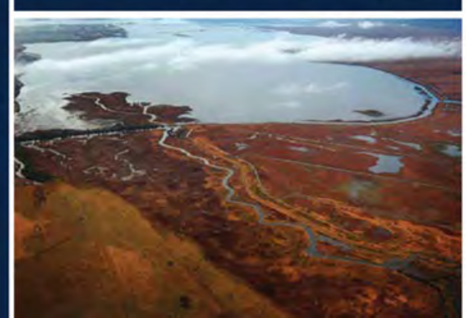
FINAL

Upper Klamath Lake Watershed Assessment

June 2010

Prepared for
Klamath Watershed Partnership

Prepared by
David Evans and Associates, Inc.



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CONTRIBUTORS AND ACKNOWLEDGEMENTS

This watershed assessment is the work of a community. To all those who live, work, and play in the Upper Klamath Lake Subbasin, and to all who have had a hand in putting this document together, our sincerest thanks. You should thank yourselves too, because this document is, after all, yours.

Contributors

Nathan Jackson, Klamath Watershed Partnership - Project Lead

Adam Argo, David Evans and Associates, Inc. - GIS specialist, map production

Angie Jones, David Evans and Associates, Inc. - Project Assistant, report formatting and document preparation

Christine Immroth, David Evans and Associates, Inc. - Technical Editor, Bibliography

Crystal Grinnell, David Evans and Associates, Inc. - Channel Habitat Typing and Modifications, Hydrology and Water Use, Sediment Sources Assessment, Riparian Assessment, Wetlands Assessment

Ethan Rosenthal, David Evans and Associates, Inc. - Assistant Project Management, Water Quality Assessment, Fish and Fish Habitat Assessment, contributor to Wetlands and Riparian Assessments, and report photography (except where noted)

Eve Henrichsen and Kirk Moghamer, David Evans and Associates, Inc. - GIS modeling of Rosgen channel habitat types

Jennifer Miller, David Evans and Associates, Inc. - Project Management

Kim Seymour, David Evans and Associates, Inc. - Introduction, Historical Conditions Assessment, Watershed Condition Evaluation, and document preparation

Melissa Foltz, David Evans and Associates, Inc. - Graphics Specialist, cover, and report graphics and figures

Danette Watson, Ranch and Range Consulting - Personal Interviews, Historical Conditions Assessment, contributor to Riparian Assessment, and technical review

Interviewees and Meeting Attendees

The following people gave the most precious things to the assessment process - their time and their knowledge:

Neil Anderson, USFS
Mark Buktenica, Crater Lake National Park
Mark Campbell, Jeld-Wen Timber & Ranches

Chris Cook, Running Y Ranch
Rick Craiger, OWEB
Bev Demetrakos, Odessa Ranch
Debbie Demetrakos, Odessa Ranch
Jon Elliott, Odessa Ranch
Chris Engel, Fishing Guide
Heather Hendrixson, TNC
Martin Kerns, Landowner
Alice Kilham, Caledonia Ranch
Casey Ladner, Running Y Ranch
Paul and Cheri Little, Landowners
Jim Litts, KWERC
Walt Lucas, USFS – Fremont/Winema
Ambrose McAuliffe, Landowner
Ed Miranda, Fishing Guide
Marshal Moser, Lonesome Duck
Roger Nicholson, Landowner
Dan Rajnus, Running Y Ranch
Heather Ray, USFWS
Ben Scott, Simplexity Health
Anna Shannon, Simplexity Health
Anne Wenner, Landowner

Commenters

Alice Kilham, Caledonia Ranch
Walt Lucas, USFS – Fremont/Winema
Neil Anderson, USFS
Andrea Rabe, Rabe Consulting
Shannon Peterson, KBRT
Anne Wenner, Landowner
Roger Smith, ODFW

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Table of Contents

List of Tables

List of Figures

List of Maps

ACRONYMS

CEAP	Conservation Effects Assessment Project
CHT	Channel Habitat Type
DEM	Digital Elevation Map
DSL	Department of State Lands
ESA	Endangered Species Act
GIS	Geographic Information System
HUC	Hydrologic Unit Code
IAU	Individual Assessment Unit
KBRT	Klamath Basin Rangeland Trust
KWI	Klamath Watershed Institute
KWP	Klamath Watershed Partnership
LSR	Late Successional Reserve
LWD	large woody debris
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
OSU	Oregon State University
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Water Resources Department
RMA	Riparian Management Area
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
US GLO	United States General Land Office
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WAB	water availability basin
WQMP	Water Quality Management Plan
WRP	Wetlands Reserve Program

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CHAPTER 1:

INTRODUCTION

1 INTRODUCTION

From the snowy flanks of Crater Lake, along the meanders of the Wood River, to the broad open waters of Upper Klamath and Agency lakes and the rich farmlands surrounding them, the Upper Klamath Lake Subbasin is a landscape shaped by the strongest forces of nature: volcanic eruptions, rushing water, cold winds and man. It is a landscape that is home to fifth-generation ranchers, tribal members, bald eagles, big pines, fishing guides and redband trout of legendary size and wit.

This landscape has been altered by humans for our needs since a time before memory. These alterations have been both gentle and dramatic. While there is still so much that is whole, there are now fish whose populations are considered endangered and unhealthy levels of sediment and nutrients flowing into the very waters that define the region. Through this Watershed Assessment (assessment), the people of the Upper Klamath Lake Subbasin are working together to improve and protect the place they call home.

Purpose

This assessment has been prepared by and for the Klamath Watershed Partnership (KWP), and the community of the Upper Klamath Lake Subbasin. The primary goal of this assessment is to evaluate several key indicators of watershed health within the subbasin. This assessment does not create or provide any new data but is, instead, based solely on existing information and interviews with the community. This information is summarized for each indicator then combined to describe the overall health of the subbasin. This information provides a foundation for developing management and restoration actions that will help to maintain and improve the health of the subbasin.

A secondary goal of this assessment is to identify data gaps and subsequent research needs. This assessment relies on existing information; therefore, it is the intent of the assessment to identify critical information gaps which, if filled, could help to target restoration and management activities.

Fundamentally, this assessment is intended to engage the community of the Upper Klamath Lake Subbasin. This is their assessment because this information comes from the people that live and work here. These are the only people that can evaluate the recommended management and restoration actions because they walk this ground every day and they know best what works and what does not.

Methods

This assessment follows the framework provided by the *Oregon Watershed Assessment Manual* (Manual) of the Oregon Watershed Enhancement Board (OWEB) (WPN 1999). The requirements of the Manual have not changed since 1999, therefore, this assessment may be similar in structure and content to the several watershed assessments prepared for other subbasins in the Upper Klamath Basin, with similar landscapes and hydrology (DEA 2005;

Klamath Basin Ecosystem Foundation et al. 2007; Rabe Consulting 2009). Similar to the others, this assessment relies solely on existing information and community interviews, however, this assessment is unique in many ways, including the inclusion of recently collected groundwater and hydrology data (Gannett et al. 2007), results from ongoing wetlands restoration efforts (e.g., Wood River Wetland, Agency Ranch, Barnes Ranch) and recent water storage studies (USGS 2005). In addition, the assessment considers climate change and how to improve, rebuild and create resilient ecosystems.

This assessment focuses on the components outlined in the Manual and is arranged into the following chapters:

- Historical Conditions
- Channel Habitat Typing and Modifications
- Hydrology and Water Use
- Sediment Sources Assessment
- Riparian Assessment
- Wetlands Assessment
- Water Quality Assessment
- Fish and Fish Habitat Assessment

Each of these chapters contains the following sections: Introduction, Methods, Results and Discussion, Confidence Evaluation, Research Recommendations, and Restoration and Management Opportunities. The Introduction section provides a brief summary and the purpose of each chapter. The Methods section provides a list of data sources as well as any additional analyses that were performed in order to develop the Results and Discussion section. The Results and Discussion section provides an overview of the important relationships, patterns and conclusions that can be drawn from available data. The Confidence Evaluation rates the overall confidence in each technical chapter of the assessment, given the number of resources available, the quality of the available resources, and whether or not the information in those resources is consistent. The following general definitions of confidence ratings were used in the Confidence Evaluation section of each chapter: high: used source of information from agency records or from other trained observers with documented quality control or multiple sources of information that reach the same conclusion and photographic documentation; moderate to high: used source of information from agency records or from other trained observers or multiple sources of information that reach the same conclusion; moderate: used several sources of information that reach the same conclusion; low to moderate: used one source of information, unsure of the credibility. The Recommendations section describes known data gaps for specific technical components and provides recommendations for filling those gaps. The Restoration Opportunities section uses the technical evidence brought forward in the Results and Discussion section to recommend potential restoration actions that could benefit the watershed.

The information provided in each of these chapters is synthesized and summarized in the final chapter, Summary of Watershed Conditions, Research Recommendations and Restoration Opportunities. The purpose of this chapter is to provide KWP and the Upper Klamath Lake Subbasin communities with the information they need to prioritize, design, and implement beneficial restoration actions.

It is important to note that this assessment is not intended to provide a design-level of detail for potential restoration actions. However, this assessment should provide the level of detail necessary to develop action plans and monitoring strategies (not included in this assessment) for protecting and enhancing the health of the subbasin.

Study Area

This assessment has been conducted as part of a broader Watershed Assessment effort for the entire Upper Klamath Basin. The assessment techniques described in the Manual are generally intended for fifth-field watersheds; however, because of time and resource constraints, it was not reasonable to conduct assessments on each individual fifth-field within the Upper Klamath Basin. Therefore, the 8,000 square mile Upper Klamath Basin was broken up into Individual Assessment Units (IAUs) that generally overlapped with fourth-field or subbasin boundaries. The proposed IAUs for the Upper Klamath Basin are illustrated in Figure 1-1 (Location of the Upper Klamath Lake Subbasin). The IAU addressed in this assessment is the Upper Klamath Lake Subbasin.

The Upper Klamath Lake Subbasin is located in south central Oregon along the east side of the Cascades and along the west edge of the Upper Klamath Basin. It falls almost entirely within the boundaries of Klamath County except for a small portion on the southwest side which continues into Jackson County. It is approximately 725 square miles or 465,300 acres and extends from Crater Lake to the outlet of Upper Klamath Lake into the Link River, as illustrated in Map 1-1 (Base Map, at the end of this section).

The assessment area has a broad range of elevation, ranging from approximately 4,121 ft to 9,439 ft, as shown in Table 1-1 (Areas and Elevations of of Fifth-Field Watersheds in the Upper Klamath Lake Subbasin). The hydrology of the subbasin is characterized by an extensive, interconnected groundwater aquifer system which feeds several key water bodies such as the Wood River and Upper Klamath Lake (see Chapter 4, Hydrology and Water Use for additional information). The assessment area contains Upper Klamath and Agency lakes, which, with respect to surface area, form the largest freshwater lake in Oregon (Oregon lakes Association 2009). In addition to Upper Klamath and Agency lakes, the Wood River and Sevenmile Creek are considered significant hydrologic features.

The assessment area includes a portion of the Fremont-Winema National Forest, Crater Lake National Park, Kimball State Park, Upper Klamath National Wildlife Refuge, and the Wood River Wetland. Primary roads include Highway 97, cutting north-south through the southeastern side of the subbasin along Upper Klamath Lake; Highway 62, which runs through the most northern portion of the subbasin, near Crater Lake and along Annie Creek; and Highway 232 which also runs through the most northern portion of the subbasin, near Fort Creek and Crooked Creek. Klamath Falls, the major population center for the Upper Klamath Basin, is located just outside of the southern-most boundary of the assessment area.

Figure 1-1. Location of the Upper Klamath Lake Subbasin

The assessment area includes the following fifth-field watersheds, as illustrated in Map 1-1 (at the end of this section):

- Wood River (Hydrologic Unit Code (HUC): 1801020301)
- Klamath Lake (HUC: 1801020302)
- Fourmile Creek (HUC: 1801020303)

The areas and elevations of the fifth-field watersheds within the subbasin are provided in Table 1-1. The boundaries for these fifth-field hydrologic units were derived from the U.S. Department of Agriculture (USDA) and the Natural Resources Conservation Science (NRCS); however, they are similar to those represented by the U.S. Geological Survey (USGS) and others.

Table 1-1. Areas and Elevations of Fifth-Field Watersheds in the Upper Klamath Lake Subbasin.

Watershed	Area (mi^2)	Elevation (feet) Mean	Min	Max
Wood River	191.8	5,044	4,136	8,120
Fourmile Creek	116.6	5,544	4,143	9,439
Klamath Lake	415.2	5,633	4,121	8,205
Entire Assessment Area	**723.6**	**4,888**	**4,121**	**9,439**

Data source: USGS 2004a

Land Ownership

Information on ownership within the Upper Klamath Lake Subbasin was obtained from the Fremont-Winema National Forest database. Land ownership in the assessment area is split between public and private with U.S. Forest Service (USFS) managing most of the west side of the subbasin, and the east side of the subbasin largely in private ownership (as shown in Map 1-2, Land Ownership). The northern tip of the assessment area is managed by the National Park Service (NPS). At the north end of Upper Klamath Lake, the U.S. Fish and Wildlife Service (USFWS) operates the Upper Klamath National Wildlife Refuge. General land use is characterized by forested uplands and a mix of pasture and wetlands in the lowlands. Additional information on the type and area of ownership is provided in Chapter 4, Hydrology and Water Use and is summarized by fifth-field watershed in Table 1-2, Summary of Ownership/Management.

Table 1-2. Summary of Ownership/Management

Fifth-Field Watershed:		Wood River	Klamath Lake	Fourmile Creek	TOTAL FOR SUBBASIN
USFS	**Acreage**	37,325	62,541	72,612	172,478
	%	30	24	97	37
NPS	**Acreage**	30,656	0	0	30,656
	%	25	0	0	7
USFWS	**Acreage**	0	13,016	1	13,017
	%	0	7	0	3
State Forest	**Acreage**	14,206	204	0	14,410
	%	12	0	0	3
Private[1]	**Acreage**	35,682	114,340	1,981	152,003
	%	29	43	3	33
BLM	**Acreage**	3,091	1,914	0	5,005
	%	3	1	0	1

Fifth-Field Watershed:		Wood River	Klamath Lake	Fourmile Creek	TOTAL FOR SUBBASIN
Reclamation	**Acreage**	59	7,307	0	7,366
	%	0	3	0	2
DSL	**Acreage**	1,549	660	0	2,209
	%	1	0	0	0
Undefined[2]	**Acreage**	282	65,771	0	66,053
	%	0	25	0	14
TOTAL	**Acreage**	**122,850**	**265,549**	**74,593**	**463,197**

[1]Private ownership includes Aspen Lake, Long Lake Valley, and Round Lake (BLM 2006).
[2]Undefined ownership encompasses Upper Klamath Lake and Agency Lake (approximately 103.2 mi2) (BLM 2006).
Data Source: BLM 2006

Ecoregions

The ecoregion data were obtained from the Level III and IV Ecoregion Descriptions of Oregon (Bryce and Woods 2000). Ecoregions are areas that have been identified based on similar climatic, geologic, physiographic, vegetative, soils (see USDA 1985 for more information), land use, wildlife, and hydrologic characteristics. Map 1-3 (Upper Klamath Lake Ecoregions) illustrates the ecoregions identified for the Upper Klamath Lake Subbasin. The Upper Klamath Lake Subbasin is located primarily within the High Southern Cascades Montane Forest and the Klamath/Goose Lake Warm Wet Basins. The Klamath Juniper/Ponderosa Pine Woodland ecoregion occupies the SE corner of the subbasin; the Pumice Plateau ecoregion occupies a small portion of the NE side of the subbasin; the Southern Cascade Slope ecoregion is located in the south-central portion of the subbasin; the Cascade Subalpine/Alpine is scattered amongst the High southern Cascades Montane Forest ecoregion, in the highest elevations; the Fremont Pine/Fir Forest ecoregion occupies the southwestern portion of the subbasin; the High Southern Cascades Montane Forest ecoregion occupies the west side of the subbasin and contains high elevation landscape features; and the Klamath/Goose Lake Warm Wet Basins ecoregion is located in the center-eastern portion of the subbasin and contains Upper Klamath and Agency lakes. Following are brief descriptions of the ecoregions present in the assessment area, adapted from Bryce and Woods (2000).

Klamath Juniper/Ponderosa Pine Woodland: This ecoregion is characterized by a mosaic of woodland and sagebrush-grassland. It has a wide range of topography and geology, including undulating hills, benches, and escarpments containing medium gradient streams. It has relatively impermeable soils of volcanic ash, sandstone, and siltstone. Within this ecoregion, water features are characterized by reservoirs with a few small lakes.

Pumice Plateau Forest: This ecoregion is a high volcanic plateau that is thickly covered by Mt. Mazama ash and pumice. Its residual soils are highly permeable. Prevalent water features are spring-fed creeks, marshes, and a few lakes. Forests of ponderosa pine (*Pinus ponderosa*) are common on the slopes; colder depressions and flats are dominated by lodgepole pine (*Pinus contorta*). Winters are consistently cold and precipitation falls mainly as snow. Summers tend to be mild.

Southern Cascade Slope: This ecoregion is generally comprised of midelevation mountains and medium to high gradient streams and rivers with some permanent, large lakes of glacial origin. The landscape is mostly mixed conifer in the lower elevations with some Shasta red fir (*Abies magnifica* var. *shastensis*), mountain hemlock (*Tsuga mertensiana*), and whitebark pine (*Pinus albicaulis*) in the higher elevations. This ecoregion is an important water source for lower elevation urban and agricultural areas.

Cascade Subalpine/Alpine: These areas are generally high, glaciated, volcanic peaks that rise above subalpine meadows. Elevations range from 5,600 to 12,000 feet. Active glaciation occurs on the highest volcanoes and decreases from north to south. The winters are very cold and the growing season is extremely short. The vegetation that occurs in these high elevation areas include herbaceous and shrubby subalpine meadow species and scattered patches of mountain hemlock, subalpine fir (*Abies lasiocarpa*) and whitebark pine.

Fremont Pine/Fir Forest: This ecoregion is present on steeply to moderately sloping mountains and high plateaus with high gradient intermittent and ephemeral streams. In addition, reservoirs, some glacial rock-basin lakes, and many springs are present. In lower altitudes this ecoregion is primarily ponderosa pine and western juniper (*Juniper occidentalis*) whereas in the higher altitudes it is mostly white fir (*Abies concolor*) with some whitebark and lodgepole pine.

High Southern Cascades Montane Forest: This ecoregion consists of an undulating, glaciated plateau punctuated by volcanic buttes and cones. This mixed coniferous forest is dominated by mountain hemlock and Pacific silver fir (*Abies amabilis*). Grand fir (*Abies grandis*), white fir, Shasta red fir, and lodgepole pine also occur and become more common toward the south and east.

Klamath/Goose Lake Warm Wet Basins: These areas are generally comprised of pluvial lakes containing floodplains, terraces, and low gradient streams. Soils are relatively impermeable and mostly very deep to deep peaty muck, clay loam, silt loam, and loam. This ecoregion has characteristic wet and dry cycles that can dramatically impact water levels in the ecoregion. For example, particularly wet winters result in inundation of the valley floor. This ecoregion is mostly sagebrush steppe, but was historically extensive wetland area abundant with tule (*Scirpus Eacustris occidentalis*), cattail (*Typha latifolia*), and sedges.

Community Involvement

The local community plays a crucial role in the development of a watershed assessment. The daily activities of the people who live and work in the subbasin help shape the current and future conditions of the subbasin. This assessment is based, in part, on data and interviews provided by people living and working in the subbasin. Because it is essential that this assessment be prepared by and for the Upper Klamath Lake Subbasin community, a consistent and broad-reaching community involvement was established and maintained throughout the development of this assessment.

This assessment is one of many that will cover the Upper Klamath Basin. At the beginning of the assessment process, a public outreach strategy and framework were developed to guide the outreach efforts for all of the assessments. The primary goals for the public outreach efforts were to:

- Inform community members on the purpose and process of developing a watershed assessment
- Gather comments and suggestions, facilitate, and maintain direct and consistent participation
- Identify critical issues this assessment should address
- Encourage a strong sense of stewardship toward the landscape, the habitats, and the various communities of the Upper Klamath Lake Subbasin and the Upper Klamath Basin as a whole.

These outreach efforts followed an iterative process, using public comments and suggestions to guide future community outreach events. The first step in developing the outreach strategy was to identify the tools that would be most effective in meeting the outreach goals.

The outreach efforts for the Upper Klamath Lake Subbasin emphasized public meetings, interviews, community reviews and contributions as described below.

Kick-Off Meetings. Two public kick-off meetings were held on October 14 and 15, 2009. These meetings were intended to educate people about watershed assessments in general, and the Upper Klamath Lake Watershed Assessment process in particular, and were designed to facilitate participation in the assessment process. These meetings were also used to introduce the public to the Partnership and the organizations conducting the assessment and to build a list of issues and concerns to help focus the assessment efforts.

The October 14th kick-off meeting was held in the north part of the assessment area, at the Klamath Outdoor Science School near Kimball State Park with a subsequent field trip to view management and restoration sites on the nearby Kerns Ranch and Knapp Ranch.

The October 15th kick-off meeting was held at the Running Y Ranch, in the south part of the assessment area, with a subsequent field trip to see agricultural operations of the ranch and a fish screen installation project.

Issues Identification. It is important to get a sense of the watershed issues that people living and working in the basin believe are critical to help target the assessment process. The attendees of the two kick-off meetings identified the following important issues:

- Ineffective restoration
- Sedimentation (natural rates and human caused increases)
- Trout movement/spawning
- Problems with prior restoration at the mouth of the Wood River
- Macroinvertebrate diversity and need for surveys
- Naturally high phosphorous values in the region
- Monitoring of fenced riparian areas
- The interrelationships of cattle, insects, fish, and water quality
- Grazing restrictions to “benefit” nesting birds
- Problems with single-species management approaches
- Impacts to cattle production
- Lower late flows due to “restoration”
- Deterioration of sod/native grasses due to lack of irrigation
- Deterioration of riparian/grass land vegetation
- Need for peer reviewed information/studies

Issues brought up during kick-off meetings helped the assessment team focus on the topics that were important to stakeholders and community members and served as the backbone for discussions throughout the assessment process.

Interviews. Interviews were conducted as part of the assessment outreach effort to exchange information with key community members, long-time residents, watershed stakeholders and landowners. These interviews played a significant role in learning about historic conditions within the watershed and in developing open and honest relationships with community members. The outreach process has demonstrated that developing strong relationships within the community will, ultimately, lead to successful restoration projects. These meetings were conducted in November and December 2009 by Ranch and Range Consulting and notes from these meetings were used in the preparation of the Historic Conditions section as well as the technical chapters.

Community Review of the draft Watershed Assessment. The draft assessment was distributed and made available for public review from March 30 – April 23, 2010. Comments were received from a diversity of stakeholders and on May 6, 2010 KWP and David Evans and Associates (DEA) met with the reviewers to discuss the comments that had been received and how to revise the assessment in response to these comments. All of the comments received and the subsequent discussion served to inform and improve the assessment.

Present the Final Watershed Assessment to Stakeholders. After the assessment is finalized based on the comments received, KWP will present the individual chapters/topics over a course of public meetings. During these meetings the community will learn the results of the assessment, help to prioritize the management and restoration opportunities, and develop an Action Plan with the intent of maintaining and improving environmental conditions while addressing economic and cultural concerns within the watershed.

List of Maps

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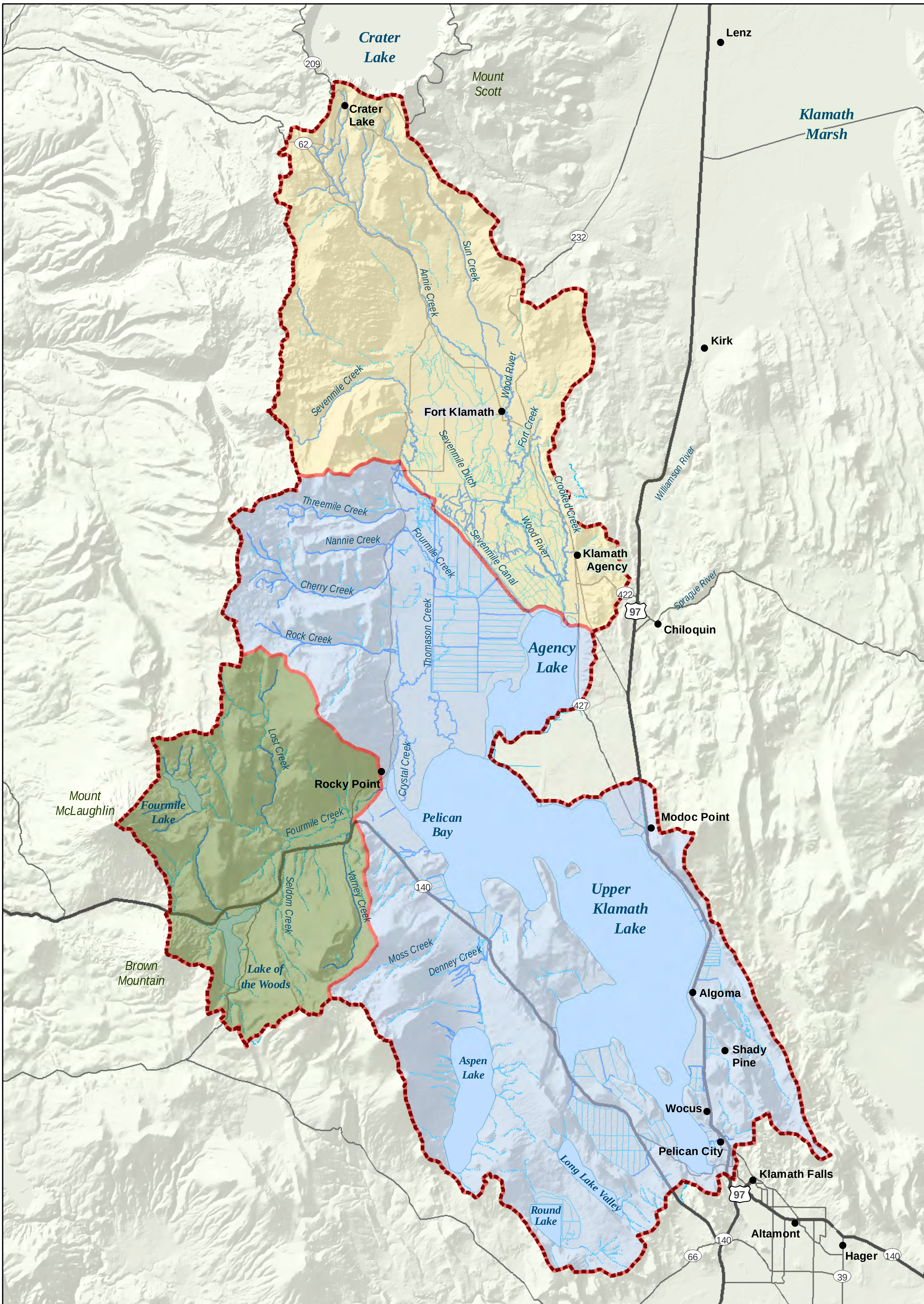

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Source Data:
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USGS (National Hydrography Dataset)

Legend

Subbasin Boundary
Stream/River: Perennial
Stream/River: Intermittent
Stream/River: Ephemeral
Canal Ditch

Watershed Boundary - 5th Field

Fourmile Creek
Klamath Lake
Wood River

Map 1-1:
Base Map

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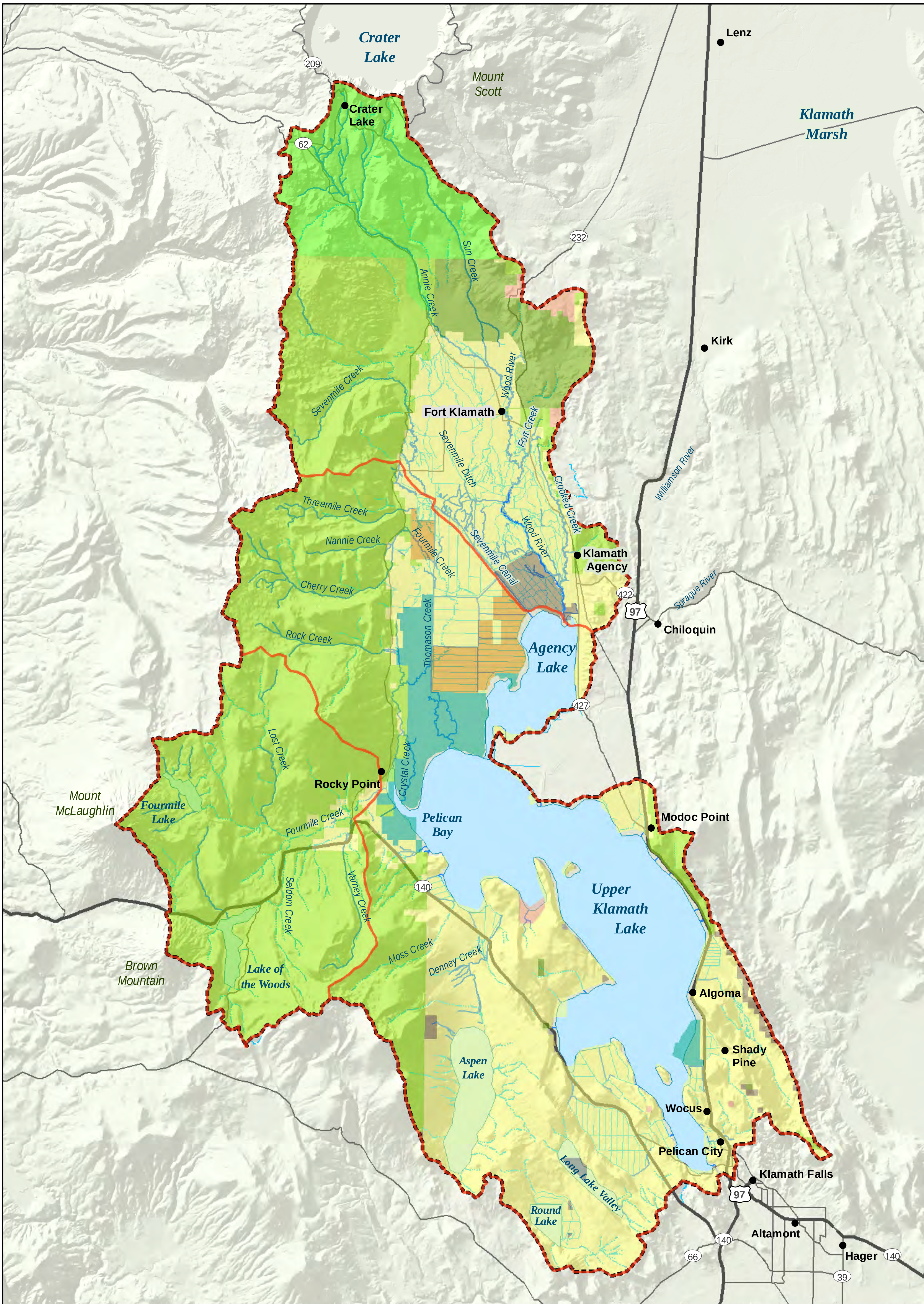

