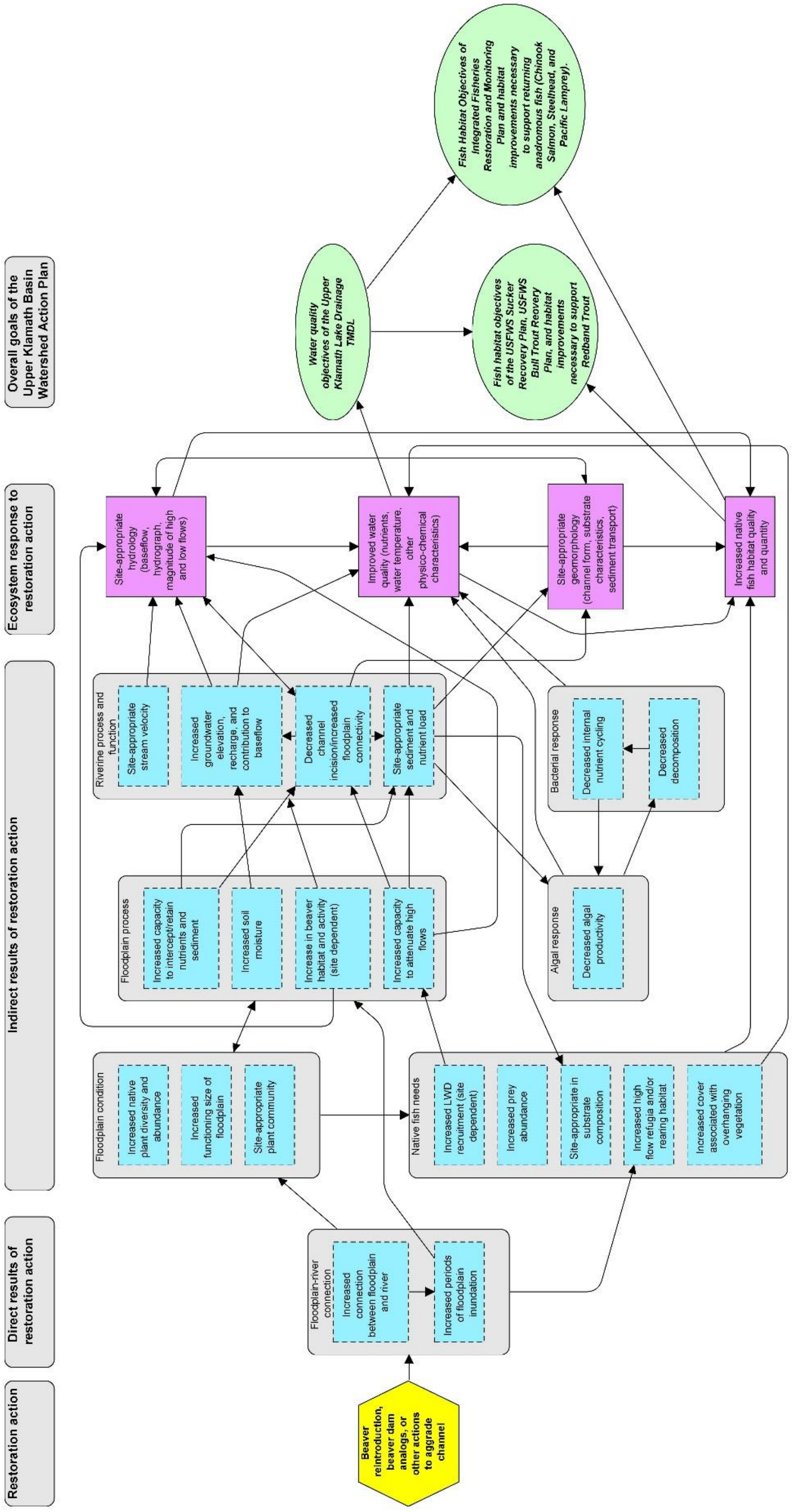


FIGURE 3-2: CHANNEL INCISION CONCEPTUAL MODEL OF RESTORATION ACTIONS

CHANNELIZATION

Understanding of UKB processes

Channelization is an engineered channel realignment practice, typically done to straighten a channel for land development, flood control, and agricultural purposes. Anthropogenic channel modifications began in the late 19th century in the UKB to support burgeoning industries, such as agriculture and timber harvesting, as well as for flood protection, water supply and delivery, and to accommodate the implementation of transportation infrastructure (O'Connor et al., 2015). Channelization, specifically, occurred extensively throughout the Sprague River Basin via the U.S. Army Corps of Engineers channelization program beginning in the 1950s (Rabe & Calonje, 2009).

Conceptual model of existing conditions

Channelization directly results in decreased sinuosity, increased velocity, changes in the width and depth of the channel, and changes in the channel gradient. There are multiple indirect impacts to geomorphic and riverine process and function as a result of channelization, including: decreased capacity to intercept/retain nutrients and sediment and decreased capacity to attenuate high flows. These impacts to channel capacity lead to increased sediment and nutrient load, channel incision, decreased floodplain connectivity, and decreased groundwater elevation, recharge, and contribution to baseflow. Indirect results from channelization also include impacts to native fish needs, algal response, and bacterial response. As with channel incision, the ecosystem responds to channelization through changes in hydrology and geomorphology, poor water quality, and decreased native fish habitat quality and quantity.

Conceptual model of restoration actions

Channel reconstruction addresses the impacts of channelization. Channel reconstruction restores channel morphology, in terms of sinuosity, channel profile and gradient. The impacts of restored channel morphology include improvements to geomorphic and riverine process and function, and native fish needs.

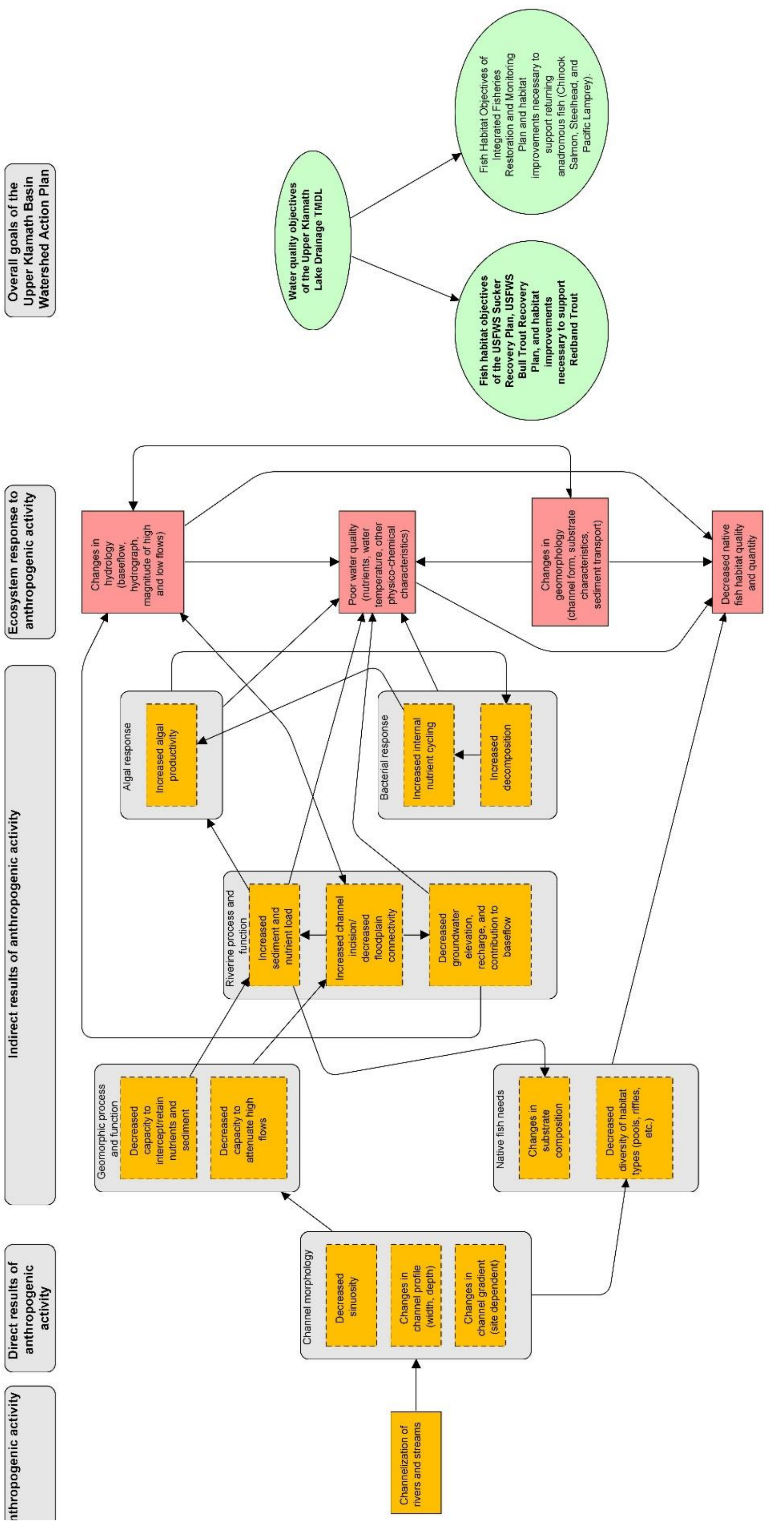


FIGURE 3-3: CHANNELIZATION CONCEPTUAL MODEL OF EXISTING CONDITIONS

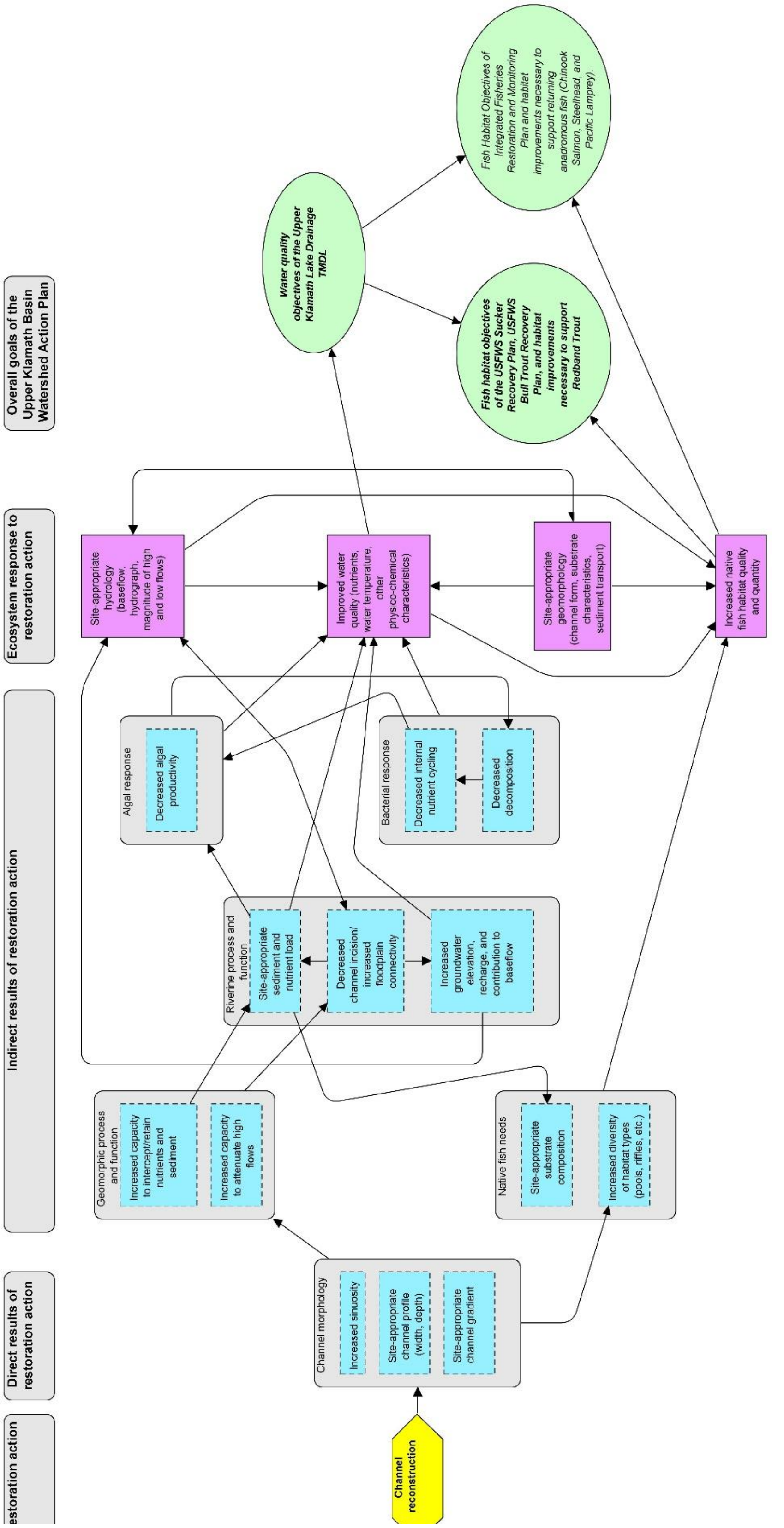


FIGURE 3-4: CHANNELIZATION CONCEPTUAL MODEL OF RESTORATION ACTIONS

TAILWATER RETURNS

Understanding of UKB processes

There are extensive irrigation networks throughout the UKB, many including ditches that concentrate tailwater returns. When a ditch is used to concentrate tailwater or facilitate drainage, this results in concentrated irrigation tailwater returns. Nonpoint source pollution from surface water runoff is the largest pollutant source in Oregon waterways (ODEQ, 2002). Constructed wetlands can improve water quality through several mechanisms, including: nutrient sequestration by aquatic vegetation, capture of suspended sediments, the trapping of chemical constituents in soils, and providing a buffer for spikes in dissolved oxygen (DO), pH and temperature (USBR, 2013).

Conceptual model of existing conditions

Tailwater returns can have a high nutrient and sediment load, which increases sediment transport, algal productivity and bacterial response, leading to poor water quality. The substrate composition is also affected, further deteriorating native fish habitat.

Conceptual model of restoration actions

By constructing wetlands sedimentation and nutrient sequestration can be increased, leading to more site-appropriate nutrient and sediment loads. This leads to a decrease in algal and bacterial activity and results in a more site-appropriate substrate composition. As an additional benefit, wetland construction can also lead to groundwater recharge, increase of wetland habitat for wildlife and creation of new recreation opportunities.

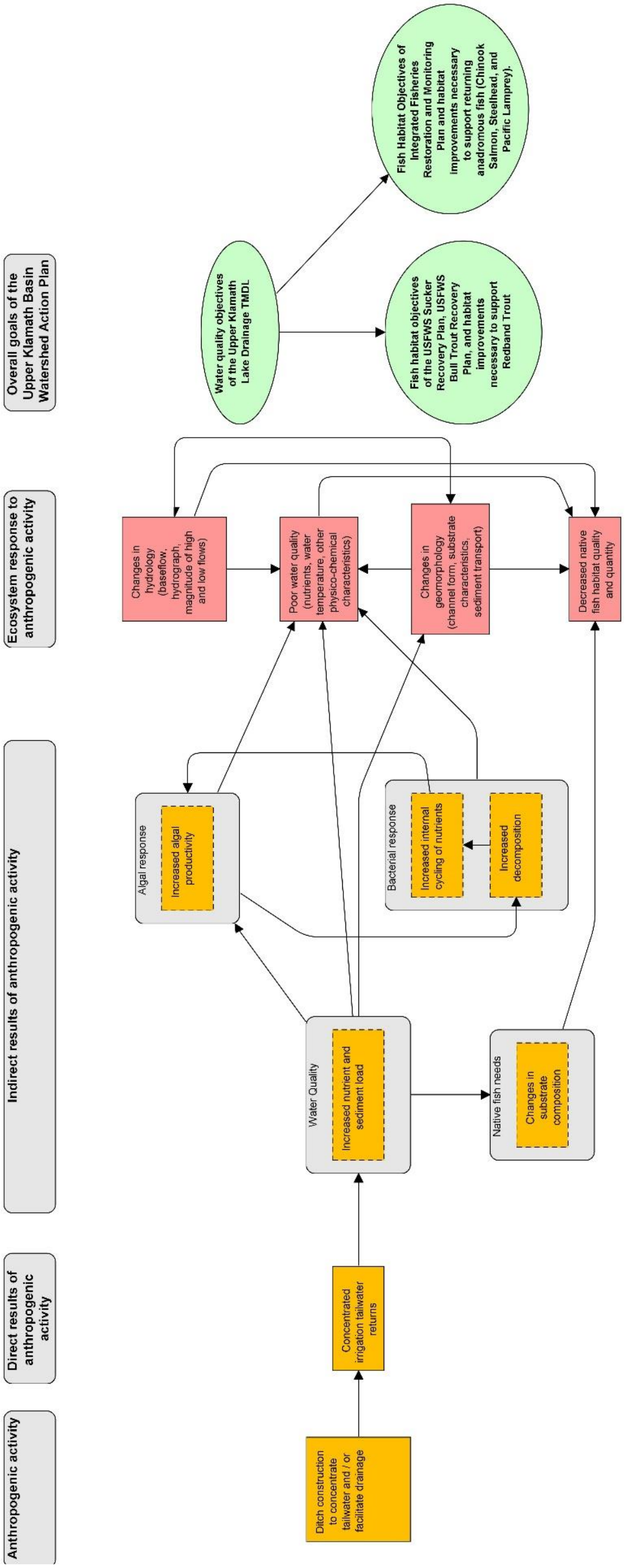


FIGURE 3-5: TAILWATER RESTURNS CONCEPTUAL MODEL OF EXISTING CONDITIONS

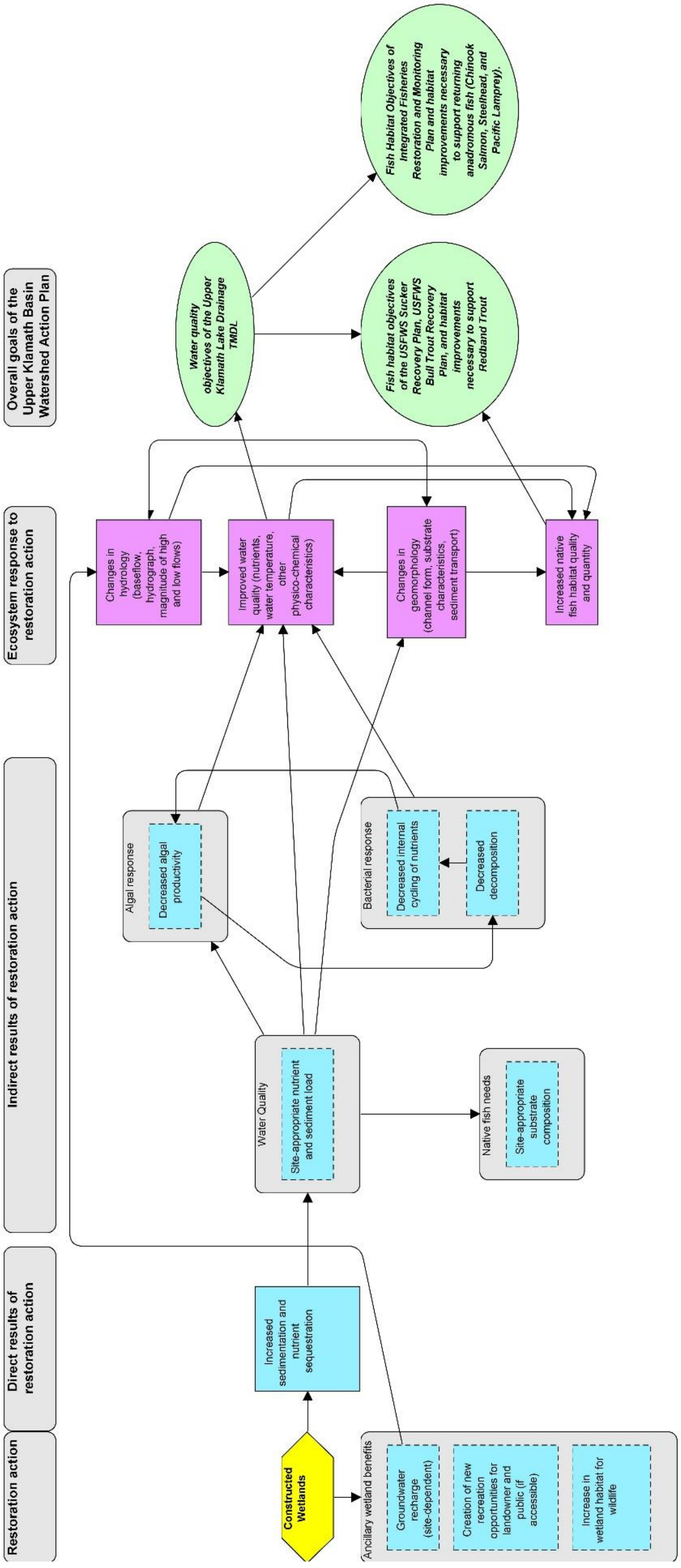


FIGURE 3-6: TAILWATER RETURNS CONCEPTUAL MODEL OF RESTORATION ACTIONS

WATER WITHDRAWALS

Understanding of UKB processes

Instream flows are reduced by water withdrawals for irrigation. Water withdrawals are limited in the UKB by the Klamath Tribes instream water right claims, which designate required flows to maintain physical and riparian habitat per the Administrative Phase of the Klamath Basin Adjudication in 2014. Compounding the water supply challenges are recent impacts from warmer winter temperatures and snowpack reductions--earlier peak runoff flows in the spring and reduced groundwater recharge (Mayer & Naman, 2011). Declining base flows are especially significant in the UKB, as groundwater flows maintain rivers and inflow to Upper Klamath Lake in the summer months. These changes highlight the urgency for restoration actions to improve instream flow.

Conceptual model of existing conditions

Substantial water withdrawals can decrease instream flows and the connection between river and floodplain, resulting in negative effects for both ecosystems. The floodplain will experience decreased periods of inundation, affecting flora and fauna, as well as the water quality. The river will experience changes in hydrology, geomorphology and water quality. If present, tailwater returns from flood irrigation practices can further impact water quality.

Conceptual model of restoration actions

To restore instream flows, irrigation withdrawals can be reduced through efficiency measures, instream flow transfers and improved diversion infrastructure. Reduced withdrawals improve instream flows, making the hydrograph resemble the natural state more. This improves the connection between river and floodplain, correcting the hydrology, geomorphology and water quality. Irrigation improvements can reduce tailwater returns, decreasing water quality impacts on the receiving waterway. These actions will improve native fish habitat.

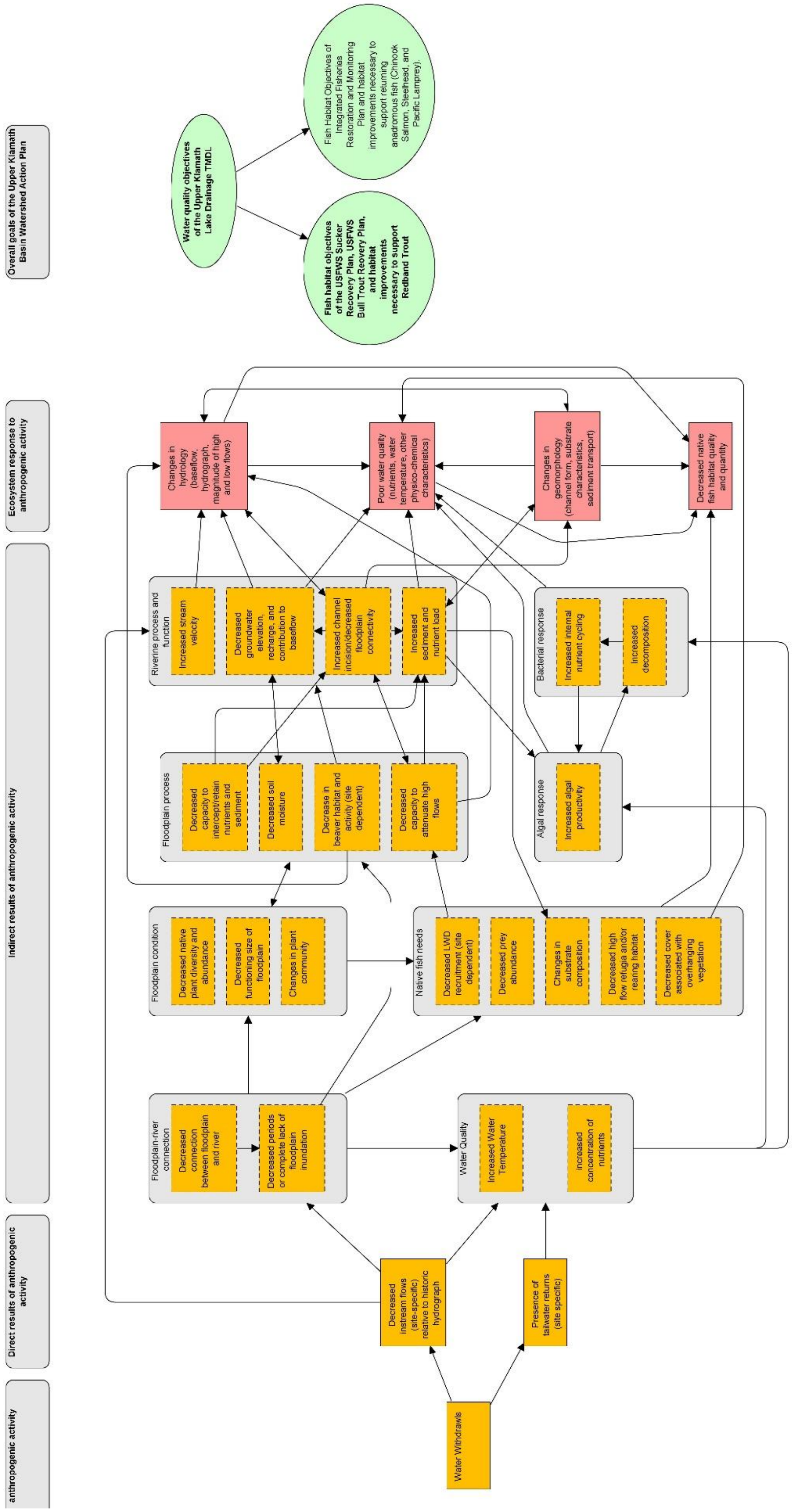


FIGURE 3-7: WATER WITHDRAWALS CONCEPTUAL MODEL OF EXISTING CONDITIONS

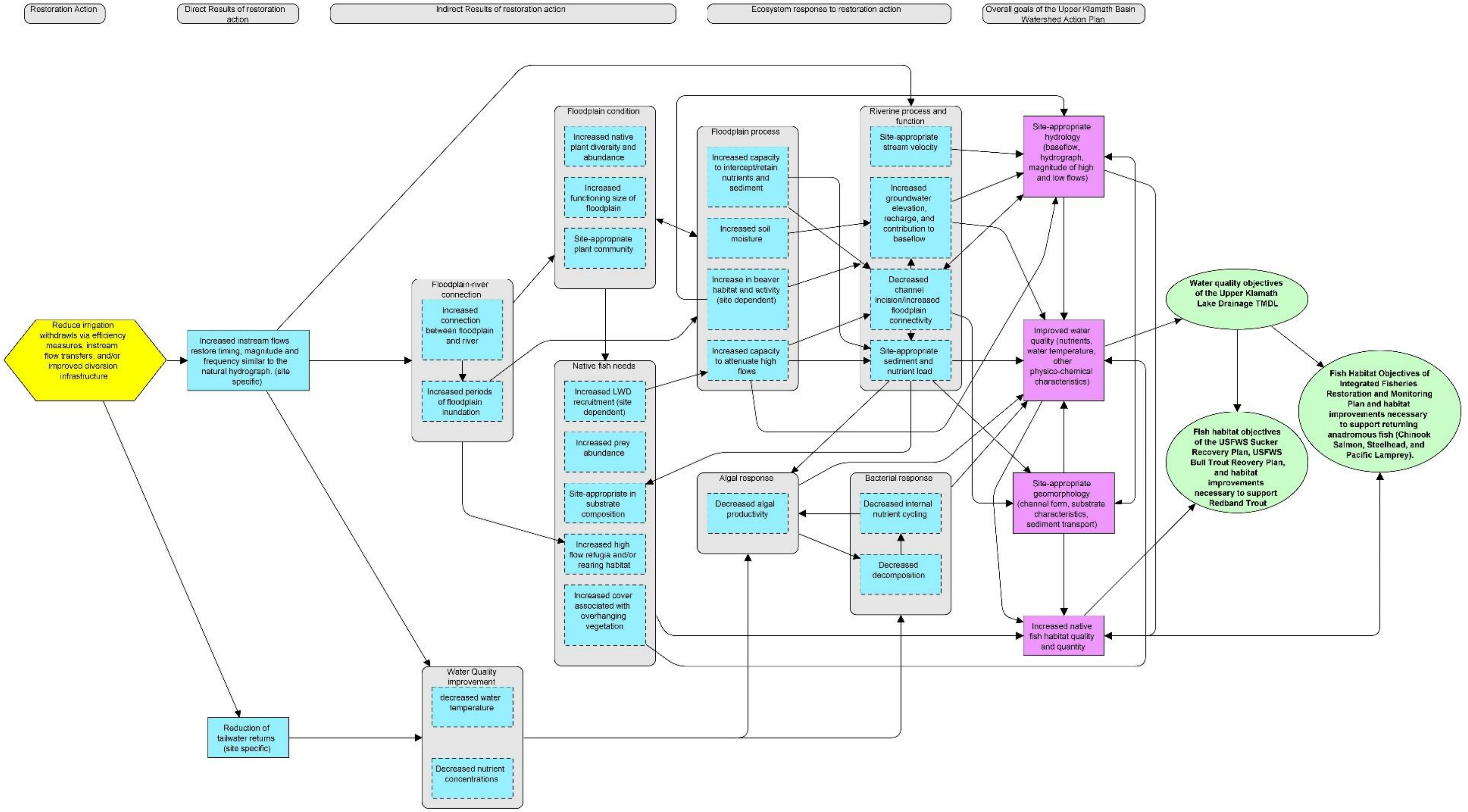


FIGURE 3-8: WATER WITHDRAWALS CONCEPTUAL MODEL OF RESTORATION ACTIONS

FISH SCREENS

Understanding of UKB processes

When fish are entrained (transported to waters outside of their habitat and into potentially harmful conditions) by water diversions (either for irrigation or for water-management structures), they can permanently lose the connection to their habitat. Irrigation diversion screening is effective; a study in the Umatilla River basin estimated irrigation diversion screens prevented up to 25% of steelhead population losses to irrigation canals (Simpson & Ostrand, 2012). Simpson & Ostrand (2012) also found that fish entrainment rates do not necessarily correlate with the size of the diversion canal, and thus smaller diversions can be important to screen as well. Although significant efforts in placing screens have been made in the Klamath Basin through the Oregon Department of Fish & Wildlife's (ODFW) fish screening program, maintaining installed screens has been a challenge to ensure passable status, and additional screens are still needed in the UKB (ODFW, 2019).

Conceptual model of existing conditions

Irrigation diversions through unscreened structures lead to a higher fish entrainment risk, ultimately increasing mortality associated with entrainment. This causes decreased fish populations in UKB.

Conceptual model of restoration actions

Installing screens to irrigation diversions reduces fish entrainment risk and associated mortality.

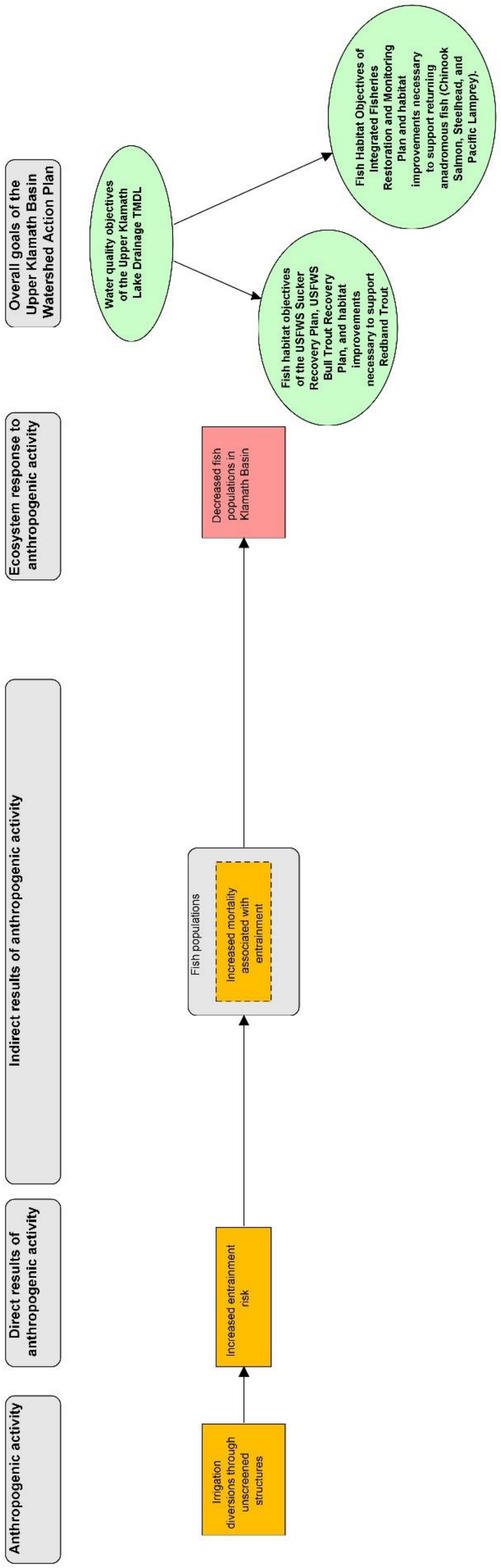


FIGURE 3-9: FISH SCREENS CONCEPTUAL MODEL OF EXISTING CONDITIONS

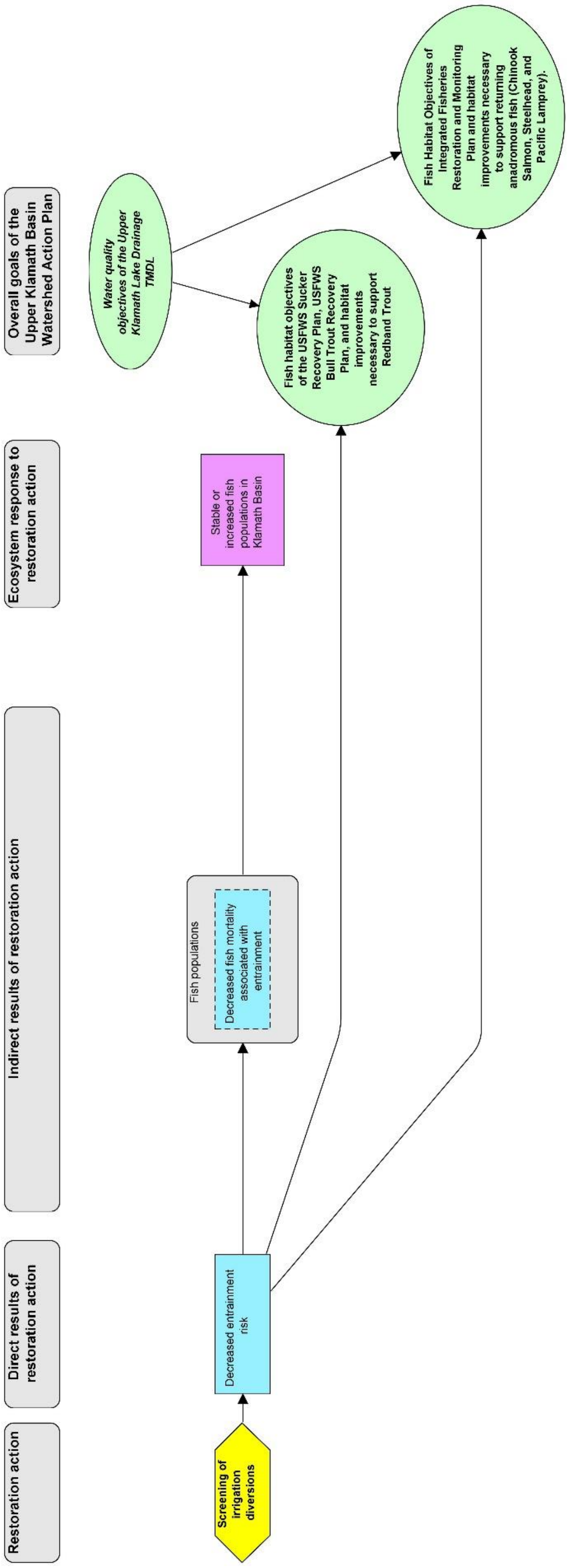


FIGURE 3-10: FISH SCREENS CONCEPTUAL MODEL OF RESTORATION ACTIONS

LEVEES AND BERMS

Understanding of UKB processes

The construction of the U.S. Army Corps of Engineers levees in the UKB began after major flooding events in 1950 and 1964 (KBEF & KBREC, 2007). Although these structures are intended to protect against flooding, they also cut off floodplains from high flows, leading to loss of valuable ecosystems. In locations where the channel is not incised and infrastructure is not threatened, the floodplain can be reconnected to the river. By removing or breaching levees, or by setting back levees further from the channel, ecological benefits can be restored and the potential for the floodplain to reduce flood risk further downstream can be regained (Opperman et al., 2009).

Conceptual model of existing conditions

The construction of levees and berms directly impacts the floodplain-river connection similarly to channel incision, as levees and berms can lead to channel incision. The direct results are a decreased connection between floodplain and river and decreased periods or complete lack of floodplain inundation. This leads to changes in soil characteristics and plant communities on the floodplain, which in turn affects numerous ecological processes of the floodplain. The effects on floodplain function resonate in the riverine processes as well, influencing water quality, hydrology and geomorphology of the stream. All these factors have a negative impact on native fish habitat.

Conceptual model of restorations actions

By levee and berm removal, set-back or breaching, the floodplain can be reconnected to the river. The increased periods of floodplain inundation enhance riparian plant communities and increase the functioning size of the floodplain. Spatial and temporal increases in floodplain inundation restore the ecological and hydrological processes of the floodplain, as well as its natural nutrient and sediment filtering capacities. Restored floodplain-river connection leads to improvements of the riverine processes as well as decreasing channel incision and sediment and nutrient loads. The stream takes on more site-appropriate hydrology and geomorphology, and the overall quality and quantity of native fish habitat improves.

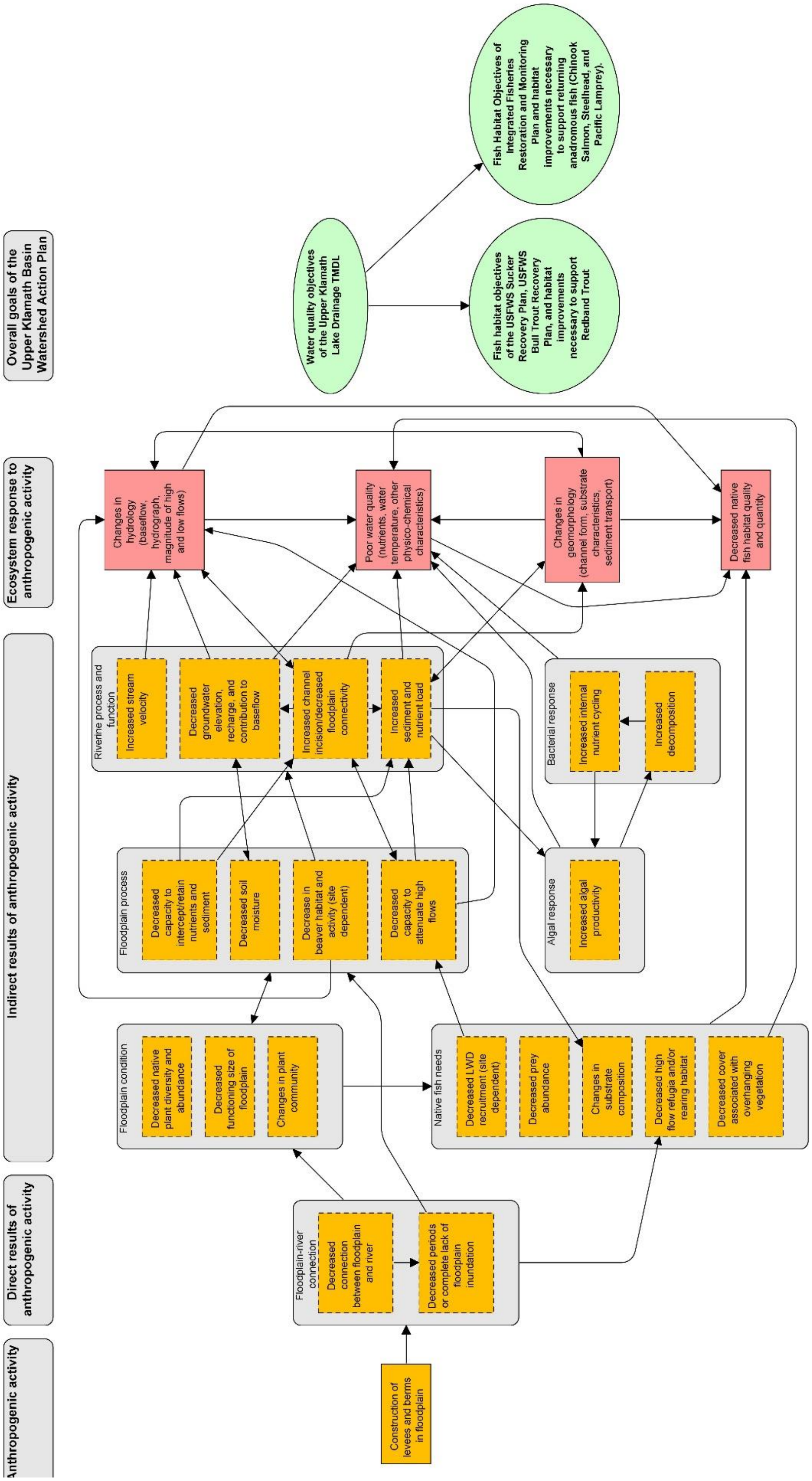


FIGURE 3-11: LEVEES AND BERMS CONCEPTUAL MODEL OF EXISTING CONDITIONS

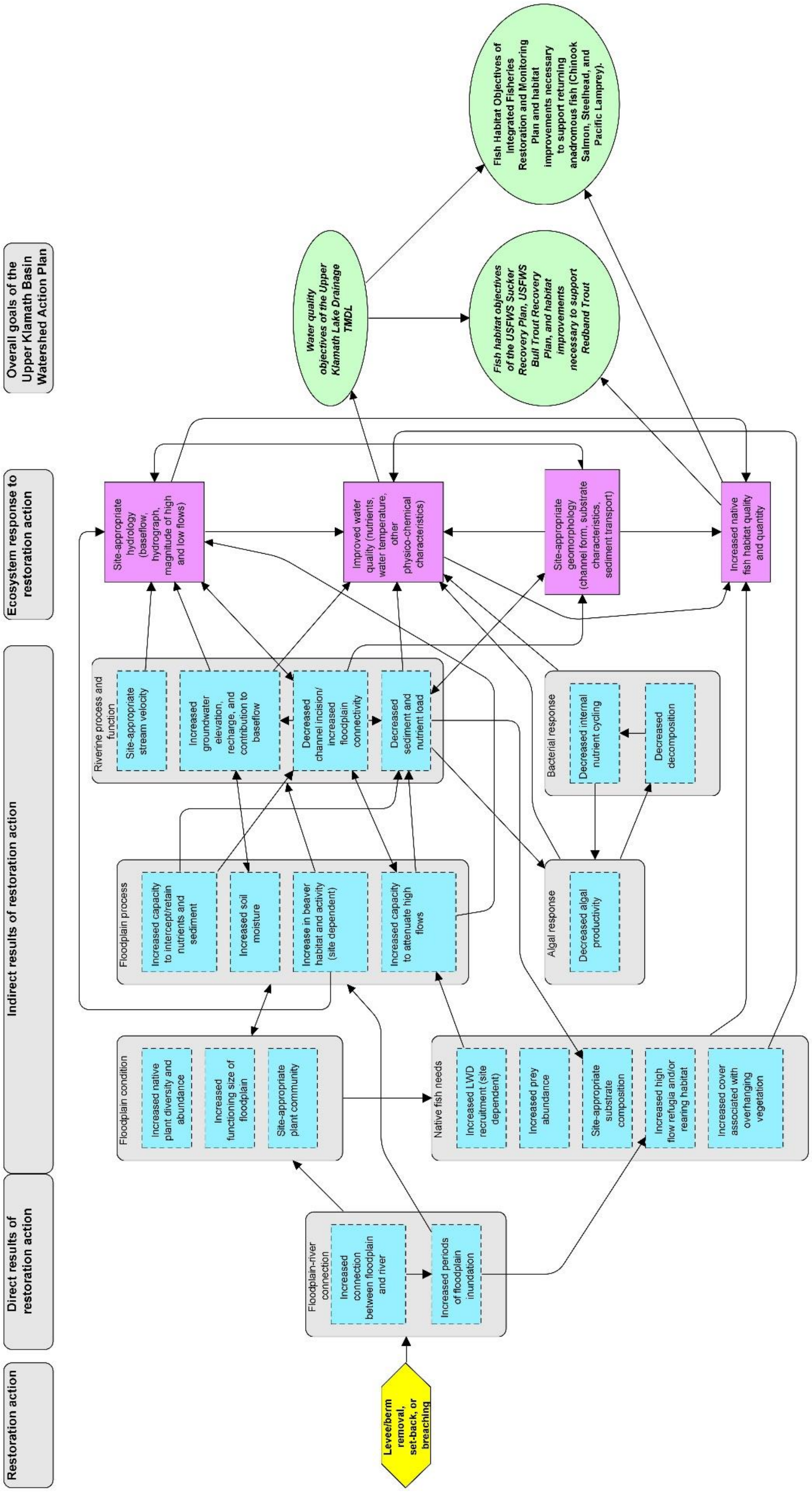


FIGURE 3-12: LEVEES AND BERMS CONCEPTUAL MODEL OF RESTORATION ACTIONS

LARGE WOODY DEBRIS

Understanding of UKB processes

Large woody debris (LWD) forms an important element of river ecology in certain stream systems. LWD increases channel complexity and can lead to changes in channel morphology, such as formation of bars, pools, and islands (Abbe & Montgomery, 1996). For fish, particularly salmonids, these pools are an important part of their habitat (Harmon et al., 1986). LWD sources may be removed from a system through clearing of upland sources or by intentional removal of instream material for aesthetics, access, flood control, or safety purposes. Removal of LWD however reduces essential habitat for native fish species (Oregon DSL et al., 2010).

Conceptual model of existing conditions

A lack of LWD decreases lateral and longitudinal complexity of the channel. This results in a decreased capacity to intercept and retain nutrients and sediment, as well as a decreased capacity to attenuate high flows. This leads to poor water quality and changes in river/stream hydrology and geomorphology. Additionally, a lack of LWD decreases instream cover and diversity of instream habitat for native fish. It also decreases high flow refugia and holding and rearing habitat. This has a negative effect on the quality and quantity of native fish habitat.

Conceptual model of restorations actions

By placement of site appropriate LWD, the complexity of the channel profile will increase. This will increase the capacity to intercept/retain nutrients and sediment and the capacity to attenuate high flows. These effects will lead to a more site-appropriate hydrology and geomorphology and improved water quality. The instream cover increases, as well as the diversity of instream habitat and high flow refugia and holding and rearing habitat. This will improve the quality and quantity of native fish habitat.

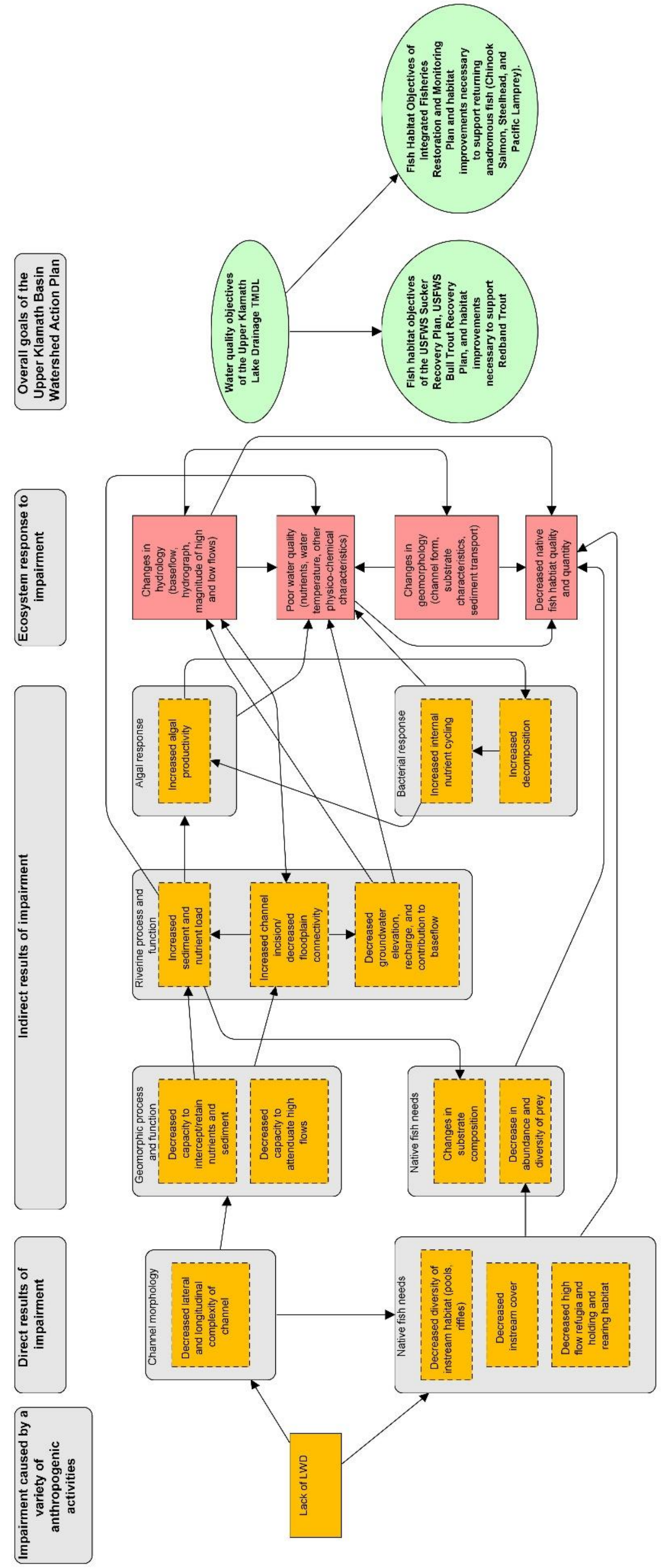


FIGURE 3-13: LARGE WOODY DEBRIS CONCEPTUAL MODEL OF EXISTING CONDITIONS

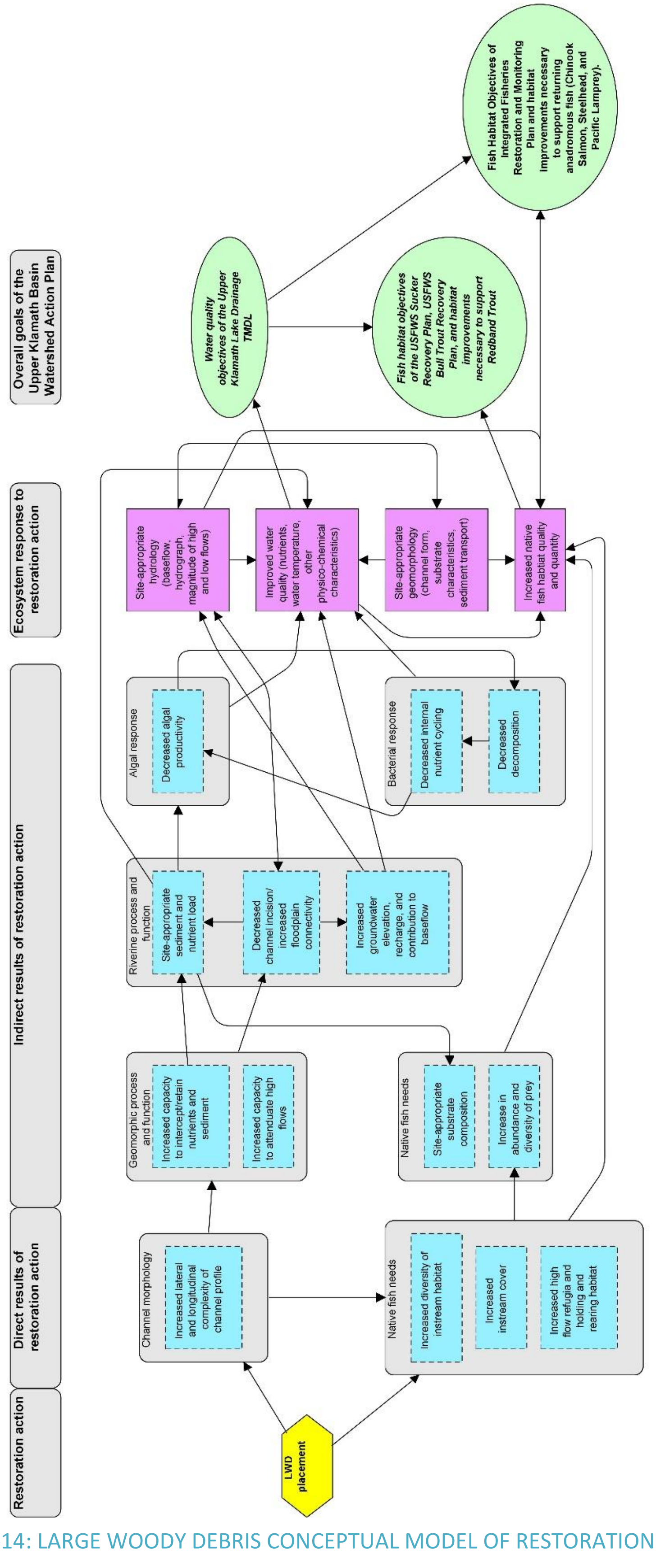


FIGURE 3-14: LARGE WOODY DEBRIS CONCEPTUAL MODEL OF RESTORATION ACTIONS

WETLAND CONVERSION

Understanding of UKB processes

Wetlands have a multitude of functions, and Zedler & Kercher (2005) list the most important four: biodiversity support, water quality enhancement, reducing floods, and carbon sequestration. When wetlands are lost, these important ecological functions are lost too, often at a disproportionate rate to the area lost (Zedler & Kercher, 2005). Draining of wetlands in the UKB began in the late 19th century for agricultural use and saw a second boom starting at the end of the 1940s until the present time (Platt Bradbury et al., 2004; Snyder & Morace, 1997). Natural wetlands in the Upper Klamath Basin and surrounding the Upper Klamath Lake have been drained.

Conceptual model of existing conditions

Reclamation of natural wetlands leads to exposure of wetland sediment, decreased standing water, and decreased native wetlands vegetation. These direct results of wetland reclamation impact wetlands process and function by reducing attenuation of high flows, the capacity for wetlands to trap nutrients and sediment, and groundwater recharge. Native fish needs are also impacted via the reduction of in-water cover, prey abundance, and rearing habitat.

Conceptual model of restorations actions

By restoring natural wetlands, wetland conditions will improve by inundation of wetland sediment, increased standing water, and increased abundance of native wetland vegetation. Wetland restoration thereby improves wetland process and function, and also supports native fish needs. Ancillary benefits of natural wetland restoration include possible creation of new recreation opportunities and an increase in wetland habitat for wildlife and waterfowl.

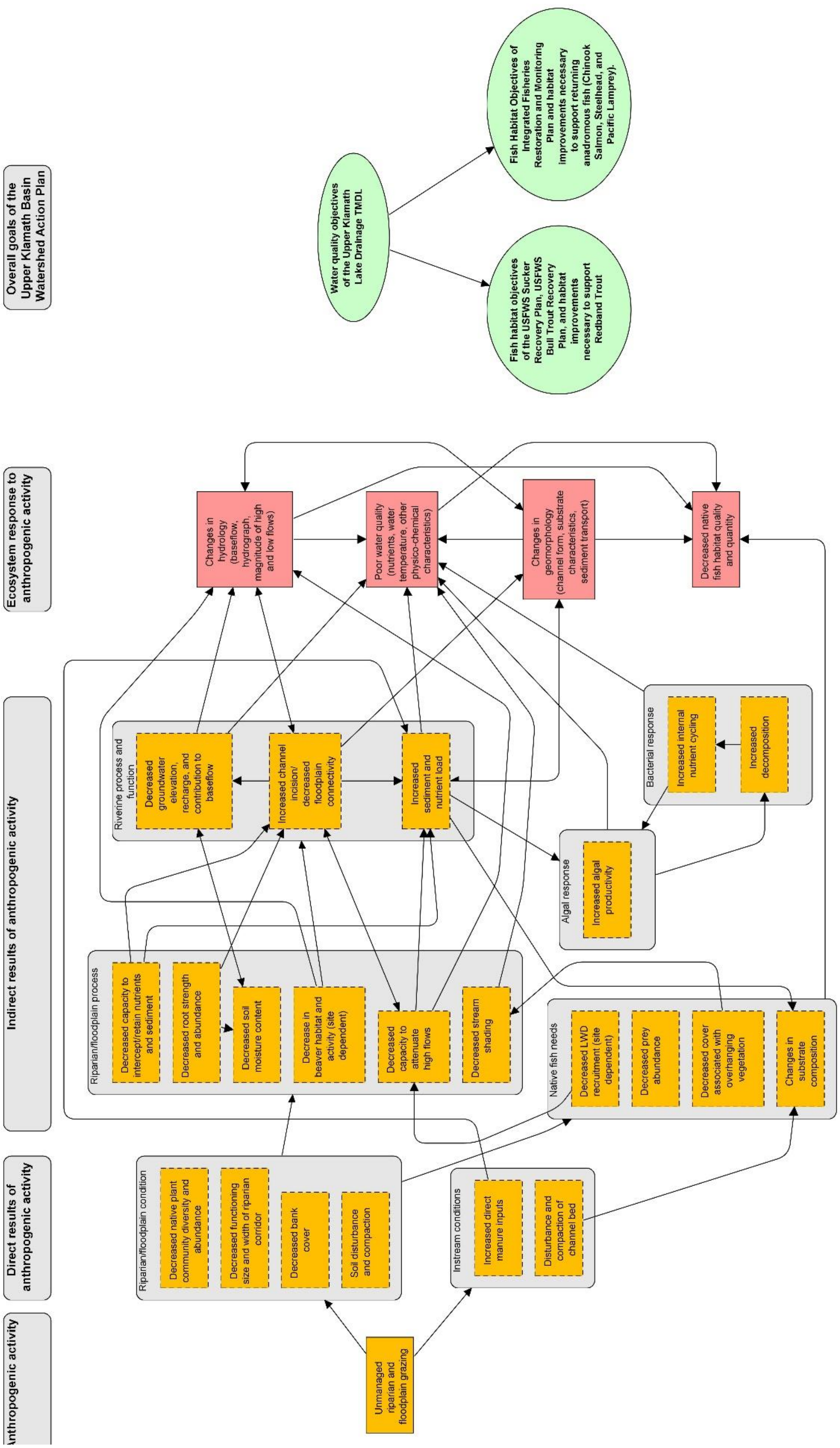


FIGURE 3-15: WETLAND CONVERSION CONCEPTUAL MODEL OF EXISTING CONDITIONS

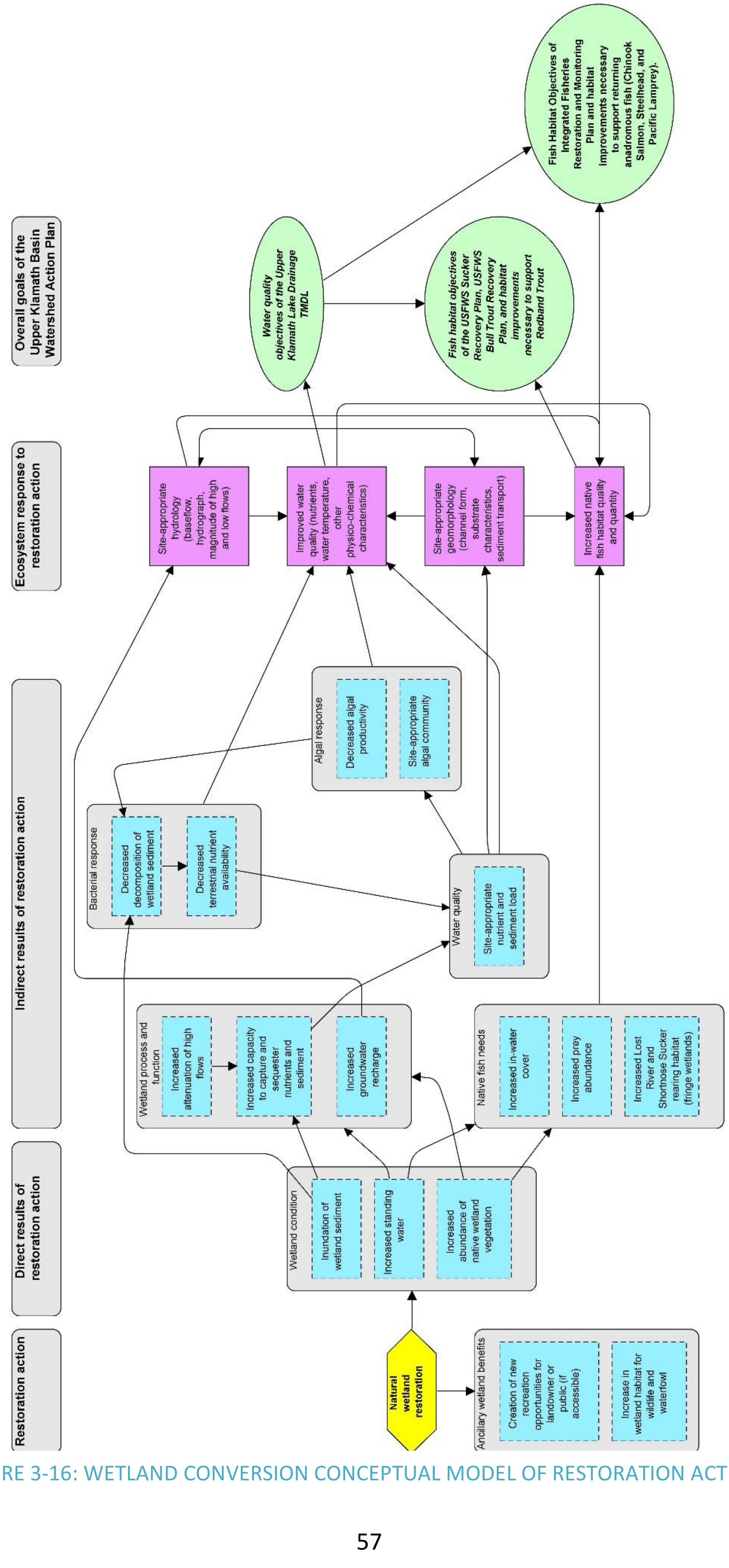


FIGURE 3-16: WETLAND CONVERSION CONCEPTUAL MODEL OF RESTORATION ACTIONS

FISH PASSAGE BARRIERS

Understanding of UKB processes

Dams and other barriers can hinder anadromous fish in reaching upstream (spawning) habitat. There is currently substantial commitment to restoring passage barriers in the Klamath Basin, as demonstrated by the removal of the Chiloquin Dam in 2008 and the planned removal of four large dams in the Lower Klamath Basin, which will improve the connection to the Upper Klamath Basin as well (KHSA, 2010). However, concerns persist about numerous impassable culverts, dams, and barriers in the UKB (KBEF & KBREC, 2007). A 2006 study found that 102 out of 114 culverts in the Upper Sprague River subbasin restricted fish passage to some extent (KBEF & KBREC, 2007). Culverts impact stream habitat in other ways as well, including the modifications to the channel morphology to install the culvert, loss of nearby habitat, and replacement of natural streambed material (WDFW, 2003).

Conceptual model of existing conditions

Construction of culverts, dams or other fish passage barriers causes limited or no fish passage at the barrier site, preventing species from accessing habitat. Passage barriers can also cause local changes in the channel profile and gradient, which can lead to changes in hydrology, sediment transport, local hydraulics, and geomorphology. Water quality is degraded from changes in the thermal regime and nutrient dynamics. Changes in substrate composition can further decrease native fish habitat quality and quantity.

Conceptual model of restorations actions

By mitigation or removal of passage barriers, fish passage can be restored. A more site-appropriate channel profile and gradient will develop, restoring hydrologic, hydraulic and sediment transport conditions. This improves the water quality and substrate composition, leading to increased quality and quantity of native fish habitat.