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Source Data:
ESRI, Klamath County, Oregon GEO,
US Department of Forestry,
USGS (National Hydrography Dataset)

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch

Owner

- Bureau of Land Management
- Bureau of Reclamation
- National Park Service
- Oregon Dept. of Forestry
- Oregon Dept. of State Lands
- US Dept. of Agriculture Forest Service
- US Fish and Wildlife Service
- Private

Map 1-2: Land Ownership

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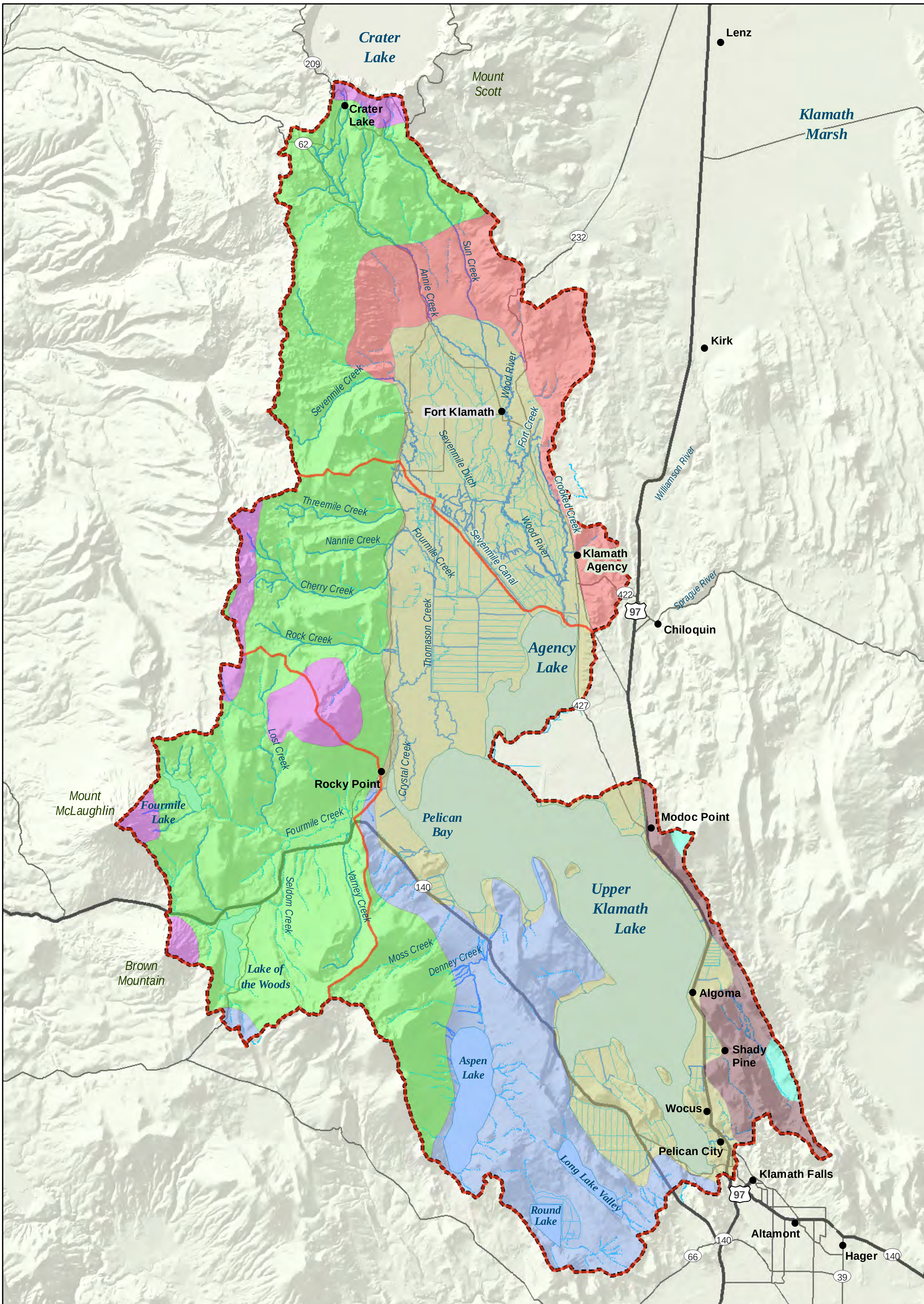

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Source Data:
ESRI, Klamath County, Oregon GEO,
USGS (National Hydrography Dataset)

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch

Ecoregion Name

- Klamath Juniper/Ponderosa Pine Woodland
- Pumice Plateau Forest
- Southern Cascade Slope
- Cascade Subalpine/Alpine
- Fremont Pine/Fir Forest
- High Southern Cascades Montane Forest
- Klamath/Goose Lake Warm Wet Basins

Map 1-3: Ecoregions

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CHAPTER 2:

HISTORICAL CONDITIONS

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2 HISTORICAL CONDITIONS

Pre Settlement

The Upper Klamath Basin has a history as a rich, dynamic ecosystem with thriving fish populations and dense forests. Historically, the Wood River Valley contained abundant ponderosa and lodgepole pine (the assemblage commonly known as yellow jack pine) and various trout and sucker species were abundant in the surrounding lakes and streams. Aquatic habitat had plentiful large woody debris (LWD), deep pools, and gravel pockets ideal for spawning. It is estimated that there were approximately 43,000 acres of wetlands surrounding Upper Klamath and Agency lakes (USDA 2009).

A diverse mixture of tribes inhabited the Upper Klamath Basin. Modocs inhabited the south and southeast, Yahooskin Paiute inhabited the upper portion of the basin in the east and north, and the Klamaths inhabited the majority of the northern portion of the basin and Upper Klamath Lake. It is estimated that between 1,200 and 2,000 native people inhabited the entire Upper Klamath Basin before European settlement (DEA 2005).

The Klamaths' territory was rather extensive and bounded by major geographic features in the region. Their western most boundary was the Cascade Range, the northern boundary was the headwaters of the Deschutes River, the eastern boundary was Abert Lake, and the southern most boundary was Upper Klamath River (Allied Cultural Resource Services 2003).

Although referred to as one group, the Klamaths actually consisted of five tribal bands, each occupying distinct areas (Allied Cultural Resource Services 2003). The Au'kckni inhabited Upper Klamath Marsh, the Dukwakni inhabited the Williamson River Delta, the Iu'lalonkni inhabited both ends of the Link River, the Kowacdikni inhabited Agency Lake, and the Gumbotkni inhabited the western edge of both Upper Klamath and Agency lakes (Allied Cultural Resource Services 2003).

Tribes' harvesting of surrounding natural resources was subsistence based. Diets were based on locally abundant and seasonal food sources such as fish, seeds, nuts, roots, berries, fruits, vegetables, waterfowl, eggs, and mammals (Allied Cultural Resource Services 2003). To prevent food scarcity in winter and fall months, food harvested in summer and spring was processed and preserved for later use (DEA 2005).

In addition to preserving food for later use, indigenous communities implemented management techniques such as fire to enhance productivity of edible plants and animals. The use of fire helped to encourage open understory in forested areas and flushed game into grassland areas to be hunted (DEA 2005).

The primary staple of the native people was the wocus (yellow pond lily, *Nuphar polysepalum*). Shallow open water wetlands, which were naturally abundant in the region at that time, provided ideal habitat for wocus and, therefore, made for a very sustainable food source for the surrounding tribes. Wocus was the primary source of carbohydrates for tribal members. Wocus harvesting was seen as an important community activity, often bringing together different indigenous communities. The beginning of the wocus harvest marked the start of the New Year (Allied Cultural Resource Services 2003). Wocus was harvested from the expansive wetland areas surrounding the lakes during late summer and early fall, primarily by women, using dug out canoes (Figure 2-1)(DEA 2005).

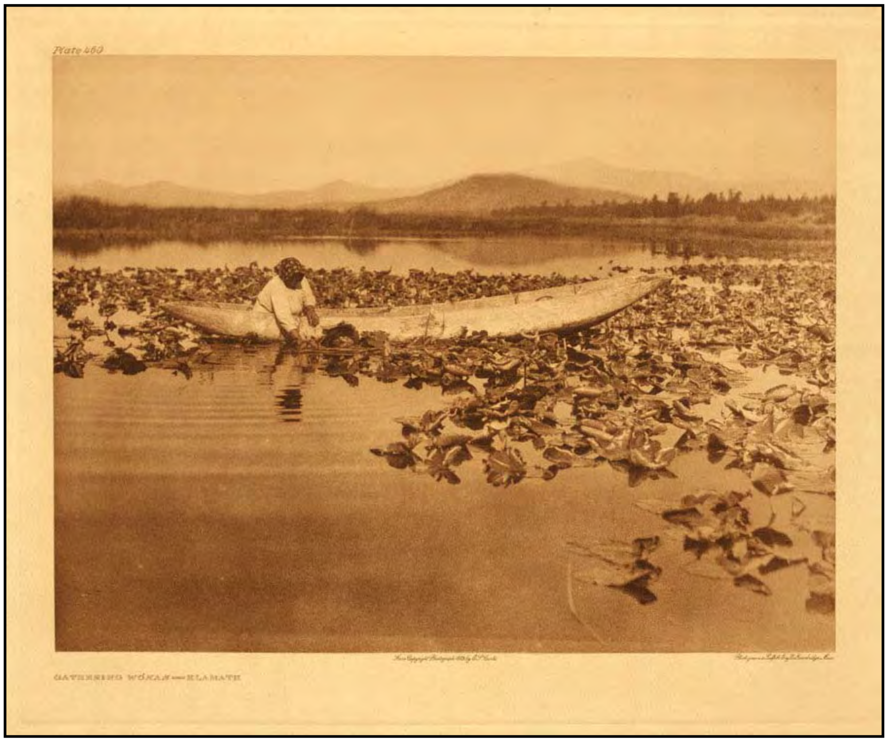


Figure 2-1. Wocus Harvest

Another important food source for native tribes was fish, particularly the sucker (Figure 2-2). Because suckers occupied the bottom of lakes, they were hunted using spears (ka'leks). These spears were made of a long pole with sharp hard wood prongs at the end (Allied Cultural Resource Services 2003). Suckers was consumed fresh and dried, beginning in the early spring and ending in late September, as they were the first run of fish in the region. It is estimated that seven different sucker species were abundant in the surrounding streams, rivers, and lakes of the Klamath region (Allied Cultural Resource Services 2003). In fact, suckers were so abundant that, during spawning, they formed almost a solid mass of fish in the streams and rivers.

> *"The large suckers in kerosene oil tin were collected at Modoc Point, Upper Klamath Lake, April 4, 1887. At this place several cold springs breaks at the edge of the shore; others a few feet or yards from the lake, forming shallow brooks. There the suckers collect in great numbers to spawn. In 1887 they first appeared during the morning of March 18, none having been seen the previous day; by noon they were in such numbers that in certain rocky pockets along the shore, where they could not readily escape, as many as forty or fifty dead ones were seen, crowded and jammed to death.*

The stage road here runs by the shore of the lake, crossing the little streams up which the fish run, many are crushed by the horses' hoofs, and horses often refuse to cross, the almost solid mass of fish frightening them."

- J.C. Merrill, 1887

Figure 2-2. Klamath Indian women holding a string of sucker (1911)

Other fish species with later runs, such as salmon, were caught, dried, and stored for consumption during the winter months when food was scarcer (DEA 2005). One of the Iu'lonkni band's favorite places to catch fish was located on the edge of the current Running Y Resort and, at the time, was referred to as "netting place" (De'ktconks). Typically, two men would go out at night in a canoe and harvest several fish at one time, using different techniques to scare the fish into pyramid shaped scoop nets (Allied Cultural Resource Services 2003).

In addition to nets and spears, indigenous communities constructed small fish dams to increase harvesting opportunities (Allied Cultural Resource Services 2003). Fish dams were generally built where naturally occurring shelves of rocks were present in stream beds (Allied Cultural Resource Services 2003). Fish would gather in the still water created by the dam in relatively large numbers, seeking refuge from strong river currents. The refuge, however, was short-lived, as fish were swept up in a net or caught by a hook by tribal fishermen.

During late spring, as the fish runs were ending, tribes spread out over the region to collect more food including roots, berries, eggs, waterfowl, and mammals. Female tribal members spread out over the lowlands of the valley to harvest yampa root (*Carum gairdneri*), camas (*Quamasia quamash*), arrowroot (*Sagittaria arifolia*), tule, cattail, and waterfowl eggs while men went to the highlands to hunt mammals such as deer, elk, mountain sheep, and goats (Allied Cultural Resource Services 2003). During the late summer and early fall while men hunted mammals in the high ground and waterfowl in the marshes, the women focused on harvesting wocus. After the wocus harvest was over in fall, tribal members reconvened and women joined the men in the high grounds and to harvest fruits such as huckleberries (*Vaccinium membranaceum*), serviceberries (*Amalanchier alnifolia*), currants (*Ribes cerum*), chokecherries (*Prunus demissa*), and wild plums (*Prunus subcordata*). As mentioned previously, many of these roots and fruits were processed and stored for consumption during the winter.

In addition to wocus, tule was an important local plant. Tribes used tule for a variety of purposes including house construction, insulation, floor mats, sleeping mats, basketry, clothing, sandals, cradleboards, arrow quivers, and canoes (Allied Cultural Resource Services 2003).

As European explorers and French Canadian trappers came to the region, introducing tribes to new transportation and communication technologies, as well as new policies, indigenous communities' cultural practices changed dramatically. Introduction to new technologies catalyzed a chain reaction, perpetuating greater demand on natural resources. These new technologies enabled tribes to enter broader markets and trade goods with prospective settlers and trappers. As a result, tribes began extracting more natural resources than traditional subsistence so that they could be traded for other goods such as horses and guns. The introduction of the horse and gun changed the way rival tribes interacted, and allowed for increased hunting and harvesting of goods. Simultaneously, new policies were enacted by the US government which encouraged tribes to manage the land in a more resource intensive manner than traditional practices.

Settlement

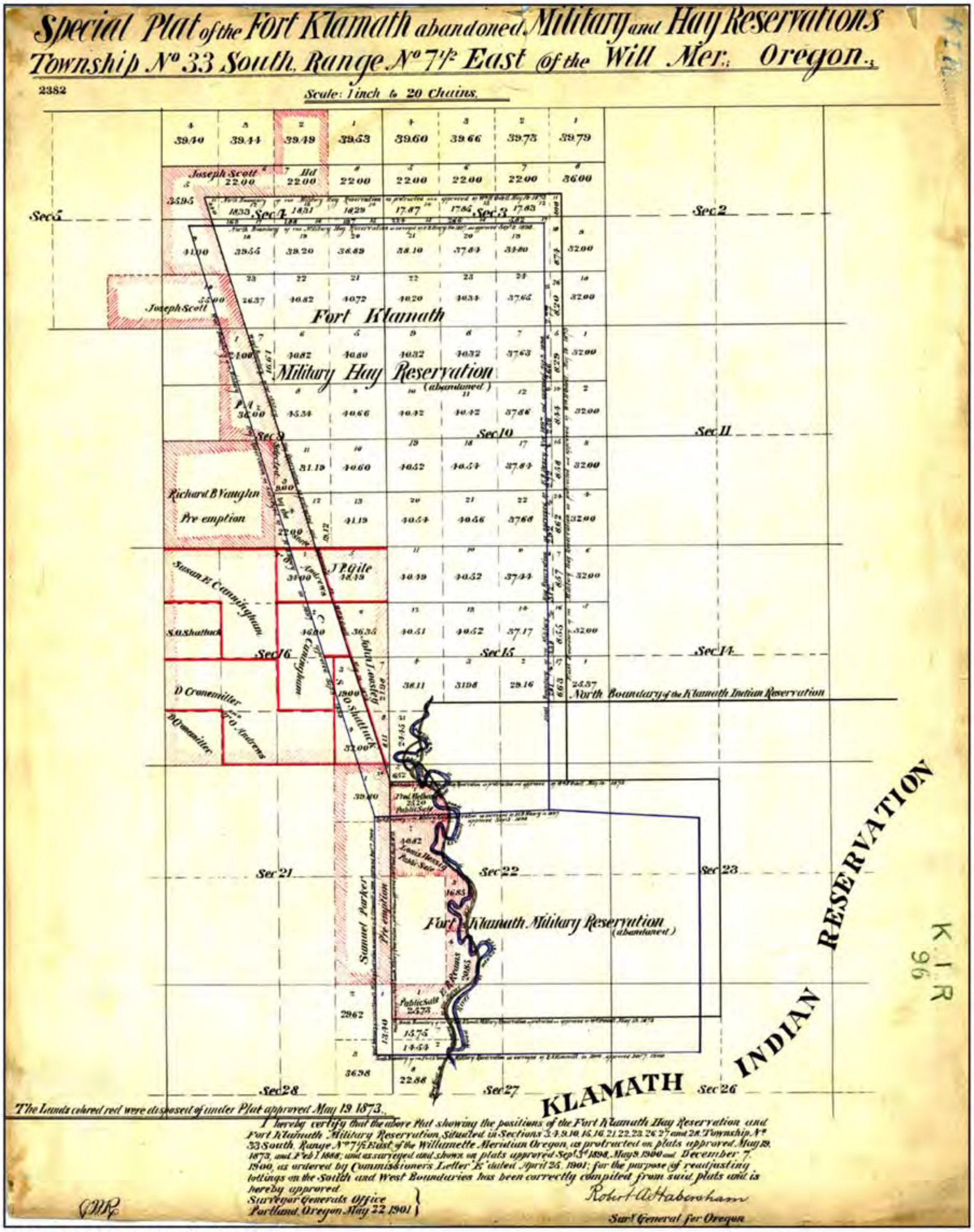
European settlement of the Klamath Basin began in the early nineteenth century (USDA 1985). One of the first documented journeys to the basin was that of Peter Skene Ogden who came to "Clammitte" camp, or what is now know as the Williamson River. Ogden came to the area with Hudson's Bay Company to trap beavers and explore the land. However, prior to his party's arrival, much of the Upper Klamath Basin may have been trapped out by Spanish or French trappers from the south, as this area was part of the California Spanish land grant. Following Ogden's quest, two military expeditions organized by John C. Fremont took place first in 1840 and then in 1846 (USDA 1985). At the same time of the second military expedition in 1846, the Applegate brothers sought to map a trail beginning in Oregon, passing through the Klamath and Goose Lake Basins, and heading east (USDA 1985).

Nearly twenty years later, the Treaty of 1864 was ratified, establishing the "Klamath Tribe" and designating the Klamath Indian Reservation. The Treaty was developed to reduce conflicts between settlers and tribes and allow for more open settlement in the basin. The Treaty reserved the Klamaths one million acres of land, extending 45 miles east and 50 miles north of Upper Klamath Lake (Allied Cultural Resource Services 2003). Figure 2-3 (1888 GLO Historic Map of Upper Klamath Lake Subbasin) shows a portion of the historic location of the Klamath Indian Reservation, Fort Klamath, and the meanders of the Wood River. The treaty established a single political, economic, and geographic unit, held in trust by the federal government and managed cooperatively by the Indian Services and tribal leaders (DEA 2005). In addition to political and economic shifts, this treaty marked a significant shift in land use patterns in the basin. Traditional subsistence living practices were replaced with more large scale agriculture with the purpose of more efficiently utilizing surrounding natural resources.

Over the next two decades, development continued to increase and logging was on the rise, the federal government passed the General Allotment Act of 1887. The General Allotment Act was the tribal counterpart to the Homestead Act of 1862. The General Allotment Act granted individual Indians citizenship and allowed private tracts of land to be held in trust for at least twenty five years (DEA 2005). The purpose of this act was to promote self sufficiency through ownership and management of the land. The Indian Agent characterized the Klamath Indian Reservation land as primarily grazing land, with a small portion of land available for growing crops. In addition, the Indian Agent encouraged certain mountainous portions of the reservation be held in common by the tribes (Allied Cultural Resource Services 2003). However, contingencies in the act allowing for timber harvest and lease and sale of the allotments resulted in unanticipated changes to the landscape (DEA 2005).

By the same token, in the late 1800’s, with irrigation and timber harvesting on the rise, the natural landscape of the basin was changing rapidly. At this time, settlers were focused on improving agricultural and grazing opportunities. In 1883, settlers began irrigating the Wood River Valley. Around the same time, ponderosa and lodgepole pine were removed from the valley to provide lumber and increase grazing areas. As a result, from the late 1800’s up until the early 1900s, large-scale grazing occurred over much of the watershed (USFS 1996a).

While the first saw mill was built in 1863 by the United States Army in order to provide lumber to local tribes (USDA 1985), logging didn’t take flight until the introduction of the railroad (Figure 2-4, Sawmill in Klamath Valley 1907). In the late 1890’s, it is estimated that local timber sales exceeded a quarter of a million board feet annually and logging was a primary revenue source for the reservation economy (DEA 2005). However, at this time sale of timber was confined to local markets because transporting the extracted timber long distances was physically impossible. With the introduction of the railroad, extracted timber could be easily loaded onto train cars and transported to distant markets. Consequently, timber harvest dominated the local economy and land use for nearly century (Figure 2-5, Log Storage 1940s).



1888 GLO Historic Map: T 33S, R 7.5E

Figure 2-3
1888 GLO Historic Map

Not to Scale

Figure 2-4. Sawmill in the Klamath Valley (1907)

Figure 2-5. Log Storage (1940's)

In 1902, the Reclamation Act was passed, spurring irrigation development in the basin (Figure 2-6, Main Klamath Canal, Ankeny Canal, and the Head of Link River 1907). In 1903, the Modoc Point irrigation system was established (USDA 1985). In 1910, the first dam in the Upper

Klamath Lake Subbasin, Fourmile Lake dam, was constructed by Fish Lake Water Company. The dam was 35 feet high and resulted in a 30 ft rise in the Fourmile Lake water level (USFS 1996A). In addition to the dam, the Cascade Canal was built to divert water from Fourmile Lake to the west side of the Cascades to irrigate crops in the Rogue Valley (USFS 1996A). In 1915, the Klamath Water Users Association approved the Klamath Irrigation District, formerly the Klamath Project (USDA 1985).

Figure 2-6. Main Klamath Canal, Ankeny Canal, and the Head of Link River (1907)

In 1916, after returning from service in the First World War, the Geary brothers, Edward, Arthur, Rolland, and Everett inherited a piece of marshland located approximately seven miles west of Klamath Falls on Highway 140 from their uncle E.P. McCornack. Each brother contributed their special skill to the venture: Edward with an agricultural degree from Oregon State and Wisconsin, Arthur as an attorney, Rolland as the business partner, and Everett as an engineer (Alice Kilham interview with Ranch and Range Consulting 2009).

Previously, in the late 1880s, E.P. and Frank McCornack were already cutting hay on both the Caledonia and Wocus Marshes and grazing cattle in the late summer and fall. At the turn of the century, they improved a dike built to separate Wocus Marsh from Upper Klamath Lake and for the next decade pursued a massive construction effort facilitated by the purchase of a dredge, the Klamath Queen, in order to reclaim lands from Upper Klamath Lake. The Geary brothers continued the diking efforts and by 1929 the entire Caledonia marsh was reclaimed and Everett was laying out the irrigation system for Wocus. The main irrigation ditch is six miles long and provides irrigation water to 4,000 acres via lateral ditches every quarter of a mile. One man is able to irrigate the entire 4,000 acres by himself because the design is so efficiently laid out (Alice Kilham interview with Ranch and Range Consulting 2009).

The Geary dike and other dikes around Upper Klamath Lake became a focal point in 1921 with the construction of the Link River Dam. Many surrounding landowners feared that higher water levels resulting from the Link River Dam would compromise the structural integrity of the earthen dike systems the Geary Brothers and other landowners had constructed (Alice Kilham interview with Ranch and Range Consulting 2009). An agreement was made between the Bureau of Reclamation and the power company not to exceed a maximum lake level of 4,143.3 ft.

Prior to construction of the dam, lake elevations fluctuated between approximately 4,139.5 ft and 4,143.08 ft. After construction of the Link River Dam, Reclamation operated the Lake with a maximum water surface elevation of 4,143.3 ft. Lake levels above 4,143.3 ft can result in unstable shoreline dikes (Reclamation 2002). While the intent of the Link River Dam was to increase water storage, the dam did not provide additional storage. With the construction of the Link River dam in 1921, the lake was regulated to change the natural flow pattern of the Klamath River during spring and summer and to provide relatively moderate flows (J.C. Boyle 1964).

Below, Table 2-1, Historic and Recent Water Surface Elevations of Upper Klamath Lake, compares historic water surface elevations to those from recent history. The historic elevations listed below are those that were present prior to the construction of the Link River Dam 1904-1918, a fairly wet period (Hicks, pers. comm. 2010). Recent elevations are dictated by the U.S. Bureau of Reclamation’s regulation and the current Biological Opinion for Klamath Project Operations.

Table 2-1: Historic and Recent Water Surface Elevations of Upper Klamath Lake

	Historic (pre – Link River Dam)	**Recent History (post Link River Dam) Regulated by Feb. 24, 1917 Contract between the Cal-Ore Power Co (Copco) and Reclamation**
Physical Maximum	4,143.08	4,146.2
Managed Maximum	NA	4,143.3
Physical Low	4,139.5	4,137.0 - Lower than historic; natural reef was breached during dam construction
Managed Low	NA	4,138.0 – established by the Biological Opinion
Dam crest height	NA	4,145.0

Data Source: Reclamation (data is in feet)

In 1920, the Geary Brothers sold 2,200 acres of their ranch in Caledonia Marsh to Klamath Mint Company (Alice Kilham interview with Ranch and Range Consulting 2009). At this time, the prospects of peppermint were thought to be great. Approximately 40 acres of the marsh was planted with peppermint, producing around 40 pounds of peppermint per acre (Deller 1984). There were plans to plant another 300 acres of peppermint along with plans to develop a large summer colony consisting of 250 homes (Deller 1984). Despite what appeared to be a promising industry, the venture failed, and ownership of the property reverted to the Gearys (Deller 1984).

Caledonia Marsh produced mostly grain and pasture. On the Wocus Ranch, however, Edward Geary discovered that grass seed was a successful, but challenging crop, requiring experimentation, invention, and the manufacturing of new machinery. Hundreds of acres were devoted to seaside bent grass, used for golf courses, along with other grass seeds. As the Geary's seed company expanded, the brothers expanded the Wocus Ranch Headquarters, constructing a seed cleaning mill and storage building, additional equipment sheds, a cook house, a bunk house, and multiple dwellings.

In 1928, the Upper Klamath National Wildlife Refuge was established to protect land for birds and animals to breed. In 1964 the Kuchel Act expanded the purpose to include wildlife conservation, waterfowl management, and simultaneously high productivity agriculture (USFWS 2009a). Currently, the refuge provides approximately 15,000 acres of freshwater marsh and open water (USFWS 2009a).

In 1930, the Geary Brothers entered the grazing business with the grass hay providing winter feed and the hillsides providing good spring forage (Figure 2-7, Cutting Beargrass at Geary Ranch 1939). Sheep were grazed briefly and then ten years later, cattle, with the purchase of 150 Hereford cows from the Yamsi Ranch, owned by Buck Williams (Alice Kilham interview with Ranch and Range Consulting 2009).

Figure 2-7. Cutting Beargrass at Geary Ranch (1939)

In 1954, the Klamath Termination Act ended federal supervision of and aid to the Klamath Tribes' properties. The legislation required adult tribal members to choose between remaining a member of the tribe or withdrawing from the tribe and receiving payment from the government for the value of their property. After an election in 1958, 77 percent of tribal members chose to withdraw from the tribe and convert their assets to cash. Many of the unsold parcels were transferred to the USFS and became part of the Fremont-Winema National Forest. The remaining 23 percent of tribal members who chose to remain members of the tribe became part of a tribal management plan. The tribal management plan became part of a trust with the U.S. National Bank of Portland and approximately 144,000 acres remained as tribal member lands held in trust (USFS 1998).

Recent Development (1960's-1980's)

From the 1960's to the 1980's proved there were significant declines in fish populations. Land ownership remained relatively constant and despite intensive irrigation and agricultural production at the time nearly all diversions had paddle screens to prevent fish entrainment (Martin Kerns interview with Ranch and Range Consulting 2009). Thus, many landowners attribute the significant population declines to the aerial application of insecticide targeted at reducing mosquito populations. However, there is no scientific evidence to support the claim that insecticide was the primary cause of the fish population declines.

While the cause of the population declines is in debate, as Martin Kerns recalls, before 1970, large trout (species unknown, but assumed to be redband trout), up to three feet in length, were abundant in the Wood River (Martin Kerns interview with Ranch and Range Consulting 2009). As a result of diminishing populations of trout, the government began stocking fish (species unknown, but assumed to be non-native trout) at the bridge near the Kerns' house. Consequently, trout species (coastal rainbow/non-native trout) were observed in the area, but they were less abundant and smaller in size (Martin Kerns interview with Ranch and Range Consulting 2009).

Around the same time, in 1966, the Geary Brothers sold a portion of the ranch to Ruth Teasedel. After purchasing the ranch, Ruth changed the name to the Running Y Ranch. In 1974, Teasedel sold the ranch to Roy Disney and Pete Dailey, although later Roy Disney bought out Pete Dailey. The ranch changed hands again when in 1994, Roy Disney sold the ranch to Jeld-Wen.

In the 1980's, a severe drought struck the Upper Wood River Valley (Martin Kerns interview with Ranch and Range Consulting 2009). At this time, Sun Creek, which supplied enough water to irrigate the Kerns' family ranch, dried up. Fortunately, naturally occurring springs located on the farm property provided enough water to irrigate the farm during the drought and thus the Kerns family suffered no losses (Martin Kerns interview with Ranch and Range Consulting 2009).

In 1986, the Klamath Restoration Act was passed and restored the Klamath Tribes as a sovereign nation. Passage of this act helped retain treaty rights to hunt, fish, trap, and gather plants on former reservation lands. In addition, the act helped reinstate federal aid to tribal members for education, health care, housing, and other resources.

In the 1990's, the diversion dam on Fort Creek (east of Fort Klamath) washed out, resulting in restored access to approximately one mile of additional spawning habitat. Following this, many restoration projects were implemented in the Wood River area. One of these projects was the re-opening of Tecumseh Springs. Within a few weeks of the completion of the project, fish, most likely from the Wood River, were accessing this habitat to spawn. In addition to the Tecumseh Springs project, the Fort Creek dam was removed. Similar to the Tecumseh Springs project, fish such as redband trout were attracted from the Wood River up to Fort Creek.