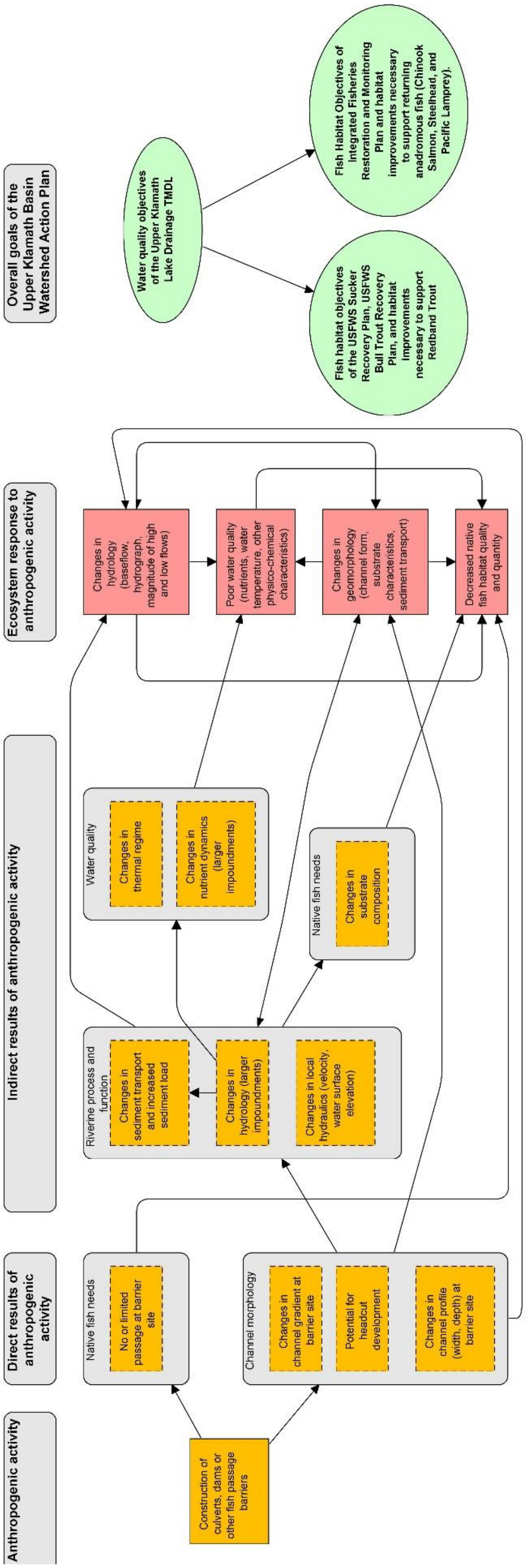


FIGURE 3-17: FISH PASSAGE BARRIERS CONCEPTUAL MODEL OF EXISTING CONDITIONS

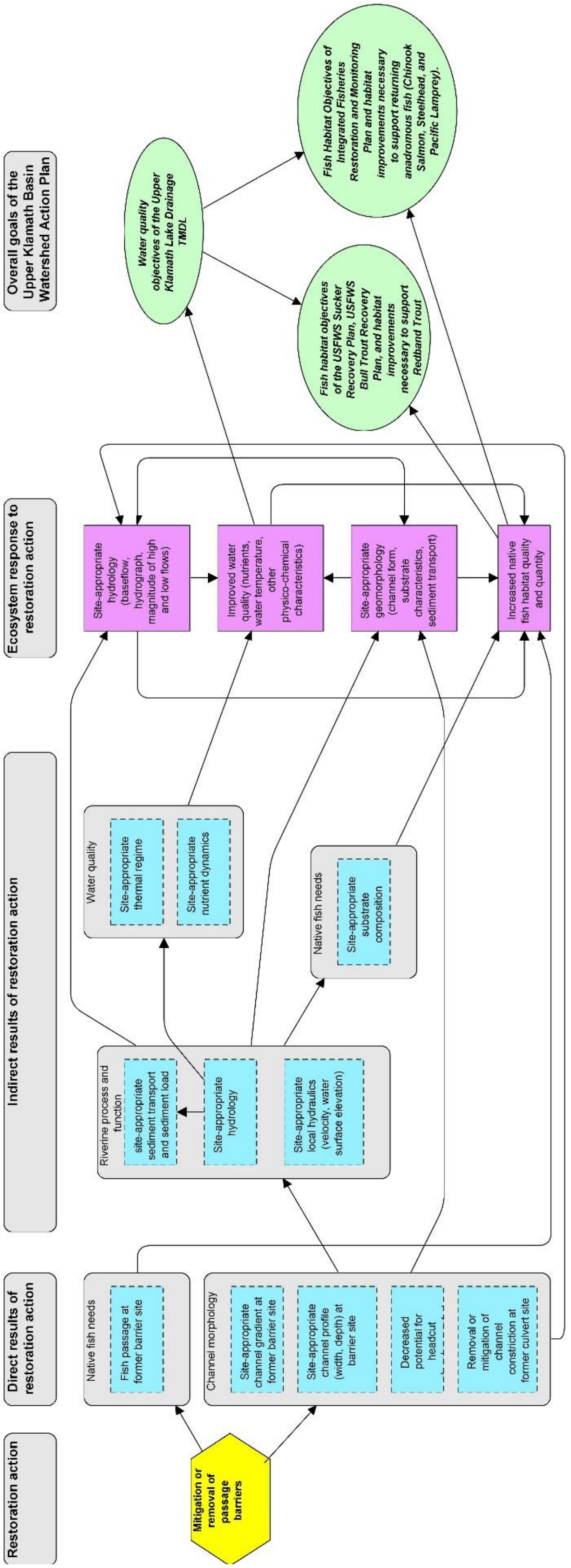


FIGURE 3-18: FISH PASSAGE BARRIERS CONCEPTUAL MODEL OF RESTORATION ACTIONS

RIPARIAN GRAZING

Understanding of UKB processes

When unmanaged livestock grazing takes place on in riparian zones and in the active channel, it can detrimentally affect native fish habitat and decrease water quality. By grazing at the stabilizing vegetation and by trampling and direct shearing, livestock can destabilize the streambed and banks (FlowWest, 2017). Destabilization of the channel can result in changes to the channel dimensions and increase fine sediment and nutrients in the water column. In addition, overgrazed bare patches of land cause erosion and invasion of noxious weeds, which can be hazardous to the aquatic ecosystem (U.S. Department of the Interior, 2014).

Conceptual model of existing conditions

Unmanaged riparian and floodplain grazing can decrease stabilizing vegetation and lead to soil disturbance and geomorphological changes in the floodplain and riparian zone. These results of unmanaged grazing influence a range of ecological processes, as well as the hydrology and water quality. Impacts to riverine processes include changes to hydrology, geomorphology and water quality, leading to decreased quality and quantity of native fish habitat. Additionally, the disturbance of the channel bed and the manure input to the channel by grazing animals have a direct negative impact on native fish habitat.

Conceptual model of restorations actions

By placing fences in the riparian zone and/or introducing grazing management, the condition of native fish habitat can be improved. The geomorphology and vegetation of the floodplain in the riparian zone is restored, improving ecological processes, hydrology, and water quality. Instream conditions are further improved by a decreased direct manure input and improved channel bed characteristics. As ancillary benefits, the improvements can increase other wildlife habitat and potentially increase forage abundance and quality. Furthermore, the aesthetic value of the floodplain and riparian zone can improve, potentially creating opportunities for recreation.

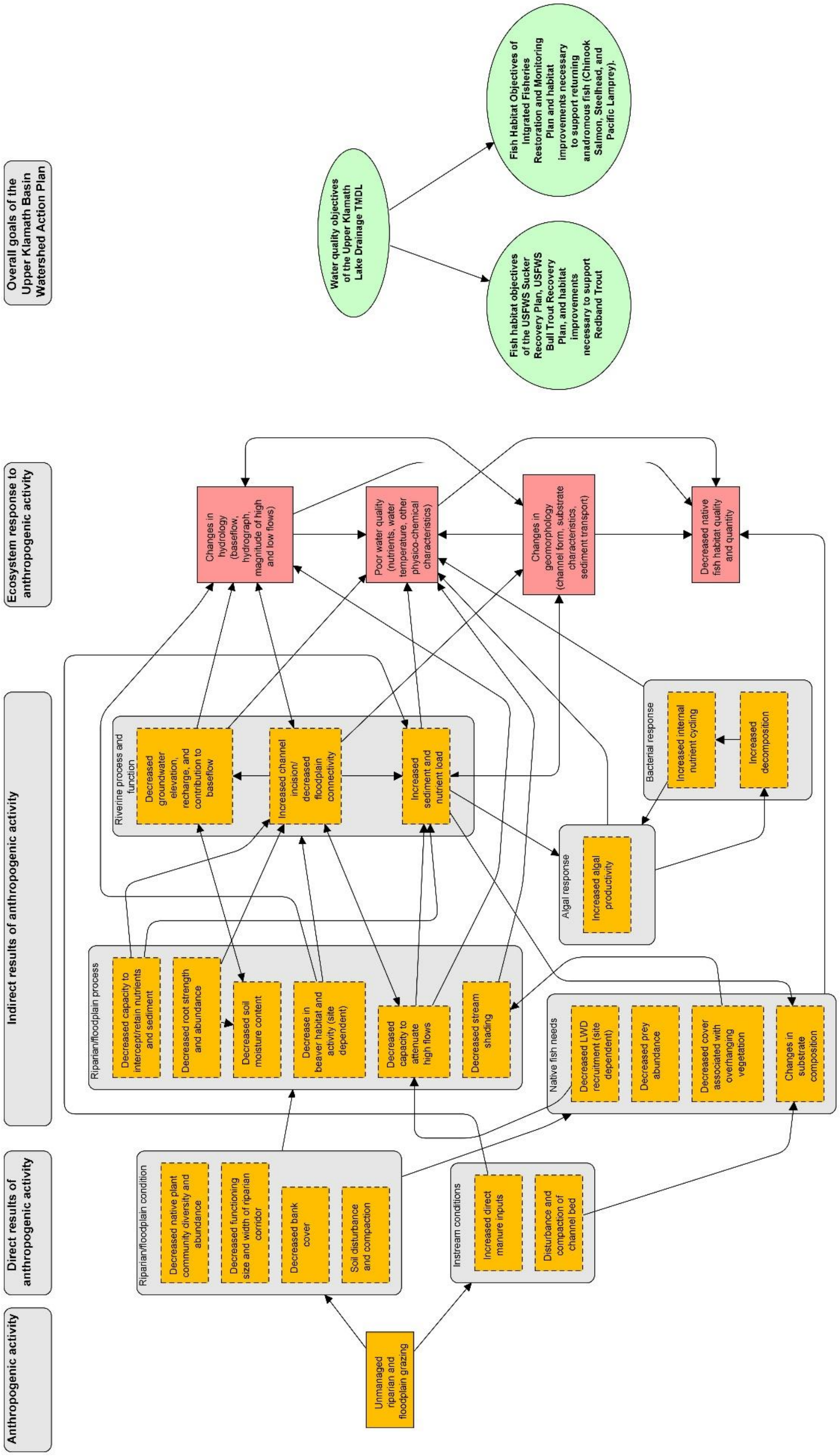


FIGURE 3-19: RIPARIAN GRAZING CONCEPTUAL MODEL OF EXISTING CONDITIONS

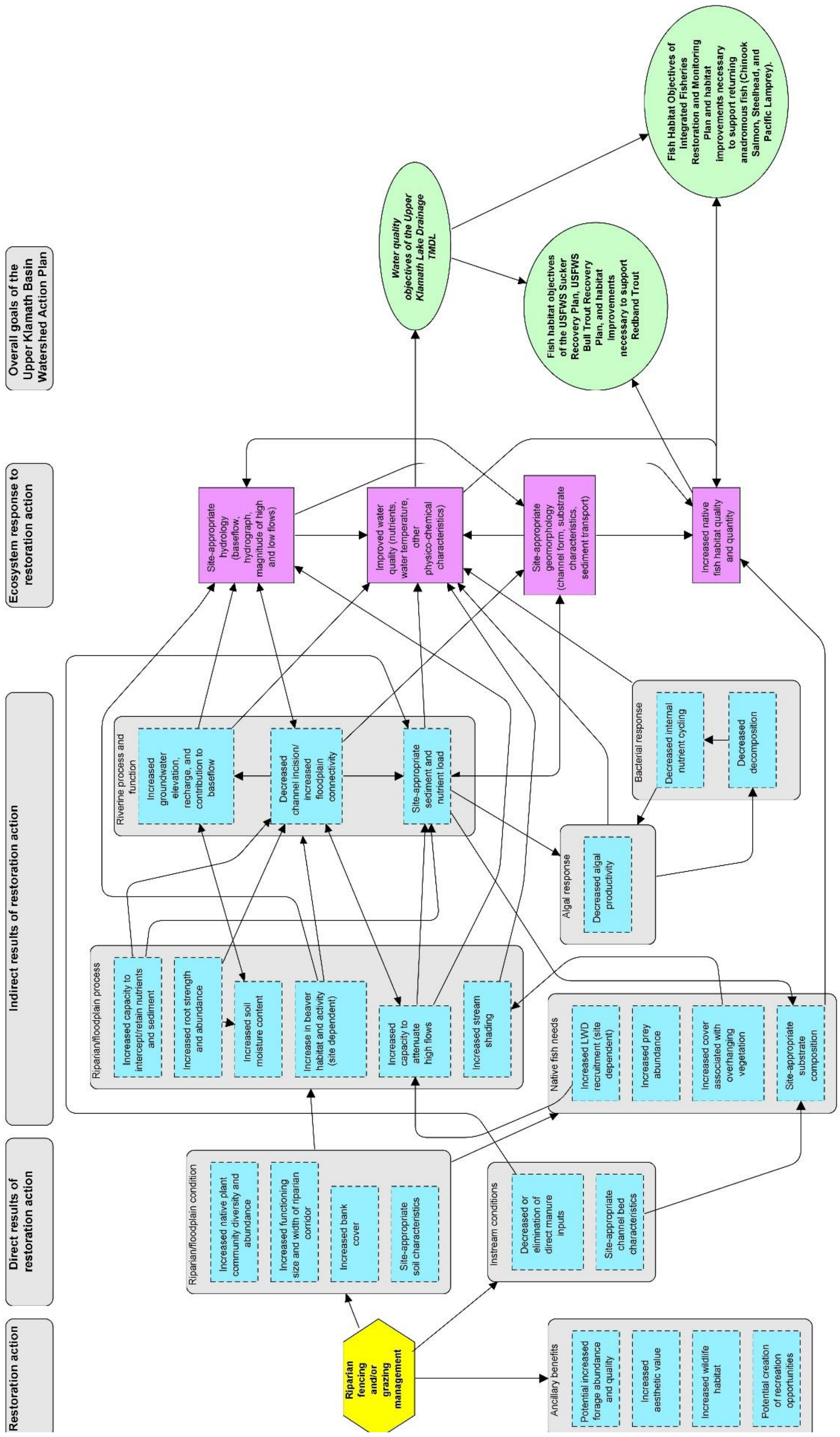


FIGURE 3-20: RIPARIAN GRAZING CONCEPTUAL MODEL OF RESTORATION ACTIONS

ROADS

Conceptual model of existing conditions

Road construction near a stream or river can have effects on the local hydrology, geomorphology, and the water quality, decreasing native fish habitat quality and quantity. The construction of the roadbed can change the drainage topography and introduce non-native materials. This can lead to changes in groundwater elevation, increased channel incision, and increased sediment and nutrient load, which can trigger increased algal and bacterial growth. In some cases, culverts are installed to guide water under the road, which can form an obstacle for fish passage. Culverts can also influence the channel morphology by causing local changes in the velocity and direction of the stream flow.

Conceptual model of restorations actions

Road decommissioning, including removal or replacement of culverts, can improve ecosystem conditions by removing obstacles for fish passage and restoring channel morphology. The removal of the roads results in site-appropriate drainage topography and soil characteristics, and decreases non-native materials associated with the roadbed, reversing the algal and bacterial response. Thus, road decommissioning leads to improved water quality, more site-appropriate hydrology and geomorphology, and increased quality and quantity of native fish habitat.

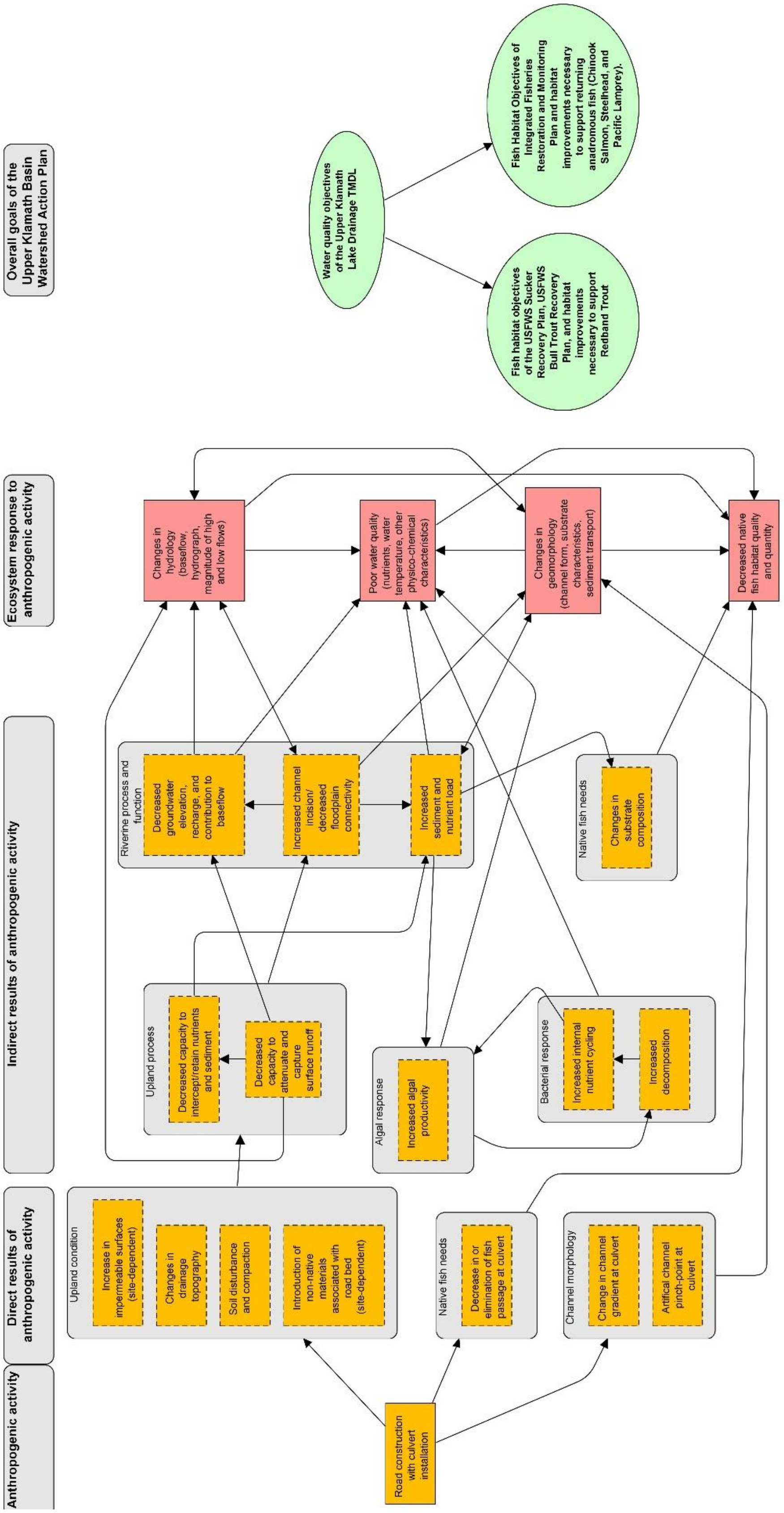


FIGURE 3-21: ROADS CONCEPTUAL MODEL OF EXISTING CONDITIONS

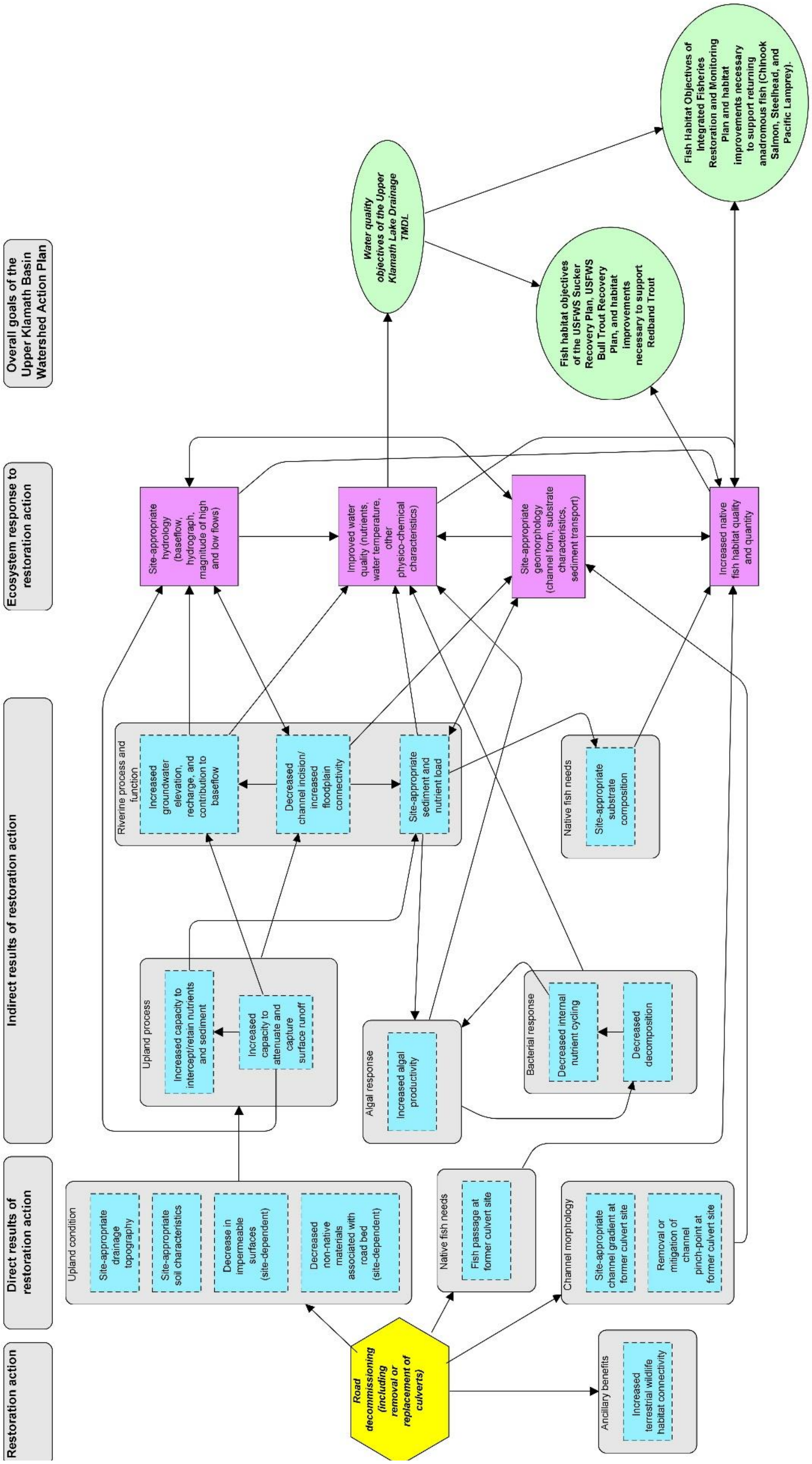


FIGURE 3-22: ROADS CONCEPTUAL MODEL OF RESTORATION ACTIONS

SPAWNING GRAVEL

Understanding of UKB processes

Stable, well-oxygenated gravel of different sizes is required for the spawning processes of bull trout, redband trout, chinook salmon and steelhead (KBEF & KBREC, 2007). When fine sediments fill up the spawning gravel deposits or when gravel is otherwise lost, this decreases suitability as spawning habitat and the resulting spawning success and embryo survival. Oregon state agencies have developed a guide for (gravel) habitat restoration (Oregon DSL et al., 2010). Resupplying a reach with gravel can be effective for restoring spawning habitat but temporary in some cases; the guide stresses the importance of identifying the cause of limited gravel in the reach and addressing the cause when possible (examples include "lack of structure to retain gravel, upstream dams that are blocking gravel recruitment") (Oregon DSL et al., 2010).

Conceptual model of existing conditions

A lack of available spawning gravel directly results in a lack of spawning habitat. This leads to a decreased success of spawning and embryo survival in fish species. The resulting reduction in fish recruitment leads to decreased fish populations in the UKB and inhibits recovery of fish populations.

Conceptual model of restorations actions

Addition of spawning gravel increases spawning habitat. This improves success of spawning and embryo survival, increasing fish recruitment. Fish populations in UKB will increase or stabilize.

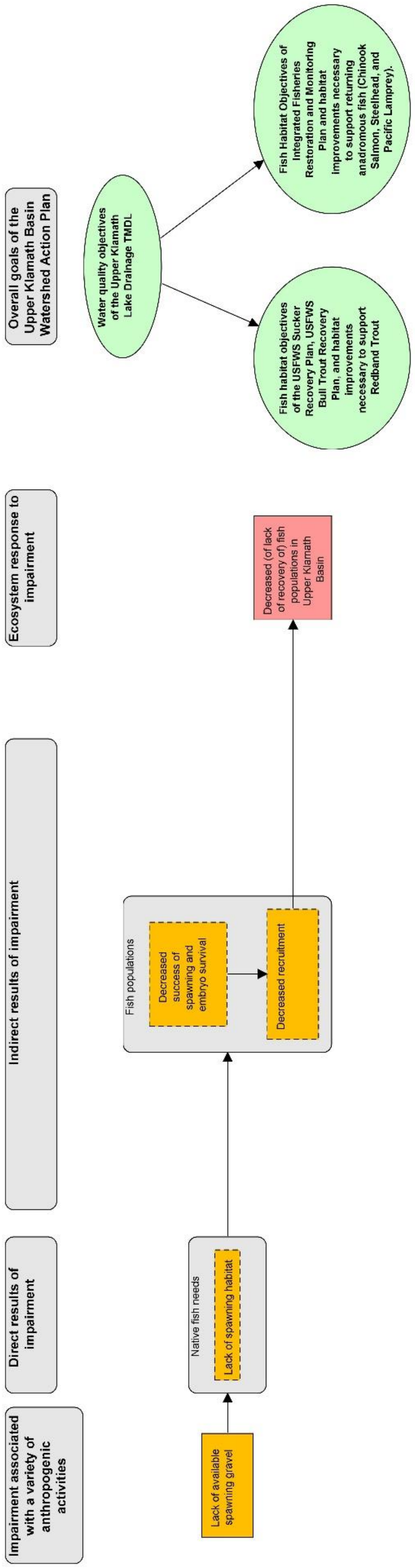


FIGURE 3-23: SPAWNING GRAVEL CONCEPTUAL MODEL OF EXISTING CONDITIONS

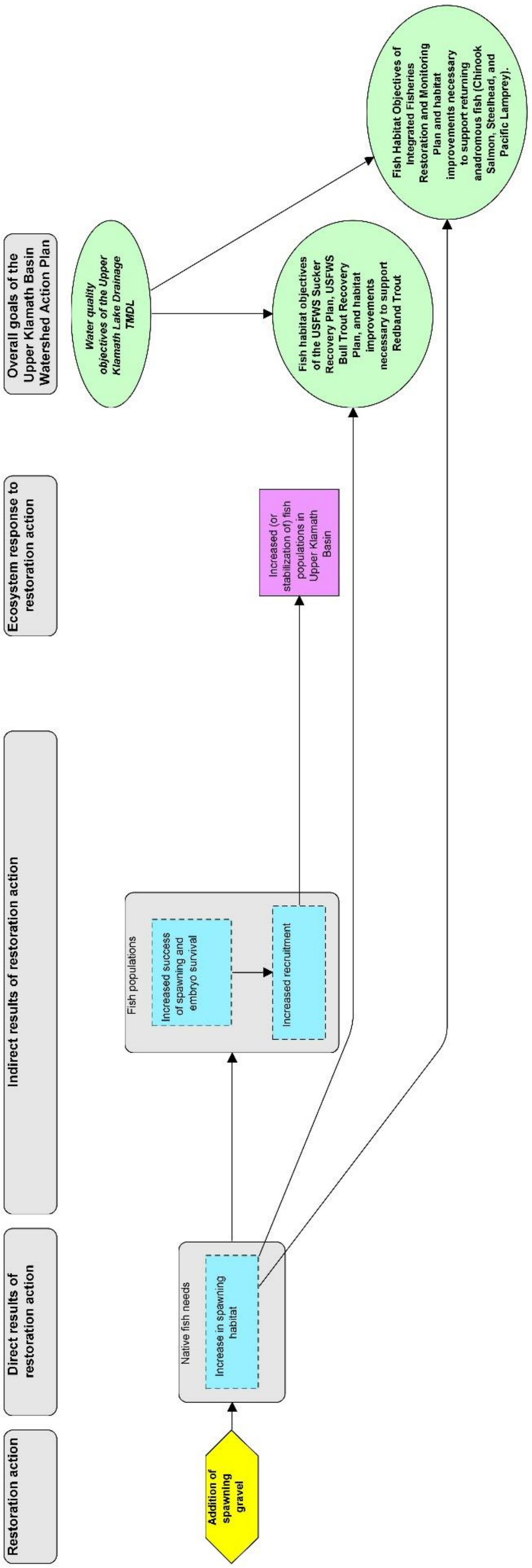


FIGURE 3-24: SPAWNING GRAVEL CONCEPTUAL MODEL OF RESTORATION ACTIONS

SPRINGS

Understanding of UKB processes

In cold-water springs, cool groundwater reaches the surface. These springs have an important ecological function because they can substantially influence downstream water temperatures, improving habitat conditions for cold-water fish (Nichols et al., 2014). When spring water is diverted or otherwise disconnected from the stream through landscape modifications, this can change the flow regime of the stream, which can decrease floodplain inundation during high flows (Null et al., 2010). Restoring cold, groundwater-driven flows provides substantial benefits to salmonids and the subsequent water quality improvements can even reduce instream flow requirements for species (Null et al., 2010).

Conceptual model of existing conditions

Landscape modification leads to disconnection and loss of the ecological function of cold-water springs. First, an increase in water temperature affects the water quality. Second, the habitat of native fish is directly affected. Third, a decrease of instream flows occurs, leading to a decreased connection between the floodplain and the river and a decreased frequency and duration of floodplain inundating flows. This has a negative effect on the ecosystems of the river and floodplain, and it changes their hydrology, ultimately leading to poor water quality, changes in geomorphology and decreased quality and quantity of native fish habitat.

Conceptual model of restorations actions

By restoring the connection to cold-water springs, water temperature goes down and the water quality improves, thereby improving spawning and rearing habitat. The connection between floodplain and river increases and the floodplain inundation periods increase as well. This improves the ecology and hydrology of both river and floodplain, leading to further improved water quality, more site-appropriate hydrology and geomorphology, and increased quality and quantity of native fish habitat.

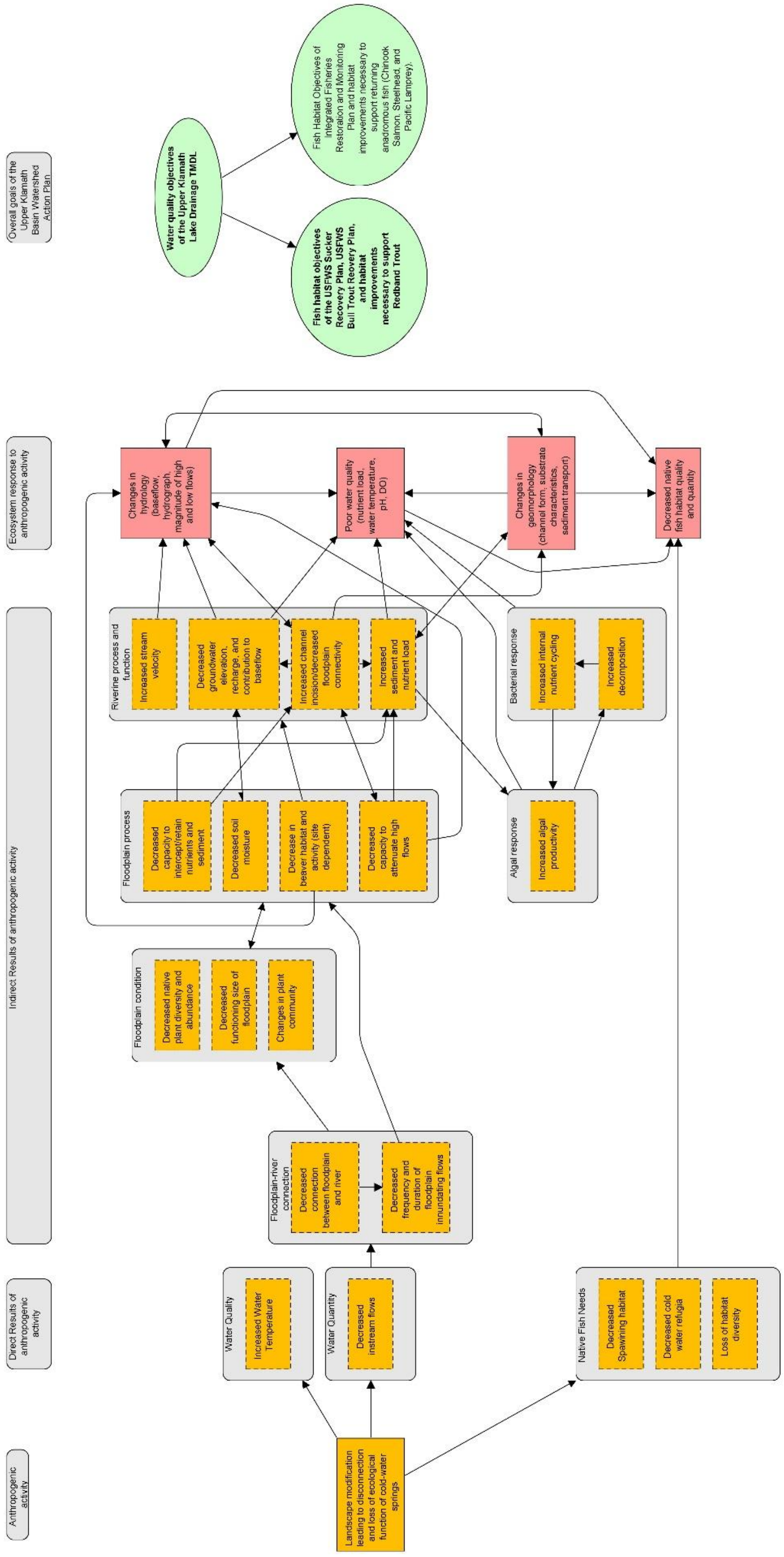


FIGURE 3-25: SPRINGS CONCEPTUAL MODEL OF EXISTING CONDITIONS

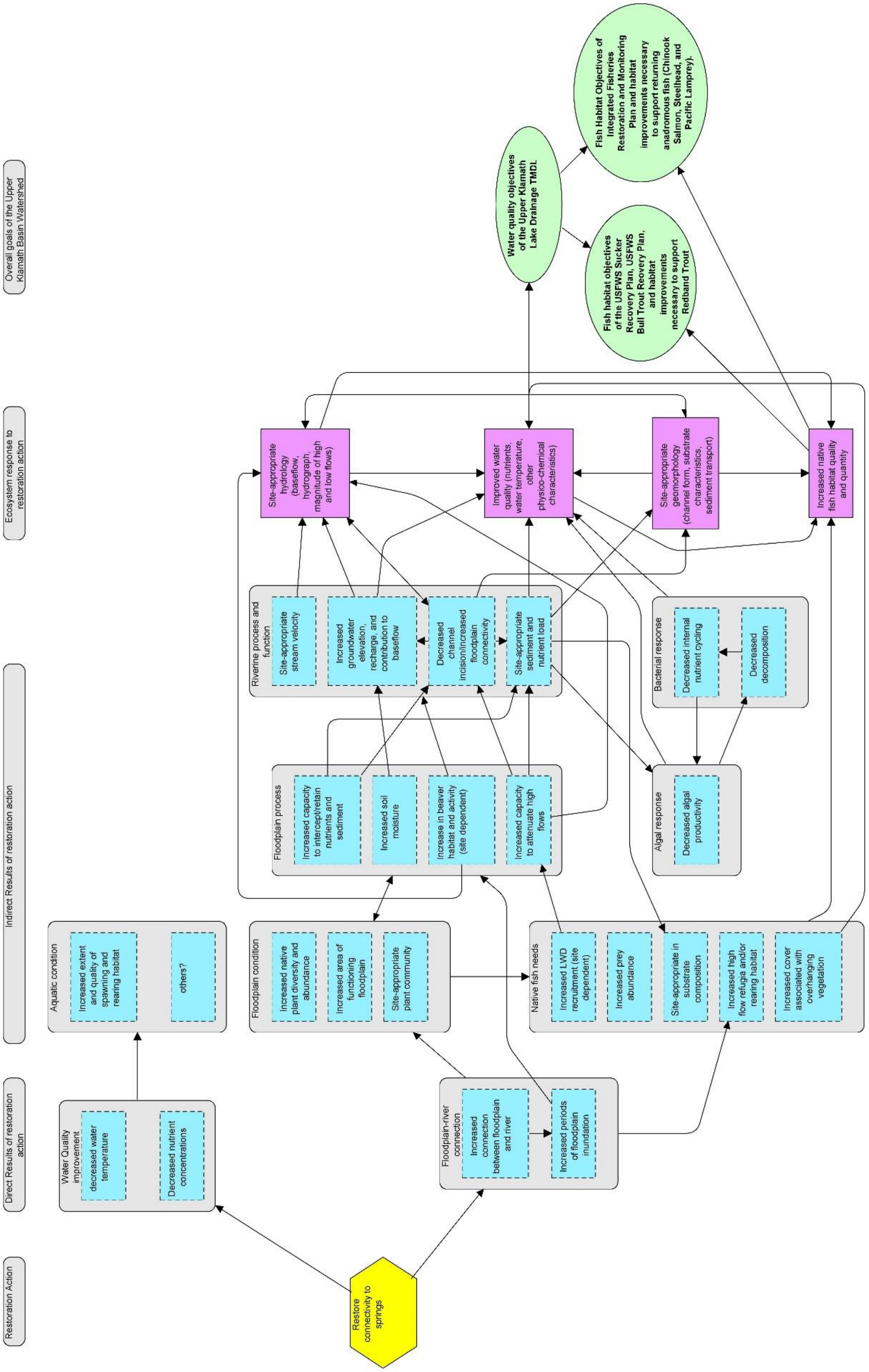


FIGURE 3-26: SPRINGS CONCEPTUAL MODEL OF RESTORATION ACTIONS

REFERENCES

Abbe, T.B., & Montgomery, D.R. (1996). Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers: Research and Management, 12, 201-221. DOI: 10.1002/(SICI)1099-1646(199603)12:2/3<201::AID-RRR390>3.0.CO;2-A

Ciotti, D., Griffith, S.M., Kann, J., & Baham, J. (2010). Nutrient and sediment transport on flood-irrigated pasture in the Klamath Basin, Oregon. Rangeland Ecology & Management, 63(3), 308-316. DOI: 10.2111/08-127.1

FlowWest (2017). Upper Klamath Basin adaptive aquatic restoration guide. Prepared for The Klamath Tribes.

Harmon, M.E., Franklin, J.F., Swanson, F.J., Sollins, P., Gregory, S.V., Lattin, L.D., … Cummins, K.W. (1986). Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research, 15, 133-302. DOI: 10.1016/S0065-2504(08)60121-X

Klamath Basin Ecosystem Foundation (KBEF), & Oregon State University Klamath Basin Research and Extension Center (KBREC) (2007). Upper Sprague Watershed Assessment. Retrieved from https://nrimp.dfw.state.or.us/web%20stores/data%20libraries/files/OWEB/OWEB_916_2_Upper%20Sprague%20WS%20Assessment.pdf

Klamath hydroelectric settlement agreement (KHSA). (2010). Retrieved from https://klamathrestoration.gov/sites/klamathrestoration.gov/files/Klamath-Agreements/Klamath-Hydroelectric-Settlement-Agreement-2-18-10signed.pdf

Mayer, T.D., Naman, S.W. (2011). Streamflow response to climate as influenced by geology and elevation. Journal of the American Water Resources Association (JAWRA) 1-15. DOI: 10.1111/j.1752-1688.

Nichols, A.L., Willis, A.D., Jeffres, C.A., and Deas, M.L. (2014). Water temperature patterns below large groundwater springs: Management implications for coho salmon in the Shasta River, California. River Research and Applications, 30(4), 442-445. DOI: 10.1002/rra.2655.

Null, S.E., Deas, M.L., and Lund, J.R. (2010). Flow and water temperature simulation for habitat restoration in the Shasta River, California. River Research and Applications, 26(6), 663-681. DOI: 10.1002/rra.1288

O’Connor, J.E., McDowell, P.F., Lind, Pollyanna, Rasmussen, C.G., and Keith, M.K. (2015). Geomorphology and floodplain vegetation of the Sprague and lower Sycan Rivers, Klamath Basin, Oregon (U.S. Geological Survey Scientific Investigations Report 2014–5223), 122 p., 1 pl., http://dx.doi.org/10.3133/sir20145223.

Oregon Department of Environmental Quality (ODEQ). (2002). Upper Klamath Lake drainage total maximum daily load (TMDL) and water quality management plan (WQMP). Retrieved from https://www.oregon.gov/deq/FilterDocs/UKtmdlwqmp.pdf

Oregon Department of Fish & Wildlife (ODFW). (2019). Fish screening. Retrieved from https://www.dfw.state.or.us/fish/screening/index.asp

Opperman, J.J., Galloway, G.E., Fargione, J., Mount, J.F., Richter, B.D., Secchi, S. (2009). Sustainable floodplains through large-scale reconnection to rivers. Science, 326(5959), 1487-1488. DOI: 10.1126/science.1178256

Oregon Department of State Lands (DSL), Oregon Department of Forestry (ODF), Oregon Watershed Enhancement Board (OWEB), & Oregon Department of Fish and Wildlife (DFW) (2010). Guide to placement of wood, boulders and gravel for habitat restoration. Oregon Dept. of State Lands. Retrieved from https://digital.osl.state.or.us/islandora/object/osl%3A14170

Platt Bradbury, J., Colman, S.M., & Reynolds, R.L. (2004). The history of recent limnological changes and human impact on Upper Klamath Lake, Oregon. Journal of Paleolimnology, 31(2), 151-165. Retrieved from http://kbifrm.psmfc.org/wp-content/uploads/2018/01/Bradbury_et_al_2004_0428_The-history-of-recent-limnological-changes-1.pdf

Rabe, A., & Calonje, C. (2009). Lower Sprague-lower Williamson watershed assessment. Prepared by Rabe Consulting with maps and figures by E&S Environmental Chemistry, Inc., Corvallis, Oregon, for the Klamath Watershed Partnership, Klamath Falls, Oregon.

Simon, A., & Rimaldi, M. (2006). Disturbance, stream incision, and channel evolution: The roles of excess transport capacity and boundary materials in controlling channel response. Geomorphology, 79, 361–383. DOI:10.1016/j.geomorph.2006.06.037

Simpson, W.G., & Ostrand, K.G. (2012). Effects of entrainment and bypass at screened irrigation canals on juvenile Steelhead. Transactions of the American Fisheries Society, 141(3), 599-609. DOI: 10.1080/00028487.2012.683473

Snyder, D.T., & Morace, J.L. (1997). Nitrogen and phosphorus loading from drained wetlands adjacent to Upper Klamath and Agency Lakes, Oregon (U.S. Geological Survey water-resources investigations report 97-4059). Retrieved from https://pubs.usgs.gov/wri/1997/4059/report.pdf

U.S. Department of the Interior Bureau of Reclamation (USBR) (2013). Guidelines for collecting data to support statistical analysis of water quality for wetland planning. Retrieved from: https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/Wetland%20water%20quality%20manual32-pmrevBender.pdf

U.S. Department of the Interior (2014). Environmental assessment for aquatic and riparian habitat enhancement. Retrieved from: http://kbifrm.psmfc.org/wp-content/uploads/2016/12/USDI_2014_0024_Environmental-Assessment.pdf

U.S. Department of the Interior (2018). 2018 Annual operations plan. Klamath Project, Oregon-California, Mid-Pacific Region. Retrieved from: https://www.usbr.gov/mp/kbao/programs/docs/2018-klamath-project-ops-plan.pdf

Washington Department of Fish and Wildlife (WDFW) (2003). Design of road culverts for fish passage: 2003 edition. Retrieved from: https://wdfw.wa.gov/sites/default/files/publications/00049/wdfw00049.pdf

Zedler, J.B., & Kercher, S. (2005). Wetland resources: status, trends, ecosystem services, and restorability. Annual Review of Environmental Resources, 30, 39-74. DOI: 10.1146/annurev.energy.30.050504.144248

Chapter 4 RESTORATION PRIORITIZATION FRAMEWORK

INTRODUCTION

The purpose of the Restoration Prioritization Framework (RPF) is to guide and inform restoration actions in the Upper Klamath Basin (UKB). The original intention of the framework was to include prioritization of restoration actions (aligned with the modified condition conceptual models) in response to impairments. During the course of the project however, the Upper Klamath Basin Watershed Action Plan (UKB WAP) Team determined there is currently not enough data available to apply a prioritization to restoration actions. Instead, the UKB WAP Team proceeded by quantifying impairments where possible, to enable restoration practitioners to make informed decisions on the allocation of restoration resources.

The quantified impairments form the basis of the RPF decision support tool (an online mapping interface), which enables practitioners to create an overlay analysis of select existing conditions models (impairments). The goal of the tool is to use the best available data to describe the existing conditions in the UKB as defined by the conceptual models, and direct practitioners to where in the UKB restoration and/or further study is most needed.

The UKB WAP Team recommends ground-truthing and further study at all potential restoration sites identified by the RPF decision support tool to confirm the level of impairment and determine appropriate restoration actions. The impairment metrics provided by the RPF tool are not static and were developed to ingest new and better data as it becomes available. This flexibility gives practitioners the option to refine the metrics as new ideas and conceptual models emerge.

Table 4-1 summarizes which existing conditions conceptual models are represented in the RPF tool, and the name of the corresponding metric. For the conceptual models without adequate data to quantify impairment the table entry for the RPF tool field is blank. Note, for the tailwater returns conceptual model, a water quality metric was developed because there was not data to more explicitly quantify impairments of tailwater returns; this is described in more detail in the “Water quality” section (beginning on page 82).

Development process

The RPF development process began with a review of the conceptual models of impairments, their systematic causes (abiotic and biotic), and associated restoration actions developed prior to the UKB WAP process. The FlowWest team conducted a thorough survey of available data and studies related to the conceptual models with input from the UKB WAP Team. Upon review with the UKB WAP Team, the group identified many data gaps, and conceptual models with insufficient data (both temporally and spatially) to adequately quantify as metrics within the RPF tool. Given the available data, the UKB WAP Team focused on metric development for impairments for select conceptual models as shown in Table 4-1.

The UKB WAP Team then formed subgroups for each impairment conceptual model, in order to review in greater detail, the available data for that impairment and determine the best approach for quantification in a metric. Subgroups included UKB WAP Team members as well as identified experts from other agencies and organizations in the UKB. The first meeting of the subgroups involved reviewing the proposed data sources, determination of whether that data could quantify the impairment--if not directly, then indirectly, and finally a discussion around the ideal data to measure the impairment. The

TABLE 4-1: SUMMARY OF CONCEPTUAL MODELS AND REPRESENTATION IN RESTORATION PRIORITIZATION FRAMEWORK

Conceptual Model	**Quantified in RPF tool as:**
Channel incision	--
Channelization	Channelization metric
Tailwater Returns	Water Quality metric
Water Withdrawals	--
Fish Screens	Fish screens metric
Levees and berms	Levees and berms metric
Large woody debris	--
Wetland conversion	--
Fish passage barriers	Fish passage barriers metric
Riparian grazing	Riparian metric
Roads	--
Spawning gravel	--
Springs	--

subgroups also explored creating metrics to define costs or constraints related to addressing impairments and quantifying the benefits of doing so, however, the group determined there was inadequate data to do so. Typically, what came out of the first meeting for each impairment were recommendations for impairment measures from the subgroup that the FlowWest team could generate draft versions of for subsequent review. The measures could then be synthesized into a metric representing spatially explicit, scaled impairment.

Once FlowWest had prepared draft measures from the available data for each impairment, the results were reviewed with the subgroup to determine which measures should be incorporated into the impairment metric. The subgroups also determined how to scale or score the metrics. For consistency across metrics, the subgroups determined to calculate scores at the reach-scale; each reach would be given a score per impairment metric and these could be readily overlaid in GIS. Reaches were defined geomorphically, based on the O’Connor et al. (2015) reach designations in the UKB. Where reaches were undefined in the UKB study area for the UKB WAP by the O’Connor study, FlowWest geomorphologist Anthony Falzone, designated geomorphic reaches following using the same methods as in O’Connor et al. (2015). For consistency across metrics, the reach scores were determined based on the quantile values of the metric results. For example, a metric may consist of more than one measure and those resultant values summed per reach. The distribution of those values was then calculated and reach scores were assigned based on the quantile values; a reach scored a “1” if it was less than or equal to the 25th percentile, a “2” if between the 25th percentile and the median, a “3” if between the median and the 75th percentile, and a “4” if greater than the 75th percentile.

After draft metrics were prepared, the subgroups reviewed the metric results, presented as maps of scaled impairment, to refine and revise the methods and to further identify limitations and strengths of the metrics based on their knowledge of the UKB and current impairment conditions. The metrics were then presented to the entire UKB WAP Team for additional review, feedback, and revision. Next, UKB WAP Team members sought out additional feedback on the metrics from external reviewers. This feedback was reviewed by the FlowWest team, and in some cases by the metric subgroups, to determine the best way to incorporate the feedback into the metric and/or into the description of metric limitations.

IMPAIRMENT METRICS: EXISTING CONDITIONS CONCEPTUAL MODELS QUANTIFIED IN THE RPF TOOL

RPF decision support tool methods

Spatial data was used to create each impairment metric in GIS, and appropriate metadata written for each data layer. Statistical analysis of the data was completed using R rather than in GIS to enable more readily available documentation of the analysis and to save a code repository. The R code repository is available on GitHub for UKB WAP Team members. Using R for the statistical analysis enables the work can be replicated and modified for future versions of the UKB WAP.

Reach-scale impairment metrics per watershed are visualized as maps in the subsequent section. The reach delineations originally developed by O'Connor et al. (2015) for the mainstem Sprague River were expanded to cover the streams in the Klamath Tribes UKB streams layer within the project extent. The GIS data of the reaches, along with the metric results, will be available to explore and download on the UKB WAP web based RPF tool.

Impairment metrics

In the RPF tool, impairments are quantified using impairment metrics. The metrics work with a scoring system that adds points for factors that increase impairment and subtracts points for factors that mitigate impairment. For each metric below, the data and methods used are described, a map of the results is provided, as well as the limitations of the metric.

As each impairment is influenced by different factors, each impairment metric has its own scoring system. Therefore, different impairments cannot be quantitatively compared to each other. For instance, an impairment score of 3 for channelization should not be interpreted as more impaired than an impairment score of 2 for riparian grazing, as they are both being calculated in a different way.

Channelization (channel straightening)

Data and methods

The channelization metric quantifies impairment based on the channelization conceptual model, which is defined as an engineered channel realignment practice, including channel straightening. The data used for this metric is a shapefile of channel alignment changes (Klamath Tribes, 2015), a result of the Klamath Tribes Restoration Opportunities Analysis (FlowWest, 2017). The data shows the linear extent of channel alignment changes from historic conditions for the Sprague, Upper and Lower Williamson, and Wood River. For the metric, the FlowWest team added the reach name for each channel alteration feature from our expanded reach delineation dataset. Most of the channelization (channel straightening) alteration features fell within one reach. There was one case where a channelization (channel straightening) change spanned two reaches (Upper Sun Creek and Sun Creek); and that feature was split at the reach boundary and the two parts were assigned to the respective reaches. There was also one channelization feature that nearly spanned two reaches. In this case, 50% of the total alignment change length was assigned to the Sevenmile Canal reach and 50% to Lower Sevenmile Canal reach.

The channelization metric was calculated using the following steps:

1. For each reach, the channelization lengths were summed.
2. The length of total channelization per reach was divided by the reach length.
3. The distribution of the normalized channelization per reach values was calculated, and the metric score was based on the quantile values (25th percentile, median, and 75th percentile) as shown in Table 4-2. The channelization metric score was assigned on a scale of 1- 4 (with 4 being most impaired).

TABLE 4-2: METRIC SCORING BASED ON DISTRIBUTION QUANTILES

[Minimum - Q25]	[Minimum - Q25]	[Minimum - Q25]	[Minimum - Q25]
(Q25 - Q50]	(Q25 - Q50]	(Q25 - Q50]	(Q25 - Q50]

Impairment metric results

See page 89, Figure 4-2.

Limitations

Limitations for the channelization metric relate to the data used. The FlowWest channel alignment change dataset was digitized using aerial imagery. Aerial photos were only available beginning in the 1950s, after significant anthropogenic changes had already occurred. Furthermore, in some areas the channel was not visible in historical aerial imagery, particularly where the channel is narrow and/or under dense vegetation canopy. The FlowWest data was also not ground-truthed, so the information is solely based on what was identifiable in aerial imagery and elevation data. Based on feedback from the external reviewers, they recommended in particular that the results in Upper Williamson should be ground-truthed.

Levees and berms

Data and methods

The levees and berms metric quantifies impairment based on the levees and berms conceptual model, which identifies these structures as impairments to the floodplain-river connection and has a variety of impacts as described in Chapter 3. The data used for this metric is the flow obstructions geodatabase (Klamath Tribes, 2016a), a product of the Klamath Tribes Restoration Opportunities Analysis (FlowWest, 2017). From this geodatabase of flow obstruction features for the Sprague, Upper and Lower Williamson, and Wood River, berms and levees features were selected out for the analysis. Feature attribution from this data was also used in creating the metric, including: the number of banks obstructed by a levee or berm, the feature length, the distance from the channel, and feature height measurements. For this metric, impairment was defined at the feature-, rather than the reach-scale, given the resolution of available data.

The levees and berms metric is the sum of five separate measures described below:

1. *Number of banks obstructed*
   Levees or berms that obstructed one bank were assigned one point, and those that obstructed both stream banks were assigned two points.
2. *Length of levee or berm*

Levees and berms were scored on a three-point scale based the feature length: one point for less than or equal to 300 feet, two points for between 300 and 800 feet, and three points for greater than or equal to 800 feet.

3. *Proportion of reach that is obstructed by levees or berms*
   The levee and berms lengths were grouped by reach, summed, and then divided by the reach length. The distribution was then calculated for the proportion of leveed or bermed length within a reach, and each reach was given a score based on the distribution quantiles as shown in Table 4-2, with a "4" being most impaired. These reach-level scores were then assigned to the levees and berm features within the respective reaches.
4. *Distance from channel*
   If the feature was less than or equal to 25 feet from the channel, it was assigned four points, three points for from 25 to 50 feet, two points for from 50 to 75 feet, and one point for from 75 to 100 feet.
5. *Floodability index*
   The floodability index is defined as the difference between the elevation of ground surface at the backside (away from the channel) of the levee or berm and the water surface elevation. The distribution of flood indices per feature was calculated and each feature was given a score based on the distribution quantiles as shown in Table 4-2, with a "4" being most impaired.

The sum of the above five measures was calculated and assigned per levee and berm feature as the overall metric. The median of levee and berm feature scores was assigned as the reach metric score.

Impairment metric results

See page 90, Figure 4-3.

Limitations

Limitations of this metric associated with the data used include that the features mapped based on remotely sensed elevation and imagery data with minimal field verification. Field verification included confirmation of the presence of levees and berms as indication from the data and did not include any confirmation of measurements associated with the data (distance from channel, backside levee elevation, etc.).

There are also limitations associated with this metric in regard to assumptions about floodplain area made accessible if the levee or berm were to be removed. To approximate potential access to floodplain area the UKB WAP Team used the floodability index, however this proxy is a coarse representation of the potential impact of levee removal. To evaluate levee removal scenarios more adequately, a hydrodynamic model should be developed to investigate increases in floodplain inundation from levee breaches and removal.

As with all the metrics, the UKB WAP Team recommends ground-truthing and future investigation into potential restoration sites based on the metric results. Many levees and berms provide flood protection and other beneficial functions, which were not integrated into this metric. The benefits of levees or berms should be reviewed on a case by case basis when evaluating potential restoration projects. Levee or berm breaches and removal should also be prioritized based on proximity to other quality habitat, and/or leverage cumulative effects of other nearby projects. Also, the metric does not distinguish between riverbank levees and berms versus levees near lakes and delta areas, and is more suited to identify impairments associated with channel confinement rather than shoreline or delta impairments associated with levee structures.

Fish passage barriers

Data and methods

The passage barriers metric quantifies impairments based on the fish passage barriers conceptual model, which defines the impacts to fish needs and channel morphology associated with the construction of barriers, as described in Chapter 3. The data used for this metric is the fish passage barriers database developed by Trout Unlimited (Trout Unlimited, 2018). This data was synthesized from Oregon Department of Fish and Wildlife (ODFW) passage barrier data, FlowWest diversion point data, the National Anthropogenic Barrier Dataset (USACE), Trout Unlimited data based on aerial imagery, and road and stream intersection points. All of the passage barriers in the data are within one kilometer of redband trout distribution layer and were reviewed to remove overlaps and potential barriers on canals or ditches. The passage status attribution was also reviewed and updated by Trout Unlimited.

The metric was developed by first selecting passage barriers within 1,000 feet of the channels in the study area. The selected barriers were then filtered to remove barriers that were recorded as having a passable status. Next, the barriers (point data) were spatially joined the UKB reach layer to assign a reach with each barrier. A barrier count per reach was calculated and normalized by the reach length. The distribution of the normalized passage barrier counts per reach was calculated and each reach was scored based on the distribution quantiles as shown in Table 4-2, with a “4” being most impaired.

The geomorphically-defined reaches were also ranked in ascending order from the confluence with the mainstem (i.e. the reach closest to the mainstream received a “1”, the next reach upstream received a “2”, and so forth). The reach ranking was integrated into the metric to prioritize addressing passage barriers nearer to the mainstem and quantify the importance of continuous passage moving upstream. If the reach rank was a “1” (confluent with mainstem) an additional two points were added to the barrier count score, and if the reach rank was “2” (next upstream reach from reach ranked “1”), one additional point was added. No additional points were added for reaches ranked “3” and above.

Impairment metric results

See page 91, Figure 4-4.

Limitations

The passage barrier metric does not include information about fish species life stage or seasonality. The barrier status needs to be regularly reviewed and updated, and an updated passage barrier dataset from ODFW is anticipated to be made available in 2019 and should be integrated into this metric if possible. The UKB WAP Team considered a scenario in which a restoration practitioner may want to prioritize removal of a passage barrier if it was the only barrier in a reach; the passage barrier metric would not be useful in this scenario, but the point passage barrier data is also provided in the UKB WAP web-based RPF tool and could be used for that type of analysis.

Riparian grazing

Data and methods

The riparian areas metric investigates impairment based on the riparian conceptual model. This conceptual model describes the potential impacts to floodplain, riparian, and instream condition from unmanaged grazing in these areas, as described in Chapter 3. The data used for this metric (Klamath Tribes, 2018) was developed by FlowWest for the Klamath Tribes Upper Klamath Basin Riparian Conditions Analysis using spectra-based land cover classification of aerial imagery (FlowWest, 2018). To decrease variability between years in land cover and to minimize shadows, a median composite image was used in the land cover classification process. The composite image was generated using the median value for each band at each pixel across the NAIP images taken in years: 2009, 2011, 2012, 2014 and 2016. This output polygon data covers the Sprague, Upper and Lower Williamson, and Wood River basin, and identified the following land cover classes within a 100-foot buffer of the channel edge: bare earth / dead or dormant grass, grasses (native and non-native), and trees.

The riparian areas metric was developed by first creating a 200-foot buffer on the Klamath Tribes UKB stream layer. Next, the land cover categories within the buffer were tabulated for each reach. The proportion of the bare earth / dead or dormant grass land cover type was used to identify potentially impaired riparian areas, where a higher proportion bare earth / dead or dormant grass was classified as more impaired. The distribution of the proportions of bare earth / dead or dormant grass per reach was calculated and each reach was scored based on the distribution quantiles as shown in Table 4-2, with a "4" being most impaired. The distribution of the proportion of the trees class results by reach was also calculated and interpreted as reaches having a higher proportion of tree class were less impaired in the riparian areas. For the Williamson and Wood River basins, a point was deducted from the impairment score if the reach had a tree class proportion in the top 25th percentile. The point deduction was not applied in the Sprague River basin because of the likely inclusion of sagebrush species in the trees land cover class.

Impairment metric results

See page 92, Figure 4-5.

Limitations

A land cover dataset is very limited in terms of the capability of quantifying impairment based on the riparian and floodplain grazing, especially given the coarse scale of the land cover classes. Notably, the metric is not based on riparian function and does not account for fluvial geomorphology as an impairment measure. However, given the lack of available data, the UKB WAP Team determined to use this data to at least guide restoration practitioners in terms of areas where further study is warranted based on the land cover type. Other caveats to note about the land cover include: the imagery was collected in the summertime for all of the years used to create the median composite image and field-verification was not conducted for the data. Furthermore, grass results could indicate irrigated lands, and dead/dormant grass and bare earth were classified in the same category. Shrubs were likely classified in the trees category. The data provides no indication of species, wetland indicator status, soil stabilizer properties, diversity, age, or vigor of vegetation. The presence/absence of grazing was not confirmed or evaluated.

Fish screens

Data and methods

The diversion screening metric quantifies impairments based on the irrigation diversion screening conceptual model, which defines the entrainment impacts to fish from irrigation diversions through unscreened structures, as described in Chapter 3. The data used for this metric includes a geospatial dataset of irrigation diversions and returns points developed by FlowWest (Klamath Tribes, 2016b). FlowWest created this layer of irrigation diversion and return points for the Klamath Tribes Restoration Opportunities Analysis, by mapping features from aerial imagery and the National Hydrography Dataset, and integrating data from ODFW, the Oregon Watershed Restoration Inventory, and a 2007 airborne thermal infrared remote sensing study (FlowWest, 2017). The data layer is a point file with attribute information that identifies the point as an irrigation diversion point or a return flow location and includes a screen status field. This data covers the Sprague and Williamson rivers. For the Wood River

Valley, a dataset of points of diversion developed by Trout Unlimited was used (Trout Unlimited, 2016). Trout Unlimited created this layer of diversion points based on water rights spatial data from the Oregon Water Resources Department (OWRD) website, OWRD's Water Right Information System (WRIS) data, and Klamath Basin Fish Screen Inventory for the Wood River Subbasin. This data also includes a screen status field.

For the FlowWest diversion and return point data (Sprague and Williamson), the agricultural return points were filtered out. Each diversion feature was assigned a point value based on the screen status. Diversions with a screen status of 'No Screen' were assigned two points, 'Unknown' and 'Undefined' status were assigned one point, and 'Screened' status were not assigned points. For the TU diversion data (Wood), points were assigned based on the following screen status values: 'Does not meet ODFW criteria,' 'Nonfunctioning,' and 'No' were given two points; 'Unknown' and 'Unknown status' were assigned one point; and 'Functioning' and 'No longer a diversion' were not assigned points.

The total points for all diversion features within a reach were summed and normalized by reach length. The distribution of the normalized diversion points per reach was calculated and each reach was scored based on the distribution quantiles as shown in Table 4-2, with a "4" being most impaired.

Impairment metric results

See page 93, Figure 4-6.

Limitations

The dataset used for this metric is limited; the only information on screening comes from ODFW fish passage database. Additional surveying efforts and field verification are needed. Due to the limited information on screening, much of fish screen status is classified as unknown or unidentifiable (79% in the FlowWest data, 50% in the Trout Unlimited data). Ground-truthing of diversion screen status is also needed to confirm the impairment. This metric does not provide information about where fish are entering and exiting irrigation systems, and there is a sense from local landowners that fish may be entrained at irrigation returns as well as diversions.

Water quality

Data and methods

The water quality metric investigates impairment based on the tailwater returns model. This conceptual model describes the impacts to water quality and fish needs resulting from ditch construction to concentrate tailwater and facilitate drainage, as described in Chapter 3. Data used for this metric includes the irrigation return point features from the irrigation and return database developed by FlowWest for the Klamath Tribes Restoration Opportunities Analysis (Klamath Tribes, 2016b; FlowWest, 2017). The data layer is a point file with attribute information that identifies the point as an irrigation diversion point or a return flow location. This data covers the Williamson and Sprague rivers. Additionally, an analysis of water quality in the Sprague at the subbasin scale was conducted to further investigate water quality impairment for this metric. This analysis summarized the Klamath Tribes water quality monitoring data by subbasin and was developed in collaboration with one of the authors of the Walker et al., 2015, which analyzed spatial and temporal nutrient loading in the basin. The cumulative flow-weighted mean concentration of constituents was used per subbasin to quantify impairment. The subbasins used in the analysis are show below in Figure 4-1.

For the Sprague River, the water quality metric includes measures based on the irrigation return data and well as the Sprague subbasin water quality analysis. For the Williamson River, the metric includes

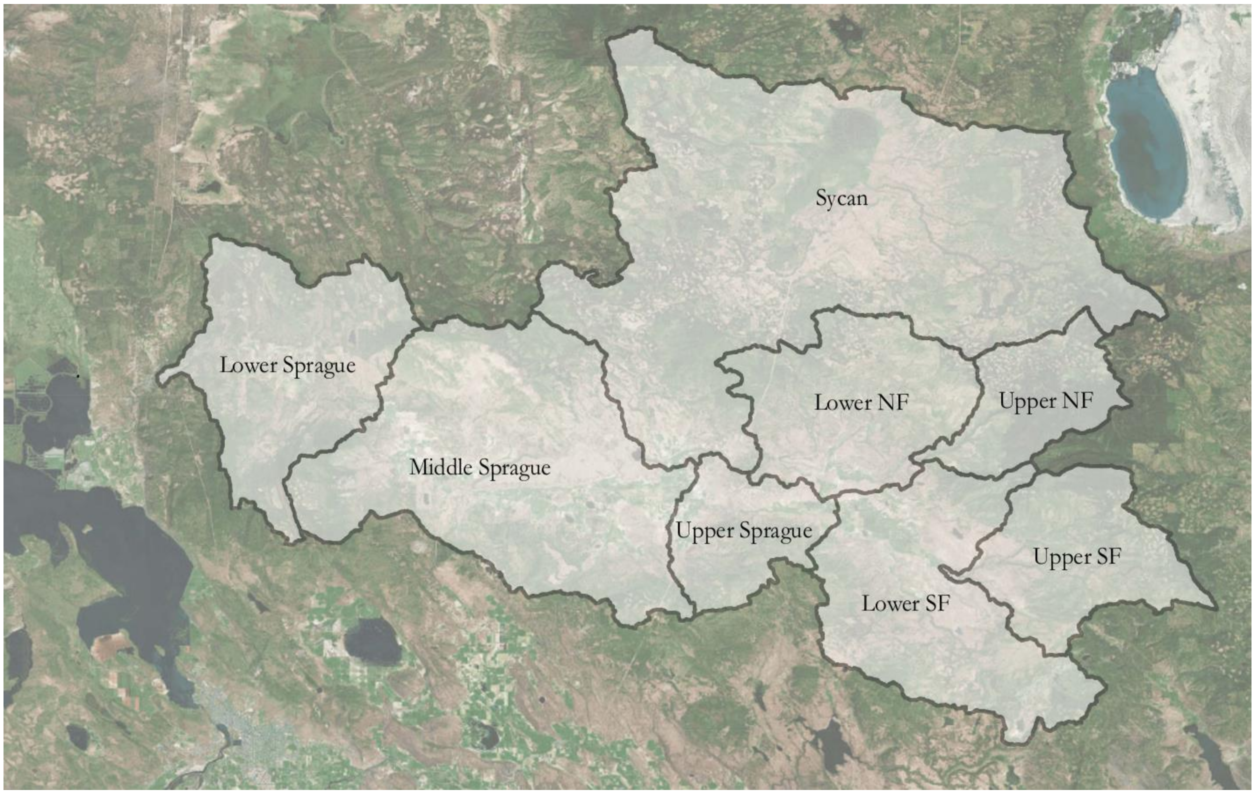


FIGURE 4-1: SPRAGUE SUBBASINS IN WATER QUALITY ANALYSIS

the irrigation return measure alone. The metric was not developed for the Wood River Valley due to a lack of available data.

Irrigation return measure

As with other metrics, the number of irrigation returns were summed by reach and normalized by reach length. The distribution of the normalized irrigation return points per reach was calculated and each reach was scored based on the distribution quantiles as shown in Table 4-2, with a "4" being most impaired.