Between 2002 and 2003, Agency Creek and the old Fort Klamath Reservation were restored. Additional information on this project can be found online at:
http://wildfish.montana.edu/Cases/browse_details.asp?ProjectID=38"

In 2006, the Caledonia dike was breached. As a result, part of the Running Y Resort golf course was flooded, as well as a portion of Highway 140. In the ensuing negotiations, Jeld-Wen purchased the flooded Caledonia property which, at the time, was still owned by the Geary family.

In the last decade, much has been accomplished in the way of ecosystem restoration. For example, the Kerns family and neighboring landowners have worked together to implement several ecosystem restoration projects such as enhancing farming management practices, installing riparian fencing to manage livestock access, and adding LWD and spawning gravel to streams. The Kerns' also participate in the Natural Resources Conservation Science (NRCS) Conservation Security Program (CSP). In addition, current Geary family members are working on stewardship plans for their 398 acres of hillside land to protect and enhance their mixed white oak and conifer forest and wildlife habitat (Alice Kilham interview with Ranch and Range Consulting 2009).

In addition, programs such as in-stream water leasing have worked to preserve historic farming practices while ensuring better quality habitat conditions to support fish and other aquatic species. Since the implementation of water leasing, large areas of native grasslands have been restored.

While much has been done in the last two decades to improve native aquatic and terrestrial species' habitat, competing anthropogenic and species' demands on the resources continue to be a problem in the basin. Cattle ranches and other agricultural operations are under increasing pressure, meanwhile increasing demands on water supply continue to threaten native fish species in the basin (Paul and Cheri Little interview with Ranch and Range Consulting 2009). Currently, in Upper Klamath Lake, there are two listed endangered sucker species, shortnose sucker (*Chasmistes brevirostris*) and Lost River sucker (*Delistes luxatus*). In addition, salmon are unable to access streams where they were historically present because of dams. Furthermore, Bull Trout (*Salvelinus confluentus*) is listed threatened. Current bull trout presence has been documented in Threemile Creek and Sun Creek; however, historically they had a much broader range. Sevenmile Creek contained a population of bull trout, but this population is now considered extinct (ODFW 2005).

Historical Timeline

1848: Oregon Territory is established (USFS 1998).

1850: Oregon Donation Land Act is passed, whereby each adult United States citizen could get 320 acres of free land in the Oregon Territory (USFS 1998).

1863: The first saw mill is built by the U.S. Government to help tribes extract timber resources.

1864: Central and Eastern portions of the basin are set aside as the Klamath Indian Reservation under the Klamath Indian Treaty of 1864. The treaty set aside 1,196,872 acres for the exclusive use of Indian peoples, and had the effect of removing Indians from about 20 million acres so that they could be used for non-Indian settlement and agriculture (USFS 1998).

1883: Settlers began irrigating the Wood River Valley.

1887: General Allotment Act is passed allowing individuals to own and sell property resulting in increased timber extraction and large-scale agricultural production.

1880s and 90s: Settlers, sheep herders, and timber companies begin to have a notable effect on timber resources, particularly on west side of the basin (USFS 1998).

1900 to 1940: A large percentage of marshes and wetlands located on private lands are converted to agricultural uses during this time (USFS 1998).

1902: Crater Lake National Park is established "as a pleasure ground for the benefit of the people of the United States" (Greene 1984:99 as cited in USFS 1998).

1902: Reclamation Act is passed resulting in increased irrigation.

1909: Commercial timber harvest on National Forest, Klamath Reservation, and large privately owned timberlands becomes significant with the arrival of the Southern Pacific Railroad, which opens the Klamath basin to outside markets (USFS 1998).

1910: Fourmile Creek Dam is constructed.

1921: Link River Dam is constructed.

1928: The Upper Klamath National Wildlife Refuge is established to protect land for birds and animals to breed.

Mid-1950s to 1980: The greatest rate and overall change in irrigated agricultural acreage takes place during this time period. In addition, cattle grazing expanded in the lowland areas of the subbasin.

1950: Highway 140 is constructed across the marshlands of the subbasin.

1954: The Klamath Termination Act of 1954 terminates federal supervision over the property of the Klamath Tribes (USFS 1998).

1960: Most virgin timber stands have been harvested from the subbasin. Emphasis shifts to second growth stands on private and newly created Winema National Forest lands in 1961. Overall volumes are much lower than in the past (USFS 1998).

1961: Winema National Forest is established from forestlands under other National Forest management (USFS 1998).

1969: Remaining Klamath Tribes members with land holdings elect to terminate the trust, and in 1974 the lands become part of the Winema National Forest (USFS 1998).

1980s: Severe drought strikes the Upper Wood River Valley.

1986: The Klamath Restoration Act of 1986 restores the Klamath Tribes as a federally recognized tribe; although, reservation lands are not restored (USFS 1998).

1990s: Timber supplies become tighter within the basin, resulting in private landowners playing a more prominent role in supplying harvestable timber than in the past (USFS 1998).

1990s: Diversion dam on Fort Creek washes out.

2001: In response to an extremely low water year and Endangered Species Act (ESA) requirements, deliveries to Reclamation’s Klamath Project were curtailed.

CHAPTER 3:

CHANNEL HABITAT TYPING AND MODIFICATION

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3.1 CHANNEL HABITAT TYPING AND MODIFICATIONS

Introduction

The purpose of this section is to differentiate the channel habitat types within the Upper Klamath Lake Subbasin and to address the following two critical questions:

- What is the distribution of channel habitat types throughout the subbasin?
- What is the location of channel habitat types that are likely to provide specific aquatic features, as well as those areas that may be the most sensitive to changes in watershed conditions?

Classifying stream channels within a watershed helps provide further understanding of the inherent spatial variation in aquatic habitat conditions. In addition, it helps identify the possible limitations and opportunities of restoration activities. The underlying assumption in any channel-typing scheme is that the morphological channel characteristics are the result of geologic, climatic, hydrologic, and vegetative interactions. Furthermore, channel types with similar characteristics or of the same channel habitat type can be expected to respond in a likewise manner to natural or human-caused changes within a watershed in the supply of water, sediment, or wood inputs.

Methods

Given the extensive number of streams throughout the subbasin, an abbreviated form of the Channel Habitat Type (CHT) classification scheme included in the Manual (WPN 1999) was used. The analysis covered approximately 180 individual stream reaches of key streams within the subbasin. The classification scheme used in this analysis is based on the Rosgen methodology (Rosgen 1996). The Rosgen methodology utilizes a hierarchical approach to channel classification. The most extensive classification within the methodology, the Level I classification, is based on broad-scale landscape features that can be remotely derived (Table 3-1, General Stream Type Descriptions).

The Rosgen Level I classification is based primarily on four factors: the stream entrenchment ratio, which is the ratio of the flood-prone area to the bankfull channel width; the bankfull channel width to bankfull depth ratio; channel sinuosity; and channel gradient or slope. All these parameters, with the exception of the width-depth ratio, can be estimated based on remote sensing data. Evaluating the stream entrenchment ratio requires extensive observation and analysis of topographic maps in combination with digital ortho photographs, therefore, only channel sinuosity and channel gradient were analyzed for this assessment.

Channel gradient was estimated using digital elevation model (DEM) data with a pixel resolution of approximately 10 meters (USGS 2009a). Using GIS, sinuosity was estimated for each stream segment as the ratio of the channel length to valley length[1].

As can be seen from Table 3-1, all channels having gradients greater than 10 percent can be classified as type “Aa+” channels, and all channels with gradients of 4 percent to 10 percent as class “A” channels. Similarly, channels having gradients of 2 percent to 4 percent were initially classified as type “B/G” channels, indicating that they are either “B” or “G” channel types. The remaining low-gradient channels (<2 percent) will fall within either the “C,” “E,” or “F” types (type “D” channels are unlikely to be found in the assessment area). This last grouping was initially broken out into two groups, based on channel sinuosity. Those channel segments having a sinuosity of 1.5 or greater were grouped as type “E/F” channels, indicating that they are either type “E” or type “F,” depending on the level of entrenchment and width-to-depth ratios. Similarly, segments having a sinuosity of <1.5 were grouped as type “C/F” channels.

Table 3-1. General Stream Type Descriptions

Rosgen Stream Type	Comparable OWEB Stream Type(s)	General description	Entrenchment ratio	W/D ratio	Sinuosity	Slope	Landform / soils / features
Aa +	VH SV	Very steep, deeply entrenched, debris transport streams.	< 1.4	< 12	1.0 to 1.1	>0.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps withdeep scour pools; waterfalls.
A	SV BC MV MH	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	< 1.4	< 12	1.0 to 1.2	0.04 to 0.10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step-pool bed morphology.
B	MH MM	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	> 12	> 1.2	0.02 to 0.039	Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with occasional pools.
C	LM FP1 FP3	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains	> 2.2	> 12	> 1.4	< 0.02	Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology.

[1] *Approximated by calculating the vector distance from the channel segment start point (X_1, Y_1) to the end point (X_2, Y_2).*

Rosgen Stream Type	Comparable OWEB Stream Type(s)	General description	Entrenchment ratio	W/D ratio	Sinuosity	Slope	Landform / soils / features
D	AF FP2	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	N/A	> 40	n/a	< 0.04	Broad valleys with alluvial and colluvial fans. Glacial debris and depositional features. Active lateral adjustment, with abundance of sediment supply.
DA	LM LC	Anastomosing (multiple channels) narrow and deep with expansive well vegetated floodplain and associated wetlands. Very gentle relief with highly variable sinuosities. Stable streambanks.	> 4.0	< 40	Variable	< 0.005	Broad, low-gradient valleys with fine alluvium and/ or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition with well-vegetated bars that are laterally stable with broad wetland floodplains.
E	FP1	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	> 2.2	< 12	> 1.5	< 0.02	Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well vegetated banks. Riffle-pool morphology with very low width/depth ratio.
F	LC	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	< 1.4	> 12	> 1.4	< 0.02	Entrenched in highly weathered material. Gentle gradients, with a high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology.
G	MC MM	Entrenched "gulley" step/pool and low width/depth ratio on moderate gradients.	< 1.4	< 12	> 1.2	0.02 to 0.039	Gulley, step-pool morphology with moderate slopes and low W\D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials; i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

Data Source: Rosgen 1996; WPN 1999

Given the limitations of remote sensing and the inability to perform field verification, the channel groupings were not further subdivided. The spatial distribution of Rosgen channel types is shown in Map 3-1 (Rosgen Habitat Classification) and summarized in Figure 3-1 (Summary of Rosgen Channel Types in the Upper Klamath Lake Subbasin).

Results and Discussion

Type Aa+ Channels:

The Aa+ stream types are very steep streams (>10 percent channel gradient) located primarily near the headwaters within the assessment area. Type Aa+ streams occur on the slopes of the Cascade Mountains to the west, and at a few small, discreet locations in the middle of stream reaches (Figure 3-1). Transport processes dominate in these reaches, as they are often source areas for downstream deposition. Type Aa+ channels are found within all three watersheds, making up 5 percent of the total channel length analyzed within the assessment area. The

Klamath Lake watershed has less than 1 percent of total channel length, the Fourmile Creek watershed has just over 1 percent and the Wood River watershed has 4 percent (Figure 3-1).

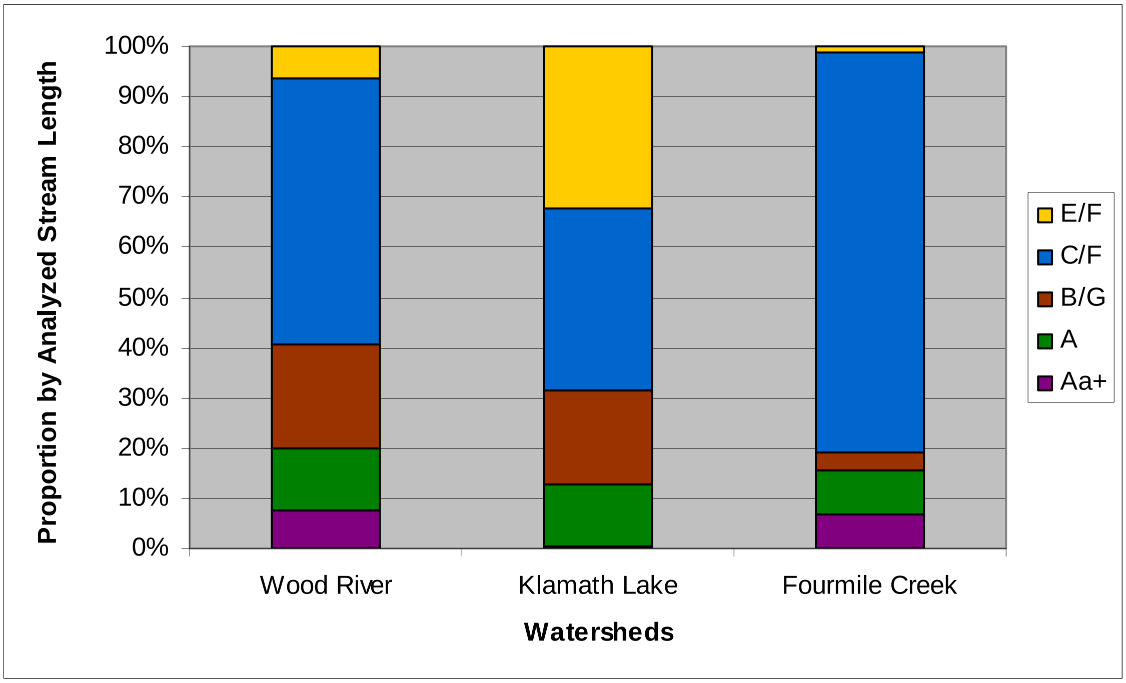

Figure 3-1. Summary of Rosgen Channel Types in the Upper Klamath Lake Subbasin

Type A Channels:

Channel type A is similar to the Aa+ classification, the primary difference being that these channel types are lower gradient (4 percent to 10 percent). Consequently, these channel types tend to be located immediately downstream of the type Aa+ channels (Figure 3-1).Type A channels are found within all watersheds, with the Fourmile Creek watershed containing 2 percent of the total channel length, 3 percent in the Klamath Lake watershed, and 6 percent of the channel length in the Fourmile Creek watershed. Type A channels make up 12 percent of the channel length in the entire assessment area (Figure 3-1). The headwaters of Sevenmile Creek, located in the Wood River watershed, are an example of a type A channel.

Type B/G Channels:

The B/G channel designation indicates that these channels are either Rosgen type B or type G channels, but there is insufficient information available to parse out these two groupings. This grouping is often positioned downstream of type A channels, but in the Upper Klamath Lake Subbasin these channels also are widespread in headwater positions within gently sloping terrain (Map 3-1). Both the B and G channels are moderate in gradient (2 percent to 4 percent). Although type B channels are morphologically dominated by hillslope (as opposed to floodplain) processes, they often contain some areas of floodplain development and may be both transport and depositional reaches. Rosgen type G or "gullied" channels are narrow, entrenched, non-meandering channels that are often downcut within alluvial deposits. Entrenched channels are those that are incised and vertically confined, not able to access their adjacent floodplain. Although there are undoubtedly naturally occurring G channels within the assessment area, it is reasonable to assume that the B channels represent functioning channel types, and the G channels represent the degraded condition.

Type B/G channels are the second most common type found within the assessment area (17 percent of total channel length overall), the Fourmile Creek watershed containing just 1 percent of the total channel length, 5 percent in the Klamath Lake watershed and 11 percent in the Wood River watershed (Figure 3-1). Although the Fourmile Creek watershed had few channels designated as B/G in this assessment, the USFS watershed analysis from 1996 found nearly 70 percent of the channels in the Fourmile Creek watershed (this includes Lost, Horse, and upper Fourmile Creeks) to be B-type channels (USFS 1996). This assessment and the USFS analysis both define Lost Creek as a B-type channel, however the categorization of upper Fourmile Creek is different. This difference may be attributed to the overlap of characteristics between A and B-type channels which have the same channel sinuosity ratio, except A channels are steeper (Table 3-1, General Stream Type Descriptions). In addition, field verification performed by USFS may have been able to locate small sections of more gradual slopes, whereas the GIS analysis for this assessment took an average of the slope for the whole section and found that it was steeper than 4 percent, and, therefore, an A-type channel.

Type C/F Channels:

The C/F channel designation indicates that these channels are either Rosgen type C or type F channels; however, there is insufficient information available to parse out these two groupings. Rosgen type C channels consist of relatively low-gradient streams with well-developed floodplains and are typically highly responsive to sediment and wood inputs. Type F channels are similar in gradient, and may have a similar planform geometry (thus the difficulty in differentiating these from type C channels using remotely sensed data), but the type F channels are entrenched, have a high width-depth ratio, and may have high bank erosion rates. For this analysis it is reasonable to assume the C channels represent functioning channel types, and the F channels represent degraded condition channel types.

Type C/F channels are the predominant type within the subbasin, and are found within all watersheds, making up 53 percent of all streams that were analyzed. These channel types occur primarily in the lower reaches of many stream channels (Figure 3-2, Aerial Photo of Crystal Creek, a Rosgen C/F Channel) but can also be found in the gently sloping reaches below headwater channels. Based upon descriptions in various USFS watershed analyses, some of these lower reaches have characteristics more typical of type F channels, including entrenchment and potential for bank erosion, where channels have been modified by dredging or for agricultural use. Type C/F channels make up 10 percent of the total analyzed channel length in the Klamath Lake watershed, 16 percent in the Fourmile Creek watershed and 27 percent in the Wood River watershed (Figure 3-1).

Figure 3-2. Aerial Photo of Crystal Creek, a Rosgen C/F channel (DEA 2009).

Type E/F Channels:

The E/F channel designation indicates that these channels are either Rosgen type E or type F channels; however, there is insufficient information available to parse out these two groupings. Rosgen type E channels consist of low-gradient, meandering streams with a low width/depth ratio, and often are characteristic of meadow systems. Type F channels are similar in gradient, and may have a similar planform geometry (thus the difficulty in differentiating these from type E channels using remotely sensed data), but the type F channels are entrenched, have a high width-depth ratio, and may have high bank erosion rates. For this analysis it is reasonable to assume E channels represent functioning channel types, and the F channels represent degraded channel types.

Type E/F channels are only found in significant quantity within the Wood River and Klamath Lake watersheds, and occur in the lower stream reaches of the Wood River and Sevenmile Creek (as shown in Map 3-1 and Figure 3-3, Aerial Photo of a Meandering Rosgen E/F in the Wood River Valley). These channels predominantly occur in areas of intensive agriculture or grazing. Type E/F channels make up 13 percent of the total analyzed channel length, with less than 1 percent located in the Fourmile watershed, 3 percent in the Wood River watershed, and 9 percent in the Klamath Lake watershed (Figure 3-1).

Figure 3-3. Aerial photo of a meandering Rosgen E/F channel in the Wood River Valley (DEA 2009).

Ditched Channels:

During the course of the assessment, it became apparent that there is a significant group of channels that are so highly modified that they are not considered by the Rosgen channel classification system (and, therefore, not included in Figure 3-1). These channels occur primarily in the vicinity of Upper Klamath and Agency lakes (Map 3-1), and consist of either natural streams that have been excavated and straightened for drainage, or constructed drainage ditches (Figure 3-4, Aerial Photo of Ditched Portion of Denney Creek). Significant quantities of these channels are found within the Klamath Lake and Wood River watersheds, with the most ditched channels occurring in the Klamath Lake watershed, totaling 56 percent of all ditched channels in the subbasin. The Wood River watershed has 44 percent of all the ditched channels within the subbasin. While available digital data do not identify any canals or ditches in the Fourmile Creek watershed, the last two miles of Fourmile Creek, before it enters Upper Klamath Lake, have been channelized (USFS 1996a) (Map 3-1).

Currently, the USFWS is leading efforts to restore lower Fourmile Creek. Work is planned to begin in the fall of 2010. The channelized reaches will be restored to a more natural condition, resulting in extended periods of inundation, and restoration of the wet meadow habitat.

Figure 3-4. Aerial photo of Ditched portion of Denney Creek (DEA 2009).

Confidence Evaluation

Overall, the confidence in the channel typing is low to moderate. The assessment was based exclusively on remotely sensed data (channel gradient and sinuosity from DEM data), with no field verification. There were no data available for the areas along the east edge of Upper Klamath Lake, near Algoma. Additional material from several USFS watershed analyses was incorporated as a check to the initial channel type assignments. Significant data gaps remain which must be filled before a meaningful prioritization of channel restoration can be completed. Implementation of the recommendations, below, would result in better management and restoration choices.

Research Recommendations

Future research should be focused on determining which reaches are most in need of protection or would provide the greatest benefit and response from restoration efforts. Based upon the results and known data gaps, the following recommendations are made:

1. Refine understanding of channel conditions. As discussed in the Methods section, the channel typing performed for this assessment was based exclusively on remotely sensed parameters, specifically, channel gradient and sinuosity. Additional information on channel entrenchment, width-depth ratio and channel substrate is required to refine our understanding of the existing channel types, extent of habitat degradation, and possible restoration opportunities. Channels that have become severely entrenched lose the ability to use their floodplain for water storage, potentially reducing stream baseflows. There is a concern that floodplain functions have been impaired, but the extent to which this has occurred is unknown. It is recommended that an assessment of stream channel conditions on private lands is conducted. Because further analysis is necessary to distinguish a "C" or "E" channel from the entrenched F-type channel, the focus should be the low-gradient type "C/F," "E/F," and "Ditched channels" (Map 3-1).

2. Identify locations of, and feasibility of removing, channel modifications. This analysis should evaluate the feasibility of removing or modifying existing levies, berms and dikes that impede the natural meander pattern. This evaluation can be incorporated into the channel survey needs identified above.

Restoration and Management Opportunities

This section provides restoration opportunities that have been made evident during the channel habitat typing investigation.

1. Protect channels that currently provide proper functioning condition. Those channels that are currently in a proper functioning condition should be protected from future degradation. Given the current data gaps on channel conditions (described above) it is not possible to identify all channel reaches that are in proper functioning condition. Cherry Creek, near the wilderness boundary, provides an excellent example of a functioning reach (Anderson, pers. comm. 2009). Additionally, those channels that currently have good riparian vegetation should be considered as the primary candidates for protection (see Chapter 6, Riparian Assessment).

2. Prevent future infrastructure encroachment on channels; remove existing impacts. In many portions of the assessment area, roads were impacting the natural function of stream channels by occupying a portion of the naturally occurring floodplain. The USFS has identified, removed or improved most major roads that were impacting adjacent channels on their lands within the subbasin (Anderson, pers. comm. 2009). There may be locations on private property where road construction or crossings are influencing the adjacent channel. These locations would be identified in the stream assessment (research recommendation 1) mentioned above. Where possible, these impacts should be mitigated and future impacts should be prevented. Priority for removal should be given to low-gradient unconfined channels (i.e., "C/F," "E/F" channels; Map 3-1).

3. Restore floodplain connections and natural channel form in low-gradient unconfined reaches. In many of the lower reaches of channels within the subbasin (i.e., "C/F," "E/F" channels; Map 3-1), channelization, channel downcutting, direct disturbance from livestock, and degradation of riparian vegetation has combined to change the physical attributes of the stream, resulting in aquatic habitat degradation. Many channelized streams have become narrower and deeper and have become isolated from their floodplains. Through a combination of grazing management, control of sediment inputs, and riparian recovery, the geomorphic processes that create channel conditions will begin to improve aquatic habitat. The rate of recovery for channels affected by grazing appears to be strongly influenced by the flow and sediment regime available to initiate change (GMA 2008). For example, Sevenmile Creek has a more extensive watershed and higher winter storm and spring snowmelt runoff compared to the spring-dominated Crooked Creek (GMA 2008). In addition, upstream areas have higher gradients, providing more energy to scour the bed, creating deeper pools and improving substrate by selectively winnowing fines. As a result, lower gradient reaches will take longer to recover (GMA 2008). With respect to riparian recovery, fencing to manage livestock access to the stream channel has proven to be one of the most successful land management activities. Improvements in channel and habitat conditions will likely be most effective in the low-gradient unconfined reaches (i.e., “C/F,” “E/F” channels; Map 3-1).

Several streams have been diverted into ditches, consequently de-watering their historic channel. In locations where the historic channel has not been completely wiped out, re-directing water back into the channel will help restore floodplain function. An example of such a project, Figure 3-5 (Aerial Photo of Crane Creek Following Restoration To Re-direct Flows From an Irrigation Ditch to the Historic Channel), was completed in 2007 on Crane Creek, a tributary to Sevenmile Creek (Peterson, pers. comm. 2009). This project successfully restored redband trout fish habitat, as they were recorded using the area for spawning the winter following construction (KBRT 2009).

Figure 3-5. Aerial photo of Crane Creek following restoration to re-direct flows from an irrigation ditch to the historic channel (DEA 2009)

3.2 CHANNEL MODIFICATION ASSESSMENT

Introduction

The purpose of this section is to identify current and historic channel modifications in the Upper Klamath Lake Subbasin, on both public and private lands, to the extent feasible given available data.

A channel modification is a human-caused alteration that influences channel geomorphology and often disrupts biotic function. Direct modifications include channelization, dams, roads, bridges, riprap, ditches, culverts, instream mining, dredging, levee building, and other bank stabilization efforts. Channel disturbances can move a stream from its natural channel, affect water velocities, change sediment transport relationships, reduce available habitat for aquatic organisms, and change water temperature. In addition, the effects of channel modifications may often cause geomorphic adjustments that may impact a given channel for significant distances, both upstream and downstream of the original action. Such geomorphic adjustments include channel incision or downcutting. Further, once channel instability is initiated, the area of disturbance can then propagate downstream as the excess sediment from bed or bank erosion is deposited in downstream reaches causing additional instability and habitat impacts. It is often difficult to identify these indirect, off-site effects of channel modification.

Even without human-caused alterations to a stream channel, a channel can naturally undergo morphological changes over time. Channel gradient, underlying geology and substrate allow the channel to change in a somewhat predictable way. Over time, channels located in higher reaches with steep gradients will continue to down cut, until they reach bedrock, in response to snow-melt and precipitation events, carrying sediment to lower channel reaches. Channels located in low gradient reaches that are recipients of fine sediments from above, continue to accumulate sediments over time. Fine sediments can be easily transported during flood events, allowing the channel to change shape and location. During a flood event, channel meanders can be abandoned as the fast-moving water takes a path of least resistance, potentially resulting in a straightened portion of the channel. During droughts, channels do not receive large enough flows to move sediments and therefore accumulate sediments, raising the stream bottom and creating a very shallow channel.

The purpose of this chapter is to identify current and historic channel modifications in the Upper Klamath Lake Subbasin, including both public and private lands, to the extent feasible.

The Channel Modification assessment methodology outlined in the Manual (WPN 1999) is designed around a series of critical questions that form the basis of the assessment. These critical questions are:

- Where are channel modifications located?
- Where are historic channel disturbances, such as dam failures, splash damming, hydraulic mining, and stream cleaning, located?

- What channel habitat types have been impacted by channel modification?
- What are the types and relative magnitude of past and current channel modifications?

Methods

Data on the location, timing (unavailable for most sources), and nature of channel modifications were gathered from a variety of agencies and sources, but primarily from the USFS watershed analyses (USFS 1994, 1995a, 1996a and 2003c). See Table 3-1 for information on Rogen stream classifications.

Results

As described in Chapter 2, Historical Conditions, the Upper Klamath Lake Subbasin has a long history of human activity. Timber harvest and road building occurred in certain parts of the subbasin as early as the late 1800's (USFS 1996a). Irrigation and drainage networks were constructed to increase the farming and grazing potential of land surrounding Upper Klamath and Agency lakes (USFS 1996a). Changes to overall channel condition have been brought about by a combination of land management activities in the subbasin, as described below.

Locations of Channel Modifications and Disturbances

Channel modifications have occurred in all of the fifth-field watersheds within the subbasin. Map 3-2 (Channel Modification Type) illustrates many of the channel modifications, especially the channelization, dams and constructed drainage networks within the subbasin. Generally, modifications are concentrated in the low gradient drainages surrounding Upper Klamath and Agency lakes. Channels have been modified to varying degrees for development and agricultural use. Map 3-2 does not illustrate the diking that has occurred as well as the removal of riparian vegetation, including lodgepole stands and aspen-cottonwood groves that historically surrounded the lakes (USFS 1994).

Some upper elevation channels have been modified as the result of logging activities, however, most of the channel modifications throughout the subbasin are in the lower stream reaches, before entering Upper Klamath and Agency lakes. Therefore, most of the channel habitat types that have been altered are C/F and E/F channel types.

Little information has been documented about locations of disturbances such as dam failures. Modifications, such as splash damming, did not occur within the subbasin because none of the channels are large enough for this application (Anderson, pers. comm. 2009). Stream cleaning has occurred throughout the subbasin, but the quantitative extent is unknown.

The following sections describe the channel modifications in more detail, including examples within each fifth-field watershed within the subbasin.

Types and Magnitude of Modifications

This section describes the following channel modifications:

- Dam construction
- Water diversions, canal and ditch construction intended both to facilitate seasonal draining of wetlands or irrigation for agricultural purposes
- Installing roads, culverts, and bridges across streams
- Installing railroad grades along and across streams
- Instream dams and ponds
- Removal of woody debris and riparian vegetation
- Instream habitat projects and riparian fencing

Dam Construction: The construction of the Link River Dam, built in the 1920's, raised the water levels in Upper Klamath and Agency lakes by approximately two feet. This had the general effect of raising base flows in the lower reaches of some channels, specifically Recreation and Crystal Creeks (USFS 2003c). It is not possible to quantify the impact that this had on adjacent wetlands and streams entering the lake because of the modifications undertaken by landowners that immediately followed construction of the dam. Such modifications include building ditches and dikes to drain land so that it could be used for agricultural purposes. Additionally, because the water levels are now regulated, the lake elevations drop lower than they would have historically (USDA 2007). Prior to dam construction, most channels in the lower reaches of all three watersheds would have been shallow, lacking a defined channel, and would have more complexity, such as woody debris and terrestrial and aquatic vegetation (USFS 2003c).

The Fourmile Creek watershed has been altered by the construction of a dam at the Fourmile Creek headwaters, at Fourmile Lake. This dam diverts water from the lake over to the west side of the Cascades (to the Rogue River drainage), significantly reducing the amount of water that would otherwise flow east, into Fourmile Creek (USFS 1996a). Loss of water from the headwaters (due to the trans-basin diversion of water from Fourmile Lake to the Rogue River drainage) has caused a reduction in channel-forming, bankfull flows. The decreased ability to transport sediment loads has resulted in aggradation of the streambed evidenced by instream bar formation, lateral migration, and stream branching. Aggradation is seen in the section of Fourmile Creek just above the confluence with Lost Creek where Fourmile Creek is in the process of reaching equilibrium with present flows. From near the confluence with Lost Creek, downstream into the Fourmile Flat area, the channel condition has become unstable and susceptible to blowouts during storm events. Stream width/depth ratios have increased and pool formation has decreased.