Sprague subbasin water quality measure

From the Klamath Tribes water quality data, total phosphorus (TP) and particulate phosphorus (PP) were selected to represent impairment in the summer, and TP and Total Suspended Solids (TSS) were used to represent impairment for the winter. The cumulative flow-weighted mean concentrations in each subbasin for Summer TP and PP, and Winter TP and TSS, were scaled to be between 0.5 and 1.0. These values were then summed to create the subbasin-scale water quality measure (values range from 2.05-3.95). The water quality measures were then assigned to the reaches that intersect with the subbasins. If a reach intersected more than one subbasin, the higher score was assigned to the to the reach.

To address the lack of water quality data in the Wood River Valley reaches, the UKB WAP Team created a dataset identifying reaches that are known to be impaired in terms of water quality.
A map of these reaches is shown along with the metric results maps below and presented in the web based RPF tool.

Impairment metric results

Sprague River subbasin: see page 94, Figure 4-7.
Williamson River subbasin: see page 95, Figure 4-8.
Wood River subbasin: see page 96, Figure 4-9.

Limitations

As noted in the Data and Methods section above, the spatial extents for available water quality data in UKB are inconsistent. Also, the water quality metric is calculated at the subbasin-scale but attributed to the reach-scale, so in the Sprague basin differentiation between reaches in the same subbasin is reflective of the irrigation return density results rather than the water quality analysis findings. The type of tailwater return is not defined in the data used. For instance, a tailwater return that flows directly into the river, may have a more significant impact on water quality than a ditch that flows through an intact riparian area prior to returning to the river. Practitioners should also note, particularly when using the metric in the Williamson reaches, many other factors impact water quality besides direct tailwater returns, including riparian condition, floodplain connection, channel complexity, and more. To identify priorities, it is recommended to overlay these other metrics along with tailwater returns. As with all the metrics, field-verification of impairment are strongly recommended for practitioners looking to plan and implement restoration in areas identified with the decision support tool.

Critical habitat

Data and methods

Critical habitat data are not tied to a specific conceptual model, but were identified during the UKB WAP process as helpful data to overlay with the impairment metrics. The following critical habitat layers are provided as part of the decision support tool:

1. Lost River and shortnose sucker stream critical habitat (USFWS, 2012)
2. Bull trout stream critical habitat (USFWS, 2010)
3. Oregon spotted frog critical habitat (USFWS, 2016)

Critical habitat maps

Lost River and shortnose sucker: see page 97, Figure 4-10.
Bull Trout: see page 98, Figure 4-11.
Oregon spotted frog: see page 99, Figure 4-12.

Web-based RPF tool

To aid restoration practitioners in the identification of impairments in the UKB, the UKB WAP Team has provided an online Restoration Prioritization Framework (RPF) tool. As mentioned at the start of this chapter, this tool does not suggest a prioritization of restoration actions. Instead, it quantifies impairments on a local (reach-level) scale using impairment metric results. These metric results enable restoration practitioners to make informed decisions on the allocation of restoration efforts.

The RPF tool consists of a website with a range of impairment maps of the basin which can be interactively explored. The maps display the above described impairment metric results on a reach-scale level. Next to this, the metric results data can also be downloaded from the tool, to enable restoration practitioners to use the data in their own applications. The RPF tool was made using ESRI Story Maps.

The tool can be found under the following link:
[INSERT LINK TO TOOL]

RPF tool use cases

The RPF tool can be used for many purposes. For example, if a restoration practitioner is seeking to improve a certain type of impairment in the basin, for instance by focusing on riparian grazing management. They can use the tool to determine where impairment by riparian grazing is highest and focus their efforts on those locations. As another example, assume a restoration practitioner is looking to gather data on impairments in the basin. They can download the impairment data set from the RPF tool in order to initiate or complement their own data sets. Moreover, downloading the impairment data sets will enable the restoration practitioner to immediately identify gaps in the available data that can be prioritized for future data gathering efforts.

DATA GAPS AND FUTURE EFFORTS

Throughout the metric development process, the UKB WAP team identified data gaps, data or analysis desired to better quantify impairments, and data needed to quantify costs and benefits associated with implementing restoration actions. Table 4-3 describes data gaps and desired data per conceptual model.

The UKB WAP Team also identified other data needed to better quantify impairments, support decision-making for restoration actions, and estimate the potential costs and benefits of implementation. These are listed below. Some of these data encompass and/or relate to the more specific data desired for the conceptual models in Table 4-3.

Land ownership and land use

Land ownership data with updated contact information is needed for future outreach in order to coordinate landowner support and cooperation, as well as to evaluate the feasibility of restoration actions and their implementation and maintenance. Private land ownership is not desired for regulatory purposes, but instead for future outreach efforts. Public versus private ownership data also informs the regulatory context of implementing restoration projects. Parcel-scale information on irrigation practices in some places would be helpful to evaluate and optimize placement of restoration actions. Private versus public land use data is also critical for evaluating potential restoration actions, to ensure actions are compatible with current land use practices.

Habitat

Additional information about habitat location and quality was a key data need identified during this project. Specific examples of data needs in this category are described in Table 4-3, particularly to support the Riparian and Fish Passage Barrier Metrics, and to enable quantification of several models that were not quantified in this study due to a lack of available data. Data on existing habitat and habitat quality, miles of protected stream, and miles of managed riparian areas were all discussed as important information for future efforts to improve the RPF. During the expert feedback process, a reviewer identified a dataset on groundwater-driven reaches in the UKB as a potentially valuable addition for quantifying instream habitat for fish species. A future version of the UKB WAP could incorporate this data from the Walker et al. (2007) study via the Oregon Department of Water Resources, when available.

Hydrodynamic model

A hydrodynamic model of the UKB is needed to examine different scenarios of changes to existing channel geometry and/or flood control infrastructure, evaluate the potential impacts of restoration actions, and plan and prioritize implementation. This data need came up in the UKB WAP Team discussions regarding the Levees and Berms metric, as well as with the Channelization metric. Even with improved information about levee and berm features, without potential inundation extents, depths, and velocities that could be provided from such a model, it will be difficult to prioritize levee changes under the goal of restoring floodplain-channel connection. Similarly, evaluating and planning channel reconstruction restoration will be greatly advanced by access to hydrodynamic modeling outputs.

Cost

Cost information is a significant data gap for prioritizing restoration activities in the UKB. As described earlier in this chapter, data is currently available to quantify select impairments from the conceptual models outlined in Chapter 3, but not so for the associated restoration actions necessary to achieve restored conditions. Cost information for certain restoration actions was developed in a study for the Klamath Basin Restoration Agreement (Barry et al., 2010). However, now that this assessment is nearly a decade old, it does not include a wide range of techniques which are now available to restoration practitioners.

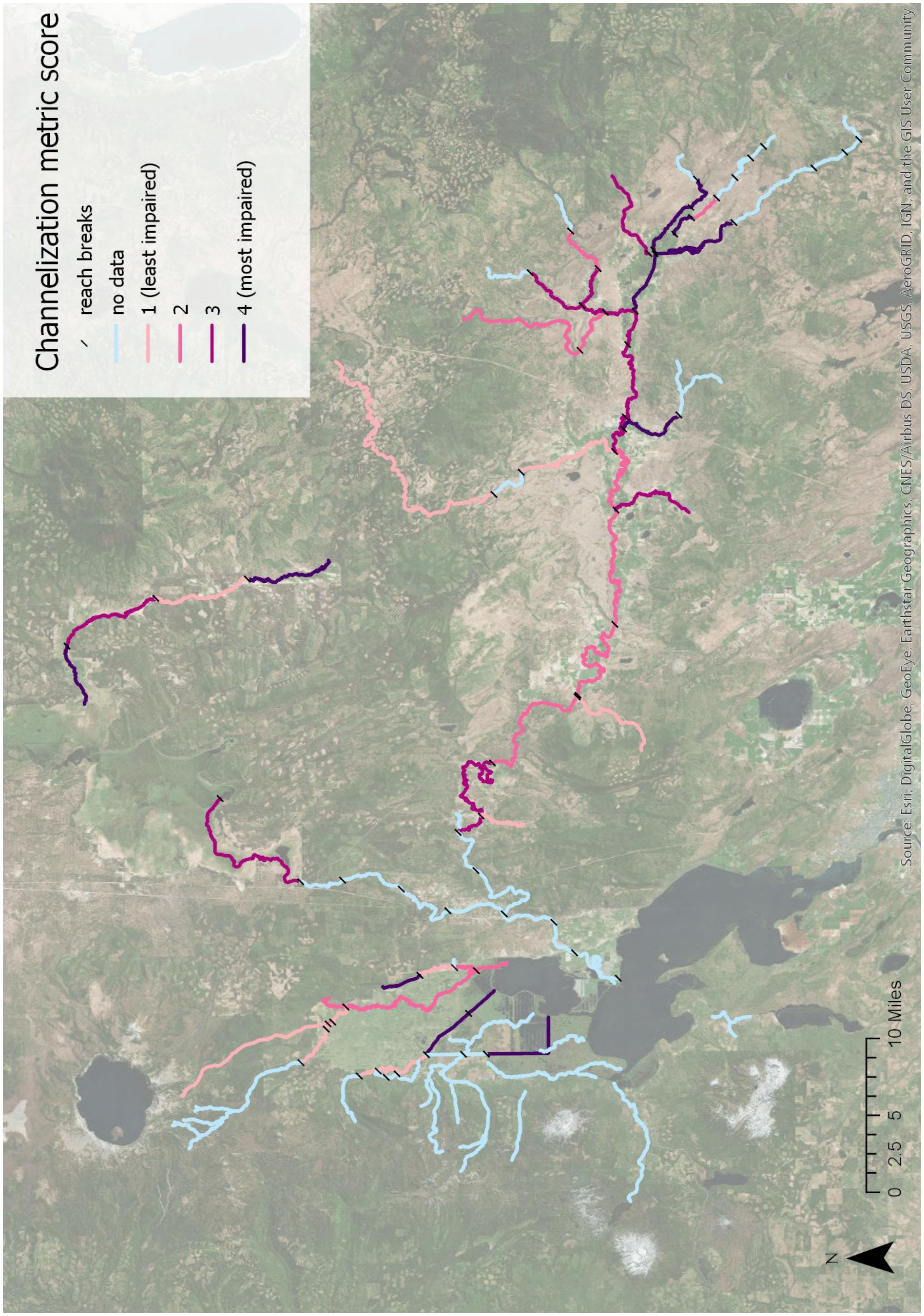
Future cost estimates should be confirmed by pilot projects that are currently on-going and should also include reflections on the efficacy of pilot projects and projected maintenance estimates. There is also spatial data available for many implemented restoration projects from USFWS, USDA Resource Advisory Committees, Bureau of Reclamation, Oregon Watershed Enhancement Board, and the Bureau of Land Management; it would be valuable to future restoration activities to attribute these data with cost information whenever possible.

TABLE 4-3: SUMMARY OF CONCEPTUAL MODELS AND REPRESENTATION IN RPF

Conceptual model	**Available data**	**Future data needs**
Channel incision	--	❖ Historical and current cross sections and bathymetry
Channelization	❖ Channel alignment changes GIS data (FlowWest/Klamath Tribes, 2017)	❖ Sinuosity ❖ Braided index ❖ Flood control infrastructure (to evaluate constraints of any proposed channel realignment)
Tailwater returns	❖ Sprague subbasin water quality analysis ❖ Irrigation diversions and returns (FlowWest)	❖ Additional water quality and flow monitoring throughout UKB
Water withdrawals	--	❖ Additional flow gage data throughout UKB
Fish screens	❖ Irrigation diversions and returns (FlowWest) ❖ Wood River Valley diversions (TU)	❖ Detailed, field-verified irrigation infrastructure data

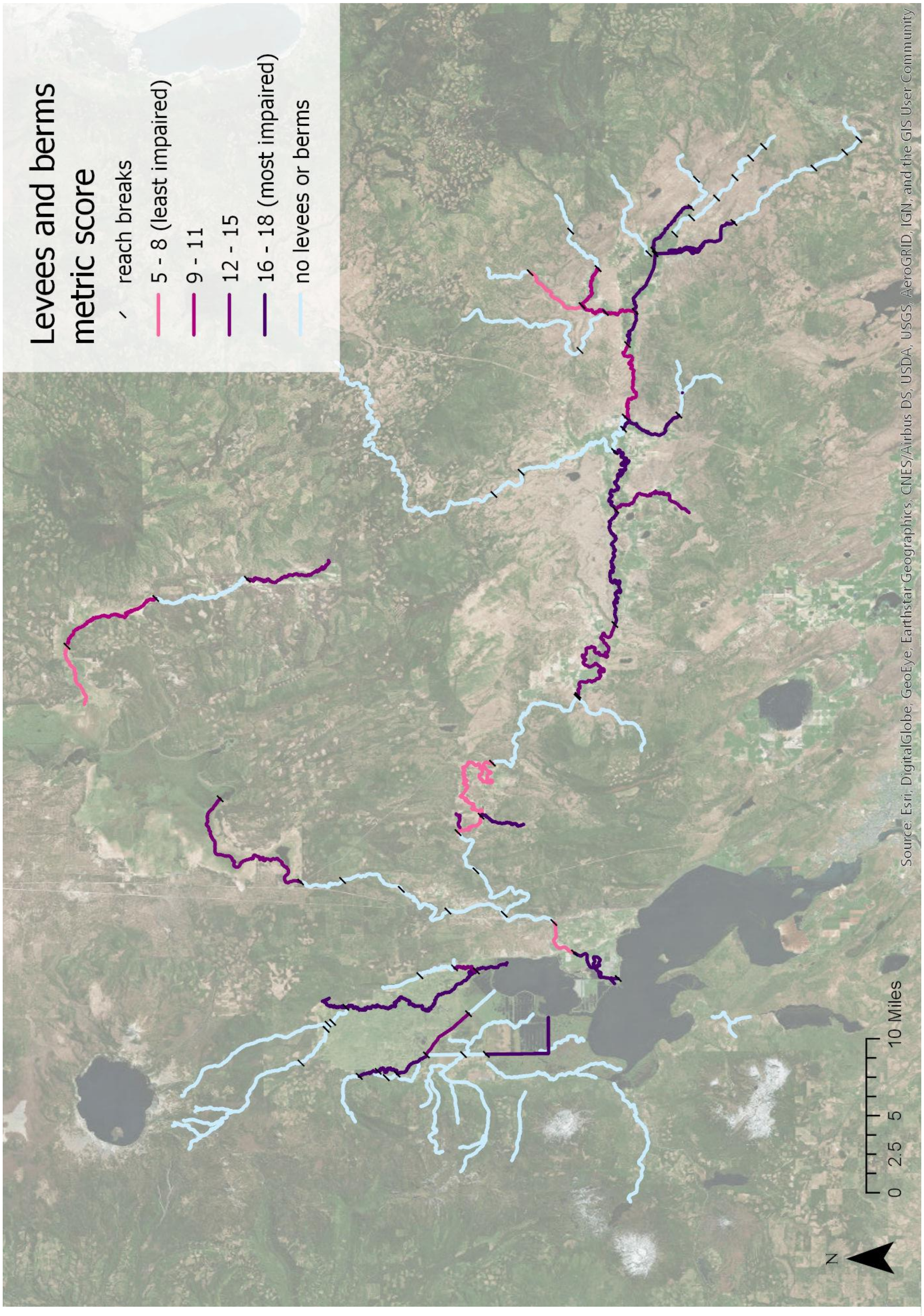
Levees and berms	❖ Channel alignment changes (FlowWest/Klamath Tribes, 2017) ❖ Flow obstructions (FlowWest/Klamath Tribes, 2017) ❖ Critical habitat for fish species	❖ Amount of floodplain made accessible by levee removal (as in results from a hydrodynamic model discussed below on pages 15 and 16)
Large woody debris (LWD)	--	❖ Map areas with lack of LWD ❖ Habitat mapping ❖ Change in riparian zones and forested areas using historical aerial imagery
Wetland conversion	--	❖ Map historic and current lake fringe and floodplain wetlands
Fish passage barriers	❖ Passage barriers data (TU) ❖ Irrigation diversions and returns (FlowWest) ❖ Critical habitat for fish species	❖ Detailed, field-verified irrigation infrastructure data ❖ Species life stage ❖ Seasonality of use by species ❖ Channel gradient ❖ Stream velocity and depth information
Riparian grazing	❖ Landcover classification (FlowWest, 2018)	❖ Vegetation maps with species, wetland indicator status, soil stabilizer properties, diversity, age, and vigor ❖ Farmed and/or grazed lands ❖ Fencing and/or other grazing management practices locations. ❖ Assessment of riparian function ❖ Landcover data with more resolved classes (different grasses, shrubs, etc.)
Roads	❖ Road data (Klamath County) available but does not help quantify associated impairment	❖ Adding culvert attributes to road layer ❖ Road surface ❖ Road condition inventory
Spawning gravel	--	❖ Mapped areas with limited spawning gravel ❖ Habitat mapping

Springs	--	❖ Mapping of disconnected springs



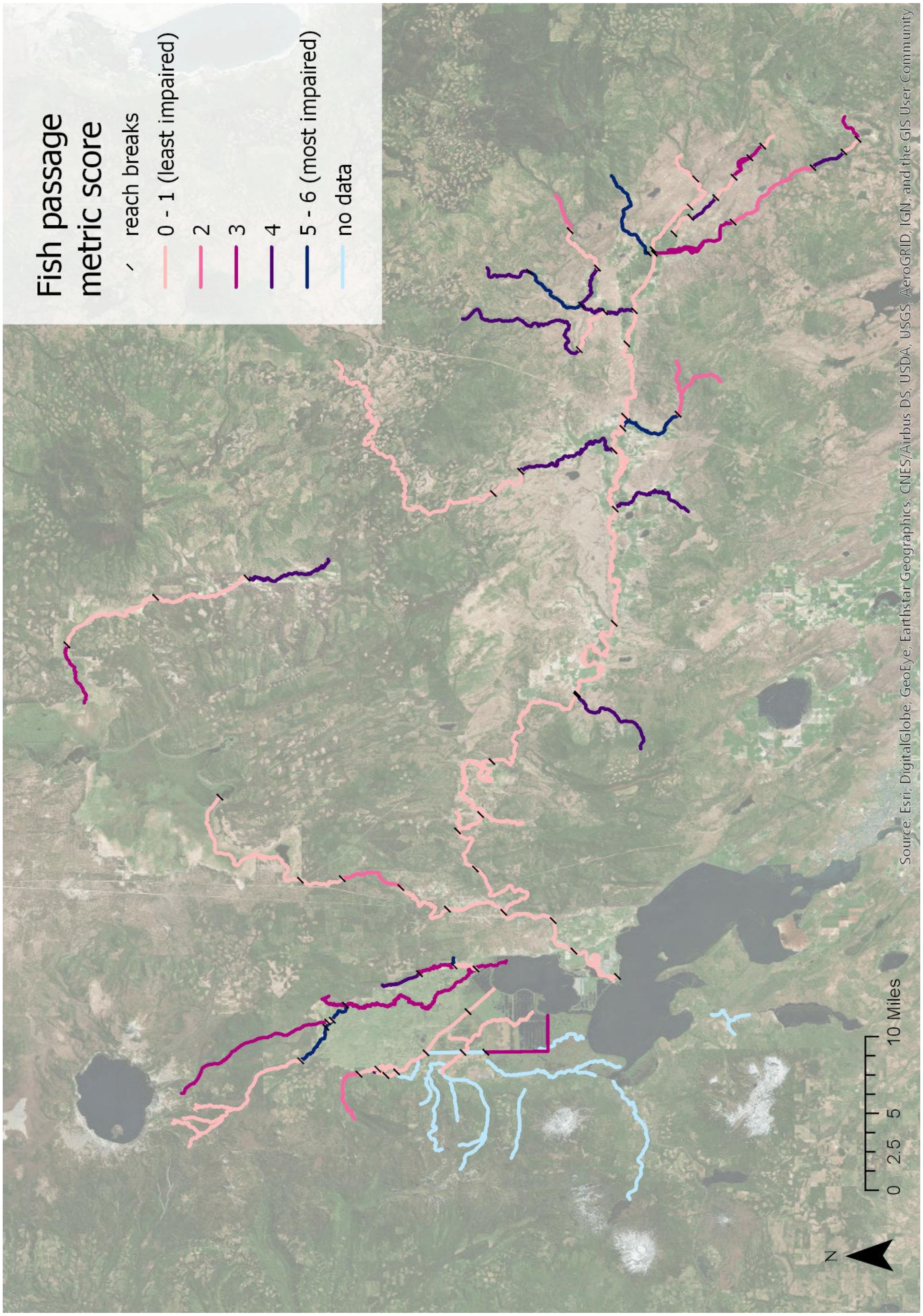
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-2: CHANNELIZATION METRIC SCORE MAP



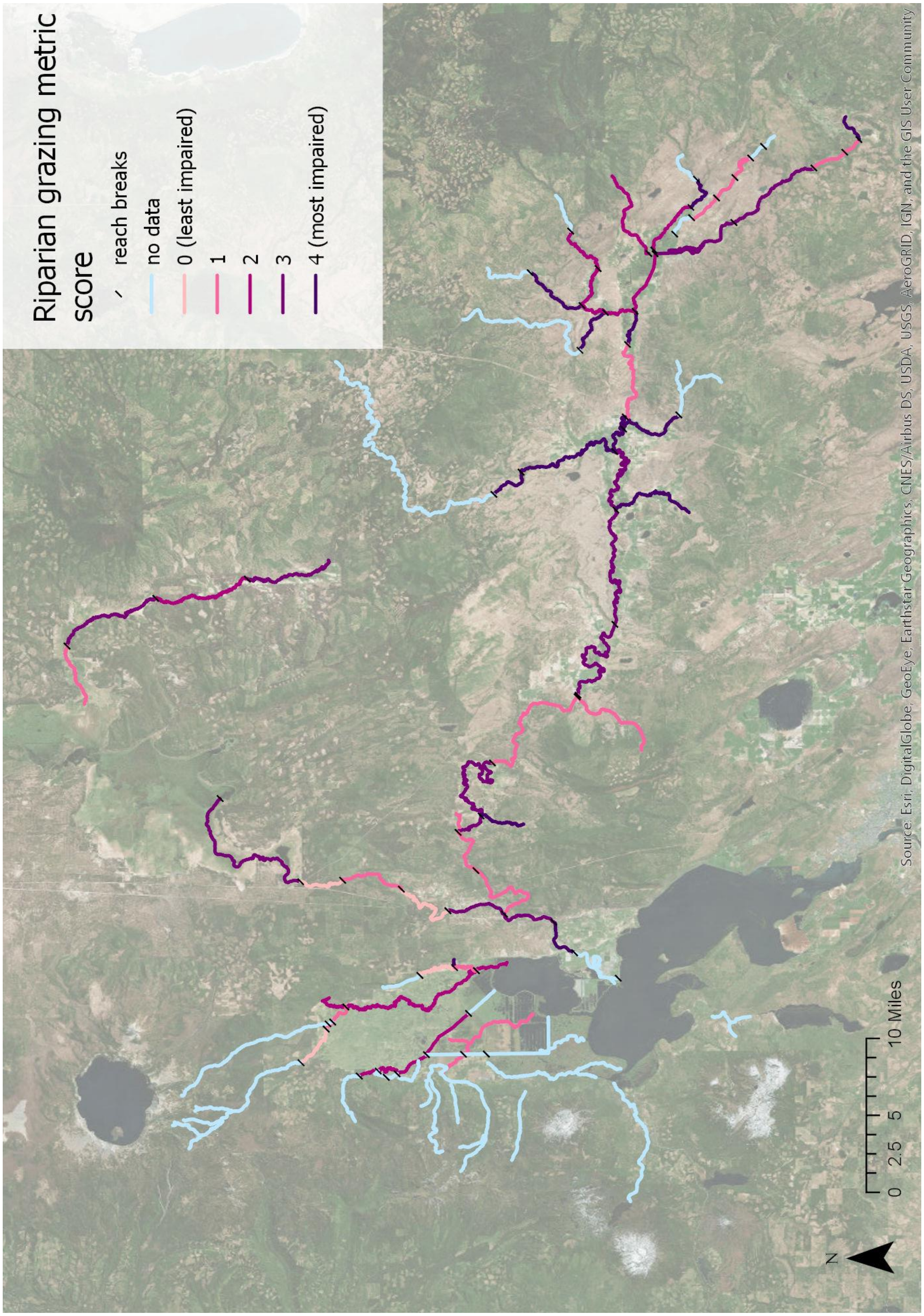
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-3: LEVEES AND BERMS METRIC SCORE MAP



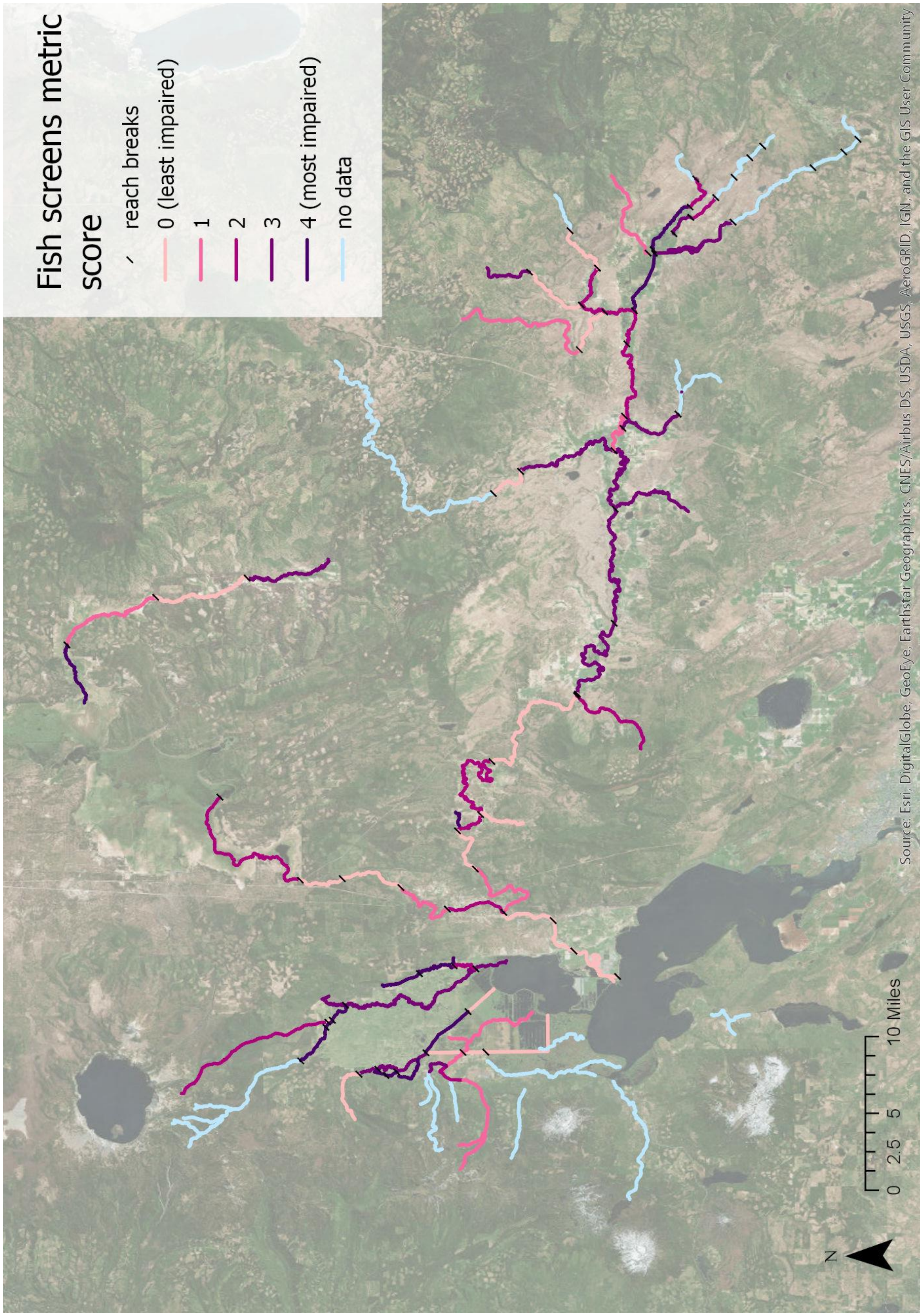
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-4: FISH PASSAGE METRIC SCORE MAP



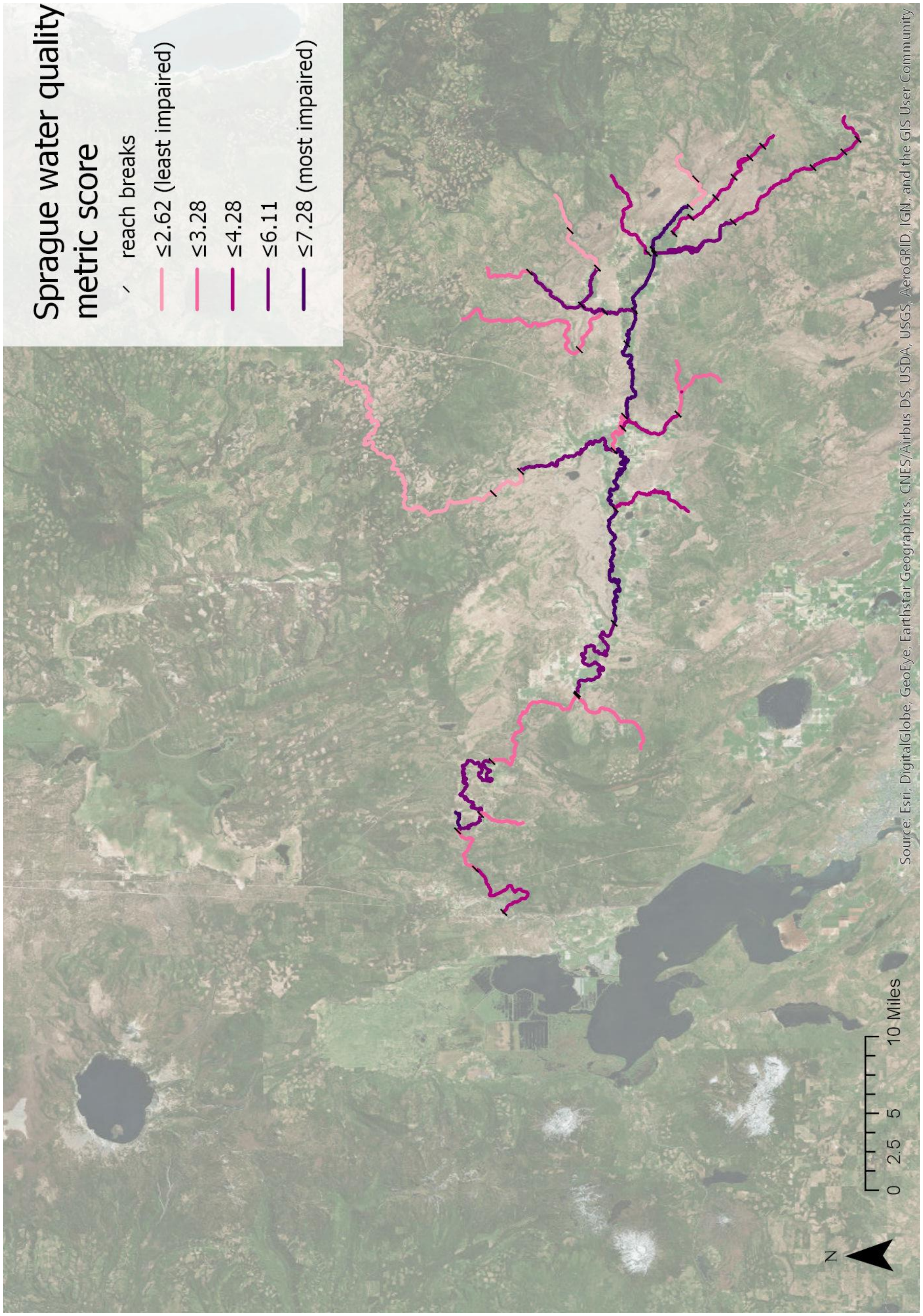
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-5: RIPARIAN GRAZING METRIC SCORE MAP