Channelization: Channelization, which includes channel straightening, relocation, and excavation, has occurred throughout the subbasin. Channelization was done for a number of reasons, including water delivery for irrigation purposes, seasonal draining, and realignment to benefit agricultural operations (Figure 3-6, Aerial Photo of an Example of Channelization Adjacent to Agency Lake). Existing digital coverage obtained from USGS (Map 3-2) is the primary data source for identifying these channels. It is highly probable that additional reaches of channelized streams occur in the assessment area, particularly short reaches too small to appear on the map.

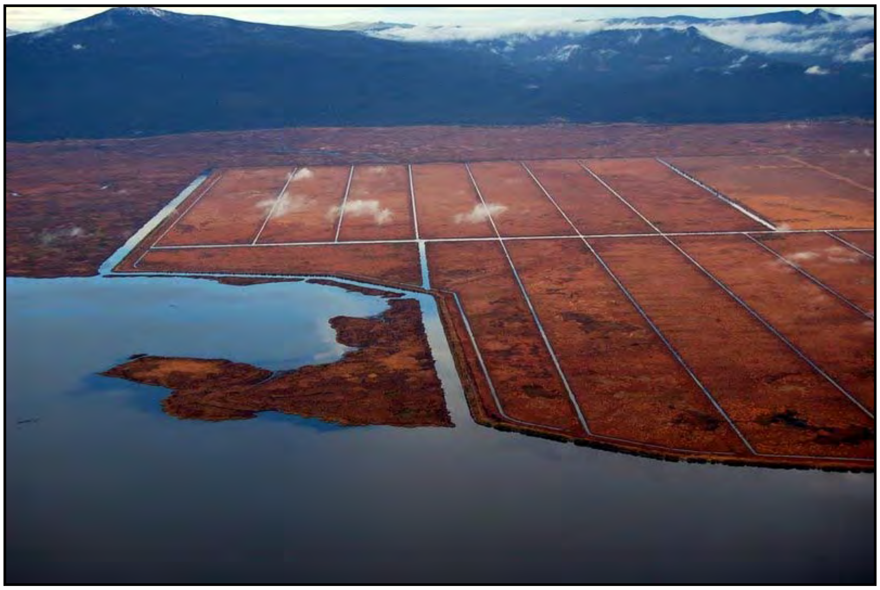

Figure 3-6. Aerial photo of an example of channelization adjacent to Agency Lake (DEA 2009).

Channelization has a direct effect on habitat conditions in the affected reach. The primary impact is simplification of aquatic habitat because the stream structure that produced pools, riffles, and steps is removed. In addition, downstream reaches can be affected as flow velocities increase and sediment delivery rates and timing are altered. This can result in increased peak flows and a lowered water table, reducing the duration and volume of base flows. Channelization and channel simplification can also cause significant bank erosion.

While much of the channelization occurred around the time of the construction of the Link River Dam in the 1920's, the precise dates of some of the work is unknown (USFS 1995a). Sevenmile, Fourmile, Nannie and Cherry Creeks are a few examples of streams that were channelized around this time (USFS 1994, 1995a). Channelization of Crystal Creek occurred earlier, around 1909 when the creek was dredged and became a major travel route for tourists traveling by steamboat up to Crater Lake (USFS 1994). Crystal Creek was subsequently used for logging activities including floating barges and log rafts to transport timber to Klamath Falls and Algoma (USFS 1994).

Channelization has significantly altered the channel condition and aquatic habitat functionality of the last two miles of Fourmile Creek (USFS 2008). Channel sinuosity, side-channels, vegetation on streambanks, pools, riffles, large substrates, and instream woody material historically dissipated stream energy within this reach (USFS 2008). The loss of channel roughness elements has resulted in increased stream velocity leading to streambank instability, bank erosion, increased sedimentation, and a lowered ground water table (USFS 2008).

Water Diversions and Ditch Construction: Many low gradient areas suitable for agricultural use have been impacted by water diversions and ditch construction. Impacts from diversions include reduction of instream flows, dewatering, and reductions in fish populations. Low gradient streams with diversions have reduced instream flows to the extent that some channels no longer reach Upper Klamath or Agency lakes. The diversion of Cherry Creek has reduced its flow so significantly as to cut off its historical connection to Upper Klamath Lake (USFS 1994). Additionally, construction and maintenance of the Fourmile Canal, has created an impediment to fish passage up Thomason Creek (Anderson, pers. comm. 2009). Other streams that have been diverted include Wood River, Annie, Nannie, Sevenmile and Threemile Creeks (Shapiro 2000, USFS 1994, 1995a). In addition, diversions can also harm fish populations if the diversion does not include a fish screen. See Chapter 9, Fish and Fish Habitat Assessment, for specific locations of potential fish barriers.

Road Construction: Roads, primarily associated with timber harvest, have been built parallel to or crossing major drainages, throughout the subbasin (USFS 1994, 1995a, 1996a). Road construction alters erosional processes through compaction, which increases overland flow and causes subsequent sedimentation of nearby streams (USFS 1996a). For example, road construction within the Fourmile Creek watershed caused observable increases in sediment loading in adjacent streams (USFS 1996a). Roads can also create fish passage barriers, such as the two-mile section of Rock Creek, which was identified by the USFS Rock, Cherry and Nannie Creek Watershed Analysis (1994), where roads and skid trails associated with timber harvest have severely modified tributaries to Rock Creek. In recent years, the USFS has implemented many projects that have eliminated or reduced the impact of roads, such as those along Rock Creek and Threemile Creek (USFS 1994). These projects typically include lining roadside ditches and re-surfacing and re-contouring roads (Anderson, pers. comm. 2009).

Railroad Construction: There is an unknown quantity of historic railroad grades in the subbasin. Most of the railroad grades were constructed for logging purposes in the early 1900's and therefore are located on USFS land (Ward Tonsfeldt Consulting 1995). The Fourmile Creek watershed has a large concentration of historic railroad grades; however, the USFS North Fourmile Watershed Analysis (1996a) did not identify any locations where the grades are significantly impacting adjacent stream channels.

Instream Dams and Ponds: Aside from the Link River and Fourmile Lake Dams, a number of instream dams have been constructed within the subbasin for water diversions, stock watering, and to provide fishing areas. There are three diversion dams along Fourmile Canal (Map 3-2). Several other diversion dams have been removed in recent years. The overall impact to the aquatic resources of all of these structures is unknown.

Removal of Woody Debris and Riparian Vegetation: Areas in both upper and lower reaches of the subbasin have experienced the removal of woody debris and riparian vegetation in association with timber harvest and agricultural activities. Once the riparian vegetation has been removed, continuous activities, such as grazing, can limit the re-growth. Currently, some riparian zones are being managed to include only occasional grazing or have been fenced to exclude grazing in the riparian zone altogether. The removal of woody debris and vegetation from a channel can have many effects including increased velocities, bank instability, increased bank erosion, reduced sediment storage, reduced habitat complexity and increased water temperatures. As such, the combination of these issues has greatly influenced water quality, particularly to a receiving body, in this case, Upper Klamath and Agency lakes (water quality has been addressed in greater detail in Chapter 8, Water Quality Assessment). As part of a timber sale that took place in 1971 on Rock Creek, all the riparian vegetation and woody debris was removed from a two-mile section. Bank erosion has been observed at this site, with limited vegetation re-establishment (USFS 1994).

Instream Habitat Projects and Riparian Fencing: A variety of public and private partners have been undertaking instream habitat projects, riparian planting, and riparian fencing in the assessment area over the last 20 years. Attempts to quantify the effects of these, and other efforts, has been initiated by the Klamath Basin Rangeland Trust (KBRT) and NRCS as the Wood River Conservation Effects Assessment Project (CEAP). Data collection included stream flow, water quality, bank stability, evapotranspiration data and shallow groundwater levels (Peterson, pers. comm. 2009). A site visit conducted by DEA on 10-14-09 documented a recently completed restoration project on the Knapp's property (Figure 3-7, Photo of Habitat Enhancement Project Along the Wood River). The project was designed to improve instream habitat through the installation of woody debris and spawning gravels in the upper reaches of the Wood River.

Discussion

In general, channels that are most sensitive to changes are low gradient (<2 percent) reaches with a developed floodplain (Montgomery and Buffington 1993). These alluvial channels generally lack geomorphic controls such as bedrock, boulders, or confining terraces or hillslopes. Alluvial valley reaches in river systems often act as "response reaches" because they respond to changes in stream flow and sediment discharge by adjusting their storage and stream channel geometry. Thus, episodic events such as large floods may cause the channel location to change, sometimes dramatically, in response to the energy of high flows that exceed the resisting forces of the stream channel banks and riparian vegetation. In a similar manner, large influxes of sediment, whether derived in a single large storm event or delivered chronically over a longer time period, may cause changes in channel form in these response reaches as sediment deposition locally overwhelms the capacity of the channel to transport it. In the low gradient reaches of the Upper Klamath Lake subbasin, channel form has adjusted to increased sediment loads, loss of bank stabilizing riparian vegetation, and channel modifications in several ways. For example, in reaches directly affected by channelization, the channel has incised and become isolated from its floodplain.

Historic dam and road construction, timber harvest and agricultural practices have significantly altered the lower reaches of channels within the subbasin. It is difficult to quantify the impact of a single alteration; however, numerous studies have documented degraded water quality within Upper Klamath and Agency lakes, which can be attributed, in part, to widespread channel modifications. Monitoring activities, such as those performed in the Wood River CEAP, have shown improvements in water quality and quantity once channel modifications are reversed (NRCS 2009).

Figure 3-7. Photo of habitat enhancement project along the Wood River (DEA 2009).

Although all of the fifth-field watersheds have channels that have been modified in one way or another, Horse, Lost and Cold Springs creeks, within the Fourmile Creek watershed, have generally been unaltered by past management (USFS 1996a).

Confidence Evaluation

Confidence in the evaluation is moderate to high. Data gaps exist regarding the direct impact of individual channel modifications on aquatic resources; however, existing information is insufficient to determine where and when the modifications occurred. The combination of USFS watershed analyses, other agency reports, US GLO surveys and personal interviews with long-time property owners provides an adequate inventory of modifications at the subbasin scale.

Research Recommendations

1. Continue Researching Modified Channels to Better Understand Potential Return on Investment from Restoration Efforts. As mentioned in the text above, many streams in the subbasin have been modified for agricultural and other human uses resulting in poor water quality and degraded fish habitat. While many of these streams would benefit from restoration, there are little data (i.e., geomorphic) available to determine with greater certainty that these streams would provide a high return on investment if restored. For example, some streams that have been channelized have severe sedimentation problems that would not be fixed through conventional restoration efforts. Therefore, additional research and data collection are necessary to fully understand the potential benefits that could be generated through strategic restoration efforts.

Currently, there is a lot of interest from public and private landowners in restoring historical connections between some modified streams and Upper Klamath and Agency lakes. Fourmile Creek at Pelican Bay has been identified as providing important refugia habitat for fish during stressful summer conditions (USFWS 1994); thus, restoring its connection to Upper Klamath and Agency lakes could greatly benefit fish. However, it is recommended that additional data be collected before implementing restoration actions to better understand how these restored connections will benefit aquatic species and water quality. More specifically, it is recommended that a thorough geomorphic analysis be conducted on Thomason, Cherry, and Fourmile Creeks.

2. Consistently Monitor the Effectiveness of Restoration Actions. While much has been done in the subbasin to improve channel and habitat conditions and monitor these improvements, some efforts have not been consistently monitored. Without consistent monitoring, it is difficult to identify and implement those activities that yield the greatest benefit. Additionally, there needs to be effective communication and coordination of monitoring efforts across the subbasin because of the various public agencies and private property owners participating in restoration activities. Future monitoring tasks should begin with an inventory of those improvements that are already in place.

Restoration and Management Opportunities

Restore Natural Geomorphic Processes. In the lower reaches of streams throughout the subbasin, the combination of dam construction, removal of riparian vegetation and woody debris, channelization, and diversion has changed the physical attributes of these streams, resulting in aquatic habitat degradation. Many channels have become deeper and straighter, while others have lost their connection to Upper Klamath Lake because of dewatering or sediment accumulation. Channelization has led to lack of channel complexity necessary for aquatic species and downcut conditions, which both separates the stream from its floodplain and contributes to sedimentation. Downcut channels and the associated loss of floodplain connectivity can reduce the amount of water stored in the soil profile by lowering the water table. Additionally, the changes to channel morphology and removal of riparian vegetation have contributed to degraded water quality, including excessive water temperatures (see Chapter 8, Water Quality Assessment for additional information). Specific restoration actions such as restoration of channel complexity, promotion of riparian recovery and reduction in sediment yields can influence the geomorphic processes that control channel conditions and will begin to improve aquatic habitat. A good example of such a project is the lower Fourmile Creek channel restoration project where USFWS, private landowners, USFS and others are engaged in restoring channelized reaches to a more natural condition, resulting in extended periods of inundation and restoration of wet meadow habitat (Anderson, pers. comm. 2010).

List of Maps

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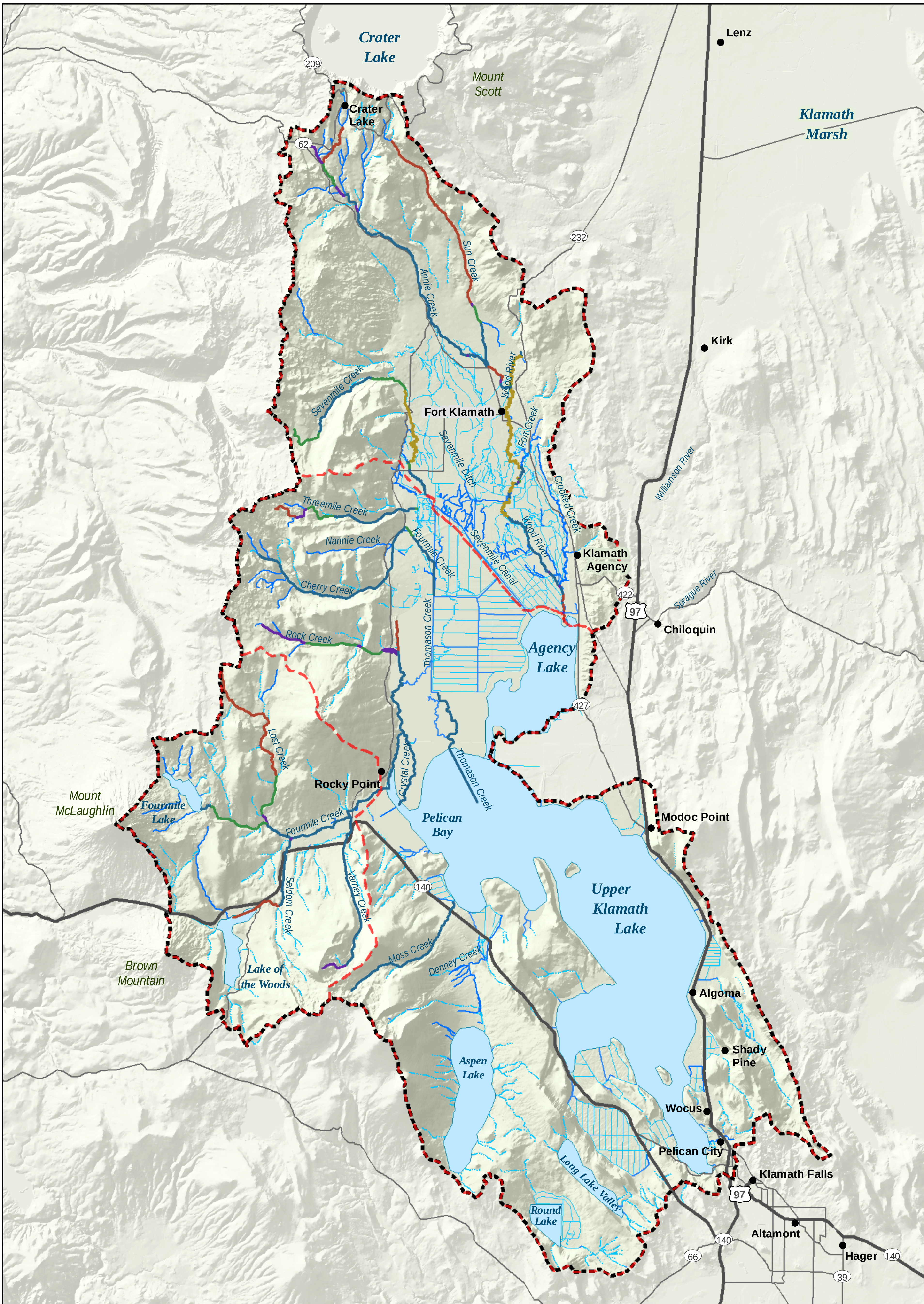

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Source Data:
ESRI, Klamath County, Oregon GEO, USGS (National Hydrography Dataset)

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch

Rosgen Channel Habitat Types

- A
- Aa
- B/G
- C/F
- E/F

Map 3-1: Rosgen Level 1 Channel Types

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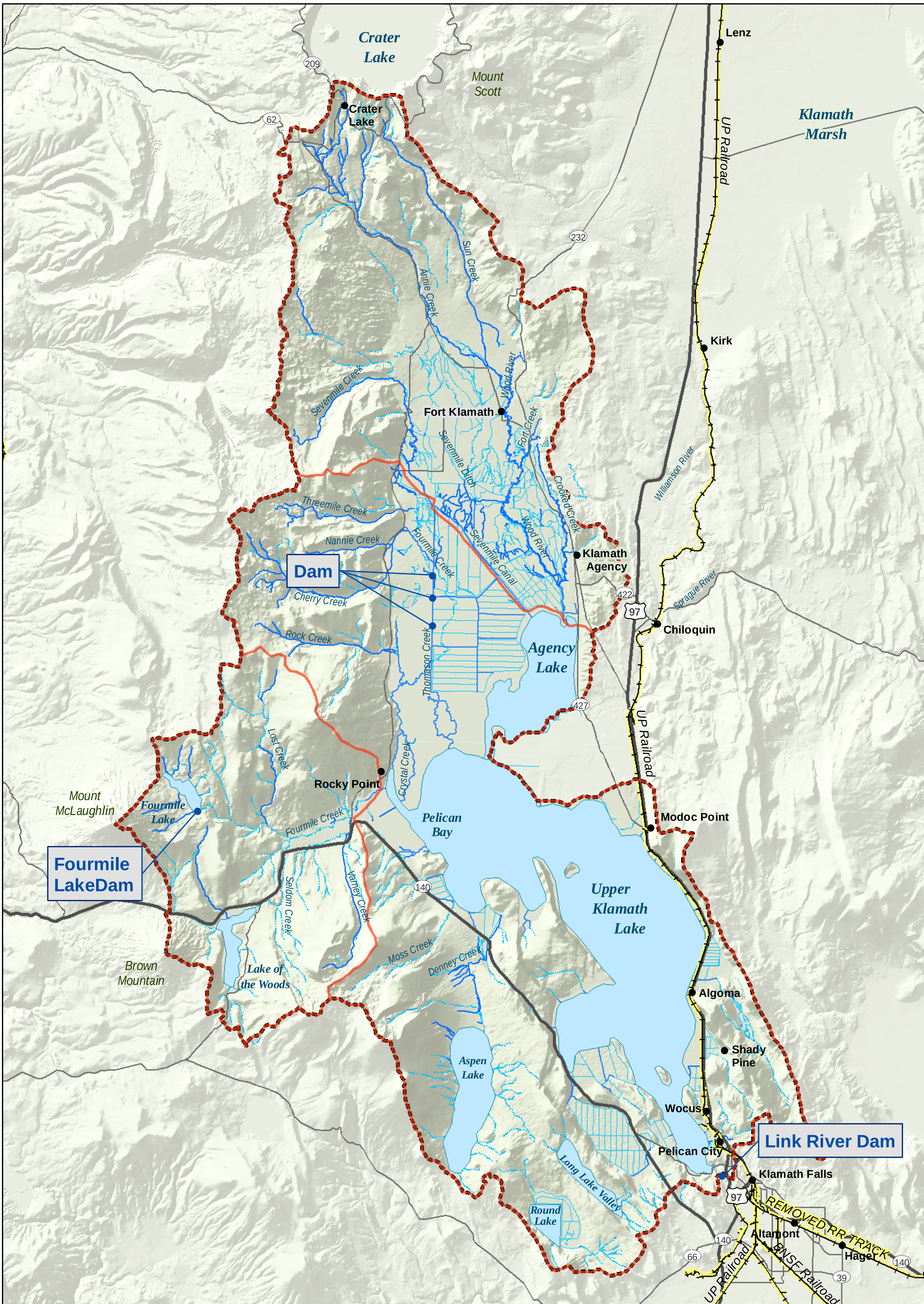

N

0 4 8

Miles

Source Data:
ESRI, Klamath County, Oregon GEO,
USGS (National Hydrography Dataset)

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch

Map 3-2: Channel Modifications

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CHAPTER 4:

HYDROLOGY AND WATER USE

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4 HYDROLOGY AND WATER USE

Introduction

The purpose of this chapter is to summarize existing information sources, identify data gaps that may require further study, and identify opportunities for improving stream flow conditions. Using existing information, streamflow patterns, water use, and land use effects on streamflow are summarized in the results section of this chapter. The results are followed by recommendations on future monitoring and research needs in order to fill data gaps and to help identify steps that can be taken to improve streamflow conditions.

Methods

The Hydrology and Water Use assessment methodology outlined in the Manual (WPN 1999) is designed around a series of critical questions that form the basis of the assessment. These critical questions are:

- What land uses are present in the watershed?
- What is the flood history in the watershed?
- Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?
- For what beneficial use is water primarily used in the watershed?
- Is water derived from a groundwater or surface-water source?
- What type of storage has been constructed in the basin?
- Are there any withdrawals of water for use in another basin (interbasin transfers)? Is any water being imported for use in the basin?
- Do water uses in the basin have an effect on peak and/or low flows?
- Are there any illegal uses of water occurring in the subbasin?

In general, the methodology used in this assessment follows the outline presented in the Manual (WPN 1999). The Results section provides a summary of the existing hydrologic regime, streamflow data available for the assessment area, current land uses, describes the flood history of the area, and characterizes the water use among the subwatersheds. The Discussion section considers the effects that current land use may have on streamflow in the watersheds. The Recommendations section outlines information gaps, monitoring needs, and restoration opportunities.

Results

Hydrologic Regime

The purpose of this section is to characterize the hydrologic regime in the various portions of the Upper Klamath Lake Subbasin. General descriptions of the overall hydrology of the area are summarized from Gannett et al. (2007), with further detail provided by USFS watershed analyses (1994, 1995a, 1996a, and 2003c).

The Upper Klamath Lake Subbasin is characterized by an extensive regional groundwater flow system. Volcanic geology throughout the region is generally permeable and includes a system of interconnected aquifers. This allows groundwater to feed several key streams throughout the subbasin. However, water does not indefinitely flow downward through these permeable soils because a layer of less permeable, older, volcanic and sedimentary rock limits its movement. A notable exception to permeable soils that are typical throughout the subbasin exists within and immediately surrounding Upper Klamath and Agency lakes. Historic fine-grained lake sediments limit permeability and contribute to the existence of wetlands in these areas (Gannett et al. 2007).

By far the largest lake in the subbasin is Upper Klamath Lake, which has a surface area between 100 and 140 square miles (including non-drained fringe wetlands) depending on stage (Hubbard 1970; Snyder and Morace 1997). The primary tributaries to Upper Klamath Lake include the Williamson River, the Wood River, and several streams from the eastern slopes of the Cascade Range (Gannett et al. 2007). The Williamson River is not addressed in this study, but has been addressed in prior watershed assessments and analyses (USFS 1996b, 1998, no date; DEA 2005, Klamath Basin Ecosystem Foundation et al. 2007; Rabe Consulting 2009).

Hydrology of the Upper Klamath Lake Subbasin will be addressed by the individual watersheds that make up the subbasin; the Wood River, Klamath Lake and Fourmile Creek watersheds (Map 1-1 Base Map).

Wood River Watershed

The Wood River watershed is dominated by a groundwater system (Gannett et al. 2007 Within the Wood River watershed, Wood River, Annie, Crooked, Fort, Sun and Sevenmile Creeks are all significant drainages. Wood River, a spring-fed stream, originates on the eastern edge of the valley and, with its tributaries, provides almost one-half of the groundwater discharge in the subbasin and 15% of the inflow volume to Upper Klamath Lake (Gannett et al. 2007 and DEQ 2002). The channel is diverted in several locations for irrigation purposes before flowing into Agency Lake (Figure 4-1, Aerial Photo of Irrigation Diversions, Common Throughout the Subbasin). The headwaters of Annie and Sun Creeks are located in high elevations on the edge of Crater Lake National Park and are fed mostly by springs with some snow-melt. Annie and Sun Creeks are tributaries to Wood River, but contribute a small amount, just 14 percent, of groundwater discharged into the Wood River (Gannett et al. 2007).

Figure 4-1. Aerial Photo of irrigation diversions, common throughout the subbasin (DEA 2009).

Sevenmile Creek originates in the forested slopes of the Fremont-Winema National Forest, then is channelized and diverted for agricultural use before emptying into Agency Lake (USFS 1995a). The Sevenmile drainage, including its tributaries, contributes a small amount of total flow to Upper Klamath and Agency lakes (USFS 1995a).

Klamath Lake Watershed

The western portion of the Klamath Lake watershed includes Threemile, Fourmile, Nannie, Cherry, Rock, Recreation and Crystal Creeks. In the southwestern part of the watershed, the major drainages include Moss Creek and the drainages associated with Aspen Lake, Long Lake Valley and Round Lake. The eastern edge of the watershed includes springs at the base of the hillside, directly adjacent to Upper Klamath Lake, such as Barkley Springs at Hagelstein Park.

Nannie, Cherry and Rock Creeks were addressed previously in a 1994 USFS watershed analysis (USFS 1994). All three drainages originate at the crest of the Cascades and flow eastward to Upper Klamath Lake. Their upper reaches all have a snow-melt dominated hydrologic regime, with the addition of spring seepage at lower elevations where the gradient is much more gradual (Gannett et al. 2007). Climate variability can affect the connections of these creeks to Upper Klamath Lake. Aerial photos indicate that all three systems originally had at least an intermittent connection to Upper Klamath Lake, and flows in Cherry Creek have been reduced through irrigation diversions (USFS 1994). Connectivity of Rock Creek to Crystal Creek was improved from 2008 to 2009 when USFWS, NRCS, USFS, and the private landowner reengineered the existing stream channel through private land.

A 2003 USFS watershed analysis of the Pelican Butte area describes the hydrologic regimes of Recreation and Crystal Creeks (USFS 2003c). There are no defined stream channels on the east slope of Pelican Butte to convey spring melt down slope, but rather there are swales or depressions that allow water to infiltrate through the porous soil (USFS 2003c). Once the snow melt has infiltrated, it then discharges at lower elevations in the form of spring or seep flow. Two of these springs, Malone and Crystal Springs, feed Crystal and Recreation Creeks before they flow into Pelican Bay of Upper Klamath Lake. Crystal and Recreation Creeks have a very low gradient in their lower reaches, connecting with Upper Klamath Lake as a wetland rather than through a defined channel (USFS 2003c). At summer low flow, Recreation Creek has an average width ranging between 50 to 75 feet (USFS 2003c). Figure 4-2 (Aerial Photo of Channels Altered for Drainage and Irrigation) shows a loss of channel connectivity between Crystal and Thomason Creeks.

Figure 4-2. Aerial Photo of channels altered for drainage and irrigation (DEA 2009).

Fourmile Creek Watershed

The Fourmile Creek watershed includes Lost, Fourmile, Seldom and Varney Creeks. Lost Creek is located between the east slope of Mount McLaughlin and the west slope of Pelican Butte (Figure 4-3, Aerial Photo of East Slope of Mount McLaughlin, Fourmile Creek watershed). Given its north-south orientation, the narrow valley that makes up Lost Creek typically retains snowpack late in the year (USFS 1996a). Lost Creek drains into Fourmile Creek, increasing flows during snow-melt (USFS 1996a). Fourmile Creek, which originates at Fourmile Lake, has been impacted by the construction of Fourmile Lake Dam since the early 1900's (USFS 1996a). This dam holds back snow-melt, water that would have historically fed Fourmile Creek, and diverts it to the west side of the Cascades (USFS 1996a). This has resulted in upper portions of Fourmile Creek that used to be perennial now being intermittent and a loss of channel shaping peak flows (USFS 1996a). Downstream from its confluence with Lost Creek, Fourmile Creek is also fed by the combination of Seldom and Varney Creeks.

Like other watersheds in the subbasin, the higher reaches of this drainage, which include slopes of Pelican Butte and Mount McLaughlin, have high infiltration rates (USFS 1996a) resulting in low stream volumes and stream sections that are intermittent at times. The lower reaches of the

Fourmile drainage are primarily made up of deposited glacial till, which can be easily transported by water, resulting in frequent changes in channel location (USFS 1996a). This historic channel movement is no longer possible because the lower reaches of Fourmile Creek, before it enters Upper Klamath Lake, have been channelized.

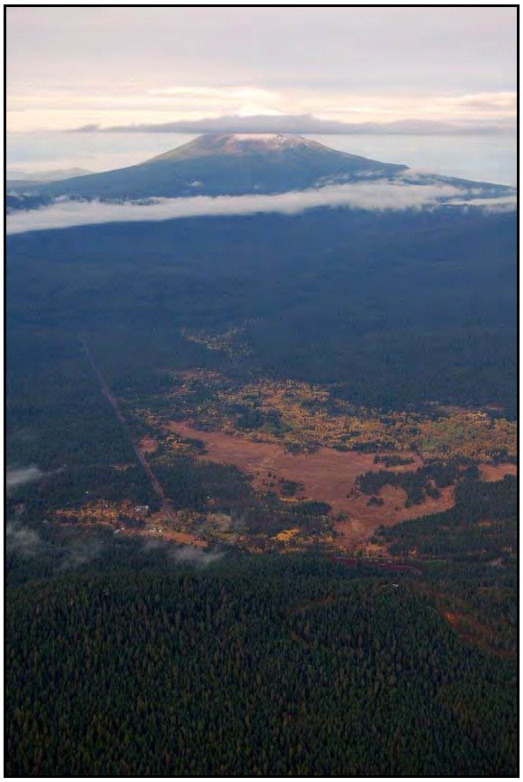


Figure 4-3. Aerial Photo of the east slope of Mount McLoughlin, Fourmile Creek watershed (DEA 2009).

Stream Flow Measurements

Five stream gages are active within the assessment area. The locations of gages and flow measurement sites are shown in Map 4-1 and summarized in Table 4-1 (Gages and Flow Measurement Sites in the Upper Klamath Lake Subbasin). Monthly stream flow statistics were calculated for the three gages in Table 4-1 having the longest flow record, and are discussed below. Statistics calculated for each of the three gages includes median monthly flow and the 80- and 20-percent exceedance flows.[1] Although active gages measuring lake levels are included in Table 4-1, they were not used to calculate flow statistics because they were not tied to an individual stream reach.

[1] *The median, or 50 percent exceedance stream flow, is the stream flow that occurs at least 50 percent of the time in a given month. The 80 percent exceedance stream flow is exceeded 80 percent of the time, and can be thought of as the stream flow that occurs in a particularly dry month. Conversely, the 20 percent exceedance stream flow is exceeded only 20 percent of the time, and can be thought of as the stream flow that occurs in a particularly wet month.*

Table 4-1. Gages and Flow Measurement Sites in the Upper Klamath Lake Subbasin

Map #	ID #	Hydrologic Unit	Description	Drainage Area (mi^2)	Gage Elev. (ft)	Period of record: Mean daily flow	Period of record: Peak flows (water years)	Current status/ responsible agency
1	11502900	18010203	Diversion From Annie Spring By Pumpage			5/1977 to 9/1981		Discontinued
2	11502940	18010203	Wood River at Dixon Road Near Fort Klamath		4,200	7/1927 to 9/2005		Active/ USGS
3	11502950	18010203	Sun Creek at Ranger Station near Fort Klamath			7/1927 to 9/1927		Discontinued
4	11502970	18010203	Sun Creek at Dixons Ranch Near Fort Klamath			7/1927 to 10/1927		Discontinued
5	11503000	18010203	Annie Creek Near Crater Lake, OR	0.21	6,030	6/1977 to 9/2004		Discontinued / USGS
6	11503001	18010203	Combined Flow of Annie Spring and Diversion			6/1977 to 9/1981		Discontinued
7	11503500	18010203	Annie Creek Near Fort Klamath (Annie Creek Var)		4,300	11/1922 to 7/1927		Discontinued / USGS
8	11503650	18010203	Mehasse D Near Fort Klamath			7/1927 to 8/1927		Discontinued
9	11504000	18010203	Wood River at Fort Klamath, OR	81.2	4,180	10/1913 to 9/1936	1913-1936	Discontinued
10	11504040	18010203	Fort Creek Near Fort Klamath			7/1927-9/1927		Discontinued
11	11504050	18010203	Wood River at CV Loosly Ranch Near Fort Klamath			7/1927 to 9/1929		Discontinued
12	11504090	18010203	Wood River at Weed Ranch Near Fort Klamath			7/1927 to 10/1927		Discontinued
13	11504100	18010203	Wood River Near Fort Klamath, OR	91.1	4,210	10/1964 to 9/1967		Discontinued / USGS
14	11504120	18010203	Sevenmile Creek at Ranch Station Near Fort Klamath			7/1927 to 9/1927		Discontinued
15	11504150	18010203	Sevenmile Creek at Fk Loosely Ranch Near Fort Klamath			7/1927 to 10/1927		Discontinued

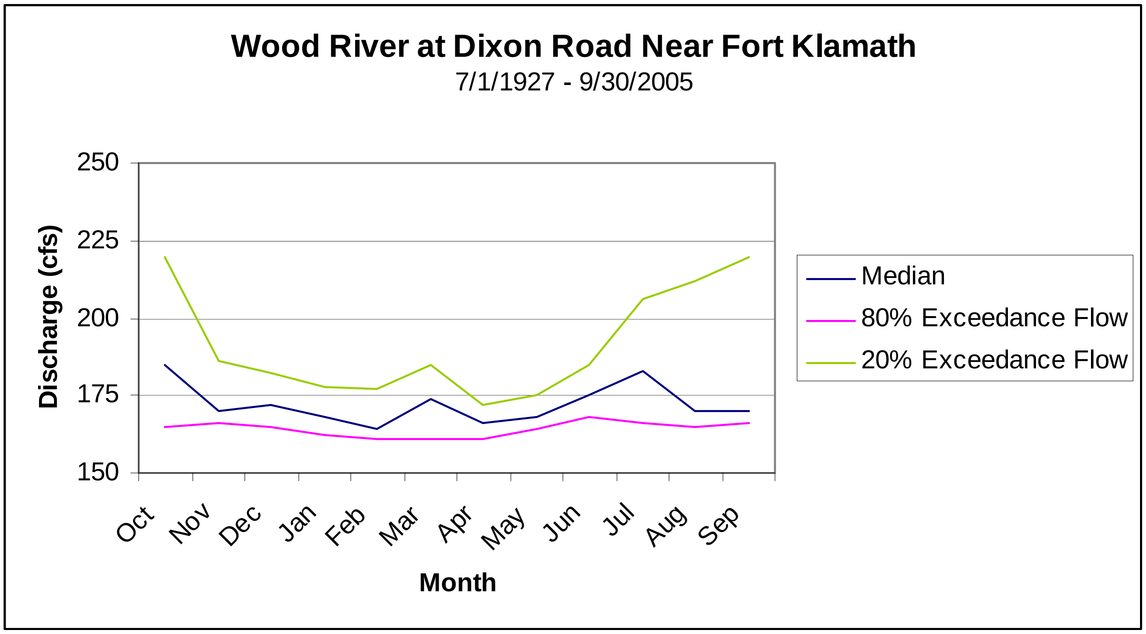
Map #	ID #	Hydrologic Unit	Description	Drainage Area (mi^2)	Gage Elev. (ft)	Period of record: Mean daily flow	Period of record: Peak flows (water years)	Current status/ responsible agency
16	11504170	18010203	Crane Div to Sevenmile Creek Near Fort Klamath					Discontinued
17	11504200	18010203	Crooked Creek Near Fort Klamath	5.2	4,190	10/1964 to 9/1967		Discontinued / USGS
18	11504400	18010203	Threemile Creek Near Crystal		4,570		1965-1970	Discontinued / USGS
19	11504500	18010203	Fourmile Lake Near Recreation					Discontinued
20	11504600	18010203	Cascade Canal at Fourmile Lake Near Lakecreek			10/1922 to 9/1991		Discontinued / USGS
21	11505500	18010203	Fourmile Creek Near Odessa, OR (nr Fourmile Lake)	10.8	5,730	4/1912 to 8/1917		Discontinued / USGS
22	11505550	18010203	Lost Creek Near Rocky Point, OR	13.6	5,320		peak flows only, 1966-1982	Discontinued / USGS
23	11505600	18010203	Fourmile Creek Near Rocky Point, OR	108	4,200	10/1964 to 9/1967		Discontinued / USGS
24	11505700	18010203	Varney Creek Near Rocky Point, OR	7.39	4,150	10/1964 to 9/1967		Discontinued / USGS
25	11505800	18010203	Upper Klamath Lake at Rocky Point	3810	4,100	9/1973 to present	1988-2008	Active/ USGS
26	11505900	18010203	Upper Klamath Lake at Rattlesnake Point	3810	4,100	9/1973 to present[1]	1988-2008	Active/ USGS
27	11507000	18010203	Upper Klamath Lake Near Klamath Falls, OR	3810	4,100	10/1969 to present[1]		Active/ USGS
28	11507001	18010203	Upper Klamath Lake Near Klamath Falls, OR	3810	4,100	10/1974 to present[1]	1975-2008	Active/ USGS

[1] Gages recording lake level rather than mean daily stream flow

Data Source: OWRD, USFS, USGS

The gage for Wood River at Dixon road is located just downstream of the headwater springs, before its tributaries have contributed flows (Map 4-1, Stream Gage Locations). Major tributaries to the Wood River are also spring-fed and include Annie, Sun, Crooked and Fort Creeks. Spring sources for Annie and Sun Creeks are at high elevations and can become frozen in the winter, reducing their winter base flow and winter-time contribution to Wood River.

Wood River maintains consistent perennial flow, with minimal seasonal variations (Gannett et al. 2007). Even though some years of data are missing, Figure 4-4 (Monthly Streamflow Statistics for Wood River at Dixon Road Near Fort Klamath) illustrates this generally consistent year-round flow. However, climatic events, such as drought, can significantly influence the available groundwater within a spring-fed system. Gannett et al. (2007) used data from various sources to show how base flows for Wood River were reduced in response to drought and increased during years of higher than average precipitation.



Data Source: OWRD 2009

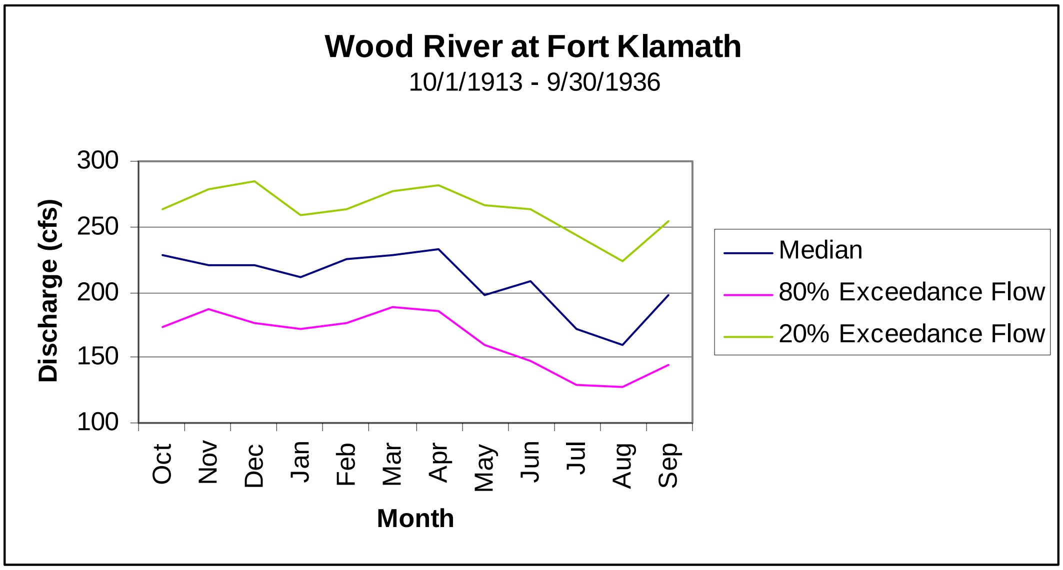
Gage #11502940 (Gage #1 on Map 4-1); Table 4-1

Figure 4-4. Monthly Streamflow Statistics for Wood River at Dixon Road Near Fort Klamath

There are several diversions for irrigation located along the length of Wood River and its tributaries. Gage information shown in Figure 4-5 (Wood River at Fort Klamath) is located below some of these diversions. Since 1913, many different gages have been installed on the Wood River, however, they have gathered only intermittent and inconsistent information (Gannett et al. 2007).

Annie Spring is located in Crater Lake National Park, providing the park with its main source of potable water (NPS 2009). The spring is located at a high elevation that receives a large amount of snow. Groundwater that supplies the spring is frozen for much of the winter, resulting in low flows January through March (Gannett et al. 2007). This seasonal reduction in flow is apparent in Figure 4-6 (Monthly Streamflow Statistics for Annie Spring near Crater Lake). A combination of snowmelt and thawing groundwater initiate peak flows in early summer, providing water to Annie Creek.

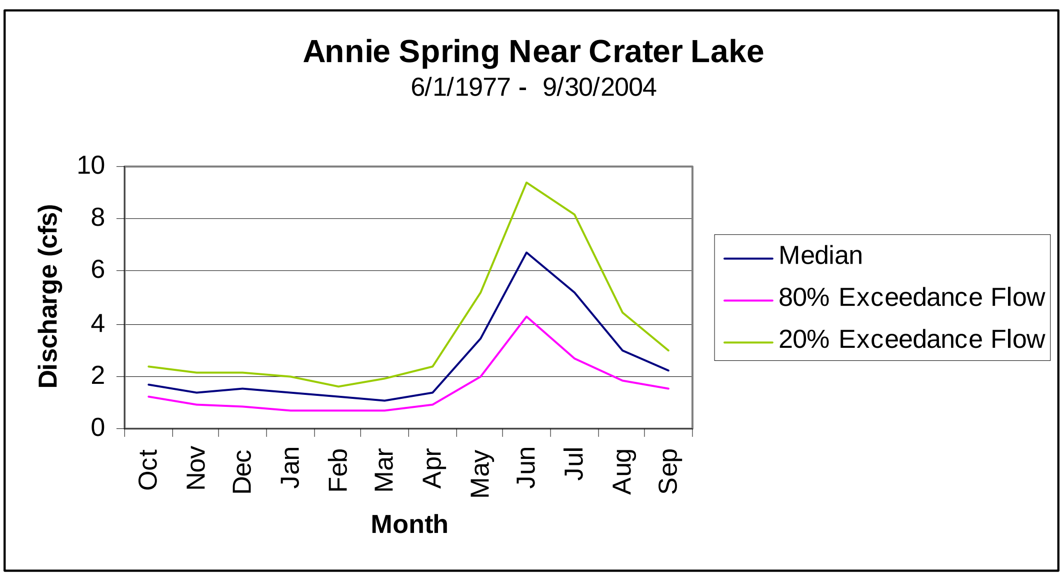
The gage for Wood River at Fort Klamath, shown in Figure 4-5, reveals higher baseflows than those at the Dixon Road gage (Figure 4-4). This additional input can be attributed to groundwater and surface water associated with Annie and Sun Creeks. The reduction in flows during the summer, seen in Figure 4-6, is typical of a large-scale spring system (Gannett et al. 2007).



Data Source: OWRD 2009

Gage #11504000 (Gage #3 on Map 4-1); Table 4-1

Figure 4-5. Wood River at Fort Klamath



Data Source: OWRD 2009

Gage #11503000 (Gage #2 on Map 4-1); Table 4-1

Figure 4-6. Monthly Streamflow Statistics for Annie Spring Near Crater Lake

Land Uses

This section addresses the following critical question 1: what land uses are present in the watershed?

Primary land uses in the subbasin are closely tied with land ownership (Map 1-2, Land Ownership). Generally, much of the forested upper elevations are publicly owned and lower elevations, surrounding Upper Klamath and Agency lakes, are a mix of public and private. Nearly all of the upper elevations of the western half of the assessment area are managed by the USFS as the Fremont-Winema National Forest. Land uses within the forest include timber harvest, recreation and wildlife habitat. Higher elevations, to the north, are managed by the NPS as part of Crater Lake National Park. This land is managed primarily for habitat and natural resource preservation. In the northwest portion of the assessment area, the Oregon Parks and Recreation Department manages Kimball State Park. Land use within this State Park includes recreation and wildlife habitat (Shapiro 2000). Oregon Department of Forestry manages Sun Pass State Forest.

Lower elevations, surrounding Upper Klamath Lake, are a combination of public and private ownership. Bureau of Reclamation (Reclamation) and USFWS are intending to restore wetlands on Agency Lake Ranch and Barnes Ranch. Bureau of Land Management (BLM) manages a parcel on Fourmile Creek and the Wood River Wetland (formerly Wood River Ranch) and has also initiated restoration activities (Shapiro 2000). USFWS manages several refuges, the largest of which is Upper Klamath National Wildlife Refuge. Private ownership is concentrated in the Wood River Valley and both southwest and southeast of Upper Klamath Lake. Agricultural land uses on private land are primarily grazing, crop production and some timber harvest (Shapiro 2000).

Flood History

This section addresses critical question 2: what is the flood history in the watershed?

Map 4-3 shows areas within the 100-year floodplain, primarily adjacent to Upper Klamath and Agency lakes. The largest continuous area includes Crystal, Fourmile, Recreation and Thomason Creeks. These areas are owned and/or managed by a combination of private landowners and public agencies (Map 1-2). Public land includes Upper Klamath National Wildlife Refuge, Barnes Ranch and Agency Lake Ranch. The entire length of the Wood River, including a large area on the east side of the lower reach, is also identified as being part of the 100-year floodplain. These areas are privately owned (Map 1-2).

In the Upper Klamath Lake Subbasin, rain-on-snow events generally play a relatively minor role in regard to peak flows and associated flooding. Occasionally there are warm, moist precipitation events where large amounts of rain penetrate upper elevation winter snowpack storage. The frozen conditions prevent the rain from infiltrating the porous soils. During the winter and spring, upper elevation tributaries may experience local increased peak flows during rain-on-snow events; however, these increased flows diminish downstream due to high infiltration rates, low water tables, and relatively low typical annual precipitation.

Water Use

This section addresses the following critical questions:

- Critical Question 3: Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?
- Critical Question 4: For what beneficial use is water primarily used in the subbasin?
- Critical Question 5: Is water derived from a groundwater or surface-water source?
- Critical Question 6: What type of storage has been constructed in the subbasin?
- Critical Question 7: Are there any withdrawals of water for use in another basin (interbasin transfers) or is any water being imported for use in the subbasin?
- Critical Question 8: Are there any illegal uses of water occurring in the subbasin?

Data available from the Oregon Water Resources Department (OWRD) (OWRD 2009) were used to identify locations and characteristics of water use in the Upper Klamath Lake Subbasin. Only those water rights whose current status is given as "non-cancelled" were included in this evaluation.

Overview of Water Rights

In Oregon, any entity wanting to use the waters of the state for a beneficial use has to go through an application/permit process administered by OWRD. Under this process, an entity applies for a permit to use a certain amount of water, and then establishes that the water is being used for a beneficial use. Beneficial uses include agricultural purposes, habitat benefits, and other uses deemed appropriate by OWRD. Once the beneficial use is established, and a final proof survey is done to confirm the right, a water right certificate is issued.

Water rights entitle a person or organization to use the public waters of the state in a beneficial way. Oregon's water laws are based on the principle of prior appropriation which means the first entity to obtain a water right on a stream is the last to be shut off in times of low stream flows (OWRD 2001). In times when water is in short supply, the water right holder with the oldest date of priority can demand the water specified in their water right regardless of the needs of junior users. The oldest water right within the Upper Klamath Lake assessment area has a priority date of November 30, 1883, and the newest has a priority date of September 26, 2007 (OWRD 2009).

Types of Water Rights

OWRD approves many different types of water right certificates for different beneficial uses including surface water, storage, instream, groundwater water rights, and sometimes stock watering. These water rights are obtained for the following general beneficial uses: agricultural use, fish protection, pollution minimization, recreational use, and municipal use. Many different entities in the Klamath Basin have water rights that have not yet been adjudicated (adjudication is the process for establishing water rights initiated prior to February 24, 1909).

Agricultural irrigation water rights are either storage water rights or surface water rights and are generally seasonal. Storage water rights are those obtained from reservoirs whereas surface water rights are those obtained from rivers and streams.

Water rights for fish protection, minimizing the effects of pollution, or maintaining recreational uses are instream water rights (OWRD 2001). Instream water rights set flow levels to stay in a stream reach on a monthly basis, have a priority date, and are regulated with the same prior appropriation policies as other water rights. Instream water rights do not guarantee that a certain quantity of water will be present in the stream: under Oregon law, an instream water right cannot affect a use of water with a senior priority date (OWRD 2001).

Water rights for municipal use include surface water, groundwater, and storage water rights. Municipal use is generally for the purposes of providing potable water to local residents, but is used for other purposes as well.

As mentioned above, while most surface water use requires a water right certificate, some surface water use does not require a certificate. Exempt uses of surface water include natural springs that do not flow off the property on which they originate, stock watering (with some exceptions), fire control, forest management, and the collection of rainwater. Exempt groundwater uses include stock watering, less than one-half acre of lawn and garden watering, and domestic water uses of no more than 15,000 gallons per day.

Water Use in the Assessment Area

Water in the subbasin is mostly used for agricultural irrigation, for extensive waterfowl refuges and to support aquatic wildlife in lakes and streams (Gannett et al. 2007).

Instream Water Rights

Several instream water rights exist within the Upper Klamath Lake Subbasin, held by Oregon Department of Fish and Wildlife and OWRD (OWRD 2009). Water rights on Cherry Creek, Upper Klamath Lake, Wood River, and Sevenmile Creek are for the stated purpose, “Anadromous and Resident Fish Habitat” (OWRD 2009). Instream water rights on Annie, Fort, Sun and North Fork Little Butte Creeks (near Lake of the Woods) are for the stated purpose, “Anadromous and Resident Fish Rearing” (OWRD 2009).

All of the instream water rights, listed above, are secured year-round rather than seasonally like some of the irrigation-specific water rights. These short-term instream leases of irrigation rights are listed in Table 10-1 (Restoration Projects). Priority dates for the instream water rights for “Anadromous and Resident Fish Habitat” are October 26, 1990 and those for “Anadromous And Resident Fish Rearing are May 22, 1991 (OWRD 2009).

Locations of Water Withdrawals

OWRD identifies 824 points of diversion for water rights within the Upper Klamath Lake Subbasin (OWRD 2009). The approximate locations of these points of diversion are shown in Map 4-2, Water Rights (OWRD 2009). Points of diversion for water rights are found within all watersheds (Map 4-2) (water rights with instream leases associated with them are not included in OWRD's map information). The majority (83 percent) of the points of diversion are from surface waters, the remainder being from groundwater sources (10 percent) and reservoirs (7 percent).

Most of the land within the subbasin is irrigated with surface water rather than groundwater (Gannett et al. 2007). Wells are concentrated in the southern part of the subbasin, associated with urban development (Gannett et al. 2007).

Withdrawal Rates

Information on withdrawal rates associated with water rights within the Upper Klamath Lake Subbasin is publicly available through OWRD (2009). In the OWRD data, the rate of withdrawal is expressed as an instantaneous rate (i.e., cubic feet per second [cfs]), except for reservoir storage, which is expressed as a total yearly volume (i.e., acre-feet [af]). In addition, the withdrawal rate for many water rights is seasonal (e.g., the allowable withdrawal rate may be lower in the summer months). Withdrawal rates for the entire assessment area are summarized in Figure 4-7 (Summary of Instantaneous Withdrawal Rates within the Upper Klamath Lake Subbasin) and reservoir storage is summarized in Figure 4-8 (Summary of Reservoir Storage Within the Upper Klamath Lake Subbasin). August 1 was chosen as the date for this summary because this is typically the low flow period in the assessment area.

Instantaneous withdrawal for irrigation is the primary use of water on August 1 within the assessment area (60 percent) (Figure 4-7). Irrigated lands are concentrated in the Wood River Valley, between Sevenmile Creek/Canal and Wood River (Map 4-2). Instream water rights make up an additional 21 percent of total water rights on August 1 (Figure 4-7). Fish culture, associated with the fish hatchery on Crooked Creek, makes up 8 percent of the total water rights (Figure 4-7). A category that combines irrigation, livestock and domestic use as one type of water right accounts for 5 percent of water use on August 1 (Figure 4-7). Power development alone makes up 2 percent of total water rights on August 1 (Figure 4-7). The remaining uses collectively make up only 4 percent of the total August 1 instantaneous withdrawal rate (Figure 4-7). Reservoir storage within the assessment area is primarily for the purposes of wildlife, fish culture, livestock, multiple purposes, and fish and wildlife. Small amounts of storage are allocated to recreation, generic "storage" and domestic use (Figure 4-8).

Despite ongoing debates regarding the discrepancy between water supply and demand, it appears that demand for beneficial uses exceeds the estimated volumes of natural stream flow during certain months in some parts of the assessment area.

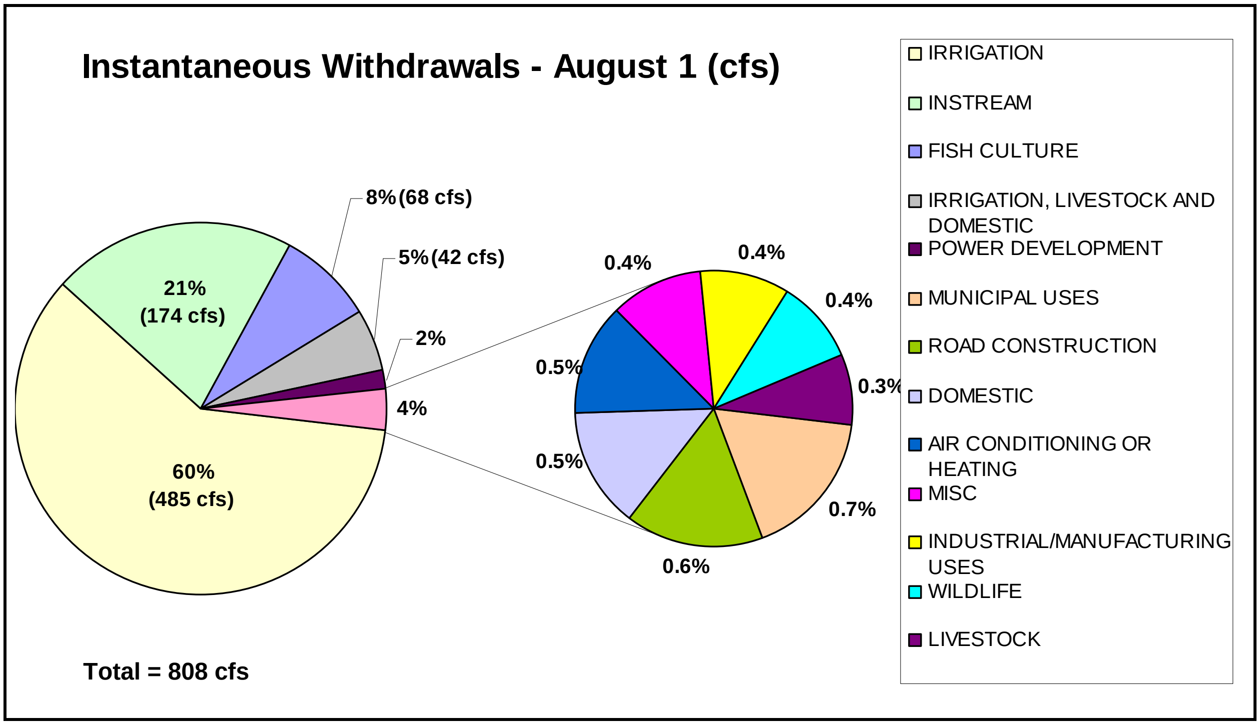


Figure 4-7. Summary of Instantaneous Withdrawal Rates Within the Upper Klamath Lake Subbasin

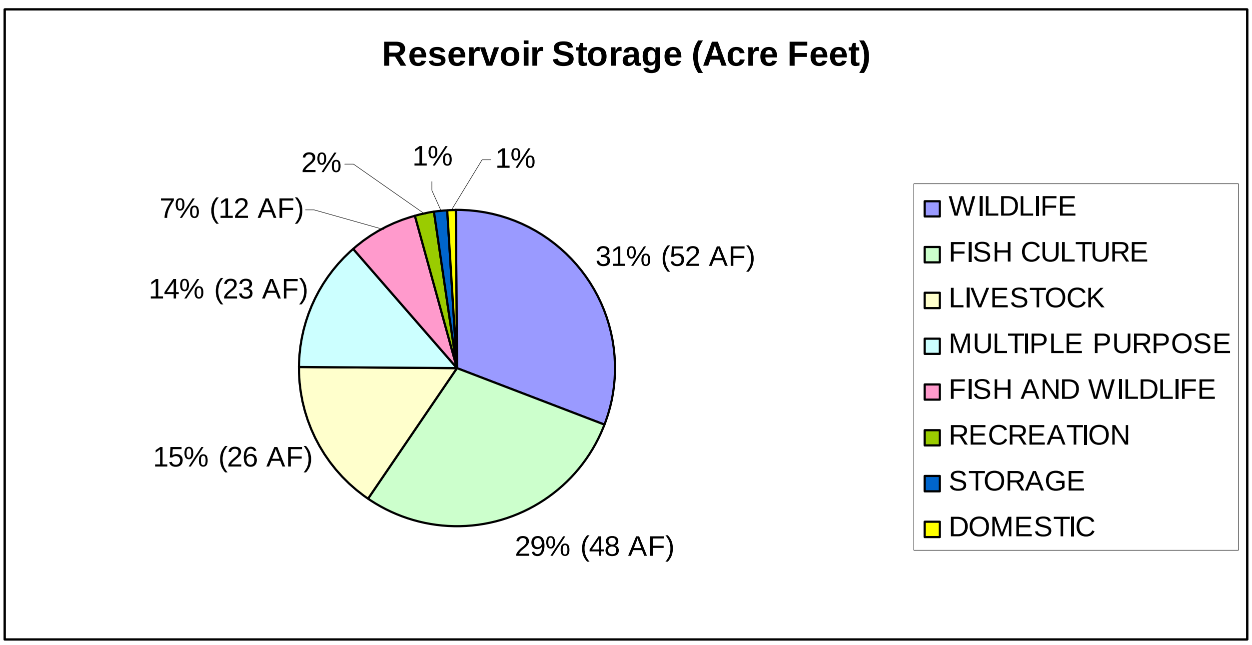


Figure 4-8. Summary of Reservoir Storage Within the Upper Klamath Lake Subbasin

Water Storage

Since 1921, when the Link River Dam was constructed at the southern outlet of Upper Klamath Lake, Upper Klamath Lake and Agency Lake have provided a regulated amount of water storage in the subbasin. Construction of the Link River Dam raised the water level approximately two feet (USFS 2003).

In addition to the Link River Dam, Fourmile Lake Dam is within the assessment area and is located at Fourmile Lake. The dam was built in 1910, raising the water level 30 feet. The water is diverted into the Cascade Canal, annually carrying 4,845 acre-feet of water out of the subbasin, to the Rogue Valley on the west side of the Cascades (La Marche 2001).

Land Use Effects on Flow Regime – Water Withdrawals

This section addresses Critical Question 8: Do water uses in the basin have an effect on peak and/or low flows?

Two pieces of information are needed to estimate the net effects of water use on stream flows at any given location: 1) an estimate of the natural stream flow volume, and 2) an estimate of the consumptive portion of all upstream water withdrawals. OWRD has estimated natural monthly stream flows at the mouths of the following three water availability basins (WABs[2]) within the Upper Klamath Lake Subbasin: Upper Klamath Lake at the mouth of Wood River, Wood River at the mouth of Fort Creek and Fourmile Creek at the mouth of Cherry Creek (OWRD 2009). The natural streamflow estimates available from OWRD are the monthly 50 percent and 80 percent exceedance flows. The 50 percent exceedance stream flow can be thought of as representing a “normal” stream flow for that month. The 80 percent exceedance stream flow can be thought of as the stream flow that occurs in a dry month. These exceedance stream flow statistics are used by OWRD to set the standard for over-appropriation: the 50 percent exceedance flow for storage and the 80 percent exceedance flow for other appropriations (OWRD 2009). OWRD used statistical models derived from multiple linear regressions to produce these estimates of natural monthly stream flows.

A consumptive use is defined as any water use that causes a net reduction in stream flow (OWRD 2009). These uses are usually associated with an evaporative or transpirative loss, or the water may be withdrawn from the system. OWRD recognizes four major categories of consumptive use: irrigation, municipal, storage, and all others (e.g., domestic, livestock). OWRD bases its estimates of the consumptive use for irrigation on estimates made by USGS, including estimates from the 1987 Census of Agriculture, estimates from the Oregon State University (OSU) Cooperative Extension Office, 1989-90 Oregon Agriculture and Fisheries Statistics, and an OSU Study of Crop Water Requirements (OWRD 2001). Irrigation uses are generally not estimated to be 100 percent consumptive. Consumptive use from other categories of use is obtained by multiplying a consumptive use coefficient (e.g., for domestic use, the coefficient is 0.20) by the maximum diversion rate allowed for the water right. The OWRD assumes that all of

Locations where the Oregon Water Resources Department has calculated natural stream flow and water availability statistics.

the non-consumed part of a diversion returns to the stream from which it was diverted. The exception is when diversions are from one watershed to another, in which case the use is considered to be 100 percent consumptive (i.e., the consumptive use equals the diversion rate). For example, the diversions from Fourmile Lake to the west side of the Cascades is considered a 100 percent consumptive use. This diversion impacts peak flows on Fourmile Creek by preventing the creek from receiving flows associated with snow melt (USFS 1996a).