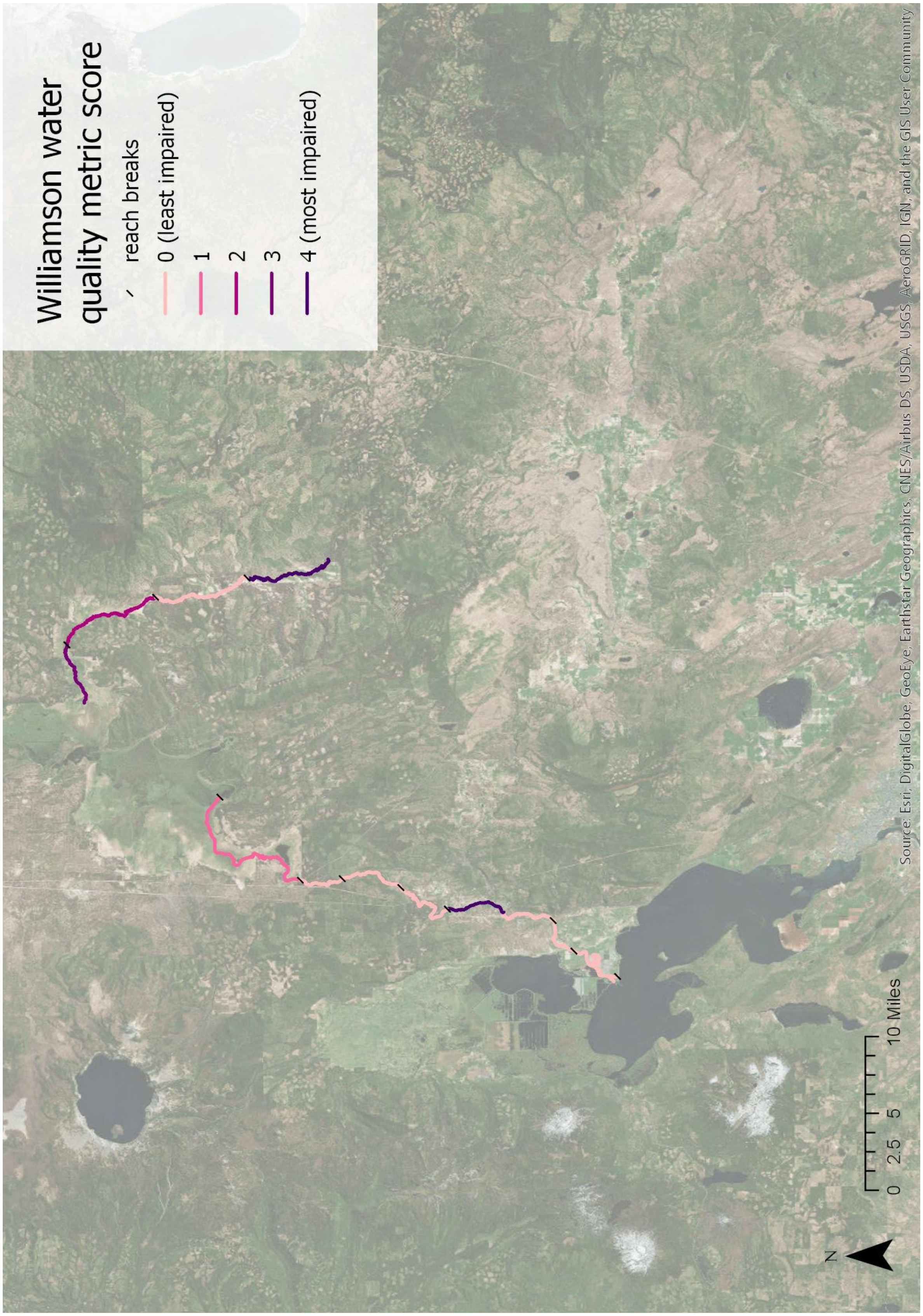
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-6: FISH SCREENS METRIC SCORE MAP



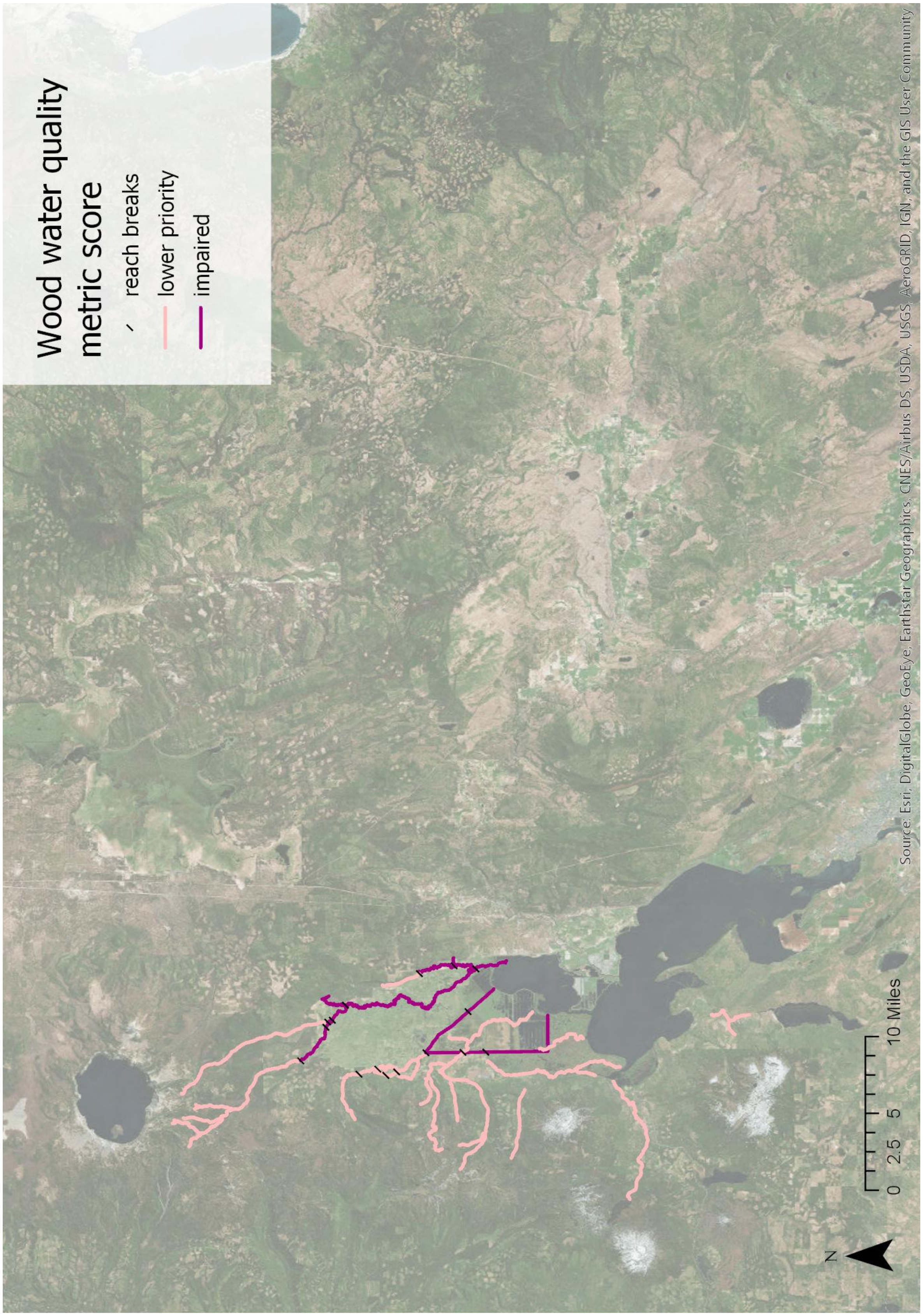
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-7: SPRAGUE WATER QUALITY METRIC SCORE MAP



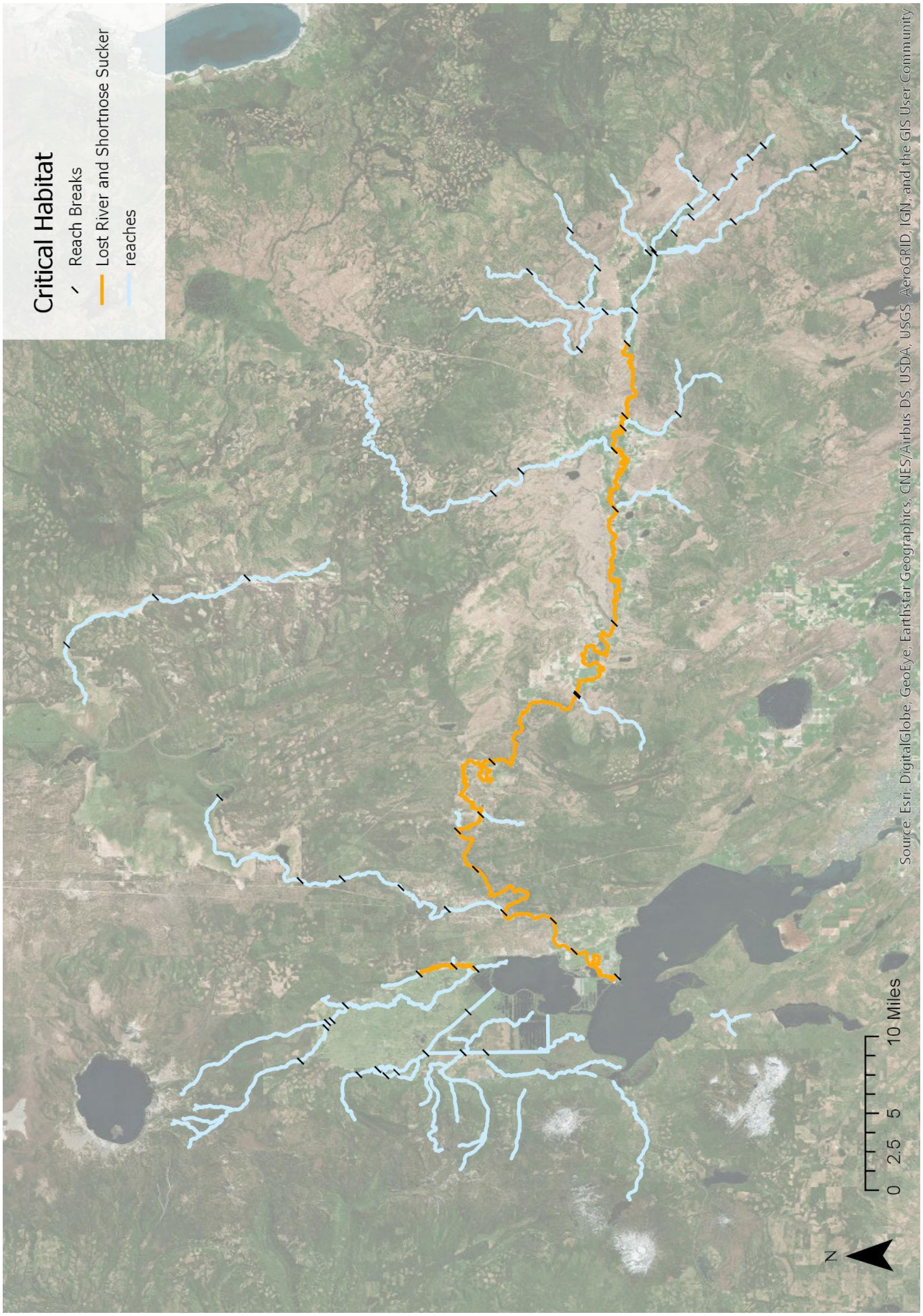
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-8: WILLIAMSON WATER QUALITY METRIC SCORE MAP



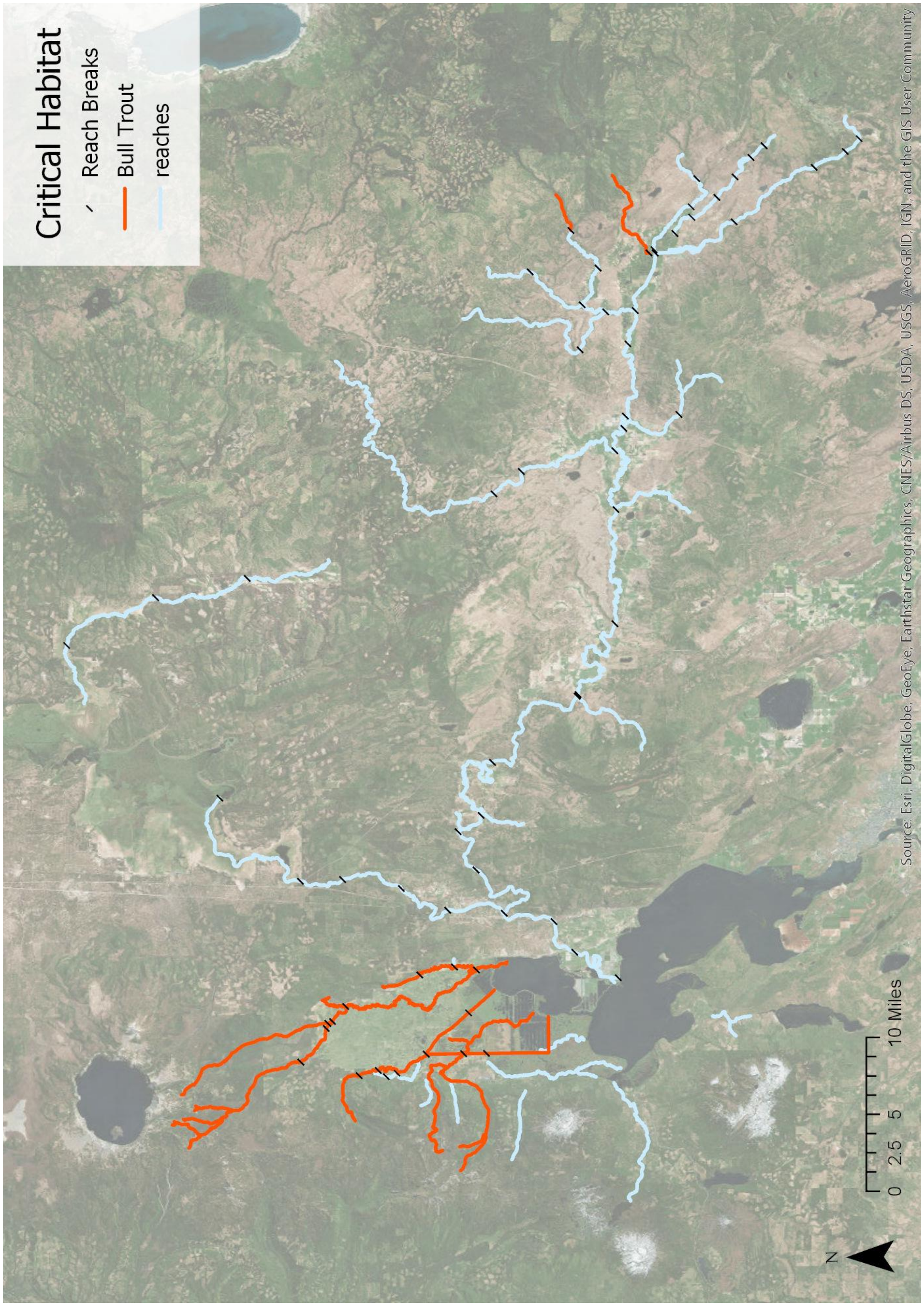
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-9: WOOD RIVER WATER QUALITY IMPAIRMENT MAP



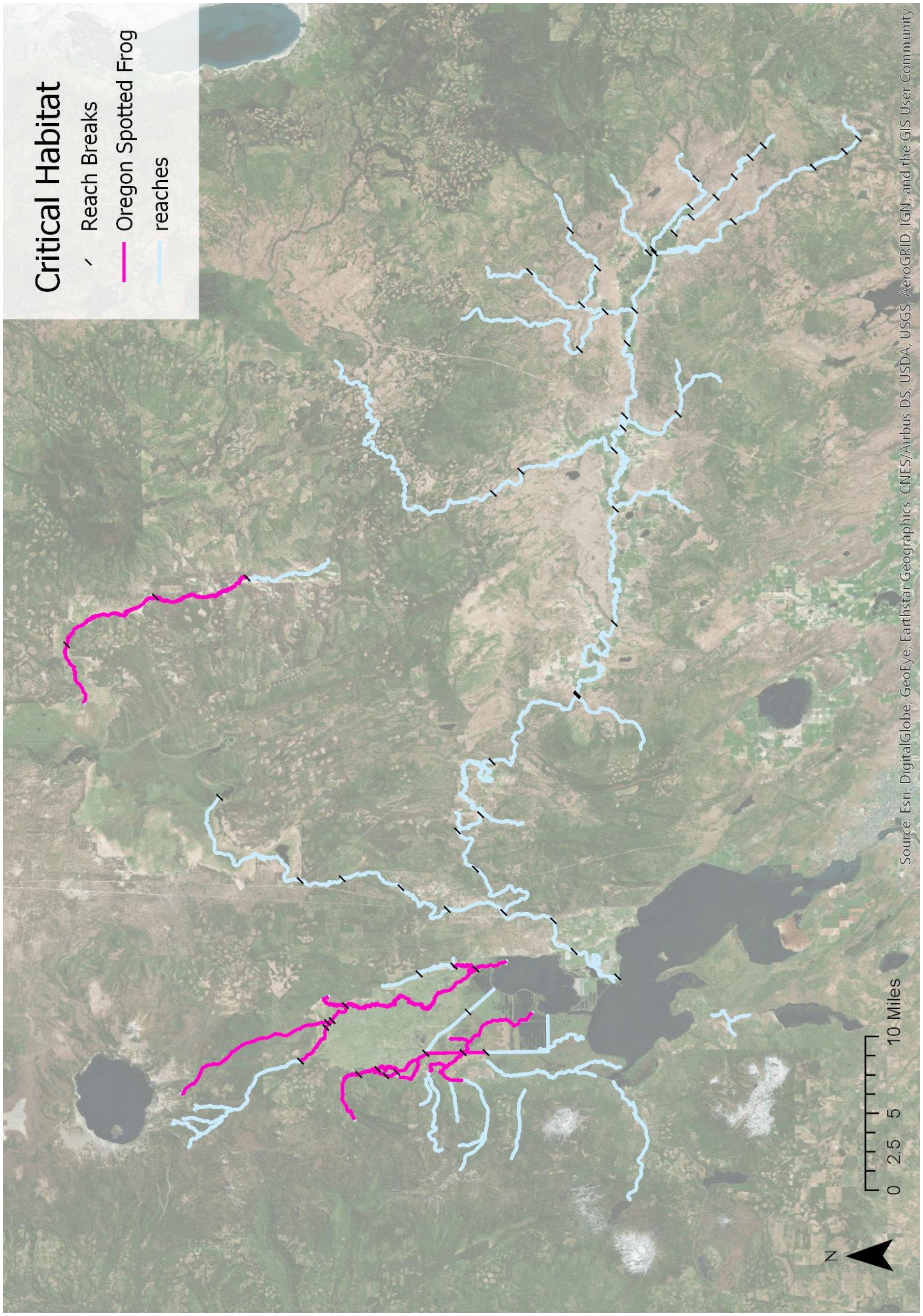
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-10: SHORTNOSE AND LOST RIVER SUCKER CRITICAL HABITAT MAP



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-11: BULL TROUT CRITICAL HABITAT MAP



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 4-12: OREGON SPOTTED FROG CRITICAL HABITAT MAP

REFERENCES

Barry, M., Mattenberger, S., Dunsmoor, L. (Klamath Tribes), Peterson, S. (Klamath Basin Rangeland Trust), Watson, D. (Ranch and Range Consulting), U.S. Fish and Wildlife Service, (July 30, 2010). Projected restoration actions and associated costs under the Klamath Basin Restoration Agreement for the Upper Klamath River Basin above Keno, Oregon.

FlowWest, (2017). Restoration opportunities analysis (ROA): Task III technical memo. Prepared for The Klamath Tribes.

FlowWest, (2018). Upper Klamath Basin riparian conditions analysis. Prepared for The Klamath Tribes.

Gannett, M.W., Lite, K.E. Jr., La Marche, J.L., Fisher, B.J., and Polette, D.J., (2007). Ground-water hydrology of the upper Klamath Basin, Oregon and California. U.S. Geological Survey Scientific Investigations Report 2007-5050, 84 p.

O'Connor, J.E., McDowell, P.F., Lind, Pollyanna, Rasmussen, C.G., and Keith, M.K., (2015). Geomorphology and floodplain vegetation of the Sprague and lower Sycan Rivers, Klamath Basin, Oregon. U.S. Geological Survey Scientific Investigations Report 2014–5223, 122 p., 1 pl., http://dx.doi.org/10.3133/sir20145223.

Walker, J. D., Kann, J., Walker, W. W., (2015). Spatial and temporal nutrient loading dynamics in the Sprague River Basin, Oregon. Prepared by Aquatic Ecosystem Sciences, J. D. Walker, and W. W. Walker for the Klamath Tribes Natural Resources Department. 73p. + appendices. Retrieved from https://s3.amazonaws.com/walkerenvres.com/reports/klamath/2015-sprague-nutrient-dynamics/Sprague_River_Nutrient_Dynamics_20151229_final.pdf

DATA CITATIONS

Klamath Tribes. (2015). alignment_changes_line_20170721 (final version) [shapefile]. Upper Klamath Basin: FlowWest. Prepared for the Klamath Tribes Restoration Opportunities Analysis.

Klamath Tribes. (2016a). fo_roa (final version) [ESRI geodatabase]. Upper Klamath Basin: FlowWest. Prepared for the Klamath Tribes Restoration Opportunities Analysis.

Klamath Tribes. (2016b). div_ret_roa3 (final version) [shapefile]. Upper Klamath Basin: FlowWest. Prepared for the Klamath Tribes Restoration Opportunities Analysis.

Klamath Tribes. (2018). prop_land_cover (final version) [shapefile]. Upper Klamath Basin: FlowWest. Prepared for the Klamath Tribes Upper Klamath Basin Riparian Conditions Analysis.

Trout Unlimited (2016). wood_river_valley_diversions_12oct16 (October 12, 2016 version) [shapefile]. Upper Klamath Basin: Trout Unlimited.

Trout Unlimited (2018). ukb_barriers_clearing_27jul18 (July 27, 2018 version) [shapefile]. Upper Klamath Basin: Trout Unlimited.

US Fish and Wildlife Service (USFWS). (2012). LRSN_2012CH_riverstream (2012 version) [shapefile].

US Fish and Wildlife Service (USFWS). (2010) BT_FCH_Streams_2010_UKB (October 8, 2010 version) [shapefile]. Oregon: USFWS. Available online at: http://www.fws.gov/pacific/bulltrout/Index.cfm

US Fish and Wildlife Service (USFWS). (2016). FCH_Rana_pretiosa_2016POLY (May 11, 2016 version) [shapefile]. Oregon: USFWS. Available online at: http://criticalhabitat.fws.gov/docs/crithab/zip/FCH_Rana_pretiosa_2016POLY.zip

Chapter 5 MONITORING RESTORATION PROJECTS

INTRODUCTION

The UKB WAP was developed under an adaptive management framework. Monitoring is an important component of adaptive management that identifies actions that are functioning as anticipated and when changes are needed to achieve the objectives of the individual restoration actions or programmatic goals and objectives. This chapter discusses three different categories of monitoring adopted from MacDonald et al (1991) applicable to the UKB:

1. Baseline - documentation and learning from projects that have been completed
2. Project and Implementation - monitoring for existing and future projects
3. Trend - status and trends of effectiveness in the UKB over time.

This chapter follows the organization and categorization of the monitoring actions presented in (MacDonald et al. 1991). To simplify the discussion of monitoring the monitoring categories from MacDonald et al. (1991) have been grouped into generalized monitoring categories for the purpose of this document.

Adaptive management

Monitoring is a key component to implementation of restoration projects in the UKB and brings scientific rigor to the full life stage of restoration projects from planning and design to adaptive management. Figure 5-1 shows how monitoring fits into the lifecycle for restoration planning and implementation in the UKB. The conceptual models (Chapter 3) that explain our understanding of physical and biological processes and linkages in the UKB are the basis for planning and design of restoration projects in the UKB. After implementation of a project, monitoring is critical for adaptive management, refinement of the conceptual models, and modification of the planning and design of future projects. Monitoring is the way we learn from restoration projects and improve future projects to achieve UKB restoration objectives.

Monitoring categories

As more restoration projects are implemented in the UKB, monitoring efforts need to be designed to access different goals and objectives. Building on the work from MacDonald et al. (1991) types of monitoring were adopted and combined into categories to address these different goals and objectives for baseline, project and implementation, and trend monitoring (Figure 5-2). Typically, separate monitoring programs are needed for baseline, project and implementation, and trend assessments. Figure 5-2 illustrates the difference in monitoring scale, resolution, parameters, duration, and effort between the different monitoring categories. Scale refers to the size or number of projects monitored, and resolution refers to the number or type of monitoring actions required for a project to access success or failure. Fine scale monitoring includes many measurements of the same monitoring type at an individual project, such as cross sections every 10 ft of channel length. Parameters refers to the number of specific metrics such as cross sections for channel dimensions or percent survival for vegetation planting needed to assess project success or failure. Duration in the period of time that is required to access success or failure and can range from a snapshot in baseline monitoring to decades for trend monitoring. Lastly, effort is a measure of the relative cost between monitoring categories and varies with the duration, parameters, and resolution.

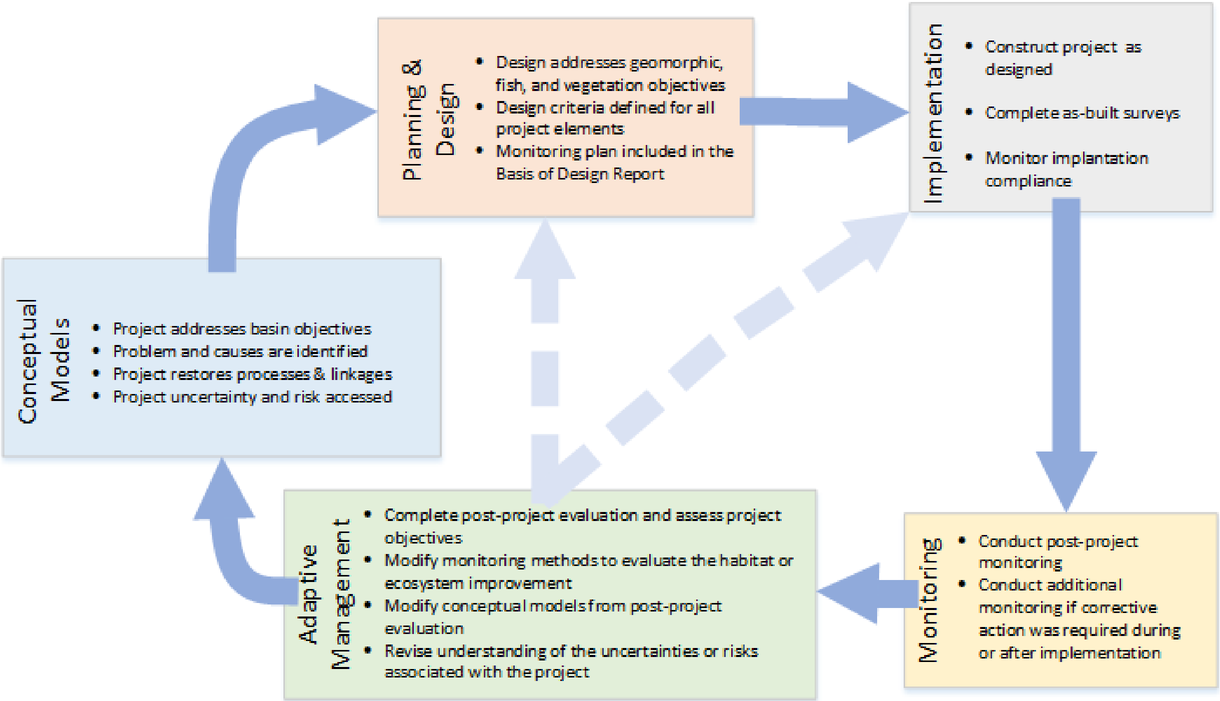


FIGURE 5-1: RESTORATION PROJECT LIFE-CYCLE SHOWING THE CRITICAL ROLE OF POST-PROJECT MONITORING

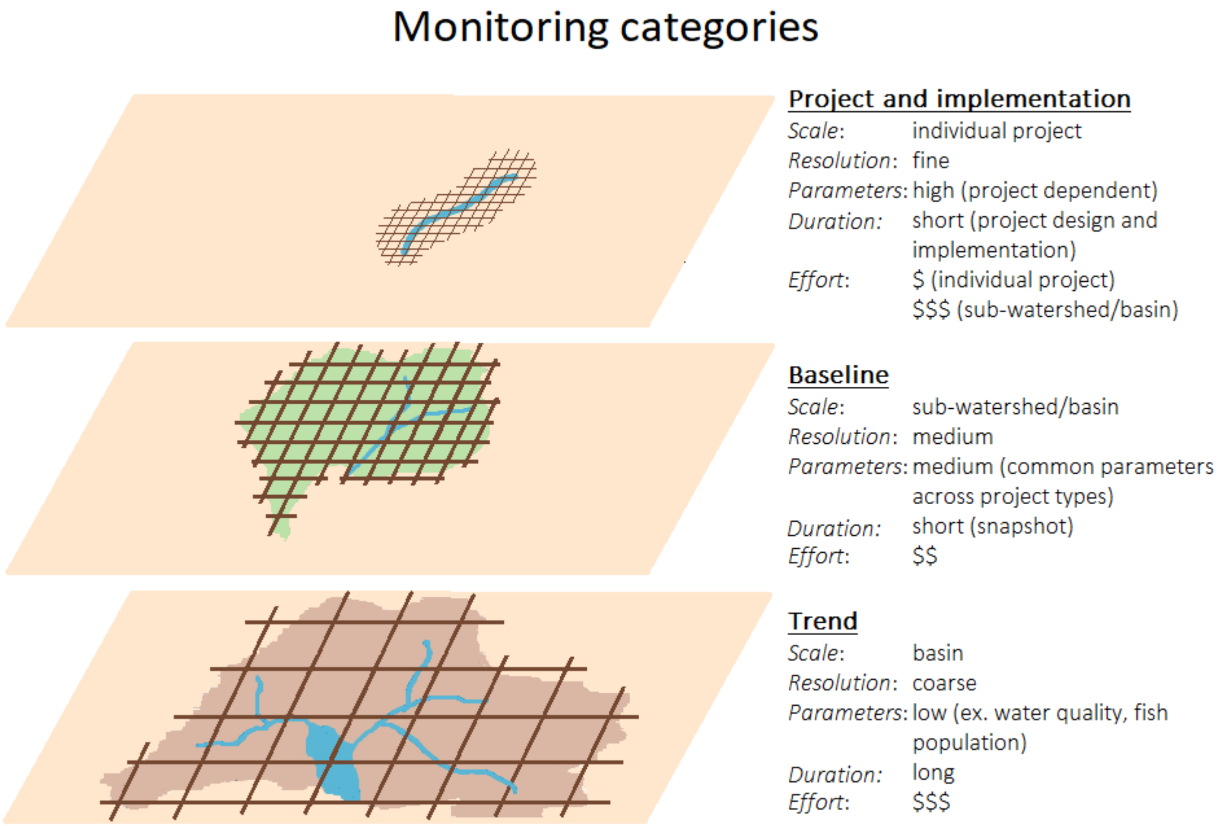


FIGURE 5-2: DIFFERENCES IN RESULUTION AND EFFORT OF MONITORING AT DIFFERENT SPATIAL SCALES

Baseline monitoring

Baseline monitoring refers to monitoring that assesses the impacts of multiple projects that are undertaken within a sub-watershed or basin. Example sub-watersheds in the UKB could be either the Sprague, Williamson, or Wood basins or key tributaries within each of these three watersheds. Baseline monitoring is designed to identify the current conditions within a sub-watershed or basin. Existing conditions in a sub-watershed or basin can be determined by linking the same type of monitoring actions, throughout the area of interest. As the watershed area increases the resolution and number of monitoring parameters required decreases. Often the level of effort for baseline monitoring is greater than project and implementation monitoring because project and implementation monitoring data is out of date and monitoring must be updated for a greater number of projects across a larger spatial extent.

Project and implementation monitoring

Project and implementation monitoring employs monitoring methods that create fine resolution data and includes the methods described in the Monitoring Framework (Appendix A) for a specific restoration action at a specific site. Monitoring method examples include surveys of channel geometry or riparian vegetation survival at a specific site. The objectives of this type of monitoring is to ensure that the project was implemented as designed, assess the change in the site condition, and to learn from successes or failures of the project compared to the project objectives. These lessons are then used to revise conceptual models that illustrate the understanding of the physical and biological linkages operating at the site or for that type of restoration action. These monitoring efforts are often carried out for short duration that includes pre-implementation and post-implementation of the project and rarely include annual post-project monitoring. Ideally, post-implementation monitoring would be continued until the project is considered self-sustaining. Typically, post-project monitoring is considered part of the project as-built design and is built into the project implementation budget.

Trend monitoring

Lastly, trend monitoring typically requires a separate monitoring program and sampling design compared to implementation and project and baseline monitoring programs. Often when looking at comparisons between watersheds there is a discrepancy in the amount and quality of data between watersheds. A common set of parameters is needed to assess trends and the cumulative benefits of restoration actions between watersheds or for the entire basin that may be inconsistent between watersheds. This requires the development of a monitoring network than can be compared across the basin, often where no existing monitoring network exists. The level of effort increases as the area of analysis increases. For large and remote areas, travel time can be a significant component of the monitoring program. The duration of the trend monitoring covers longer periods of time with rich data sets requiring decades to cultivate. Often biological and physical processes take a range of conditions to be able to access success or failure. Fish population dynamics typical take numerous generations for a trend to established and physical processes are often tied to hydrologic conditions that may occur infrequently, such as large floods.

The following sections in this chapter provide guidance on monitoring methods for restoration actions and different monitoring objectives. First, this chapter summarizes lessons learned from post-project evaluations conducted in the Sprague Watershed followed by guidance for monitoring methods for different types of restoration projects. The chapter concludes with a discussion of status and trend monitoring scale for from the project level to the UKB over time.

BASELINE MONITORING

An example of baseline monitoring in the UKB is the systematic post-project evaluation of the Sprague Watershed conducted by NewFields (2012). To learn lessons from previous restoration actions and determine the existing condition of restoration projects in the Sprague River Basin, the Klamath Watershed Partnership, the Klamath Tribes, the U.S. Fish and Wildlife Service, the Klamath Basin Rangeland Trust, Sustainable Northwest, and The Nature Conservancy hired consultants to undertake an evaluation of the previous restoration projects conducted in the Sprague Watershed in the 1990s. This effort resulted in the comprehensive report titled Evaluating Stream Restoration Projects in the Sprague River Basin (NewFields River Basin Services & Kondolf, 2012). The report was the result of the coordinated efforts of a large team committed to improving restoration practices in the Upper Klamath Basin.