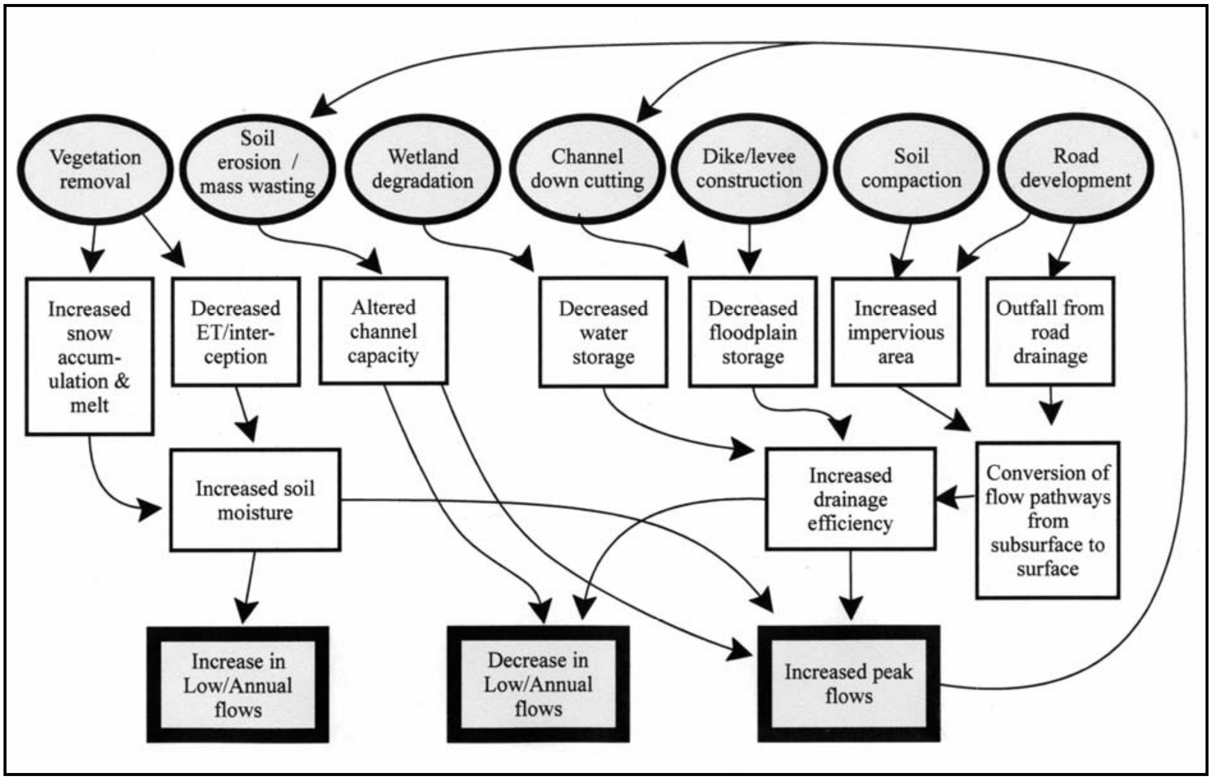
Land Use Effects on Flow Regime – Other Land Uses

This section addresses Critical Question 3: Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?

The way in which irrigation water is applied to the landscape may impact summer base flows. Using flood irrigation creates a saturated condition within the soil profile, potentially applying more water than the crop or pasture can immediately use. Excess water (not taken up by plant roots) moves vertically and laterally, augmenting the water table and thereby increasing base flows in neighboring streams. Thus, it is important to recognize that the water used for flood irrigation may or may not have been extracted from the same stream that is benefiting from augmented summer flows.

Background Information on Land Use Effects on Stream Flow

Figure 4-9 (Generalized Diagram of the Primary Interactions Between Land Uses and Changes in Peak, Annual, and Low Stream Flows) is a generalized diagram showing the primary interactions between land uses found in the Upper Klamath Lake area and changes in peak, annual, and low stream flows. Note that Figure 4-9 does not include "top-level" land uses (e.g., urbanization, agriculture, forest management, etc.) because there is considerable overlap between top-level land uses and the underlying hydrologic processes that they affect. For example, both urbanization and agricultural practices have the ability to affect vegetation removal, soil erosion/mass wasting, wetland degradation, channel downcutting, dike/levee construction, soil compaction, and road development. Rather than discussing impacts by top-level land uses, it is preferable to discuss land use impacts in terms of the underlying processes.



Data Source: adapted from Ziemer, 1998

Figure 4-9. Generalized Diagram of the Primary Interactions Between Land Uses and Changes in Peak, Annual, and Low Stream Flows

Vegetation Changes

Vegetation removal of woody species has occurred in many locations of the Upper Klamath Lake Subbasin. Early logging activities, beginning in the mid to late 1800's, removed much of the old growth ponderosa pine (USFS 1996a). Historically, there were deciduous communities along lower elevation stream channels and surrounding the wetlands of Upper Klamath and Agency lakes (USFS 1994). Grazing activities that currently occur in much of the lower elevations in the assessment area continue to limit the growth of woody vegetation.

Vegetation removal has the potential to increase peak flow through increased snow accumulation and melt during wintertime rain-on-snow events (WFPB 1997; Figure 4-9). Rain-on-snow is the common term used to describe wintertime conditions when relatively warm wind and rain combine to produce rapid runoff. Rain-on-snow flood events may occur in areas having significant wintertime snow packs. Removal of the forest canopy can augment rain-on-snow peak flows by increasing snow accumulation in canopy openings and increasing the rate of snowmelt by increasing the effective wind speeds at the snowpack surface. The extent to which forest removal may augment rain-on-snow peak flows is a function of many physical factors, as well as the amount of vegetative harvest that occurs within the rain-on-snow zone. At low elevations (below the rain-on-snow zone) winter temperatures are generally too warm to allow for significant snow accumulation, and at higher elevations wintertime precipitation generally falls as snow. Although there has been significant timber harvest within the subbasin, coniferous communities within USFS land have regenerated, resulting in dense canopy closure at mid and upper elevations (USFS 1996a). Mountain ridges and talus slopes at the highest elevations of the subbasin have a much lower percentage of canopy cover, however, site conditions such as intense wind and severe slope limit snow accumulation. Given the combination of highly permeable soils and moderate to dense tree canopy at key elevations, rain-on-snow events are not a significant cause of peak flow or flooding in the subbasin.

A secondary mechanism by which vegetation removal can affect peak and/or low flows is through changes in evapotranspiration and canopy interception, which generally lead to a loss in the total precipitation that reaches the drainage basin (Dunne and Leopold 1978; Figure 4-9). Evapotranspiration by vegetation removes moisture from the soil profile and returns it to the atmosphere. Canopy interception by vegetation prevents precipitation from reaching the soil, where it can be either absorbed by plants or permeated to recharge aquifers, because water is "intercepted" by leaves and other foliage and then evaporates. Therefore, increases in peak flow observed in some situations following harvest of trees are presumed to be the result of loss of canopy interception and evapotranspiration (Ziemer 1998). Several studies have shown the water yield increases throughout the year, with the largest relative increases occurring during the summer and early fall months following logging. These studies have reported a wide range of increases in summer flows, ranging from 15 to 148 percent.

Both increased snow accumulation and melt, and decreased evapotranspiration and canopy interception, can increase levels of soil moisture, resulting in increased peak flows, low flows, and annual stream flow volumes.

- To date, no studies have been conducted on changes in stream flow resulting from changes in vegetation in the Upper Klamath Lake Subbasin. However, a water balance study, conducted for the nearby Chiloquin area (outside of assessment area), for the period 1942-1971 (USFS 1998), identified a moisture deficit during the growing season (April through October), indicating that inputs to the soil moisture pool are less than the plants could use. Any gains in water yield from removal of vegetation will tend to reduce the period of moisture deficit. Although vegetation removal may make some additional groundwater available for release to streams in the months of April and/or October, summer stream flows are not likely to change significantly.

The relationship between watershed vegetation and hydrologic response may be further muddled by the amount of annual precipitation within the watershed. Paired watershed studies in Colorado indicate that reduced forest density has no detectable effect on water yields when annual precipitation in a watershed is less than 18-19 inches (Macdonald and Stednick 2003). This precipitation range occurs in parts of the assessment area, with precipitation varying from 13.5 inches at Klamath Falls to 65 inches near Crater Lake (Gannett et al. 2007). If there is a measurable increase in water yields due to canopy removal in the watershed during the rainy season, it is unlikely that there will be an associated significant effect on summer low flows, the period when water is in short supply (Macdonald and Stednick 2003). Based on the composite information available, it does not appear that removal of significant portions of the vegetation in the subbasin will have an appreciable effect on late season flows in the Upper Klamath Lake Subbasin.

Both increased snow accumulation and melt, and decreased evapotranspiration and canopy interception, can increase levels of soil moisture, resulting in increased peak flows, low flows, and annual stream flow volumes. Conversely, the expansion of western juniper communities may have the effect of reducing water yields. Gedney et al. (1999) documented a fivefold increase in juniper forests (defined as areas having at least 10 percent juniper crown cover) from 1936 to present. The expansion of juniper in eastern Oregon may be linked to a reduction in fire frequency. A reduction in fire frequency has resulted from natural drought-free climatic cycles, fire suppression, and the introduction of large numbers of livestock that led to a loss of fine fuels through grazing (Gedney et al. 1999, Belsky 1996, Miller and Rose 1999).

Juniper can have a significant effect on the amount of precipitation reaching the soil through canopy interception and loss through evaporation or sublimation, year-round transpiration, and through its extensive root networks, which occupy a relatively greater area than other species (Gedney et al. 1999, Deboodt et al. 2009). Although the potential exists for juniper to reduce stream flows and water availability through canopy interception and removal of soil moisture, there is very little juniper in the assessment area. In other parts of the Upper Klamath Basin, the area occupied by juniper has essentially doubled in recent history (Miller et al. 2005 in Kuhn et al. 2007); which has made juniper a significant concern. In the Upper Klamath Lake Subbasin the landscape, soils and rainfall combine to limit juniper to the southeast corner of the assessment area where there are few significant hydrologic features and the potential impact of juniper encroachment is limited; therefore, the potential effects of juniper expansion is not addressed further for this assessment.

Soil Erosion and Mass Wasting

Soil erosion and mass wasting can increase quantities of sediments transported in stream systems. Deposition of both coarse and fine sediments in stream channels can result in a decrease in channel conveyance capacity, leading to an effective increase in frequency of flooding (Dunne and Leopold 1978; Figure 4-9). In addition to the effects on peak flows, increases in aggradation of coarse sediments can increase the proportion of streamflow that travels subsurface, resulting in a reduction of effective summer low flows. Furthermore, as shown in Figure 4-9, increased peak flows can further exacerbate sedimentation problems through increased bank erosion and mass wasting.

Steep slopes within the subbasin, particularly on the east slope of the Cascades, consist of soil types that are most susceptible to erosion. However, substrates around Pelican Butte and the east slope of Mt. McLaughlin are highly permeable and therefore limit the amount of flow that stays in-stream and carries sediments down slope (USFS 1996a). The removal of stabilizing vegetation and the introduction of soil compaction, from timber harvest and road construction, can increase surface flow. Limiting the amount of timber harvest and road construction on sensitive soils will help minimize the sediment inputs from these areas.

Lower reaches of several of the channels that connect, or intermittently connect, to Upper Klamath Lake have been altered for agricultural use. Numerous streams have been channelized, diverted and dewatered. In addition, many streams have been altered to remove stabilizing riparian vegetation, for timber or for grazing purposes, causing frequent channel disturbance which can contribute sediments to the stream.

The conclusions of the sediment source assessment for this subbasin (described in Chapter 5, Sediment Sources Assessment) is that erosion is most significant in lower elevations of the subbasin and that the following factors are the primary contributors to erosion in both upper and lower elevations:

- Bank erosion/downcutting channels
- Roads
- Compaction from timber harvest

Although erosion processes have been identified, and recommendations have been developed for prioritizing erosion treatments (see USFS 1994, 1995a, 1996a, 2003c), no quantitative data are available on the effects of increased sedimentation on channel and flow conditions within the Upper Klamath Lake Subbasin.

Wetland Degradation

Wetlands have the ability to intercept and store storm runoff, thereby reducing peak flows (Mitsch and Gosselink 1986). This water is released over time and may be important to augment summertime low flows (Figure 4-9). Therefore, loss of, or modifications to, wetlands may have a significant impact on stream flows.

No studies have been conducted on the exact amount of wetland loss or degradation that may have occurred within the assessment area, or on the impacts that these changes may have had to stream flows. General changes to wetlands have been discussed in USFS watershed analyses (1994, 1995a, 1996a, and 2003c) and in several other agency reports concerning water quality within Upper Klamath Lake and wetland restoration strategy. Common elements include:

- Many former wetlands located on private lands were converted to agricultural uses starting in the late 1800's and early 1900's. These actions resulted in the most significant changes to wetlands in the area surrounding Upper Klamath and Agency lakes and the lower reaches of most major streams tributaries (Figure 4-10, Aerial Photo of the Wood River Wetland, the Site of Many Restoration Activities).
- Drainage of former wetlands (in combination with water diversions for irrigation purposes) has reduced the extent of wetlands.

- The clearing of land for pasture and crop land has reduced the extent of wetlands dominated by trees and shrubs.

Figure 4-10. Aerial Photo of the Wood River Wetland, the site of many restoration activities (DEA 2009).

Based on these changes in wetland function and distribution, and the fact that properly functioning wetland networks have the ability to mediate peak flows over a greater time period, it has been suggested that the changes to landscape-scale wetland composition may have affected late season stream flows in the subbasin (USGS 2005). Historical degradation of wetland complexes in uplands, in combination with long-term drought conditions, may in fact be contributing to diminished late-season flows in this region. However, evidence to this effect is qualitative at this time and requires further conclusive investigation. Wetland conditions within the subbasin are discussed further in Chapter 7, Wetlands Assessment.

Channel Downcutting and Channelization

Channel downcutting and channelization have the same effect on the stream system – decreasing the amount of water that can be stored in channel banks and the floodplain (Figure 4-9). The difference between the two processes is that channel downcutting occurs in response to changes in water volume and sediment loads, which can be natural or human caused, whereas channelization is the result of the construction of dikes and levees, which are entirely human caused. Potential disadvantages to dikes and levees include loss of floodwater storage within the floodplain, which can result in higher downstream peak flows, reduced groundwater recharge, and subsequently lower summertime base flows. The link between floodplains and river hydrology is discussed in Chapter 3, Channel Habitat Typing and Modifications, and briefly in Chapter 6, Riparian Assessment. Recommendations for assessing the degree and extent of downcutting and floodwater storage constraints are made in Chapter 3, Channel Habitat Typing and Modification.

Currently, no studies have been conducted on the extent of channelization or channel downcutting that has occurred within the watershed. Areas of obvious channel manipulation were noted as part of the discussion in Chapter 3, Channel Habitat Typing and Channel Modification, but additional areas of disturbance may exist. USFS has considered the effects of channel modifications as part of several watershed analyses that were conducted in the Upper Klamath Lake Subbasin (1994, 1995a, 1996a, and 2003c). Summaries of these analyses are as follows:

- Channel downcutting associated with channelization is concentrated on Rosgen C/F and E/F channel types, located primarily in the middle and lower elevations of the subbasin. Channel simplification has caused an increase in water velocities, destabilization of stream banks by removing deep-rooted vegetation and an increase in bank erosion, all of which have resulted in the creation of the unstable F channel forms. The effects of these disturbances on stream flow has not been quantified.
- Sevenmile, Threemile, Nannie, Fourmile (in the Fourmile Creek watershed), Fourmile (in the Klamath Lake watershed), Cherry and Rock Creek drainage systems have significant segments of downcut channels. Downcut channels in these areas are believed to be due to a combination of heavy grazing and lack of subbasin-wide floodplain storage due to agricultural land use. Grazing limits the amount of stabilizing streambank vegetation, allowing water to erode streambanks. Floodplain storage minimizes peak flows by delaying water release. Stream restoration projects, including riparian fencing to effectively manage cattle access, have allowed many of these channel segments to begin recovering. An extensive number of fencing projects have recently been completed for sections of Sevenmile Creek and its tributaries (Peterson, pers. comm. 2009).

Soil Compaction

Soil compaction can increase the amount of impervious area occurring in a watershed. Increases in the amount of impervious area result in increased peak flow magnitudes by eliminating or reducing infiltration of precipitation, thereby shortening the travel time to stream channels (Dunne and Leopold 1978; Figure 4-9). In addition to the effects on peak flows, increases in impervious area also reduce summer low flows by reducing groundwater recharge (Dunne and Leopold 1978).

To date, no studies have been conducted on the extent of soil compaction within the subbasin or the effects of compaction on stream flows. USFS has considered the extent of soil compaction as part of several watershed analyses that were conducted in the Upper Klamath Lake Subbasin area (USFS 1994, 1995a, 1996a, and 2003c). Summaries of these analyses are as follows:

- Due to the extensive timber harvest that has occurred on all non-wilderness, non-National Park Service lands within the assessment area, compaction is likely to have occurred in most forested areas. Although most of the USFS land has experienced compaction, very little of that compaction is showing an obvious detriment to either plant vigor (riparian areas are an important exception) or hydrologic processes.

- Grazing is currently, and has been for over a hundred years, a significant and widespread land use throughout the assessment area. Grazing intensity was much greater in the late 19th and early 20th centuries than it is currently. Beginning in the 1980s, grazing practices on public lands have undergone dramatic changes, including reductions in numbers of animals, reductions in duration of use, and exclusion of grazing in sensitive areas. Implementation of grazing management has reduced impacts in several areas in the basin. In areas that are not properly managed, it is likely that compaction effects due to grazing have occurred.

Road Construction Impacts

In addition to increasing soil compaction, road networks have the potential to affect watershed hydrology by changing the pathways by which water moves through the watershed. Road networks affect flow routing by interception of subsurface flow at the road cutslope and through a reduction in road-surface infiltration rates, resulting in overland flow (Figure 4-9). The net result may be that surface runoff is routed more quickly to the stream system if the road drainage network is well-connected with the stream channel network.

Roadway construction, by way of floodplain constriction, may alter system hydrology by eliminating the ability of the channel to meander. Restricting the channel may result in a change in velocity, increased erosion or channel downcutting. The impact of roads on sedimentation in streams is covered in Chapter 5, Sediment Sources.

Road construction, primarily associated with timber harvest, has been addressed by watershed analyses of areas within the subbasin. The USFS 1994 Rock, Cherry and Nannie watershed analysis states that "the greatest input of sediment to the creeks appears to be caused by roads" and sediment accumulation has been observed in Nannie Creek. Forest roads have been built parallel to Threemile, Sevenmile and Dry Creeks, among others (USFS 1995a). In locations where roads have visibly impacted the stream, these locations should be noted and then prioritized for road removal or modification.

Currently, no studies have been conducted on the connection of the road drainage network to the stream network within the assessment area, or the quantified effects of road drainage on stream flows. Given the relative density of unsurfaced roads, it is important to further evaluate possible impacts to key streams. As a potential starting point for this investigation, USFS maintains a database of all Forest roads, documenting location, length, width, surfacing type and maintenance type (USFS 2006b). In addition, the results of the USFS Travel Management Planning Project will be coming out in 2010 (USFS 2009a). This project is intended to assess the full system of roads and guide future management of these roads, potentially resulting in the decommissioning of unnecessary roads or surfacing of unsurfaced roads on USFS property within the subbasin.

Climate Change

A USGS 2007 study of the hydrology of the Upper Klamath Basin was able to show that the groundwater source that feeds the Wood River is directly influenced by climatic conditions (Gannett et al. 2007). During a drought, groundwater is not recharged by precipitation, causing reduced flows in the Wood River. During times of heavy precipitation, flows increase accordingly. Many other streams throughout the subbasin, that provide water for irrigation, are also supplied by groundwater. Therefore, periods of drought can have a detrimental effect on economic and environmental resources.

In an effort to understand how drought will play a role in the future, it is important to reference the climate change studies that are occurring within the region. A collaboration between the University of Oregon's Climate Leadership Initiative, the National Center for Conservation Science and Policy, USFS' Pacific Northwest Research Station, and local leaders in the Klamath Basin has resulted in the development of the Klamath Basin Climate Futures Forum DRAFT (NCCSP and CLI 2010). This report discusses how the basin might expect to be affected by climate change, and ideas about how to prepare for these changes.

The report finds that climate change will lead to more severe weather patterns, an example of which may include extensive droughts. Several strategies mentioned in this report that may help buffer against such events include increasing groundwater aquifer recharge through the restoration of wetlands and floodplains (increasing water storage), and providing incentives for water conservation (NCCSP and CLI 2010). By the same token, restoring wetland and riparian systems will make them more resilient to extreme weather events.

Confidence Evaluation

Confidence in the Hydrology/Water Use assessment is low to moderate. There is a high level of confidence in the points of diversion data as well as the ODFW diversion and screen information. Additionally, available water rights data combined with an evaluation of consumptive water use provide a good foundation for the assessment. However, the lack of consistent flow records throughout the assessment area and any quantitative information on land use impacts to peak and base flows limit the confidence of conclusions drawn in that particular portion of the assessment area. Implementation of the recommendations identified below would result in a high confidence in the subsequent assessment.

Research Recommendations

1. Evaluate gage locations, maintain all currently operational continuous stream flow gages, reestablish discontinued gages, and establish additional gages in key locations. Continuous stream flow data are essential to understanding peak flow history, estimating natural stream flows, and providing calibration data for any future modeling activities, and promotes better understanding of the effects of water use within the subwatersheds. Continuous flow records from several locations within the assessment area made it fairly easy to characterize stream flow; however, several of these gages have been discontinued (Table 4-1), and certain parts of the assessment area (e.g., Cherry and Rock Creeks) are completely without flow records.

Maintaining existing gages, reinstalling discontinued gages, and as needed, establishing new gages, will help leverage upon existing flow record data sets. However, prior to establishing new gages, there should be an effort to determine the most appropriate gage locations within the subbasin.

2. Continue to monitor existing wetland restoration projects and establish criteria for monitoring future restoration sites. Several reports have acknowledged the loss of wetlands for agricultural purposes surrounding Upper Klamath and Agency lakes. Additionally, several wetland restoration projects have been implemented within the last five to ten years, providing monitoring opportunities. Understanding the changes in water quality and quantity as a result of increased wetlands within the subbasin will help inform future restoration and land use planning, particularly in relation to climate change.

3. Implement watershed-wide evaluation of land use effects on peak flows. Information from various USFS watershed analyses (summarized above) suggest that changes in vegetative cover, soil compaction, road densities and drainage, wetlands, and other factors, may be having some, as yet unspecified, effects on both peak and base flows. A robust modeling tool (such as the Distributed Hydrology-Soil-Vegetation Model developed by the University of Washington and Battelle Pacific Northwest Research Labs) should be used to evaluate the possible effects of past activities on current conditions, as well as to evaluate the possible impacts of future management scenarios. Such a modeling effort should include an evaluation of all land use and flow interaction included in Figure 4-9.

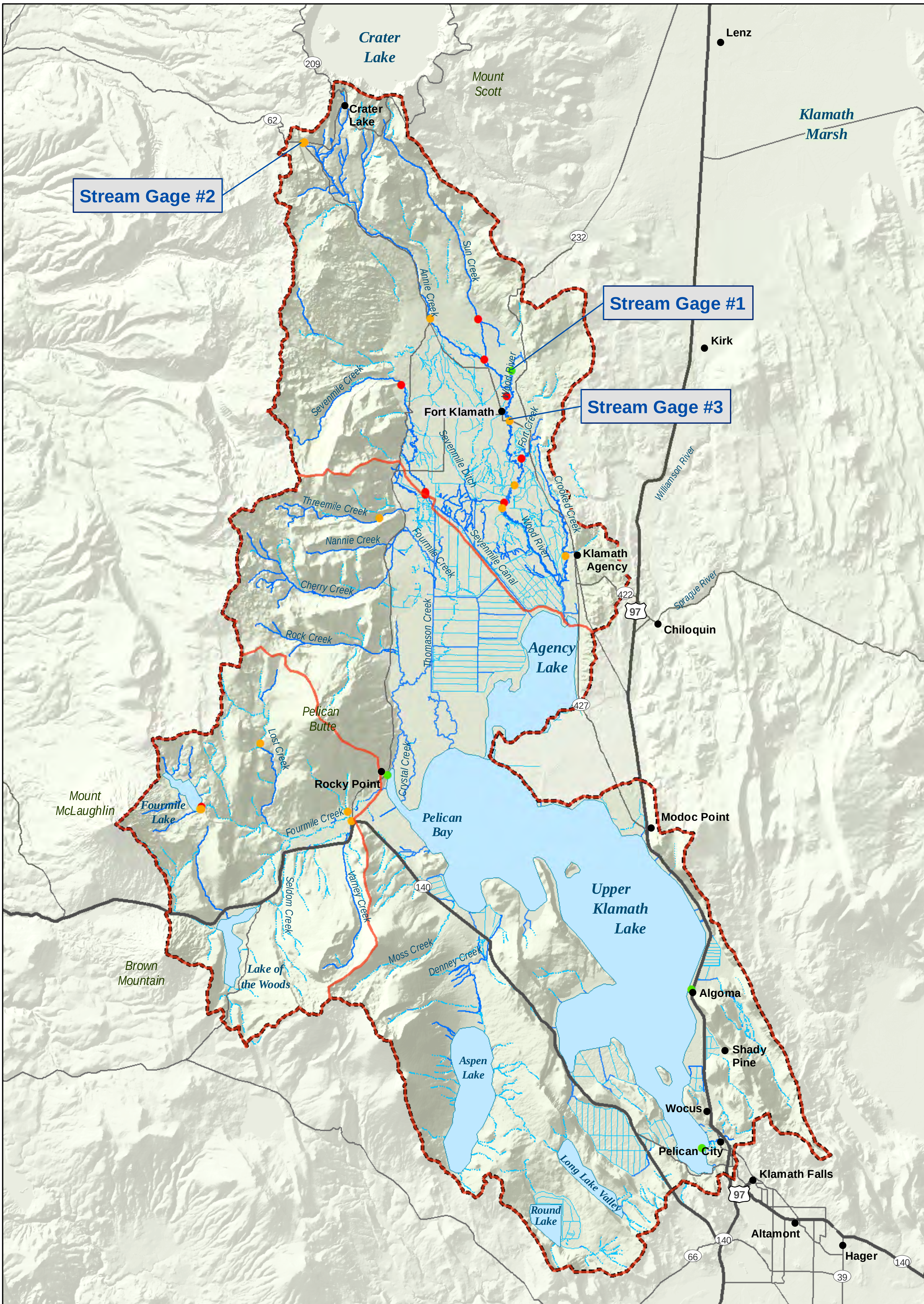
Restoration and Management Opportunities

1. Implement improvements of summertime stream flows through increased water use efficiency, transfer of water rights to instream uses, and other voluntary actions. Withdrawals may make it harder to meet minimum instream flow targets. Voluntary measures such as increased efficiency of water distribution and application to irrigated areas will help improve summertime flow conditions. However, further reductions in withdrawals are recommended. One tool for these reductions is through voluntary transfer of water rights (either temporarily or permanently) such as those facilitated by the Klamath Basin Rangeland Trust.

2. Modify or remove roads that negatively impact adjacent streams. Roads that are delivering sediment to the stream should be prioritized for removal or modification.

3. Pursue screening on water diversions with insufficient screening or sensitive habitat. Water diversions where threatened, endangered, sensitive or game fish are entrained, or lost due to insufficient screening, especially where bypass flows exist that would guarantee fish survival, should be prioritized for screening.

List of Maps



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Source Data:
ESRI, Klamath County, Oregon GEO,
USGS (National Hydrography Dataset)

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch

USGS Stream Gage Locations

Category

- Active gages
- Discontinued gages with more than 1 year of data
- (Discontinued) Gages with less than 1 year of data

Map 4-1:
Stream Gage Locations

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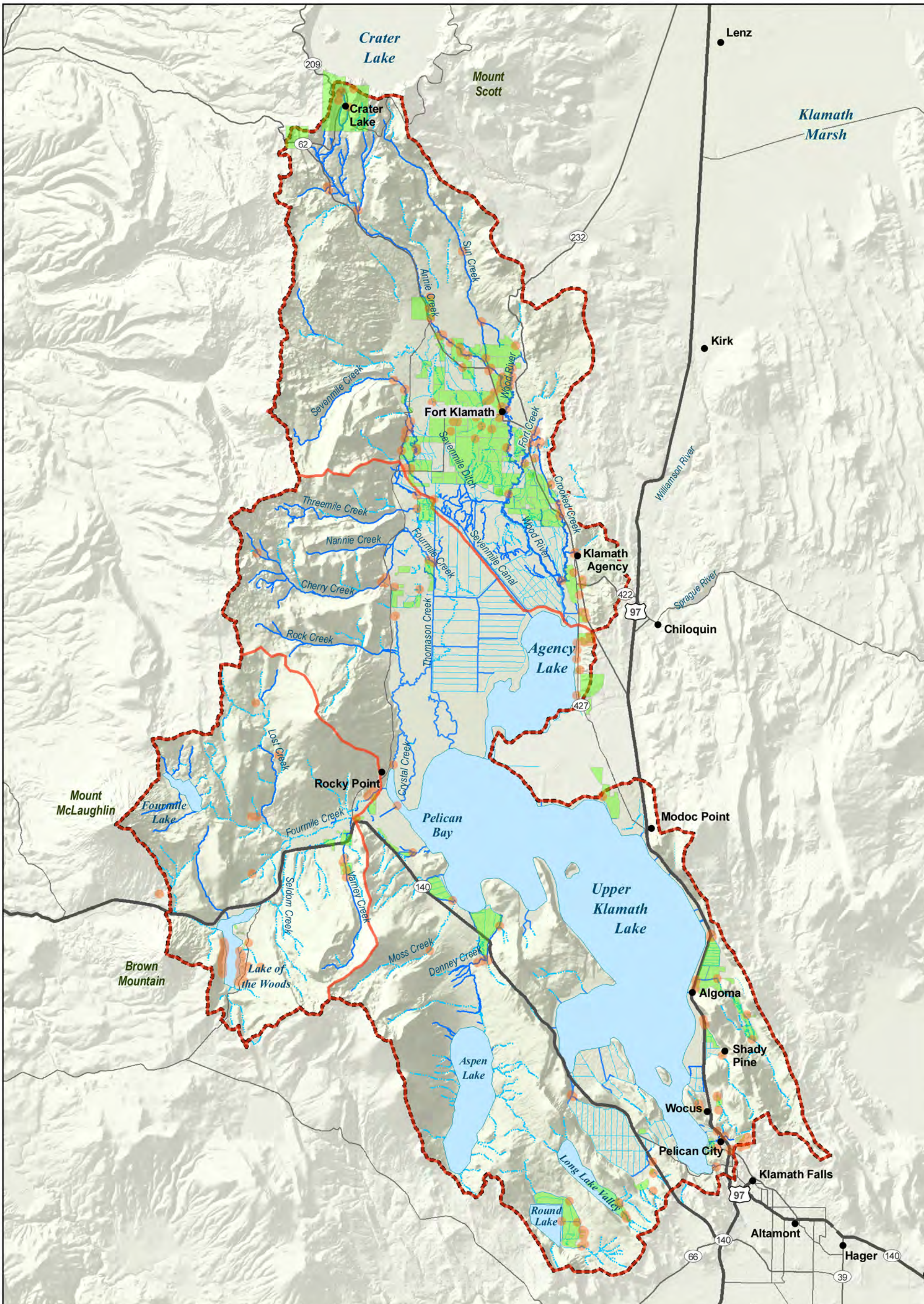

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch
- Water Right Points of Diversion locations
- Water Right Place of Use locations (point)
- Water Right Place of Use locations (polygon)

Water Rights with instream leases associated with them are not included on this map

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Source Data:
ESRI, Klamath County, Oregon GEO, USGS (National Hydrography Dataset)

Map 4-2: Water Rights - Points of Diversion and Places of Use

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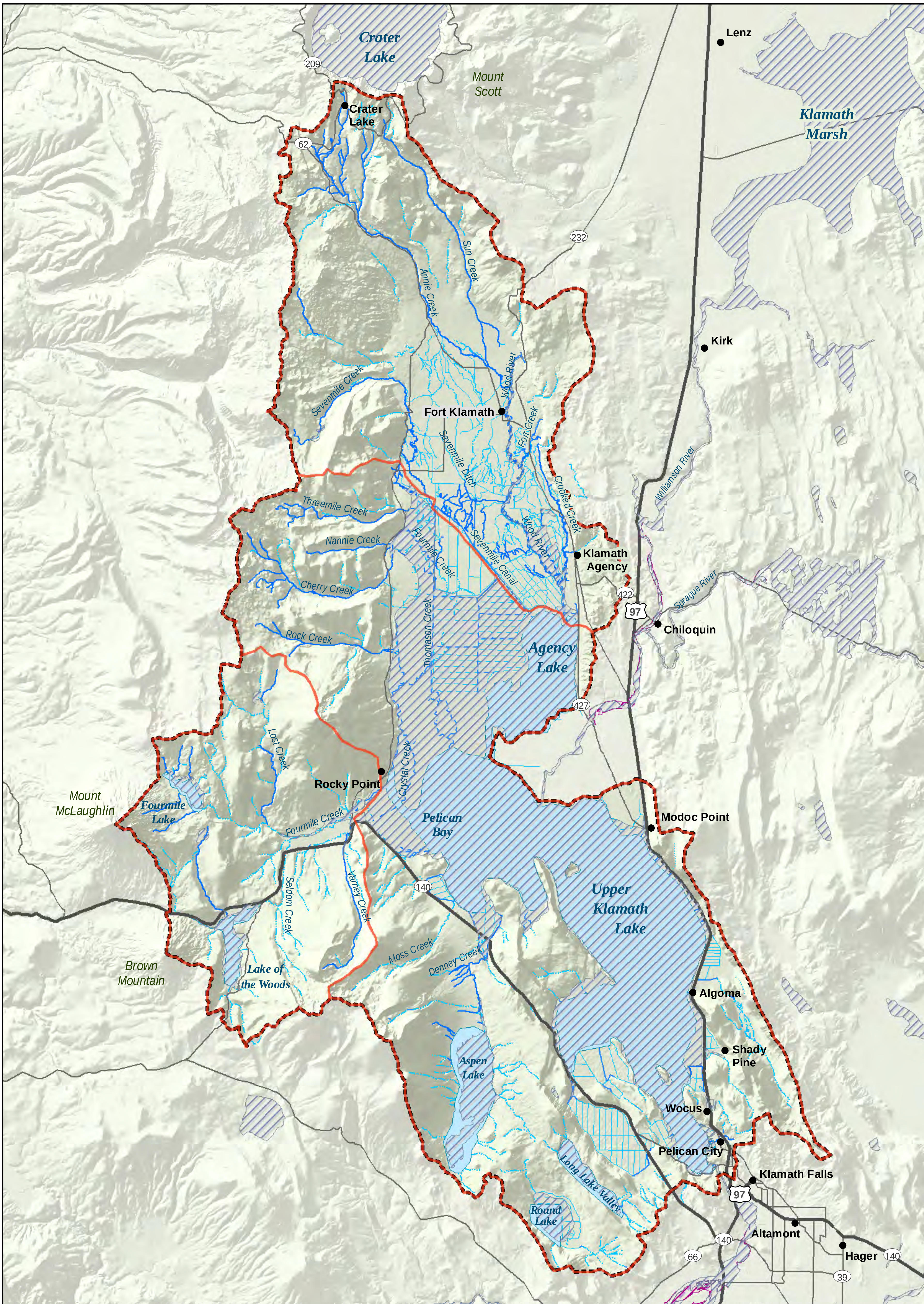

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Source Data:
ESRI, Klamath County, Oregon GEO,
USGS (National Hydrography Dataset)

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch
- 100-Year Floodplain*
- 500-Year Floodplain*

* Note: This data is based on on digitized translations of hardcopy FEMA floodplain maps, and should only be used for planning-level analysis.

Map 4-3:
Flood-potential Areas

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CHAPTER 5:

SEDIMENT SOURCES ASSESSMENT

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5 SEDIMENT SOURCES ASSESSMENT

Introduction

The purpose of this chapter is to summarize existing information, identify data gaps that may require further study, and identify opportunities for reducing sediment delivery to stream channels.

The sediment sources assessment encompasses three primary components: (1) review of pertinent literature including watershed analyses (2) indirect measurement of various parameters, such as soils, topography and streams, using GIS methods; and (3) interviews with landowners and agency personnel.

Sediment production, delivery, transport, and deposition are natural and dynamic processes that occur in all watersheds. The timing, magnitude, and significance of these processes vary over time and across the watershed. Erosion that occurs near streams, and on surrounding slopes, is a natural part of any watershed. Fish and other aquatic organisms in a region are adapted to deal with a range of sediment amounts that enter streams. The amount of erosion in a watershed and the sediment load in the streams vary considerably both during the year and between years, with most sediment moving during the few days that have the highest flows. The most significant land-forming or channel-shaping events may occur during precipitation or snowmelt events that happen more or less, once every decade.

In addition to natural levels of erosion, human activities can alter sediment-related processes (production, transport, deposition, etc.) in various ways. Separating human-induced erosion from natural erosion can be difficult because of the highly variable nature of natural erosion patterns. Furthermore, human-caused erosion may also be highly variable in timing and spatial pattern. It is difficult to specify when a human-induced change in sediment is too much for a local population of fish and other aquatic organisms to handle; however, in general, the more a stream deviates from its natural sediment levels, the greater the chance that the fish and other aquatic organisms are going to be affected. Sediment in streams can also affect human beneficial uses of water such as domestic and agricultural water supplies.

This section describes the process used to evaluate possible sources of sediment within the Upper Klamath Lake Subbasin and presents the results of these analyses. The results are followed by recommendations on future assessment and monitoring needs to fill data gaps and steps that can be taken to reduce erosion and sediment delivery.

Methods

Initial Screening

The Sediment Sources assessment methodology outlined in the Manual (WPN 1999) is designed around a series of critical questions that form the basis of the assessment. These critical questions are:

- What are important current sediment sources in the watershed?
- What are important future sources of sediment in the watershed?
- Which erosion problems are most severe and qualify as high priority for remedying conditions in the watershed?

In general, the methodology used in this assessment follows the outline presented in the Manual (WPN 1999). However, due to the large size of the subbasin, changes were made to the methodology presented in the manual. Specific deviations from the methods presented in the Manual are discussed under each of the identified sediment sources.

The first step was to identify which sediment sources are the most important in the subbasin, (i.e., address Critical Question 1). Eight potential sediment sources that have significant impacts on watershed conditions have been identified in the Manual (WPN 1999). Not all are present in every watershed, and they vary in influence depending on where and how often they occur. The potential sediment sources include slope instability, road instability, rural road runoff, urban area runoff, crop land, range or pasture lands, burned areas, and other unidentified sources.

In the Upper Klamath Lake Subbasin, streambank erosion and rural road runoff were determined to be the most significant sediment sources. The screening process used to determine the most significant sediment sources is outlined in the Manual (WPN 1999). Existing information, primarily from the various planning documents and watershed analyses prepared by USFS, combined with personal, local knowledge, was used to inform the sediment sources information in Table 5-1 (Screening for Sediment Sources in the Upper Klamath Lake Subbasin).

Table 5-1. Screening for Sediment Sources in the Upper Klamath Lake Subbasin

Upper Klamath Lake Subbasin **Source**	**Questions**	**Response**	**Priority**
Source 1: Road instability			Not an issue
	Are rural roads common in the watershed?	Yes	
	Do many road washouts occur following high rainfall?	No	
	Are many new roads or road reconstructions planned?	No	
Source 2: Slope instability (not related to roads)			Not an issue
	Are landslides common in the watershed?	No	
	Are there many high-sediment, large-scale landslides?	No	
Source 3: Rural road runoff			**2nd**
	Is sediment-laden runoff from rural roads and turbidity in streams common?	Yes	
	Is there a high density of rural roads?	Yes	

Upper Klamath Lake Subbasin Source	Questions	Response	Priority
Source 4: Urban runoff			Topic is not a high priority
	Are many portions of the watershed urbanized?	Some	
	What is the importance of these tributaries to the Watershed Council?	Low	
Source 5: Surface erosion from cropland			Topic is not a high priority
	Is there much cropland in the watershed?	Some	
	Is there much evidence of sediment in streams flowing through cropland?	Some	
Source 6: Surface erosion from rangeland			Topic is not a high priority
	Is there much rangeland in the watershed?	Yes	
	Is there evidence of sediment in streams flowing through rangeland?	Some	
Source 7: Surface erosion from burned land			Topic is not a high priority
	How many burns occurred recently (last 5 years), especially hot fires:	Some	
	Was much sediment created by these burns?	unknown	
Source 8: Other discrete sources of sediment			
	Streambank erosion due to channel instability / lack of vegetation	High	**1st**
	Timber harvest ground-disturbing activities	Some	**3rd**

While rural roads are common feature in the subbasin, road instability has not been identified as a priority because it is not common for roads to washout during storm events. Steep slopes can be found in the upper reaches of the subbasin; however, well drained soils minimize the occurrence of landslides.

The density of rural roads, especially unpaved gravel and dirt roads, indicates a high potential for sediment contribution to the stream network. Compacted soils that make up the road surface carry water and sediment to streams, rather than allowing them to infiltrate.

Urban land cover is a very small component of this subbasin, therefore, urban runoff was not analyzed in this assessment. Surface erosion from cropland and rangeland likely occur in the subbasin; however, these sources are difficult to quantify and distinguish from other sources, particularly if adjacent streambanks are unvegetated. Studies funded by Reclamation, USGS and others conclude sediment accumulation in Upper Klamath and Agency lakes, is a result of runoff from adjacent agricultural land uses, however it is unknown which specific activity was the most significant source of erosion (Eilers et al. 2001, Snyder and Morace 1997).

Surface erosion from burned land on USFS land is likely minimal given that large-scale wildfires rarely occur (USFS 1994, 1995a, 1996a, 2003c). However, if a large-scale wildfire were to occur in the future, surface erosion could potentially contribute large amounts of sediment to adjacent streams. Annual burning of agricultural lands is common and has the potential to contribute sediments, however these impacts are likely small compared to inputs from other sources, such as streambank erosion.

Streambank erosion and timber management activities are identified as high priorities within the subbasin. Streambank erosion due to channel instability is widespread throughout the subbasin, particularly in the lower stream reaches where riparian vegetation removal and channelization have occurred on a high proportion of streams. Sediment production associated with timber management has been addressed in previous USFS watershed analyses (USFS 1994, 1995a, 1996a, 2003c). Timber harvest, road construction and fire regime all impact sediment production in the upper reaches of the subbasin.

Subsequent Sediment Source Investigations

Following the initial screening, more detailed evaluations of the primary sediment sources in the subbasin were conducted through a combination of collecting and evaluating available existing information and interviews with landowners and agency personnel.

Channel Stability and Bank Erosion Investigation

Land use practices throughout the subbasin have altered many stream channels. Changes in riparian vegetation composition, unmanaged cattle access to streams and human-caused channelization all contribute to channel instability and bank erosion.

USFS Level II stream habitat surveys document the percent of unstable streambanks, an indicator of bank erosion, and could be used to identify areas of concern for future restoration. Locations of channel instability and erosion have been documented in various USFS watershed analyses within the subbasin (USFS 1994, 1995a, 1996a, and 2003c). It was not possible to conduct fieldwork as part of this assessment, therefore, further investigation is needed in order to inventory and prioritize projects that reduce erosion.

GIS mapping was used to identify land uses as well as channelization, ditches, and canals, which typically limit the amount of stabilizing riparian vegetation, increasing the risk for erosion. Additionally, aerial photography was used to verify the presence or absence of vegetation along key streams, and evaluate the riparian conditions within each watershed (See Chapter 6, Riparian Assessment, Map 6-1, Existing Riparian Conditions).

Road Investigation

Due to the lack of comprehensive road inventory data for the whole subbasin, changes were made to the methodology presented in the Manual. For example, the level of detail concerning road-related sediment presented in the Manual requires a road inventory or detailed field surveys. Detailed road inventories on USFS land already exist, limiting the ability of this study to contribute any new information to this body of data (USFS 2006b). Additionally, USFS watershed analyses have already identified areas of concern (USFS 1994, 1995a, 1996a, and 2003c). Currently, there are little or no data regarding existing roads on private land. Therefore, it is difficult to fully understand how private roads have contributed to the overall sediment issues in the basin.

Unlike surface erosion from exposed hillslopes, where revegetation usually occurs within a few years, road surfaces can continue to erode as long as the road is used. The road cutslopes and fillslopes tend to revegetate, reducing erosion from those sources over time. However, road-running surfaces continue to provide fine-grained sediments over the life of the road.

Gully erosion on roads can occur when surface runoff is concentrated along the tread or ditch for long distances. The most common causes of gully erosion are inadequate road drainage, plugged or undersized culverts, and steep unsurfaced roads (over 10 percent grade). Because gully erosion is often episodic (e.g., in response to a blocked culvert that causes a stream to flow down or across the road) it is difficult to obtain a reasonable quantitative estimate of gully erosion.

Sediment Transport Data

Limited sediment transport data have been gathered on individual streams. However, there have been many studies conducted in the subbasin focusing on water quality within Upper Klamath Lake (Brownell and Rinallo 1995, Laenen and Le Tourneau 1996, Snyder and Morace 1997, Perkins et al. 2000). These studies have primarily been conducted by, or funded by, public agencies including Bureau of Reclamation and the United States Geological Survey. Water quality issues are discussed in depth in Chapter 8, Water Quality Assessment.

Results

Map 5-1 identifies streams, including those that have been modified into canals or ditches, slopes, erodible soils, and USFS roads. In general, steeper slopes are more prone to erosion than more gradual ones; however, many other site conditions also play an important role, such as soil type and vegetative cover. Locations of highly erodible soils have been identified by NRCS; however, there may be additional soils located on USFS property considered highly erodible that were not available in GIS format. USFS roads are shown in order to understand the spatial distribution in relation to the other features such as steep slopes and streams. An inventory of stream crossings was performed as part of the USFS Roads Analysis Report (2006b).

GIS Channel Stability Analysis

Streams that have been channelized are principally located on low gradient slopes of the valley bottom, adjacent to Upper Klamath and Agency lakes (Map 5-1, Erosional Features). Many of these channels are on private land, where grazing has limited growth of stabilizing riparian vegetation. Newly acquired public land, adjacent to the lakes, provides an opportunity for restoration; however, until riparian vegetation becomes established, these areas will continue to be a sediment source.

Within the subbasin, there are existing streams that have been channelized in addition to canals and ditches. GIS data identify over 300 miles of canals and ditches throughout the subbasin (Map 5-1). These GIS data are valuable for viewing the spatial distribution of channelized drainages;

however, they does not reveal streams that have recently been fenced to manage cattle access or riparian areas newly managed to encourage growth of riparian vegetation.

Road Analysis

The majority of rural roads occur on USFS land, where steep topography and erodible soils are found (USFS 1995a). A recent USFS inventory identified roads that were causing sedimentation issues (USFS 2006b). As part of this inventory, stream crossings were identified and documented.

Eleven percent of the USFS road miles in the subbasin area lie within 200 feet of one of the creeks (USFS 2006b). Due to their extremely compacted, non-vegetated surfaces, some roads have become an extension of the stream network, funneling precipitation and sediments into stream channels and tributaries. Areas of specific concern included all road/stream crossings; the high density of roads in the Rock Creek drainage; and a road paralleling Rock Creek. The road parallel to Rock Creek was fully removed and returned to original contours after placement of large wood in the creek in the fall of 2004.

A number of efforts have been concluded in recent years to reduce the amount of compacted surface on USFS land including: limiting activities which cause soil compaction during timber harvest, improving surface water control on roads, and obliteration of riparian roads. Several USFS roads have recently received stormproofing improvements intended to reduce the amount of sediment reaching streams, such as rock surfacing roads, construction rolling dips, lining ditches with rock, and rocking inlets/outlets of culvert drains (Anderson, pers. comm. 2009).

GIS Slope Analysis

Because erosion rates are generally related to slope steepness, GIS is a valuable tool that can be used to understand the quantity and distribution of slopes within the subbasin. However, the format of available GIS data restricted the ability to define the distribution of slope classes within each fifth-field watershed.

Map 5-1 reveals that the Wood River and Klamath Lake watersheds have a high proportion of gradual to moderate slopes (0-20 percent), while the Fourmile Creek watershed contains a high percentage of steep slopes (>20 percent).

Previous Erosion Evaluations

The connection between sediment loading and impaired water quality has been confirmed by several studies (ODEQ 2002, Eilers et al. 2001). However, there are little data available regarding the quantity of sediment contributed to Upper Klamath or Agency lakes by individual stream reach. For example, evidence of erosion was observed in the lower reaches of Fourmile Creek; however, quantified data were not gathered (USFS 1995a).

Many studies have been done to understand the nature of water quality issues within Upper Klamath and Agency lakes. Eilers et al. (2001 in USFWS 2002a), using paleolimnology techniques, examined Upper Klamath Lake sediments over the past 1,000 years. Based on a variety of analyses, Eilers et al. determined that sediment accumulation rates in the subbasin have increased significantly in the past 150 years. Eilers et al, attributed these increases to anthropogenic modifications to the watershed, such as deforestation and conversion to agricultural and grazing lands. Their results were consistent with those of Coleman and Bradbury (2004), who found increased amounts of tephra (volcanic ash) in recent Upper Klamath Lake deposits, suggesting increased upland erosion rates (USGS unpublished data). Timber harvest, road construction, stream channelization, ditch construction, channel diversions and draining of wetlands have all led to an increase in sediment inputs into the lakes (USFS 2003b).

It is important to acknowledge that adjacent streams are not the only source of excessive sediment within the lakes. Several studies have determined that the shallow nature of Upper Klamath and Agency lakes allows for wind to influence wave action, thereby causing sediments from the bottom of the lakes to become suspended in the water column. These sediments, combined with elevated levels deposited by adjacent streams, negatively impacts water quality in the lakes (USFS 2003b).

Discussion

Geomorphic Setting

While slope steepness is an important variable in predicting erosion potential, soil compaction, erodibility of the soil, slope length and ground cover also play significant roles. High gradient slopes on the east side of the Cascades are generally vulnerable to erosion; however, the highly permeable nature of the soil and low annual precipitation typically minimizes large quantities of water and sediment from entering streams. An exception would be for locations that have been disturbed by logging and road construction. Particularly, removal of vegetation on continuous steep slopes causes an increase in surface flow, contributing to rilling and gully erosion. Increased rates of erosion resulting from the construction of logging roads is addressed below in the section Road Evaluation.

Areas of low topographical relief can also be prone to erosion, depending upon land use. The ditch construction and channelization within the low gradient reaches of the subbasin, like those surrounding Upper Klamath and Agency lakes, reduces channel roughness, which increases water velocities and erosion. Additionally, grazing and crop production in these areas has reduced the diversity, vigor and amount of riparian vegetation that promote bank stability. Quantitative data are required to verify the cause and severity of the erosion.

Road Evaluation

Accelerated surface erosion can occur from land management activities. Erosion from road surfaces is often a persistent source of sediment in logged basins due to the large network of dirt roads associated with harvest activities and the connectivity of the roads to the stream channels. Numerous studies have documented the role of road construction in increased sediment yields (e.g., Reid and Dunne 1984, Rice et al. 1979). Road-related sediment is a major factor in most watersheds. The location of roads on basin slopes (near stream, mid-slope, and ridgetop) can have major effects on both fluvial and mass wasting processes (Jones et al. 2000).

In the Upper Klamath Lake Subbasin, the majority of roads are unsurfaced, which produces high fine sediment yields. Soils that are most sensitive to compaction are located on the ridges and slopes of the east side of the Cascades. These conditions exist in the western half of all three watersheds within the subbasin, primarily on USFS land.

The Northwest Forest Plan of 1994 mandates that USFS roads shall minimize sediment delivery to streams, and they should be constructed in a way that routes drainage away from potentially unstable channels and hillslopes. In 2006, USFS conducted a detailed study of over 1500 miles of roads within the Winema Forest. At that time, there were just over 6000 miles of total road length in that same area (USFS 2006b). USFS maintains a database of roads that contains information about location, length, jurisdiction, width, surfacing type and maintenance level (USFS 2006b).

Bank Erosion

Bank erosion occurs along the higher elevation streams because of road building and logging activities, whereas bank erosion in the lower elevations is generally caused by loss of woody vegetation and unmanaged livestock access for grazing and agricultural purposes. Because many stream banks lack stabilizing riparian vegetation, bank erosion is extensive throughout the subbasin. Substantial efforts have been made in many areas over the past 20+ years to manage riparian areas by installing riparian fencing and replanting woody riparian vegetation. In addition, logging methods and road construction and maintenance techniques have improved, thereby reducing associated impacts.

Locations that have been identified as having eroding banks include streams and man-made ditches. All three watersheds within the subbasin have channels that would benefit from the re-establishment of riparian vegetation. These channels have been addressed in Chapter 6, Riparian Conditions.

Riparian fencing and restoration efforts have been implemented in recent years.

Summary of Results

Two significant sources of sediment have been identified: (1) bank erosion along the lower reaches of channels connecting to Upper Klamath and Agency lakes, and (2) road erosion from the extensive road network. Riparian management through fencing and planting has the potential to reduce bank erosion along streams located in agricultural areas; however, most of this area is private land. Erosion from roads can be reduced by the removal of unnecessary roads, and relocation or stormproofing of those located in close proximity (less than 200 feet) to stream channels, and drainage improvements such as lining ditches with rock.

Elevated sediment levels in streams and Upper Klamath and Agency lakes have substantial impacts to fishery resources and water quality. A holistic approach to improving water quality throughout the subbasin will require significant attention to sediment inputs from land use activities.

Confidence Evaluation

Confidence in the Sediment Sources is low to moderate. The methods used to identify and characterize sediment sources have a significant number of limitations, primarily because of lack of data. Therefore, the results provided in this chapter represent very simplified approximations of complex and dynamic sediment cycles.

Research Recommendations

Significant data gaps exist in regard to being able to evaluate potential sediment sources in this subbasin and the effect of altered sediment transport relationships on the various stream channels in the subbasin.

1. Comprehensive Road Inventory. A comprehensive road inventory is a high priority for the subbasin. The existing USFS database could serve as a starting point and should be expanded to include roads on other public and private property. If a comprehensive inventory cannot be conducted, then efforts should be focused on the road network located near fish-bearing streams and on sensitive soils, as this has the most direct effect on adjacent channels. Prioritization of road erosion sites could then be undertaken.

2. Geomorphic Analysis to Guide Restoration Options. The rate and pattern of sediment transport should be analyzed for streams that provide significant fish habitat. Fish bearing streams such as Thomason, Cherry, and Fourmile Creeks should undergo a thorough geomorphic analysis to determine the extent and specific nature of the channel instability. These geomorphic analyses should take into consideration variations in sediment sources throughout the length of a stream as well as indirect sediment transport from upslope land disturbance, such as timber harvest or grazing.

3. Baseline Monitoring. A hydrologic and geomorphic monitoring program should be established to provide baseline data, to allow for trend monitoring, and to provide feedback as to the effectiveness of restoration actions as they are implemented. Such a program should include monitoring streamflow and sediment transport at key sites, and geomorphic monitoring of channel geometry.

Trend monitoring of channel geometry can provide insight into changes to the channel due to specific events (typically large floods) and to longer-term adjustments and recovery from these flood events. Channel geometry is most often monitored through cross section and profile surveys, both of which are two-dimensional representations of channel shape, with the cross section perpendicular to the flow direction, and the longitudinal profile parallel.

Restoration and Management Opportunities

1. Prioritize roads for treatment. Roads located on USFS land can be prioritized for improvements or closures by using data already being gathered by USFS. USFS engineering road logs and data gathered for the Forest Service Travel Rule both identify current road condition and roads that are recommended for treatment.

2. Focus streambank restoration attention. Restoration sites can be identified and prioritized using streambank stability data generated from USFS streambank surveys.

List of Maps

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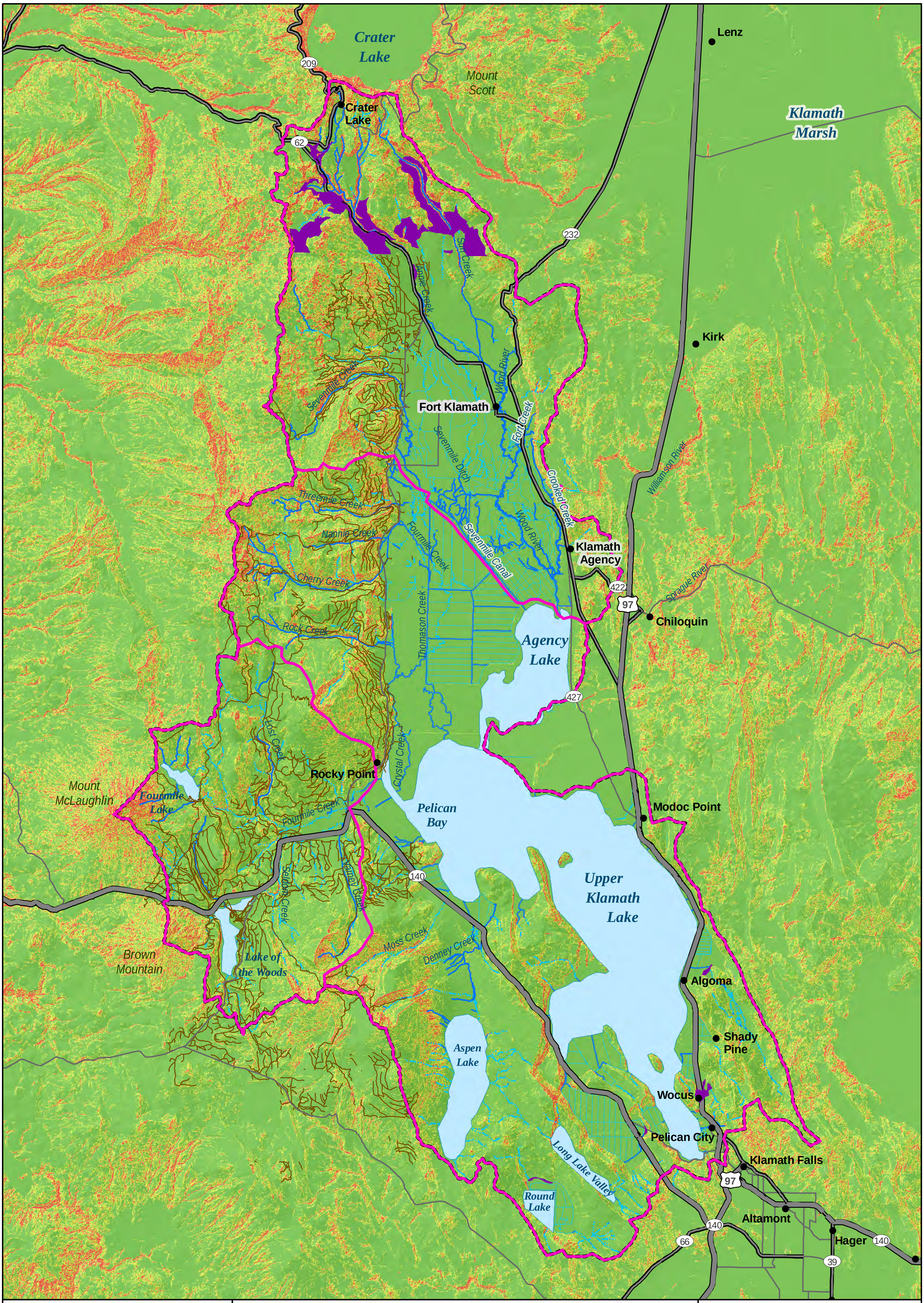

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0 4 8

Miles

Source Data:
ESRI, Klamath County, Oregon GEO,
USGS (National Hydrography Dataset)

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch
- Forest Service Roads

Slope

- 0-10%
- 10-20%
- 20-30%
- 30-40%
- >40%

Highly erodible land*

* Note: Based on available NRCS Soil Survey data. Coverage for the entire Upper Klamath Lake Subbasin requires soil survey data from both NRCS and USFS. Soils Map Unit values are not provided in USFS Soil Survey GIS data, and therefore are not shown in this map.

Map 5-1: Erosional Features

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CHAPTER 6:

RIPARIAN ASSESSMENT

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6 RIPARIAN ASSESSMENT

Introduction

The purpose of this chapter is to evaluate existing riparian conditions in relation to those historically present, identify the issues, and develop a list of potential riparian restoration opportunities. Riparian vegetation can impact water quality, erosion and bank stability, sedimentation rates, water storage within the soil profile, water table elevations, shading and stream temperature control. Biological factors affected by riparian vegetation include large wood recruitment for gravel storage and nutrient inputs, fish habitat creation and cover, and terrestrial habitat connectivity. This section addresses the following critical questions:

- What are the current conditions of riparian areas in the subbasin?
- How do the current conditions compare to those potentially present or typically present for this ecoregion?
- How can the current riparian areas be grouped within the subbasin to define patterns that increase our understanding of which areas need protection?
- What might be the appropriate restoration/enhancement opportunities?