In response to degradation of aquatic ecosystems in the Sprague River Basin from historical and current land uses including logging, dam construction, cattle grazing, and agriculture, restoration projects were implemented beginning in the mid-1990's to improve watershed conditions in the Sprague River Basin for affected fish species, including Lost River sucker, shortnose sucker, and redband trout, as well as channel stability, riparian habitat, and water quality. Upper Klamath Basin stakeholders participated in a systematic post-project appraisal of restoration projects completed in the mid-1990's to evaluate the performance of a variety of completed restoration projects in the Sprague Basin and identify key lessons learned. The conclusions of the report are used to help implement meaningful adaptive management of the basin's aquatic resources and to guide future project prioritization, planning, and design (NewFields River Basin Services & Kondolf, 2012).

NewFields River Basin Services & Kondolf (2012) used the post-project evaluation framework (Downs & Kondolf, 2002) to evaluate past project successes and failures, and provide performance feedback that enable adaptive management of environmental resources. The ten representative restoration projects that were selected for detailed analysis included the following eight components:

1. Success criteria
2. Baseline surveys / data collection
3. Design rationale
4. Design drawings
5. As-built surveys
6. Post-project periodic and event-driven monitoring surveys
7. Supplementary historical data
8. Secondary analytical procedures

Additional geomorphic and vegetation monitoring was conducted to supplement the pre- and post-project monitoring, including cross section and longitudinal profile surveys, photographic monitoring points, bank erosion assessments, "greenline" surveys, aerial photograph comparisons, hydrologic analyses, and instream structure assessments. NewFields River Basin Services & Kondolf (2012) evaluated fencing, wetland creation, floodplain reconnection, levee breaching, meander bend cutoff plugging, riparian planting, channel realignment, fish screen, spring reconnection, and wetland connection project types.

The overall conclusion and recommendation from the post-project appraisal for the Sprague Basin was that a systematic approach to all phases of the restoration project life cycle is needed to guide and prioritize all the restoration work implemented in the basin. While the findings show that restoration practices in the basin could be improved in the future, the ongoing planning, design, implementation, and monitoring efforts in the basin were found to be commendable and resulted in an extremely valuable foundation upon which future restoration efforts can be built.

Table 5-1 summarizes the observations and lessons learned from each of the ten sites that were selected for post-project appraisal. Table 5-1 is an assessment of the performance of each project with respect to its stated success criteria. NewFields River Basin Services & Kondolf (2012) scored each project on a scale of -1 to +1, with a score of -1 signifying that the project failed to satisfy its success criteria, a score of 1 signifying that the project satisfied some of its success criteria, and a score of +1 signifying that the project satisfied most of its success criteria. Table 5-1 provides a basis from which restoration practitioners in the basin can communicate about how specific projects and actions are performing, the key lessons from each project that should be applied to future similar projects, and the project-specific issues that should be addressed in the ongoing management of these completed projects (NewFields & Kondolf 2012).

TABLE 5-1: SPRAGE RIVER BASIN RESTORATION PROJECT PERFORMANCE. SOURCE: NEWFIELDS RIVER BASIN SERVICES & KONDOLF (2012)

Project Name	Stream	Location in the Watershed	Score	Rationale
Nine Mile Road	Sprague River	Lower	**1**	***Meander cutoff plugs*** are stable and restore local channel sinuosity. Uncertainty surrounding temporal and spatial trends of meander cutoff and creation and the benefits of habitat in cutoff meander bends, combined with unexpected changes in restored meander bends reduces the magnitude and certainty of benefits attributed to meander cutoff plugging.
Southside Levee Breach	Sprague River	Lower	**+1**	***Levee breaching*** effectively restores hydraulic connectivity between river channel and floodplain, provides access to fish and other organisms, and contributes to increased vegetation diversity and abundance. ***Grazing management*** contributes to increased vegetation diversity and abundance. Better understanding of breach hydraulics and sediment transport is needed to prevent fish passage problems.
Nimrod River Park	Sprague River	Middle	**1**	***Wetland creation*** has improved inundated floodplain habitat and grazing management (fencing) has resulted in more stable streambanks. Meander cutoff plugging has redirected flows into the meander bend and created backwater habitat. Woody riparian vegetation has not colonized the site and vegetation is dominated by non-native species, reducing habitat value in constructed wetlands. Vegetation management required to fully satisfy vegetation success criteria. Uncertainty surrounding temporal and spatial trends of meander cutoff and creation and the benefits of habitat in cutoff meander bends, combined with unexpected changes in restored meander bends reduces the magnitude and certainty of benefits attributed to meander cutoff plugging.

Whisky Creek	Sprague River	Middle	**1**	***Grazing management*** achieved revegetation and bank stabilization goals. However, non-native vegetation dominates species composition and desired woody vegetation has not colonized the site. ***Spring protection*** has yielded enhanced spring habitat, but ***spring reconnection*** has not been sustainable. Active management of vegetation and spring connectivity required to fully satisfy all success criteria.
Sycan River	Sycan River	Sycan	**1**	***Grazing management*** achieved revegetation and bank stabilization goals. However, non-native vegetation dominates species composition and desired woody vegetation has not colonized the site. Vegetation management required to fully satisfy all success criteria.
Beatty Station	Sprague River	Middle	**1**	***Meander cutoff plugs*** are stable and restore local channel sinuosity. Uncertainty surrounding temporal and spatial trends of meander cutoff and creation and the benefits of habitat in cutoff meander bends, combined with unexpected changes in restored meander bends reduces the magnitude and certainty of benefits attributed to meander cutoff plugging.
Five Mile Creek	Five Mile Creek	Upper	**+1**	***Constructed bypass channel*** successfully provided improved fish passage. Improper weir design has already been corrected. Short term failure to establish woody riparian vegetation not caused by failure to recognize fundamental processes and can be corrected with minimal effort.
South Fork Sprague River	S. Fork Sprague River	Upper	**1**	***Grazing management*** achieved revegetation goals. However, non-native vegetation dominates species composition. Further, because other site disturbances (e.g. levees and disconnection of secondary channels) were not addressed as part of this project, undesirable erosion still occurs. Vegetation management and consideration of other controlling processes required to fully satisfy all success criteria.

Bailey Flat	North Fork Sprague River	Upper	**+1**	***Reoccupied historical channels*** achieved improvements in instream and riparian habitat and addressed chronic erosion. Initial channel adjustments and current instability of vegetation not caused by failure to recognize fundamental processes and should establish a dynamic equilibrium over time without further intervention.
Long Creek	Long Creek	Sycan Marsh	**1**	***Exclusion of grazing*** has facilitated riparian revegetation; however, lodge pole pines have outcompeted more desirable species and channel geometry has not adjusted as expected. Ongoing vegetation management is needed to achieve desired vegetation community composition.

Next, NewFields River Basin Services & Kondolf (2012) assessed the relative potential of different project types and actions to achieve basin wide goals for the Sprague River to maintain, create, improve, and restore more normative hydrologic, geomorphic, and sediment transport processes. Restoration of these processes will create instream, riparian, floodplain, and spring conditions and variability that better support target and/or native aquatic plant communities and biota. Table 5-2 assigns a high, moderate, or low magnitude and certainty of benefit of achieving site-specific and basin wide goals and level of effort in terms of design and construction for each project type. Table 5-2 provides restoration practitioners a guide of the relative value of implementing a new project of a given type in the basin.

Table 5-2 also identifies the need for additional studies to resolve uncertainties before additional meander bend cutoff plug projects are implemented. Additionally, more analysis is needed to quantify the benefit from flow augmentation projects because there were few project case studies available in the Sprague basin. NewFields River Basin Services & Kondolf (2012) found that project types with high magnitude and certainty of benefits and low level of effort and/or number implemented in the basin (e.g. floodplain reconnection) should be implemented. Conversely, for project types with low or unknown magnitude and certainty of benefits and high level of effort (e.g. meander bend cutoff plugging), additional study should be conducted before additional projects are implemented or no additional projects of this type should be planned.

NewFields River Basin Services & Kondolf (2012) summarized guidance for future restoration projects in the Sprague River Basin into three recommendations:

1. Implement a structured monitoring and adaptive management program to ensure that monitoring is integral to project implementation, systematic, consistent, and persistent through time.
2. Establish standard monitoring and data management methods to facilitate learning and adaptive management. Monitoring metrics and assessment methods should be linked to objectives and processes addressed by restoration actions. Additionally, a central and standardized data storage system should be developed to house all relevant data on past and future restoration projects.
3. Apply the tools and lessons learned to guide future restoration projects in the basin.

TABLE 5-2: RELATIVE POTENTIAL OF DIFFERENT PROJECT TYPES TO CONTRIBUTE TO BASINWIDE GOALS FOR THE SPRAGUE RIVER. SOURCE: NEWFIELDS RIVER BASIN SERVICES & KONDOLF (2012)

Class	**Type**	**Action(s)**	**Benefit**		**Level of Effort**	**Number of Projects in Basin**
			Magnitude	**Certainty**		
Instream	Channel Manipulation	Create new channel, reconnect old channel, prevent / reverse meander bend cutoff	H/?*	H/?*	H/H*	M/M*
	Habitat Creation	Construct structure	M	H	L	M
	Flow Augmentation	Reduce diversion rate	?	?	?	L
	Fish Passage Improvement	Construct bypass channel(s), install or modify culvert(s)	H	M	H	L
		Screen diversion(s)	H	H	M	M
Riparian	Management	Construct fences, change grazing management, plant vegetation	H	M	L	H
	Expansion	Remove levee(s), create new channels	H	H	L	L
Floodplain	Reconnection	Remove levees, excavate new connection from floodplain to channel through riparian area	H	H	L	L
	Modification	Restore floodplain topography, excavate wetland(s)	M	H	H	H

	Management	Change grazing management, plant vegetation, construct fence(s)	H	M	L	L
Spring	Reconnection	Excavate new channel(s), install or modify culverts	L	M	M	M
	Enhancement	Excavate, recontour	L	H	L	L
	Management	Plant vegetation, construct fence(s), add gravel or another suitable substrate	L	H	L	L

** Instream channel manipulations were given a split score because this project type included both channel creation and reconnection and meander bend cutoffs.*

PROJECT AND IMPLEMENTATION MONITORING

Monitoring framework

Project and Implementation monitoring is typically done to access the project implementation compared to the design documents. Goals and objectives from the basis of design report, grant application, or design drawings are compared to the as-built and post-implementation conditions (MacDonald et al., 1991). This section provides a guide (Appendix A, Monitoring Framework) for restoration practitioners in the UKB select appropriate monitoring methods with expected restoration actions. The Monitoring Framework can be used to during project planning to help inform a monitoring plan or post-construction when monitoring methods are needed to access the project success. Additionally, for existing projects, the Monitoring Framework can be used to identify appropriate monitoring metrics and assessment methods to trigger adaptive management to improve project performance. The Monitoring Framework also provides a guide for restoration practitioners to identify appropriate objectives for projects that are already in the planning process or implemented.

For future restoration projects, the Monitoring Framework (Appendix A) should be referenced by restoration practitioners in the UKB to select monitoring methods for restoration projects. The Monitoring Framework also identifies processes affected by the restoration actions, which helps link the monitoring methods to the conceptual models. For each monitoring method, we have provided references for further details. Columns in the Monitoring Framework list metrics, assessment classes and methods, monitoring targets, and references for monitoring methods. Establishing goals and objectives for projects and completing post-project monitoring consistent with the Monitoring Framework will increase understanding of physical and biological processes in the UKB and maximize learning from each implemented project. This ever-evolving understanding will significantly improve the quality and effectiveness of restoration projects in the UKB over the long-term. The Monitoring Framework serves as a guide to selecting monitoring methods that directly assess improvements to ecosystem processes at the project scale that also contribute to achieving basin wide objectives of restoring watershed conditions to increase the distribution and abundance of shortnose sucker, the Lost River sucker, and the interior redband trout.

Restoration project tracking

Restoration planning in the UKB requires an understanding of the existing restoration projects that have been completed to date. Constructed projects can be reviewed to see how they are performing and identify where projects have been implemented in the past to help restoration practitioners prioritize future projects.

There are two efforts in the UKB to track restoration projects. First, the Oregon Watershed Enhancement Board (OWEB) maintains the Oregon Watershed Restoration Inventory (OWRI) through OWRI Online (OWRIO). The OWRI includes both mandatory and voluntary project reporting. For restoration grants administered through OWEB, mandatory reporting is required for restoration grants administered by OWEB, Department of Environmental Quality (DEQ) 319 grants, and some Oregon Department of Fish and Wildlife (ODFW) R & E program grants and Oregon Division of State Lands (DSL) permits. OWRI also encourages voluntary reporting of projects. More information for OWRIO can be found at the following link: https://apps.wrd.state.or.us/apps/oweb/owrio/default.aspx. The UKB WAP Team encourages all restoration practitioners in the UKB to include their projects in the OWRI.

In addition to the OWRI, the Klamath Basin Monitoring Program (KBMP) hosts the Klamath Tracking and Accounting Program (KTAP) framework. KTAP seeks to quantify the collective benefit of restoration and land management projects for water quality and habitat for native fish in the Klamath Basin. KTAP developed the Stewardship Project Reporting Protocol as a voluntary system to track restoration and conservation projects and help practitioners make informed decisions for future restoration and conservation projects. KTAP is not operational, but the framework and protocols have been collaboratively developed by stakeholders. Further information can be found at the following link: http://www.kbmp.net/stewardship/about-ktap-and-faqs.

TREND MONITORING

Trend monitoring refers to measurements that are made at regular time intervals in order to determine the long-term trend of a parameter of interest (MacDonald et al., 1991). Trend monitoring can be used to evaluate management practices and activities. One example of trend monitoring in the UKB is the Klamath Tribes water quality monitoring program.

Of the many water quality monitoring efforts being conducted in the Upper Klamath Basin, The Klamath Tribes has the most comprehensive dataset throughout the UKB with over 3.5 million water quality records. The Klamath Tribes have been collecting environmental data in the Upper Klamath Basin for decades along with the full spectrum of collaborators, stakeholders, and agencies actively engaged in the basin. The Klamath Tribes' Aquatics Program has been monitoring Upper Klamath Lake and tributary stream water quality since 1990, and since 2006 the Sprague River Water Quality Lab (SRWQL) has analyzed been analyzing water nutrient and algal toxin samples in-house. The Klamath Tribes shares these datasets containing water quality data from the Upper Klamath Lake and Upper Klamath Basin through the US Environmental Protection Agency's (EPA) water quality portal. The data can be accessed by searching under the organization identification "KlamathTribes_WQX" at this link: https://www.waterqualitydata.us/portal/. The five datasets incorporated into the EPA Data Exchange include:

1. Lake (Upper Klamath Lake, 126,544 records)
2. Tributary (sampling sites from the Wood and Williams basins, 25,095 records)
3. River (Sprague River, 32,935 records)
4. Phytoplankton (samples from Upper Klamath Lake, 2,511,098 records)
5. Zooplankton (samples from Upper Klamath Lake, 855,680 records)

Table 5-3 contains additional information about each of the datasets incorporated in the Klamath Tribes Data Exchange Network and the spatial extent of the sampling sites in shown in Figure 5-2. The Klamath Tribes continues to collect water quality data and will update the EPA database with the most recent results of their monitoring efforts.

This rich data source includes over 3.5 million water quality records collected at 30 sampling sites that has significantly improved the understanding of water quality dynamics in the Upper Klamath Basin. However, the current water quality monitoring network is not designed to capture improvements in water quality from individual projects. The water quality sampling locations should be augmented to improve monitoring results within and between sub-watersheds in the Upper Klamath Basin. A more detailed network of sampling locations is needed to assess individual water quality projects as well as further refine the water quality impacts to Upper Klamath Lake and within the tributaries to Upper Klamath Lake.

TABLE 5-3: KLAMATH TRIBES WATER QUALITY DATASETS SHARED WITH THE EPA. SOURCE: FLOWWEST (2016)

Dataset	**Period of Record**	**Geographic Extent**	**Sampling Sites (#)**	**Sampling Type**	**Parameters**
Lake	1990-2015	Upper Klamath Lake & Agency Lake	11	Water Quality	Maximum depth, Secchi depth, profile depth, photosynthetically active radiation, temperature, conductivity, dissolved oxygen, pH, percent dissolved oxygen saturation, oxidation-reduction potential, total phosphorus, phosphate as soluble reactive phosphorus, ammonium nitrogen, nitrate nitrogen, nitrate+nitrite nitrogen, total nitrogen, silica, chlorophyll a, phaeophytin

Tributary	2005-2015	Tributary rivers to Upper Klamath Lake	6	Water Quality	Discharge, depth, temperature, conductivity, dissolved oxygen, pH, percent dissolved oxygen saturation, total phosphorus, phosphate as soluble reactive phosphorus, ammonium nitrogen, nitrate nitrogen, nitrate+nitrite nitrogen, total nitrogen, silica, total suspended solids, turbidity
Sprague River	2001-2015	Sprague, NF Sprague, SF Sprague, Sycan, Whiskey Creek	9	Water Quality	Discharge, depth, temperature, conductivity, dissolved oxygen, pH, percent dissolved oxygen saturation, total phosphorus, phosphate as soluble reactive phosphorus, ammonium nitrogen, nitrate nitrogen, nitrate+nitrite nitrogen, total nitrogen, chloride, silica, total suspended solids, turbidity
Phytoplankton	1990-2013	Upper Klamath Lake & Agency Lake	11	Phytoplankton	Genus, species, biovolume standardized, percent biovolume standardized, cell density standardized, percent cell density standardized, natural unit density, percent natural unit density
Zooplankton	1990-2013	Upper Klamath Lake & Agency Lake	11	Zooplankton	Genus, species, biomass, percent biomass, abundance, percent abundance

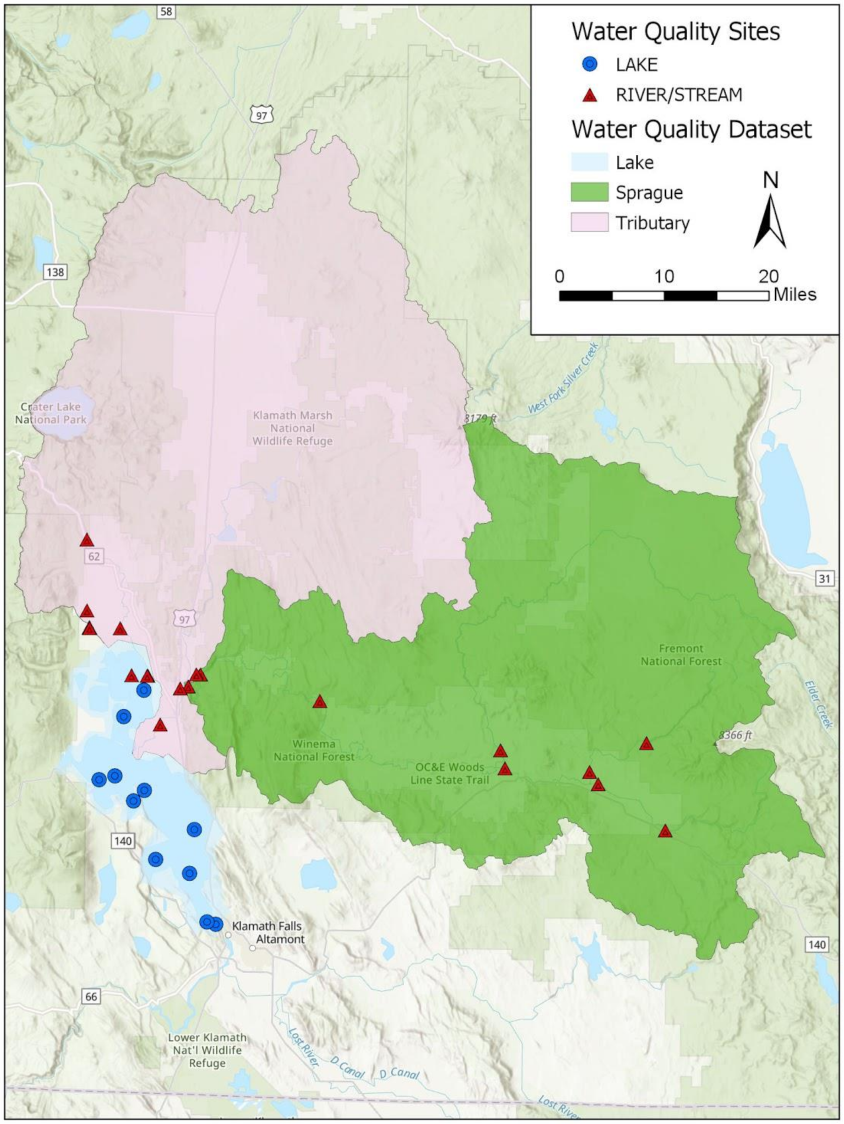


FIGURE 5-3: KLAMATH TRIBES WATER QUALITY SAMPLING SITES. KLAMATH TRIBES LAKE WATER QUALITY MONITORING LOCATIONS ARE SHOWN AS BLUE CIRCLES; SPRAGUE RIVER AND OTHER TRIBUTARY STREAM MONITORING STATIONS ARE SHOWN AS RED TRIANGLES.

REFERENCES

Anderson, J. T., & Davis, C. A. (2013). Wetland techniques. Retrieved from http://fwf.ag.utk.edu/mgray/publications/WetlandTechniquesVol2.pdf

Bernard, K., & McBain, S. (1994). Standpipe to determine permeability, dissolved oxygen, and vertical particle size distribution in salmonid spawning gravels. Fish Habitat Relationships Technical Bulletin, 15, 1–12.

Britton, L. J., & Greeson, P. E. (1987). Techniques of water-resources investigations of the United States Geological Survey: Chapter A4: Methods for collection and analysis of aquatic biological and microbiological samples. Retrieved from USGS website: https://pubs.usgs.gov/twri/twri5a4/pdf/twri_5-A4_g.pdf

Buffington, J. M., & Montgomery, D. R. (1999). A procedure for classifying textural facies in gravel-bed rivers. Water Resources Research, 35(6), 1903–1914. https://doi.org/10.1029/1999WR900041

Burton, A. T., Smith, S. J., & Cowley, E. R. (2011). Riparian area management: Multiple indicator monitoring (MIM) of stream channels and streamside vegetation (Technical Reference No. 1737–23). Retrieved from U.S. Department of the Interior, Bureau of Land Management, National Operations Center website: http://www.blm.gov/nstc/library/pdf/MIM.pdf

Cooper, D. J., & Merritt, D. M. (2012). Assessing the water needs of riparian and wetland vegetation in the western United States (General Technical Report No. RMRS-GTR-282). Retrieved from U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. website: Available at http://www.fs.fed.us/rm/pubs/rmrs_gtr282.pdf

DEQ (State of Oregon Department of Environmental Quality). (2009). Water monitoring and assessment mode of operations manual (MOMs) (No. DEQ03-LAB-0036-SOP). Hillsboro, OR.

Downs, P. W., and G. M. Kondolf. 2002. Post-project appraisals in adaptive management of river channel restoration. Environmental Management 29:477–496.

Edwards, T. K., & Glysson, G. D. (1999). Field methods for measurement of fluvial sediment: applications of hydraulics, book 3, chapter C2 [Techniques of Water-Resources Investigations]. Retrieved from U.S. Geological Survey website: http://pubs.usgs.gov/twri/twri3-c2/html/pdf.html

Florsheim, J. L., & Mount, J. F. (2002). Restoration of floodplain topography by sand-splay complex formation in response to intentional levee breaches, Lower Cosumnes River, California. Geomorphology, 44, 67–94.

Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R., & Collins, B. (2010). California Salmonid Stream Habitat Restoration Manual. Part IV, Fish Sampling Methods. Retrieved from State of California, The Resources Agency, California Department of the Fish and Wildlife website: http://www.dfg.ca.gov/fish/resources/habitatmanual.asp

FlowWest (2016). Upper Klamath Basin Environmental Data Network Draft User Guide. Prepared for the Klamath Tribes. Technical Memorandum. December.

Gordon, N. D., McMahon, T. A., Finlayson, B. L., Gippel, C. J., & Nathan, R. J. (2004). Stream hydrology: An Introduction for ecologists (2nd ed.). Wiley.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., … Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. Science Advances, 1(2). https://doi.org/10.1126/sciadv.1500052

Harrelson, C. C., Rawlins, C. L., & Potyondy, J. P. (1994). Stream channel reference sites: an illustrated guide to field technique (General Technical Report No. RM-245). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Hayslip, G. (2007). Methods for the collection and analysis of benthic macroinvertebrate assemblages in wadeable streams of the Pacific Northwest. Retrieved from: http://www.colvilletribes.com/media/files/2007_0612PNAMP_macroinvert_protocol_final.pdf

Johnson, D. H., Shrier, B. M., O'Neal, J. S., Knutzen, J. A., Augerot, X., O'Neil, T. A., & Pearsons, T. N. (2007). Salmonid field protocols handbook: Techniques for assessing status and trends in salmon and trout populations. Retrieved from: http://www.stateofthesalmon.org/fieldprotocols/

Jones, K. L., O'Daniel, S. J., Beechie, T. J., Zakrajsek, J., & Webster, J. G. (2015). Physical Habitat Monitoring Strategy (PHAMS) for Reach-Scale Restoration Effectiveness Monitoring (Open-File Report No. 2015–1069). Retrieved from US Geological Survey website: http://pubs.usgs.gov/of/2015/1069/pdf/ofr2015-1069.pdf

Kann, J., Asarian, J. E., & St. Amand, A. (2015). Standardization and initial analysis of 1990-2013 phytoplankton and zooplankton data for Upper Klamath Lake (Phase I). Aquatic Ecosystem Sciences LLC.

KBEF (Klamath Basin Ecosystem Foundation), & KBREC (Oregon State University Klamath Basin Research and Extension Center). (2007). Upper Sprague Watershed Assessment. Retrieved from: https://nrimp.dfw.state.or.us/web%20stores/data%20libraries/files/OWEB/OWEB_916_2_Upper%20Sprague%20WS%20Assessment.pdf

Kershner, J. L., Archer, E. K., Coles-Ritchie, M., Cowley, E. R., Henderson, R. C., Kratz, K., … Vinson, M. R. (2004). Guide to effective monitoring of aquatic and riparian resources (General Technical Report No. RMRS-GTR-121). Retrieved from U.S. Department of Agriculture, Rocky Mountain Research Station website: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd494541.pdf

Kondolf, G. M. (1997). Application of the pebble count notes on purpose, methods, and variants. Journal of the American Water Resources Association, 33, 79–87. https://doi.org/10.1111/j.1752-1688.1997.tb04084.x

Kondolf, G. M., & Piegay, H. (2003). Tools in fluvial geomorphology. Chichester, UK: John Wiley & Sons.

Lisle, T. E. (1987). Using "residual depths" to monitor pool depths independently of discharge (Research Note No. PSW-RN-394). Retrieved from U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station website: http://www.fs.fed.us/psw/publications/documents/psw_rn394/

Lisle, T. E., & Eads, R. E. (1991). Methods to measure sedimentation of spawning gravels (Research Note No. PSW-411). Retrieved from Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture website: http://www.fs.fed.us/psw/publications/lisle/Lisle91.pdf

Lokteff, R., Demeurichy, K., & Wheaton, J. M. (2011). High resolution mapping of instream habitat: pilot study using ground based lidar in Logan River watershed. Retrieved from: http://etal.usu.edu/Reports/ET_AL_USFS_CostShare_DelivarableReport_2011.pdf

MacDonald, L. H., A. W. Smart, & R. C. Wissmar. (1991). Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. Developed for the Region 10, U.S. Environmental Protection Agency, Seattle, Washington.

McNeil, W. J., & Ahnell, W. H. (1964). Success of pink salmon spawning relative to size of spawning bed materials (Special Scientific Report - Fisheries No. 469). Retrieved from: http://www.krisweb.com/biblio/gen_usfws_mcneiletal_1964.pdf

Montgomery, D. R., & Buffington, J. M. (1997). Channel-reach morphology in mountain drainage basins. Geological Survey of America Bulletin, 109(5), 596–611.

NewFields River Basin Services, & Kondolf, G.M. (2012). Evaluating Stream Restoration Projects in the Sprague River Basin. Prepared for: Klamath Watershed Partnership, in conjunction with the Klamath Tribes, U.S. Fish and Wildlife Service, Klamath Basin Rangeland Trust, Sustainable Northwest, and The Nature Conservancy. Retrieved from: https://docs.wixstatic.com/ugd/2f25ac_86db6dc9ea7c4bdc88d0d4fa00ba1fc9.pdf

Nichols, A. L., Willis, A. D., Jeffres, C. A., & Deas, M. L. (2014). Water temperature patterns below large groundwater springs: Management implications for coho salmon in the Shasta River, California. River Research and Applications, 30(4), 442–445. https://doi.org/10.1002/rra.2655

Nielson, D. M. (1991). Practical handbook of ground-water monitoring. Chelsea, MI: Lewis Publishers.

NMFS (National Marine Fisheries Service). (1996). Juvenile fish screen criteria for pump intakes. Retrieved from: http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_screen_criteria_for_pumped_water_intakes.pdf

NMFS (National Marine Fisheries Service). (2011). Anadromous salmonid passage facility design. Retrieved from NMFS, Northwest Region website: http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_passage_design_criteria.pdf

ODF (Oregon Department of Forestry). (2014). Forest practice administrative rules and forest practices act.

ODFW (Oregon Department of Fish and Wildlife). (2006). Oregon administrative rules: Division 412, fish passage. Retrieved from http://www.dfw.state.or.us/OARs/412.pdf

ODSL (Oregon Department of State Lands), ODF (Oregon Department of Forestry), OWEB (Oregon Watershed Enhancement Board), & ODFW (Oregon Department of Fish and Wildlife). (2010). Guide to placement of wood, boulders and gravel for habitat restoration. Oregon Dept. of State Lands. Retrieved from https://digital.osl.state.or.us/islandora/object/osl%3A14170

Opperman, J. J., Galloway, G. E., Fargione, J., Mount, J. F., Richter, B. D., & Secchi, S. (2009). Sustainable floodplains through large-scale reconnection to rivers. Science, 326(5959), 1487–1488. https://doi.org/10.1126/science.1178256

Pollock, M. M., Beechie, T. J., Wheaton, J. M., Jordan, C. E., Bouwes, N., Weber, N., & Volk, C. (2014). Using beaver dams to restore incised stream ecosystems. BioScience, 64(4), 279–290. https://doi.org/10.1093/biosci/biu036

Pollock, M. M., Lewallen, G. M., Woodruff, K., Jordan, C. E., & Castro, J. M. (2018). The beaver restoration guidebook: Working with beaver to restore streams, wetlands and floodplains. Version 2.01. Retrieved from: https://www.fws.gov/oregonfwo/promo.cfm?id=177175812

Rosgen, D. L. (1996). Applied river morphology. Pagosa Springs, CO: Wildland Hydrology Books.

Sauer, V. B., & Turnipseed, D. P. (2010). Stage measurement at gaging stations: Chapter 7 of book 3, section A (Techniques and Methods No. 3-A7). Retrieved from US Geological Survey website: http://pubs.usgs.gov/tm/tm3-a7/

Schoeneberger, P. J., Wysocki, D. A., Benham, E. C., & Soil Survey Staff. (2012). Field book for describing and sampling soils, version 3.0. Lincoln, NE: Natural Resources Conservation Service, National Soil Survey Center.

Schuett-Hames, D., Pleus, A. E., Ward, J., Fox, M., & Light, J. (1999). TFW monitoring program method manual for the large woody debris survey (No. TFW-AM9-99-004). NW Indian Fisheries Commision & Timber, Fish and Wildlife.

Simon, A., & Rinaldi, M. (2006). Disturbance, stream incision, and channel evolution: The roles of excess transport capacity and boundary materials in controlling channel response. Geomorphology, 79, 361–383. https://doi.org/10.1016/j.geomorph.2006.06.037

Snyder, D. T., & Morace, J. L. (1997). Nitrogen and phosphorus loading from drained wetlands adjacent to Upper Klamath and Agency lakes, Oregon (No. 97–4059). https://doi.org/10.3133/wri974059

Soil Survey Division Staff. (1993). Soil survey manual. Retrieved from http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/ref/?cid=nrcs142p2_054262

Steiger, J., Gurnell, A. M., & Goodson, J. M. (2003). Quantifying and characterizing contemporary riparian sedimentation. River Research and Applications, 19, 335–352. https://doi.org/10.1002/rra.708

Turk, J. T., & Water Dipper Inc. (2001). Field guide for surface water sample and data collection. Retrieved from U.S. Department of Agriculture, Forest Service, Air Program website: http://www.fs.fed.us/waterdata/PDFfiles/FieldGuide_Turk.pdf

Turnipseed, D. P., & Sauer, V. B. (2010). Discharge measurements at gaging stations: Chapter 8 of book 3, section A (Techniques and Methods No. 3-A8). Retrieved from USGS website: http://pubs.usgs.gov/tm/tm3-a8/

USBR (U.S. Bureau of Reclamation). (2001). Link River Dam fishway replacement feasibility study. Denver, CO: Bureau of Reclamation Technical Services Center.

USFS (U.S. Forest Service). (2007). Technical guide to managing ground water resources (No. FS-881). Retrieved from Department of Agriculture website: http://www.fs.fed.us/geology/FINAL_Ground%20Water%20Technical%20Guide_FS-881_March2007.pdf

WDFW (Washington Department of Fish and Wildlife). (2003). Design of road culverts for fish passage: 2003 edition. Retrieved from https://wdfw.wa.gov/sites/default/files/publications/00049/wdfw00049.pdf

Winward, A. H. (2000). Monitoring the vegetation resources in riparian areas (General Technical Report No. RMRS-GTR-47). Retrieved from U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station website: http://www.fs.fed.us/rm/pubs/rmrs_gtr047.pdf

Wolman, M. G. (1954). A method of sampling coarse river-bed material. Eos, Transactions, American Geophysical Union, 35(6), 951–956. https://doi.org/10.1029/TR035i006p00951

Chapter 6 NEXT STEPS

The Upper Klamath Basin Watershed Action Plan (UKB WAP) was developed to identify where the most important restoration opportunities exist in the Upper Klamath Basin (UKB) using a data-driven Restoration Prioritization Framework (RPF) in an adaptive management framework. This initial effort is a framework for future data collection, analysis, and adaptive management of restoration actions in the UKB to improve water quality and stabilize populations of endangered species in Upper Klamath Lake.

Through the development of the RPF, several data limitations and knowledge gaps emerged that should be addressed in future phases of the UKB WAP. We developed the functionality of the prioritization tool as much as possible given these limitations and envision that future efforts will add to and refine the RPF tools. We developed the tools and this process with the understanding that future data collection and analysis tools could be built into the RPF.

During the course of the project, the project focus shifted from prioritization of restoration activities across the basin to identification of impairments within the UKB. This was done to better meet the goals of the UKB WAP Team. The RPF therefore provides a basin wide view of scaled impairment and is able to prioritize general types of restoration needs and reach level location, but does not provide a prioritization of restoration activities across the basin or at specific sites within the basin. For example, the RPF identifies the Upper Sprague Basin as heavily impaired and lists the types of restoration actions that are appropriate for prioritization in the Upper Sprague Basin. The tool does provide a basin wide view of scaled impairment for the conceptual models listed below, for which there were adequate data. The RPF was developed by a broad base of stakeholders from water and land management agencies, the Klamath Tribes, environmental nonprofits, and nonprofits with roots in the agricultural community. In its current form, the UKB WAP demonstrates the impairment by the following types:

- Channelization
- Levees and Berms
- Fish Passage Barriers
- Riparian Grazing
- Fish Screens
- Tailwater Returns (Water Quality Metric)

Identification of impairment of the types listed above, should be considered a demonstration of what can be done instead of a comprehensive list of impairment in the UKB. Continued data collection and analysis work is needed to expand these tools for additional classes of impairment and restoration. The RPF tool can be used by restoration practitioners to view and overlay impairments aligned with their restoration priorities and identify areas of higher impairment for ground-truthing of conditions, and subsequent restoration action planning if deemed appropriate. This first iteration of the RPF is a building block for restoration prioritization in the UKB. The RPF can be made more robust by the collection of additional data and completion of studies (as identified in the Data Gaps & Future Efforts section of Chapter 4). Ultimately the RPF will enable prioritization of different activities across the basin. Another essential component of improving the RPF is collecting adequate monitoring data from implemented restoration projects in the UKB; this will greatly inform the outstanding cost and benefits data gaps associated with restoration action.

DATA AND KNOWLEDGE GAPS SUMMARY

The development of the RPF tool identified several key data and knowledge gaps essential for making well-informed prioritization of restoration activities at the UKB-scale. As described in Table 4-3 (Chapter 4), there is currently no available data for the following conceptual models in terms of quantifying impairment and the costs/benefits of restoration actions:

- Channel incision
- Large Woody Debris (LWD)
- Spawning Gravel
- Wetland Conversion
- Water Withdrawals
- Springs

Limited data is available for riparian, roads, and tailwater returns conceptual models. As discussed in Chapter 4, the data used to quantify riparian impairment is very limited in terms of scale, seasonal representation, and representation of function, however the UKB WAP determined the data is helpful for guiding practitioners in identifying areas that should be prioritized for further study at minimum. For the tailwater returns conceptual model, data is limited for directly quantifying the impacts of tailwater returns, however there was data to quantify water quality impairment, hence the metric title. There is also spatial data available for road features throughout the UKB, but the data is not attributed with information regarding pre-construction conditions and/or culvert information and therefore this data was not used to develop an impairment metric for the roads conceptual model.

The UKB WAP Team identified many future data and/or study needs to enhance and expand the RPF tool. Future data sources and studies that would aid in building the RPF include:

- Physical characteristics of the stream
- Flood control infrastructure (to evaluate constraints of any proposed channel realignment)
- Additional water quality and flow monitoring throughout the UKB
- Detailed, field-verified irrigation infrastructure data
- Amount of floodplain made accessible by levee removal (i.e. hydrodynamic model results)
- Fish species life stage encountered at passage barriers
- Seasonality of use at passage barriers by species
- Stream velocity and depth information
- Habitat assessments that include mapped areas with lack of LWD and limited spawning gravel
- Mapped historic and current lake fringe and floodplain wetlands
- Change in riparian zones and forested areas using historical aerial imagery
- Fish habitat mapping
- More spatially resolved grazing and farming data and management practices
- Vegetation maps with species, wetland indicator status, soil stabilizer properties, diversity, age, and vigor
- Farmed and/or grazed lands
- Fencing and/or other grazing management practices
- Assessment of riparian function
- Landcover data with more resolved classes (different grasses, shrubs, etc.)
- Road data attributed with culvert installation and potential impairment

- Road surface
- Road condition inventory
- Mapping of disconnected springs with relevant flow and water quality data

The level of effort required to develop the data described above varies. For instance, sinuosity and braided index can be calculated from existing stream data layers, while cross section data, channel bathymetry, habitat and riparian function assessments will require extensive field efforts. As higher resolution imagery becomes available, some of the data needs outlined above may be able to be met through remote sensing coupled with machine learning techniques.

Monitoring data collected through implemented restoration projects could also be integrated into broader datasets, particularly if implementers follow similar criteria for evaluating project impacts such as the assessment methods outlined in the Monitoring Framework provided in Chapter 5. An online UKB WAP database could be developed to allow restoration practitioners from across the basin to upload relevant data as it becomes available, which could reduce the time and effort associated with tracking studies and coordinating retrieval of data from the on-going projects in the UKB. The UKB WAP database could be integrated with the Oregon Watershed Enhancement Board (OWEB) project tracking database and databases maintained by the US Fish and Wildlife Service, Bureau of Land Management, Forest Service, and the Bureau of Reclamation. These existing databases collect basic information on restoration projects, which is a critical first step. The UKB WAP database could go a step further and incorporate design and monitoring data to further develop the RPF, implement adaptive management, and refine the conceptual models. An immediate next step for the UKB WAP process should prioritize the data and study needs, to further build the RPF and support informed selection of restoration activities in the UKB.

IMPAIRMENT SUMMARY BY WATERSHEDS

To compare impairment metrics between and within watersheds, the following watershed impairment scores were created and are shown in Table 6-1 and Figure 6-1. Based on the level of impairment, restoration practitioners and watershed managers can prioritize further study or restoration actions between metrics and watersheds. The scores were derived by summing the number of reaches with metric scores that fall within the 75th percentile (indicating higher impairment), and then normalizing that total by the sum of reaches in the watershed with data for the impairment metric. This score was not calculated for the Water Quality metric as the data used was different for each watershed (see Chapter 4).

Watershed Impairment Score = Sum of reaches with impairment metric scores in 75th percentile for metric / Sum of reaches per watershed with data for impairment metric

TABLE 6-1: WATERSHED IMPAIRMENT SCORES

Watershed	**Impairment Metric**	**Watershed Impairment Score**
Sprague	Channelization	0.21
	Levees and Berms	0.23

	Fish Passage Barriers	0.38
	Riparian Grazing	0.36
	Fish Screens	0.36
Williamson	Channelization	0.40
	Levees and Berms	0.17
	Fish Passage Barriers	0.17
	Riparian Grazing	0.09
	Fish Screens	0.17
Wood River Valley	Channelization	0.33
	Levees and Berms	0.50
	Fish Passage Barriers	0.50
	Riparian Grazing	0.10
	Fish Screens	0.57

As shown in Table 6-1, the Sprague watershed is more impaired in terms of metrics for the fish passage, riparian, and fish screens conceptual models. The Williamson is most impaired in terms of the channelization conceptual model, while the Wood River Valley is most impaired under the metrics for levees and berms, fish passage, and fish screens. The Wood River Valley also has the highest watershed impairment scores of the three watersheds.

Figure 6-1 allows for the comparison of the impairment between the Sprague, Williamson, and Wood River Valley. Channelization impairment is more significant in the Williamson followed by the Wood River Valley, and then the Sprague. The Wood River Valley has the highest impairment for levees and berms, fish passage, and fish screens followed by the Sprague and then the Williamson. For the riparian metric, the Sprague has the highest impairment followed by the Wood River Valley and then the Williamson. This illustrates an initial cut at using the tools that were developed in the RPF. Additional data and metrics will enable more refinement of this table to allow prioritization at a specific location.

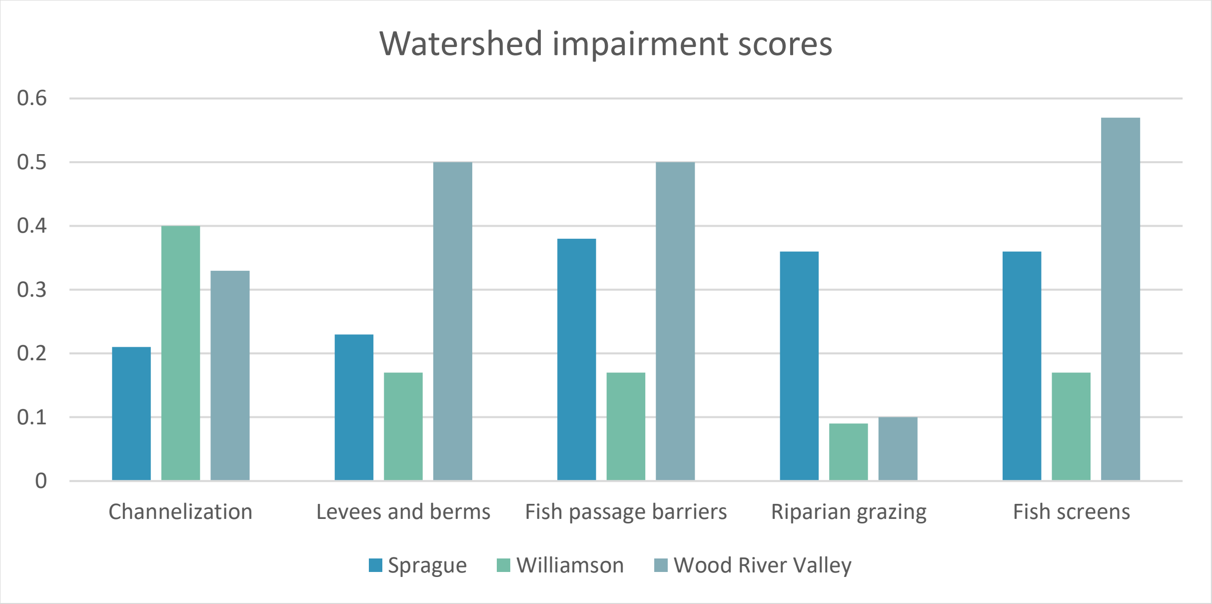


FIGURE 6-1: WATERSHED IMPAIRMENT SCORES VISUALIZATION

CONTINUATION OF THE UKB WAP

The UKB WAP is envisioned as a multi-phase project that in this first phase produced a Restoration Prioritization Framework (RPF) and monitoring guidelines. The UKB WAP is an adaptive management framework and as additional data become available, the RPF can be enhanced with additional data and the associated mapping products updates. There is no direct path forward or additional funding at this time, but the UKB WAP Team is committed to identifying additional funding sources to continue development of the UKB WAP.

In the interim period, interested parties are encouraged to contact any of the UKB WAP Team members to provide input and recommendations for future iterations of the UKB WAP. The UKB WAP Team welcomes the participation by other interested parties for development of future phases of the UKB WAP.

The UKB WAP Team looks forward to improving the RPF, identifying and prioritizing restoration actions at specific locations, and developing a detailed cost estimate for the identified restoration actions.

APPENDIX A: MONITORING FRAMEWORK

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
Beaver reintroduction, beaver dam analogs and other channel aggradation actions	Channel profile	Topographic survey	Longitudinal profile, residual depth	Channel incision/aggradation	Harrelson et al. 1994, Lisle 1987, Simon & Rinaldi 2006, Pollock et al. 2014
	Hydraulics	Inundation and magnitude	Flow depth and velocity measurements or modeling results	Velocity and depth	Turnipseed and Sauer 2010, Kondolf and Piegay 2003, Sauer and Turnipseed 2010
	Water quality	Nutrients, DO, and phyto and zooplankton abundance and presence	Point Sampling, sensor deployment	Nutrients, DO, and Phyto and Zooplankton abundance and presence	DEQ 2009, Kann et al. 2015
	Substrate	Sediment characterization	Facies mapping	Substrate composition	WDFW 2003, Buffington and Montgomery 1999
	Floodplain topography	Topographic survey	Ground based LiDAR, pools and riffle classification	Floodplain size	Pollock et al. 2018
				Connection between floodplain and river	Opperman et al., 2009, Pollock et al.2014
	Floodplain hydrology	Inundation	Velocity measurements or hydraulic modeling output	Floodplain inundation	Opperman et al., 2009
				Capacity to attenuate high flows	Opperman et al., 2009
		Stage measurements	Groundwater elevation survey	Groundwater elevation	Nielson 1991, USFS 2007, Cooper and

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
		(continuous), and peak flow inundation			Merritt 2012, Pollock et al. 2018
	Biological	Cover	Vegetation, root structure and other forms of aquatic cover	Vegetation composition and cover	Burton et al. 2011, Winward 2000
			Mapping and quantification of density and extent of large wood	Large woody debris recruitment	Pollock et al. 2018, Schuett-Hames et al. 1999
		Fish species abundance	Electro-fishing, snorkel surveys, netting, PIT tagging, rotary screw traps	High flow refugia / rearing habitat	DEQ 2009, Flosi et al. 2010, Johnson et al. 2007
				Prey abundance	DEQ 2009, Flosi et al. 2010, Johnson et al. 2007
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Prey abundance	Hayslip, 2007, DEQ 2009, Britton et al. 1987
		Beaver	Presence, survival, density, aerial photography monitoring	Beaver habitat and activity	Pollock et al. 2014, Pollock et al. 2018
Channel reconstruction	Channel geometry	Topographic survey	Cross sections	Bank erosion/deposition, channel incision/aggradation	Harrelson et al. 1994, Simon & Rinaldi, 2006
			Breakline surveys	Bank erosion/deposition	Kondolf and Piegay 2003
			Bankfull width-to-depth ratio	Entrenchment	Rosgen 1996
	Channel profile	Topographic survey	Longitudinal profile, residual pool depth	Incision/aggradation	Harrelson et al. 1994, Lisle 1987

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
	Geomorphic characterization	Channel classification	Geomorphic unit	Scour/deposition	Montgomery and Buffington 1997
	Sediment transport	Sediment dynamics	Tracers	Mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
			Scour chains	Scour/deposition, mobility thresholds	Lisle and Eads 1991, Gordon et al. 2004
			Bedload sediment transport monitoring (DH-48)	Bedload sediment transport, mobility thresholds	Edwards and Glysson 1999
			Suspended load sediment transport (BLH-84)	Suspended load sediment transport, mobility thresholds	Edwards and Glysson 1999
	Hydrology	Stage measurements (continuous)	Pressure transducers	Stage	Sauer and Turnipseed 2010, Gordon et al. 2004
			Stream flow measurements	Discharge	Turnipseed and Sauer 2010
			Groundwater elevation survey	Groundwater elevation	Nielsen 1991, USFS 2007, Cooper and Merritt 2012
			Tracer methods	Mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
			Crest stage gage	Peak stage	Sauer and Turnipseed 2010, Gordon et al. 2004

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
	Water quality	Physical water quality parameters	Point sampling, sensor deployment	Temperature & DO	DEQ 2009, Turk et al. 2001
		Biological water quality parameters	Point Sampling, sensor deployment	Nutrients, DO, and Phyto and Zooplankton abundance and presence	DEQ 2009, Kann et al. 2015
	Substrate	Sediment characterization	Facies mapping	Bed material composition	Buffington and Montgomery 1999
			Pebble counts	Bed size distribution	Wolman 1954, Kondolf 1997
			Bulk samples	Subsurface channel bed size distribution	McNeil and Ahnell 1964
	Aquatic vegetation health	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of aquatic cover,	Vegetation composition and cover	Burton et al. 2011, Winward 2000
		Recruitment	Presence, survival, density, aerial photography monitoring, survival and establishment	Survival	Kershner et al. 2004, Jones et al. 2015
	Biological	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of aquatic cover,	Vegetation composition and cover	Burton et al. 2011, Winward, 2000
		Recruitment	Presence, survival, density, aerial photography monitoring	Survival	Kershner et al. 2004, Jones et al. 2015
		Fish species abundance	Electro-fishing, snorkel surveys, netting, PIT tagging, rotary screw traps	Population	DEQ 2009, Flosi et al 2010, Johnson et al. 2007

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Species presence	Hayslip 2007, DEQ 2009, Britton et al. 1987
Replacing perched, undersized or steep culverts	Channel profile	Topographic survey	Longitudinal profile	Channel gradient	Harrelson et al. 1994, Lisle 1987
	Sediment transport	Sediment dynamics	Suspended load sediment transport (BLH-84)	Suspended load sediment transport	Edwards and Glysson 1999
	Hydraulics	Inundation and magnitude	Flow depth and velocity measurements or modeling results	Velocity and depth	Turnipseed and Sauer 2010, Kondolf and Piegay 2003, Sauer and Turnipseed 2010
		ODFW passage requirements	Flow depth, velocity, & slope measurements or modeling results	Fish passage	KBEF & KBREC 2007, ODFW 2006, USBR 2001
	Hydrology	Stage measurements (continuous)	Tracer methods	Channel constriction / mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
	Substrate	Sediment characterization	Facies mapping	Substrate composition	WDFW 2003, Buffington and Montgomery 1999
Reduce irrigation withdrawals through efficiency measures, instream flow transfers, improved diversion infrastructure	Channel geometry	Topographic survey	Cross sections	Bank erosion/deposition, channel incision/aggradation	Harrelson et al. 1994, Simon & Rinaldi, 2006
			Breakline surveys	Bank erosion/deposition	Kondolf and Piegay 2003
			Bankfull width-to-depth ratio	Entrenchment	Rosgen 1996

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
	Channel profile	Topographic survey	Longitudinal profile, residual pool depth	Incision/aggradation	Harrelson et al. 1994, Lisle 1987
	Hydrology	Stage measurements (continuous)	Pressure transducers	Stage	Sauer and Turnipseed 2010, Gordon et al. 2004
			Stream flow measurements	Discharge	Turnipseed and Sauer 2010
			Groundwater elevation survey	Groundwater elevation	Nielson 1991, USFS 2007, Cooper and Merritt 2012
			Tracer methods	Mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
			Crest stage gage	Peak stage	Sauer and Turnipseed 2010, Gordon et al. 2004
	Water quality	Physical water quality parameters	Point sampling, sensor deployment	Temperature & DO	DEQ 2009, Turk et al. 2001
		Biological water quality parameters	Point Sampling, sensor deployment	Nutrients, DO, and Phyto and Zooplankton abundance and presence	DEQ 2009, Kann et al. 2015
	Substrate	Sediment characterization	Facies mapping	Bed material composition	Buffington and Montgomery 1999
			Pebble counts	Bed size distribution	Wolman 1954, Kondolf 1997
			Bulk samples	Subsurface channel bed size distribution	McNeil and Ahnell 1964

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
	Riparian vegetation health	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of aquatic cover,	Riparian vegetation composition and cover	Burton et al. 2011, Winward 2000
	Biological	Fish species abundance	Electro-fishing, snorkel surveys, netting, PIT tagging, rotary screw traps	Population	DEQ 2009, Flosi et al. 2010, Johnson et al. 2007
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Species presence	Hayslip, 2007, DEQ 2009, Britton et al. 1987
Installation of fish screens	Hydraulics	ODFW screen requirements	Flow rate and velocity measurements at screens	Discharge, velocity, and depth	NMFS 2011, NMFS 1996
	Biological	Fish species abundance	Fish sampling at screens (relative to OWEB criteria), snorkel survey	Mortality by entrainment	Johnson et al. 2007, Simpson & Ostrand, 2012
Removal, setback or breaching of levees and berms	Channel profile	Topographic survey	Longitudinal profile, residual pool depth	Incision/aggradation	Harrelson et al. 1994, Lisle 1987
	Hydraulics	Inundation	Velocity measurements or hydraulic modeling output	Velocity	Turnipseed and Sauer 2010, Kondolf and Piegay 2003
	Hydrology	Channel stage and groundwater levels (continuous) and peak flow/inundation	Pressure transducers (continuous)	Stage	Sauer and Turnipseed 2010, Gordon et al. 2004
			Crest stage gages (peak)	Peak stage	Sauer and Turnipseed 2010, Gordon et al. 2004

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
			Stream flow measurements	Discharge	Turnipseed and Sauer 2010
			Groundwater elevation survey	Groundwater elevation	Nielson 1991, USFS 2007, Cooper and Merritt 2012
			Tracer methods	Mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
	Water quality	Physical water quality parameters	Point sampling, sensor deployment	Temperature & DO	DEQ 2009, Turk et al. 2001
		Biological water quality parameters	Point Sampling, sensor deployment	Nutrients, DO, and phyto and zooplankton abundance and presence	DEQ 2009, Kann et al. 2015
	Substrate	Soil characterization	Soil mapping, subsurface boring	Soil development	Soil Survey Division Staff 1993, Schoeneberger et al. 2012, Florsheim and Mount 2002
			Chains, sediment transport, erosion and deposition	Deposition	Florsheim and Mount. 2002, Lisle and Eads 1991, Steiger et al. 2003
	Floodplain topography and channel geometry	Topographic survey	Ground based LiDAR, pools and riffle classification	Topographic change	Montgomery and Buffington 1997, Harrelson et al. 1994, Lokteff et al. 2011

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
			Cross sections	Bank erosion/deposition, channel incision/aggradation	Harrelson et al. 1994, Simon & Rinaldi, 2006
			Breakline surveys	Bank erosion/deposition	Kondolf and Piegay 2003
			Bankfull width-to-depth ratio	Entrenchment	Rosgen 1996
	Riparian and floodplain cover	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of riparian cover. Canopy cover and solar radiation (spherical densitometer, solar pathfinder), bank stability (cross sections and line intercept transect)	Vegetation composition and cover	Burton et al. 2011, Winward 2000
	Biology	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of riparian cover.	Vegetation composition and cover	Burton et al. 2011, Winward 2000
		Fish species abundance	Electro-fishing, netting, PIT tagging	Population	DEQ 2009, Flosi et al. 2010, Johnson et al. 2007
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Species presence	Hayslip, 2007, DEQ 2009, Britton et al. 1987
Placement of large woody debris	Channel geometry	Topographic survey	Cross sections	Bank erosion/deposition, channel incision/aggradation	Harrelson et al. 1994, Simon & Rinaldi, 2006

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
			Breakline surveys	Bank erosion/deposition	Kondolf and Piegay 2003
			Bankfull width-to-depth ratio	Entrenchment	Rosgen 1996
	Channel profile	Topographic survey	Longitudinal profile, residual pool depth	Incision/aggradation	Harrelson et al. 1994, Lisle 1987
	Hydrology	Stage measurements (continuous)	Pressure transducers	Stage	Sauer and Turnipseed 2010, Gordon et al. 2004
			Stream flow measurements	Discharge	Turnipseed and Sauer 2010
			Groundwater elevation survey	Groundwater elevation	Nielsen 1991, USFS 2007, Cooper and Merritt 2012
			Tracer methods	Mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
			Crest stage gage	Peak stage	Sauer and Turnipseed 2010, Gordon et al. 2004
	Water quality	Water quality parameters	Point sampling, sensor deployment	Temperature & DO	DEQ 2009, Turk et al. 2001
	Substrate	Sediment characterization	Facies mapping	Bed material composition	Buffington and Montgomery 1999
			Pebble counts	Bed size distribution	Wolman 1954, Kondolf 1997
			Bulk samples	Subsurface channel bed size distribution	McNeil and Ahnell 1964
	Large woody debris (LWD)	LWD	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
	Aquatic vegetation health	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of aquatic cover	Riparian vegetation composition and cover	Burton et al. 2011, Winward 2000
		Recruitment	Presence, survival, density, aerial photography monitoring	Survival	Kershner et al. 2004, Jones et al. 2015
	Biological	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of aquatic cover,	Riparian vegetation composition and cover	Burton et al. 2011, Winward 2000
		Recruitment	Presence, survival, density, aerial photography monitoring	Survival	Kershner et al. 2004, Jones et al. 2015
		Fish species abundance	Electro-fishing, snorkel surveys, netting, PIT tagging, rotary screw traps	Population	DEQ 2009, Flosi et al. 2010
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Species presence	Hayslip 2007, DEQ 2009, Britton et al. 1987
Restoring and construction of natural wetlands	Hydraulics (floodplain)	Inundation	Velocity measurements or hydraulic modeling output	Velocity and depth	Turnipseed and Sauer 2010, Kondolf and Piegay 2003
	Hydrology (floodplain)	Stage measurements (continuous), and	Pressure transducers (continuous)	Stage	Sauer and Turnipseed 2010, Gordon et al. 2004

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
		peak flow inundation	Crest stage gages (peak)	Peak stage	Sauer and Turnipseed 2010, Gordon et al. 2004
			Stream flow measurements	Discharge	Turnipseed and Sauer 2010
			Groundwater elevation survey	Groundwater elevation	Nielson 1991, USFS 2007, Cooper and Merritt 2012
			Tracer methods	Mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
	Water quality	Physical water quality parameters	Point sampling, sensor deployment	Temperature & DO	DEQ 2009, Turk et al. 2001
		Biological water quality parameters	Point Sampling, sensor deployment	Nutrients, DO, and phyto and zooplankton abundance and presence	DEQ 2009, Kann et al. 2015
	Sediments (floodplain)	Soil characterization	Soil mapping, subsurface boring	Soil type	Soil Survey Division Staff 1993, Schoeneberger et al. 2012
			Chains, sediment transport, erosion and deposition	Deposition	Florsheim and Mount. 2002, Lisle and Eads 1991, Steiger et al. 2003
	Floodplain topography	Topographic survey	Ground based LiDAR, pools and riffle classification	Topographic change	Montgomery and Buffington 1997, Harrelson et al. 1994, Lokteff et al. 2011

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
			Cross sections	Bank erosion/deposition, channel incision/aggradation	Harrelson et al. 1994, Simon & Rinaldi, 2006
			Breakline surveys	Bank erosion/deposition	Kondolf and Piegay 2003
			Bankfull width-to-depth ratio	Entrenchment	Rosgen 1996
	Floodplain cover	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of floodplain cover	Vegetation composition and cover	Burton et al. 2011, Winward 2000
	Biology	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, and other forms of floodplain cover.	Vegetation composition and cover	Burton et al. 2011, Winward 2000
		Fish species abundance	Electro-fishing, netting, PIT tagging	Population	DEQ 2009, Flosi et al 2010, Johnson et al. 2007
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Species presence	Hayslip 2008, DEQ 2009, Britton et al. 1987
Removal or mitigation of (non-culvert) passage barriers	Hydraulics	ODFW passage requirements	Flow depth, velocity, & slope measurements or modeling results	Velocity, depth, and discharge	ODFW 2006, USBR 2001
Placing fences in riparian zone, grazing management	Channel geometry	Topographic survey	Ground based LiDAR, pools and riffle classification	Topographic change	Montgomery and Buffington 1997, Harrelson et al. 1994, Lokteff et al. 2011

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
			Cross sections	Bank erosion/deposition, channel incision/aggradation	Harrelson et al. 1994, Simon & Rinaldi, 2006
			Breakline surveys	Bank erosion/deposition	Kondolf and Piegay 2003
			Bankfull width-to-depth ratio	Entrenchment	Rosgen 1996
	Channel profile	Topographic survey	Longitudinal profile, residual pool depth	Incision/aggradation	Harrelson et al. 1994, Lisle 1987
	Hydraulics	Inundation and magnitude	Flow depth and velocity measurements or modeling results	Velocity and depth	Turnipseed and Sauer 2010, Kondolf and Piegay 2003, Sauer and Turnipseed 2010
	Water quality	Physical water quality parameters	Point sampling, sensor deployment	Temperature & DO	DEQ 2009, Turk et al. 2001
		Biological water quality parameters	Point Sampling, sensor deployment	Nutrients, DO, and phyto and zooplankton abundance and presence	DEQ 2009, Kann et al. 2015
	Riparian hydraulics	Inundation	Velocity measurements or hydraulic modeling output	Velocity	Turnipseed and Sauer 2010, Kondolf and Piegay 2003
	Riparian hydrology	Groundwater levels (continuous) and peak flow inundation	Pressure transducers (continuous)	Stage	Sauer and Turnipseed 2010, Gordon et al. 2004
			Crest stage gages (peak)	Peak stage	Sauer and Turnipseed 2010, Gordon et al. 2004

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
			Stream flow measurements	Discharge	Turnipseed and Sauer 2010
			Groundwater elevation survey	Groundwater elevation	Nielsen 1991, USFS 2007, Cooper and David 2012
			Tracer methods	Mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
	Riparian sediment	Soil characterization	Soil mapping, subsurface boring	Soil development	Soil Survey Division Staff 1993, Schoeneberger et al. 2012, Florsheim et al. 2002
	Riparian cover	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al. 1999
			Vegetation, root structure, streamside, and other forms of riparian cover, bank stability (cross sections and line intercept transect)	Vegetation composition and cover	Burton et al. 2011, Winward 2000
	Riparian biology	Cover	Mapping and quantification of density and extent of large wood	LWD loading	Schuett-Hames et al.1999
			Vegetation (with direct count and plot method), root structure, herbaceous, streamside, vegetation overhang, and other forms of riparian cover. Tree or shrub cover and composition with line intercept transects, herbaceous composition with gap,	Vegetation composition and cover	Burton et al. 2011, Winward 2000

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
			line-point and step-point intercept		
		Fish species abundance	Electro-fishing, netting, PIT tagging, snorkel surveys	Population	DEQ 2009, Flosi et al. 2010, Johnson et al. 2007
		Species abundance	Trapping, wildlife camera, surveys, smoke plates	Presence and abundance	Anderson et al. 2013
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Species presence	Hayslip, 2008, DEQ 2009, Britton et al. 1987
Road decommissioning including removal or replacement of culverts	Channel profile	Topographic survey	Longitudinal profile	Channel gradient	Harrelson et al. 1994, Lisle 1987
				Channel incision/aggradation	Harrelson et al. 1994, Lisle 1987, Simon & Rinaldi 2006
	Hydraulics	Inundation and magnitude	Flow depth and velocity measurements or modeling results	Velocity and depth	Turnipseed and Sauer 2010, Kondolf and Piegay 2003, Sauer and Turnipseed 2010
		ODFW passage requirements		Fish passage	KBEF & KBREC 2007, ODFW 2006, USBR 2001
		Stage measurements (continuous)	Tracer methods	Channel constriction / mobility threshold	Kondolf and Piegay 2003, Gordon et al. 2004
	Hydrology	Geohydrology	Groundwater survey	Drainage topography	Nielson 1991, USFS 2007

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
	Water quality	Physical water quality parameters	Point sampling, sensor deployment	Non-native materials associated with road bed	DEQ 2009, Turk et al. 2001
				Upland capacity to intercept/retain nutrients and sediments	USBR 2013, DEQ 2009, Turk et al. 2001
		Biological water quality parameters		Nutrients, DO, and phyto and zooplankton abundance and presence	DEQ 2009, Kann et al. 2015
	Substrate	Sediment characterization	Facies mapping	Substrate composition	WDFW 2003, Buffington and Montgomery 1999
	Floodplain hydrology	Stage measurements (continuous), and peak flow inundation	Groundwater elevation survey	Groundwater elevation	Nielson 1991, USFS 2007, Cooper and Merritt 2012
	Biological	Terrestrial wildlife	Species presence, aerial photography monitoring	Terrestrial wildlife habitat connectivity	Haddad et al. 2015
Addition of spawning gravel	Biological	Fish species abundance	Electro-fishing, netting, PIT tagging, snorkel surveys	Spawning habitat	ODSL et al. 2010, Bernard & McBain 1994, McNeil & Ahnell 1964
				Fish recruitment	KBEF & KBREC 2007, Bernard & McBain 1994, McNeil & Ahnell 1964

Action(s)	Metric(s)	Assessment Class	Assessment Method(s)	Monitoring Target	References
		Spawning success		Spawning success and embryo survival	KBEF & KBREC 2007, Bernard & McBain 1994, McNeil & Ahnell 1964
Restoring connections to cold-water springs	Hydraulics	Inundation and magnitude	Flow depth and velocity measurements or modeling results	Velocity and depth	Turnipseed and Sauer 2010, Kondolf and Piegay 2003, Sauer and Turnipseed 2010
	Water quality	Physical water quality parameters	Point sampling, sensor deployment	Temperature & DO	DEQ 2009, Turk et al. 2001, Nichols et al., 2014
	Biology	Cover	Presence, survival, density, aerial photography monitoring	Survival	Kershner et al. 2004, Jones et al. 2015
		Fish species abundance	Electro-fishing, snorkel surveys, netting	Population	DEQ 2009, Flosi et al. 2010, Johnson et al. 2007
		Insects	Macroinvertebrate species, abundance (multiplate and basket samplers), diversity	Species presence	Hayslip 2007, DEQ 2009, Britton et al. 1987