Methods

General riparian conditions were assessed for each fifth-field watershed. Key subbasin reaches were analyzed by watershed on the basis of their hydrological and biological contributions to the subbasin.

Potential /Historic Riparian Conditions Assessment

Potential riparian conditions are defined as site-specific conditions that could be achieved in the absence of disturbance or modification. The potential riparian condition of the subbasin was determined by analyzing level IV ecoregion descriptions of the subbasin (Bryce and Woods 2000). This information was balanced against information on hydrological, geological, topographical, and climactic factors from historical resources, including historic vegetation maps derived from U.S. GLO survey data, written accounts, and stakeholder interviews. From these combined data, the range of potential conditions that could exist in the project area was extrapolated.

Current Riparian Conditions Assessment

The existing riparian condition of the Upper Klamath Lake Subbasin was evaluated using a variety of existing data. Existing data sources included digitized land cover data, aerial photography, public and private riparian forestry management policies and practices, USFS watershed analyses, and interviews. These sources were used to analyze key subbasin reaches and to qualitatively assess upland riparian conditions for patterns in vegetation type, shading, and large wood recruitment. Occasionally, more detailed riparian condition information was found for specific reaches, which was included in the analysis when it contributed to understanding the riparian vegetative function and performance in the reach.

The earliest aerial photography of the assessment area was taken in 1940. Several USFS watershed analyses used these photos to assess the changes that have occurred in riparian areas since that time. These observations, where applicable, have been included in the individual watershed descriptions.

Results

Historic / Potential Riparian Condition

An assessment of the seven ecoregion types included in the area shows the variety of typical land cover conditions across the entire subbasin (Bryce and Woods 2000, Kuchler 1964) (Map 1-3). Within these ecoregions, the riparian areas differ from the uplands because of different soil, hydrologic, and topographic factors. In the highest elevations of the subbasin, the Cascade Subalpine/Alpine ecoregion generally lacks defined riparian areas but contains alpine meadows with scattered stands of mountain hemlock, whitebark pine and subalpine fir. Typical riparian areas in the High Southern Cascades Montane Forest include lodgepole pine, mountain hemlock, white fir and Shasta red fir. Douglas-fir (*Pseudotsuga menziesii*) will likely be found in the riparian areas of the Southern Cascade Slope, with ponderosa pine and white fir occurring throughout. Higher elevations within the Pumice Plateau Forest will have white fir, with lodgepole pine located in depressions. Higher elevations of the Fremont Pine/Fir Forest would also contain lodgepole pine in the wetter areas, with western juniper in lower altitudes. While ponderosa pine is typically found in the drier sites of the other ecoregions, it is found in the wetter areas of the Klamath Juniper Ponderosa Pine Woodland. The Klamath/Goose Lake Warm Wet Basins ecoregion did not historically include a woody overstory (in this document the term “woody” is used to define persistent vegetatation), but was dominated by tules, cattails, and sedges.

Upper elevation channels would have been high gradient, fed by snow-pack, and well shaded by a combination of surrounding topography and trees. Areas adjacent to riparian zones would have been characterized by large diameter coniferous trees, which would have contributed woody debris to these reaches. Large ponderosa pine and Douglas-fir, found within some of these zones, survived periodic fire and attracted large scale logging activities as early as the late 1800’s (USFS 1996a).

Much of the subbasin lowlands were comprised of wet, forested areas including lodgepole pine, aspen (*Populus tremuloides*) and cottonwood (*Populus balsamifera ssp. trichocarpa*), with willows (*salix spp.*) found along river corridors (USFS 1994). These communities transitioned into emergent wetlands surrounding the fringes of Upper Klamath and Agency lakes. On the valley floor, the deposition of glacial till and fine-grained sediments allowed stream channels to shift along the valley floor in response to peak flows and storm events (USFS 1996a). Channels would have been complex, well shaded, and contained significant quantities of woody debris.

Current Riparian Conditions

This section describes riparian conditions and characteristics shared by all fifth-field watersheds.

Extremely porous subsoil and high infiltration rates dramatically affect the hydrologic patterns in the subbasin. Riparian zones, while functioning as significant drainages for water conveyance, may not hold surface water during certain times of the year. As a result, several streams in the subbasin have both perennial and intermittent reaches, depending upon substrate and stream gradient, at various locations (USFS 1996a, Gannett et al. 2007).

There is a remarkable difference in the amount of riparian canopy between high and low elevation riparian areas in the subbasin. In general, forested upland streams managed by USFS are well vegetated and have been recently protected, after decades of logging. This management, in combination with fire suppression, has led to a riparian landscape condition broadly characterized by dense stands of young trees, with occasional patches of old growth containing large diameter mature trees. Since most of the large trees and woody debris were intentionally removed from the riparian zones (for both logging and fire prevention), it may be several decades before these areas are able to provide meaningful quantities of large wood back into the streams. Overall, USFS lands have a relatively high degree of riparian cover and buffer in forested areas resulting from guidelines that restrict activity in riparian areas.

Oregon Riparian Management Areas (RMAs), established for forestry and agricultural use on private and public land, designate minimum buffers around streams to protect riparian vegetation. The width of these buffers, or setbacks, is based upon ownership (state, federal or private), the size of the stream, and whether or not the stream is fish-bearing. The largest RMAs are for perennial streams on federal forest land, requiring a 320 foot buffer, or the equivalent of two site potential trees. Intermittent streams on federal land require buffers of 160 feet, or one site potential tree. Logging activities are prohibited within these buffers, unless they are for restoration purposes. Buffers on private forestland vary, depending on stream size and fish species present. Fish-bearing streams require 20-100 foot buffers, depending on the streamflow, and non-fish bearing streams require 0-50 foot buffers. Certain logging activities may be allowed within the buffers, but in general, no harvest can occur within 20 feet of the stream and all understory within 10 feet of the stream must remain intact (ODEQ 2009). All perennial streams on agricultural land, public or private, have buffers determined by the subbasin’s individual Agricultural Water Quality Rules. These rules are established under Oregon’s Agricultural Water Quality Management Act (1993), which was enacted to support the Federal Clean Water Act (ODA 2008).

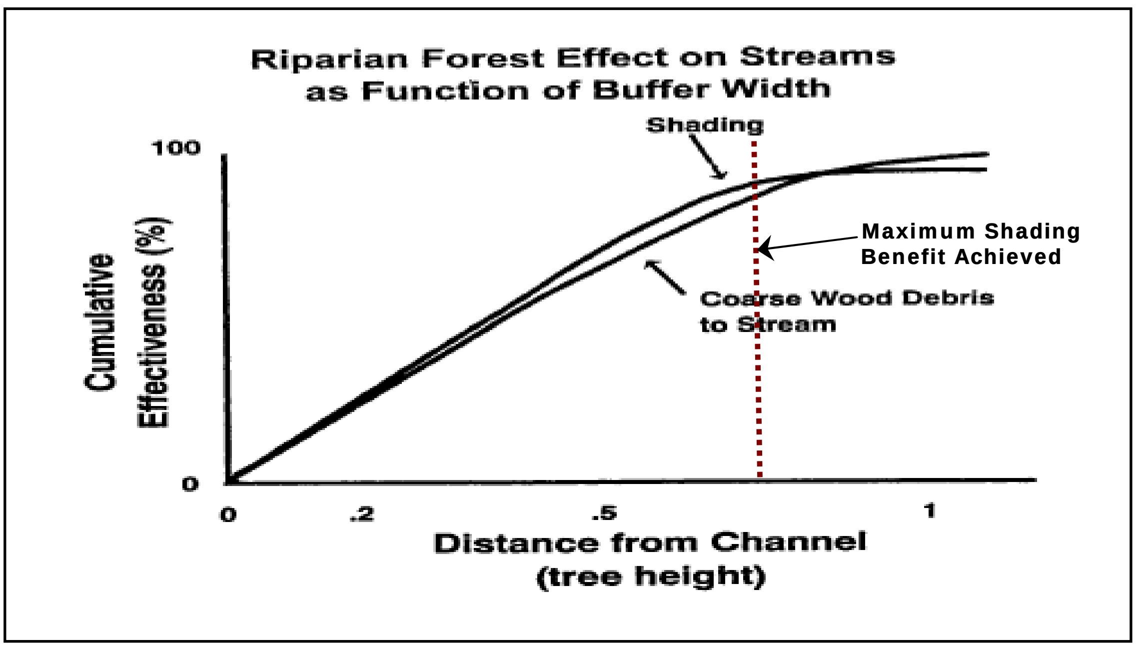
Grazing is another resource activity that occurs on a small proportion of USFS property in the subbasin. Riparian meadows are the principal locations being used for grazing, typically including cattle and horses. Management considerations include proximity to fish-bearing streams and the potential for sediment to enter those streams. The grazing allotment located along Fourmile Creek has been fenced to exclude cattle and horses, providing a 100-foot buffer from the stream (USFS 2006).

In contrast to riparian areas in the higher elevations, many of the low elevation stream reaches currently have little or no riparian cover (Figure 6-1, Aerial Photo of a Channel Lacking Overhead Canopy Adjacent to Forested Land). In the lowland areas, which are mostly privately owned, grazing has altered vegetative conditions over time. Most of the willows and hardwoods that once occupied portions of the lowland riparian vegetative zone are now gone. Various watershed analyses and interviews have identified streams throughout the subbasin, concentrated in the low elevations, that are incised and support limited riparian vegetation. However, it is important to note that not all streams have the potential to naturally support woody riparian vegetation due to bank aspect and stream gradients (e.g., less than ½% gradient). In streams that can naturally support woody riparian vegetation, this vegetation plays an important role by maintaining bank structure with a rooting network, shading stream surfaces, and contributing to terrestrial and aquatic habitat for species. Absence of woody vegetation in riparian areas results in poor stream shading, decreased opportunities for large wood recruitment, and thus low quality aquatic habitat. The structural diversity of streams has been further compromised by the fact that wood has been intentionally removed from most streams and streams have been channelized. Re-establishing riparian vegetation has the potential to reduce bank erosion, improve water quality and increase available habitat. Recent efforts to restore riparian communities along degraded stream reaches in the subbasin are discussed later in this chapter, and in further detail in Chapter 9, Fish and Fish Habitat Assessment.

Figure 6-1. Aerial photo of a channel lacking overhead canopy adjacent to forested land (DEA 2009).

Riparian conditions determine the extent to which solar radiation can increase water temperatures within the subbasin. Research has shown that shade-producing vegetation is an effective way to prevent elevated water temperatures. By allowing vegetation communities in riparian areas to grow to their site ecological status potential, shade provided to streams will be increased and stream temperatures will remain cooler in response to this increased shade (USDA and USDI 2003). Potential riparian land cover is the land cover that could grow and reproduce along a stream given certain site specific hydrologic, soil, and vegetative conditions (USDA and USDI 2003). Effective shade was used as a surrogate measure for solar radiation loading capacity in the Upper Klamath Lake Drainage TMDL instead of actual solar loading values (USDA and USDI 2003).

Figure 6-2 (Riparian Forest Effect on Streams as a Function of Buffer Width) shows that, in general, the cumulative effectiveness of shade from riparian vegetation in a forested environment reaches a maximum of about one tree height from the channel (USDA and USDI 2003). However, further review of Figure 6-2 suggests that buffering to one full tree height may not be necessary to produce the majority of shading effects, since most benefits occur around the first 75 percent of full tree height (i.e., considerable decreasing marginal returns above 75 percent distance). Therefore, greater overall land use benefits may be achieved by allowing grazing or other uses in the furthest 25 percent of the maximum tree height and focusing on repairing existing degraded riparian buffers in the first 75 percent of full tree height (i.e., slightly narrower but longer riparian buffers). However, other methods to determine maximum beneficial riparian buffer width are available and may consider other factors, such as steep slopes, high soil erosivity or provision of wildlife habitat, or stream width (for example, see Oregon's Forest Practices Act for other methods). As such, these factors, additional methods, and/or site goals may provide reasons to extend riparian buffers below, up to, or beyond the maximum tree height distance.



Data Source: USDA and USDI (2003)

Figure 6-2. Riparian Forest Effect on Streams as a Function of Buffer Width

Figure 6-2 shows riparian area or streamside buffer effectiveness as a function of tree height and distance from the stream. Maximum effectiveness of coarse woody debris inputs and stream shade occur within one tree height away from the stream (FEMAT as cited in USDA and USDI 2003).

Shade surveys have been conducted by the USFS specifically to measure existing effective shade. Current shade conditions were evaluated for randomly selected sites in seven different riparian vegetation community groups throughout USFS lands in the Upper Klamath Basin in 1999 (McNamara et al. 2000 as cited in USDA and USDI 2003). The types of plant community groups composing the riparian canopy along streams was a major factor in determining the amounts of riparian shade that could occur along a stream reach. The community groups that were monitored were sedge/grass, willow/shrub, alder, lodgepole pine, ponderosa pine, white fir, and cottonwood/aspen. Table 6-1 (Percent Shading By Riparian Community Types For Randomly Selected Sites In Upper Klamath Basin 1999 Survey) provides the results of the shade survey study.

Table 6-1. Percent Shading By Riparian Community Types For Randomly Selected Sites In Upper Klamath Basin 1999 Survey.

	Sedge/ Grass	Willow/ Shrub	Alder	Ctnwood/ Aspen	Lodgepole Pine	Pond. Pine	White Fir
Avg.% shade(n)	26(24)	31(15)	66(12)	61(7)	53(11)	42(10)	57(10)
Min	2	11	28	21	28	15	24
Max	64	69	89	82	70	78	87
SD	15	16	20	22	12	20	21

Data Source: USDA And USDI 2003

NRCS conducted a CEAP for the Wood River Valley (NRCS 2010). The CEAP reviewed the effects of irrigation and grazing within the valley with respect to forage, wildlife habitat, and water quantity and quality, in association with conservation efforts such as herd size reduction, withdrawing irrigation, and riparian restoration efforts. Study findings indicated the following:

Restoring riparian areas

- Improved riparian and aquatic habitat
- Increased populations of macro invertebrates and fish
- Deepened and narrowed stream channels (increased stability - closer to reference conditions)

Reducing or eliminating irrigation from grazing lands

- Encouraged a shift from wetland obligate to facultative vegetation
- Increased the percentage of bare ground
- Decreased forage production by 15 to 25 percent (depending on grazing regime)
- Maintained the nutritional value of forage (within the requirements of grazing animals)

Improving grazing management (Prescribed Grazing)

- Increased potential forage production (30 day rest versus 10 day rest or continuous grazing) or ameliorated production decreases from removing/reducing irrigation.

Existing Conditions by Watershed

The following sections describe the unique riparian conditions, from the high to low elevations, within each fifth-field watershed.

Wood River

Riparian areas in the upper elevations of this watershed are primarily public land, managed by the Fremont-Winema National Forest, with smaller parcels managed by Crater Lake National Park and Oregon State Parks for recreational use and species habitat. The Fremont-Winema National Forest land is managed for habitat and timber production, while Crater Lake National Park is managed for natural resource protection. Kimball State Park, managed by Oregon State Parks, is managed for recreation and habitat. Sun Pass State Forest, managed by Oregon Department of Forestry, is managed for sustainable timber production for school funding. Most of the private lands within this watershed are located in the valley bottom and managed for cattle, with a small amount of timber harvest (Shapiro 2000).

Various management units on USFS land include Late Successional Reserve (LSR) in Sevenmile drainage, Matrix lands (everything outside of Wilderness and LSR), Sky Lakes Wilderness (upper Cherry Creek drainage), and Old Growth in the Rock Creek drainage (USFS 1995a). The headwaters of perennial streams, including Annie, Sevenmile and Sun Creeks, are located on steep, forested slopes within the Fremont-Winema National Forest, fed by a combination of snowpack runoff and spring flow. Douglas-fir, ponderosa pine and western larch (*Larix occidentalis*) are the dominant species, with mountain hemlock concentrated in the highest elevations. In combination with steep channel topography, this forested condition provides shading and woody debris to these perennial, and nearby intermittent, streams. Stream reaches passing through older stands of trees, particularly those in Old Growth Management Areas and Wilderness Areas, are most likely to encounter opportunities for large wood recruitment, more so than those in reaches passing through younger stands of trees in Matrix Management areas.

In the Wood River Watershed, NPS manages the headwaters of Annie and Sun Creeks, and manages their associated riparian areas for large buffers in a “natural” or “near-natural” state (NPS 2009). Aerials indicate that the headwaters of these streams all have extensive riparian cover and natural buffers. Subalpine fir and Engelmann spruce (*Picea engelmanni* Parry ex. Engelm.) typically dominate upper riparian zones, with few hardwoods. Sitka alder (*Alnus viridis*), thinleaf alder (*Alnus incana*), and Pacific willow (*Salix lucida* spp. *lasiandra*) become more common at middle and lower elevations of the National Park (NPS 2009). Aerial photo observation indicates that riparian wood recruitment and shading are likely excellent in this portion of the watershed. However, the ability for large wood to contribute to stream morphological pool and scour characteristics may be limited by steep topography.

Streams at the mid and lower elevations of the Wood River Watershed are mostly privately owned, managed as pastureland, resulting in little overstory vegetation and woody debris and minimal shading (Figure 6-3, Aerial Photo of an Example of Scattered Riparian Cover Along Channels Located on Agricultural Lands). While there is some willow corridor present, minimal woody riparian vegetation decreases the opportunities for large wood recruitment. In addition, channelization and bank instability are common in these reaches.

Figure 6-3. Aerial photo of an example of scattered riparian cover along channels located on agricultural lands (DEA 2009).

The spring-fed headwaters of the Wood River are surrounded by ponderosa pine forest, but woody vegetation becomes sparser in lower reaches due to both natural and anthropogenic causes (aerial observation). This is the result of timber harvest in the mid to upper reaches of the river and grazing throughout its length and also because of floating peat soils which can inundate tree roots and prevent growth. Recent riparian fencing projects along the Wood River have increased the amount of overstory vegetation in some locations. Where riparian fences have been installed and grazing activities are managed, many sites have shown successful regeneration of native species i.e., willow, cottonwood, aspen and chokecherry (Peterson, pers. comm. 2009). Shading, quantities of woody debris and bank stabilization will all continue to increase as more restoration and grazing management projects are implemented.

At the mouth of the Wood River, at Agency Lake, shown in Figure 6-4 (Aerial Photo of the Wood River Wetland in the Foreground and the Wood River in the Background) restoration efforts have been underway on the Wood River Wetland since 1995 (Shapiro 2000). The BLM purchased private pasturelands, formerly called Wood River Ranch, with restoration efforts currently aimed at restoring wetland function and riparian conditions along the Wood River.

Figure 6-4. Aerial photo of the Wood River Wetland in the foreground and the Wood River in the background (DEA 2009).

Fort and Crooked Creeks, tributaries to the Wood River, have limited overhead canopy and associated shading due to natural floating peat soils as well as anthropogenic conversion to pastureland. Headwaters of these two creeks occur on USFS land with the majority of the reaches passing through private property. A fish hatchery is located at the headwaters of Crooked Creek (Figure 6-5, Photo of a Fish Hatchery Sign Located Near the Headwaters of Crooked Creek). Aerial photo observation reveals that these streams have intermittent, narrow buffers of riparian vegetation, probably most likely willow dominated, occurring along much of the length of the channel. The presence of shrub communities still provides bank stability and shade on these smaller channels; however, lack of trees limits the supply of woody debris.

Figure 6-5. Photo of a fish hatchery sign located near the headwaters of Crooked Creek (DEA 2009).

Changes in land use and the construction of the Sevenmile Creek/Canal have reduced the amount of riparian vegetation and significantly altered the channels in the lower reaches of Sevenmile Creek. However, some of these negative impacts are being mitigated through restoration implementation. Similar to the Wood River, Sevenmile Creek and its tributaries have been targeted for extensive riparian fencing projects. Fencing projects have been implemented on multiple, adjacent properties, increasing the potential to create a continuous riparian corridor along Sevenmile Creek (Peterson pers. comm. 2009). From a habitat perspective, aquatic and avian species would benefit from a continuous band of riparian cover that extends from Agency Lake up into the coniferous communities in the Cascades.

Crane Creek, a tributary to Sevenmile, was diverted and channelized for irrigation, leaving its historic channel completely dewatered. Beginning in 2007, a restoration project sponsored by private landowners, KBRT, NRCS, USFS, and USFWS, was initiated to return water to the historic channel, improve habitat and remove fish passage barriers (KBRT 2009). The project was successfully completed, with fish occupying the channel the first winter following construction.

Aerial photographs show that riparian cover associated with many ephemeral and intermittent streams scattered throughout the Wood River Valley have likely changed from historical conditions. These streams have minimal overhead or understory communities, with pasture grasses providing the only cover. However, it is important to note that in some streams in the Wood River Valley, such as in Crooked Creek, the lack of woody riparian vegetation is the result of natural floating peat soils, and therefore, the amount of woody vegetation in these area has not changed dramatically from historical conditions. In streams that currently have less riparian vegetation than historical conditions, increased solar access has increased the temperature of these waters, which make their way to nearby perennial streams or irrigation ditches, and ultimately drain into Agency Lake. In addition, LWD provided by riparian vegetation, provides valuable features for other wildlife that utilize these riparian corridors.

Klamath Lake

Like all of the watersheds in the subbasin, the Klamath Lake Watershed is composed of forested upland slopes and pastureland in the lowlands. This watershed is unique in that it has the most land area adjacent to Upper Klamath and Agency lakes and, therefore, its lower stream reaches, many of which have been channelized up to their mouths at Upper Klamath and Agency lakes, are heavily influenced by the water levels regulated by the Link River Dam.

The headwaters of key drainages within this watershed are located on Fremont-Winema National Forest land. Sky Lakes Wilderness encompasses the upper portions of Threemile, Cherry and Rock Creeks. Aerial analysis of the watershed shows intensive management of forested stands, with areas most recently cut identified on Map 6-1 (Existing Riparian Conditions). Portions of Rock and Threemile Creeks have been impacted by the removal of instream wood and large trees from the riparian zone; however, riparian areas managed by Fremont-Winema National Forest have generally been protected during recent forestry logging operations, with buffers at or above guidelines (USFS 1990, 1994). Because of this degree of protection, it is likely that, at the watershed scale, most streams are relatively shaded. The best opportunities for large wood recruitment occur when streams pass through mixed-age stands. Cherry Creek, near the wilderness boundary, benefits by flowing through a mixed age stand and offers an excellent example of a functioning riparian system (Anderson, pers. comm. 2009).

In 2004 and 2007, USFS implemented projects to increase the amount of in-stream wood in both Rock and Threemile Creeks. These projects combined placed over 300 large logs, at least two feet in diameter, in Rock and Threemile Creeks. The goal for these projects was to replace function that had been lost when the large wood was intentionally removed from these channels during logging activities. The large logs are intended to hold back water and capture smaller woody debris and spawning gravels (USFS 2008).

Channels located in the lower elevations of the watershed pass through private property, and then either Reclamation or USFWS land, before connecting to Upper Klamath and Agency lakes (Figure 6-6, Aerial Photo of Pelican Bay Including the Mouths of Fourmile, Recreation and Crystal Creeks). Recreation Creek is primarily located on Fremont-Winema National Forest land, while Crystal Creek passes through Fremont-Winema National Forest and private property before entering Upper Klamath Lake Wildlife Refuge. Recreation Creek has a coniferous canopy on the west side, while its east bank is bordered by wetland vegetation lacking an overstory component. The lower reaches of Crystal Creek within the Refuge are entirely surrounded by wet riparian marsh communities lacking overstory canopy. The historic extent of overstory vegetation on lower Crystal Creek is not known.

Figure 6-6. Aerial photo of Pelican Bay including the mouths of Fourmile, Recreation and Crystal Creeks (DEA 2009).

This watershed has several key drainages that contain both perennial and intermittent sections. Nannie Creek is mostly an intermittent stream with a half mile section maintaining perennial flow (USFS 1994) and, while not a fish-bearing stream, this stream historically influenced downstream fish habitat through the transport of wood and organics to the north fork of Cherry and Fourmile Creeks (USFS 1994).

Fourmile Creek

The majority of the upper elevations of this watershed are within the Fremont-Winema National Forest; however, the eastern slope of Mount McLaughlin is within the Rogue River National Forest (USFS 1996a). Private property exists within this watershed, concentrated in the lower reaches of Fourmile Creek, including Fourmile Flat and Rocky Point (USFS 1996a). Private land includes residences, agricultural lands and forest lands owned by JWTR (USFS 1996a).

Most of this watershed is managed by the USFS and, as discussed previously, the USFS currently manages wooded riparian areas for stream shading and large wood recruitment; however, fire suppression and logging (both historic and recent) have influenced the vegetation densities throughout this watershed. Timber harvest of ponderosa pine early in the 1900's occurred on the south and southwest slopes of Pelican Butte, in lower Lost Creek and Fourmile Flat (USFS 1996a). Overall, canopy closure has increased since 1940 (USFS 1996a). The 1996 USFS North Fourmile watershed analysis identified canopy closure in the upper reaches at greater than 40 percent for the following species: mountain hemlock, Shasta red fir and western white pine (*Pinus monticola*). The Shasta red fir zone, located on mid to upper slopes in upper Horse Creek drainage and middle reaches of Lost Creek, are relatively dense and continuous, with most of the area having canopy closure greater than 40 percent (USFS 1996a).

Shading is likely adequate in these areas, but large wood recruitment may be limited due to the young stand age and class characteristics. As streams pass through the lower elevations of USFS management, they generally have less riparian canopy cover.

At the headwaters of Fourmile Creek, Fourmile Dam diverts much of the water to the west side of the Cascades that would otherwise flow into the creek, sharply limiting flows in the upper sections of the system (USFS 1996a). By storing snow-melt and diverting the water elsewhere, the dam eliminates important stream-shaping events that would result from snow-melt and peak flows.

Private lands, concentrated in the lower reaches of the watershed, are grazed in a manner that limits stream shading and the establishment of new woody vegetation. Historic riparian species in this area included lodgepole pine and hardwood species (USFS 1996a). The lower reaches of Fourmile Creek have been channelized on both private and public land (USFS 1996a). This channelization, combined with the lack of riparian vegetation, has led to unstable banks and erosion (USFS 1996a).

Discussion

The Upper Klamath Lake Subbasin provides important economic and recreational benefits for residents and visitors, and has been doing so for many years. However, these services do not come without a cost to the natural environment. Decades of intensive logging, grazing, and road building have taken a toll on the region's riparian areas. These riparian communities perform important ecosystem services to the watershed, including protection of streambanks, maintenance of fisheries, improvement of upland-riparian connectivity, water quality and discharge functions.

Fremont-Winema National Forest manages over 40 percent of the subbasin. Its management prescriptions, applied across the subbasin upper elevations, have important effects on the health of the watershed.

Historically, much of the upper elevation areas were composed of stands of large, medium density, mature trees. The onset of fire suppression, which allowed young shoots to sprout unchecked amidst these trees, combined with frequent logging, has resulted in overstocked riparian areas with a high proportion of young overstory trees. This condition may benefit stream-shading, but does not benefit the system in terms of large wood recruitment.

Most areas below Fremont-Winema National Forest land are owned by private landowners, who primarily manage lowland areas for grazing and cattle production and upland areas for timber production.

Cattle, as primary consumers in the food chain, have a tremendous ability to alter vegetative conditions, particularly in riparian areas. Conversion of bottomland wetlands and stream channels to feed-oriented plant communities has limited the ability for riparian areas to provide ecosystem services such as bank stabilization, water quality, and biodiversity. Initiatives that address riparian vegetative land management on private lands have the potential to provide profound benefits to the entire subbasin.

This assessment suggests that land use is the key indicator for determining patterns that help to identify areas in need of protection or restoration. Considering these land uses in terms of landscape functions helps to identify and group these areas in terms of their importance and potential for protection or restoration. Within this context, landscape patterns can be separated into the following three main groups (as illustrated in Table 6-2, Land Use and Riparian Functions): best functioning riparian condition areas, fair functioning riparian condition areas, and poor functioning riparian condition areas.

Best functioning riparian areas are riparian areas that provide the riparian vegetative buffer necessary for proper stream shading and potential large wood recruitment and bank stability. These riparian areas have a relatively wide buffer and site-appropriate diameter trees. These streams are typically found on federal timberlands where management strategies limit resource extraction activities in riparian areas, or in privately owned areas where state regulations require a significant no-activity buffer due to sensitive resources (i.e., proximity to fish-bearing streams) or where the riparian area has been voluntarily managed to improve riparian conditions.

Table 6-2. Land Use and Riparian Functions

BEST Riparian Functioning Condition	FAIR Riparian Functioning Condition	POOR Riparian Functioning Condition
– Streams in National Park Service lands – Streams in USFS Old Growth Ecosystem Units – Streams in Sky Lakes Wilderness – Northwest Forest Plan Riparian Reserve Units on National Forests	– Streams in USFS General Forest Management Units (MC 12) – Perennial and fish-bearing streams privately managed for timber – Intermittent streams privately managed for timber – Streams in well managed riparian range lands	– Streams along private timberland ephemeral streams – Streams in overgrazed riparian range lands – Streams that have been channelized – Streams that have been de-watered by diversion

Fair riparian functioning condition areas are riparian areas that likely provide the riparian buffer necessary for proper stream shading, but have limited opportunities for large wood recruitment (timberlands) or bank stability (range lands). On timber-producing lands, these stream reaches are typically found where federal or state regulations require a mid-sized no-activity buffer on private lands due to fairly sensitive resources, but generally do not currently contain large trees for woody debris recruitment. In addition, range lands that are being managed with riparian function in mind (i.e., rotationally grazed or stubble-height management minimums) also qualify as fair functioning.

Poor riparian functioning condition areas do not provide the riparian protection necessary for proper stream shading, large wood recruitment, or bank stability protection. These areas typically include private timberland, ephemeral streams, and riparian grazing areas that are not managed to achieve or maintain proper functioning condition.

Functioning riparian condition is an important tool for determining the contributions riparian areas make to the subbasin. The characteristics of each condition may not apply to all sites in all areas identified, but it does provide a broad overall picture of the landscape pattern. These patterns help us determine which areas are best suited for riparian protection and restoration efforts.

Confidence Evaluation

The confidence evaluation in the Riparian Assessment is low to moderate. Because of the scale of the project, the riparian assessment relied heavily on remote sensing techniques for determining subbasin riparian vegetative condition. Remote sensing techniques are data-limited, therefore there are gaps in the results provided. However, an extensive search of all available information on the sub-basin was conducted, and the most relevant of this information was compiled and reviewed during the writing of this assessment. To the limits of available data and approach, the analysis revealed key patterns in the watershed that begin to answer the critical questions for the riparian component of the assessment. As this information is considered for implementation on the ground, it will be important to verify that site conditions reflect the watershed-scale patterns observed by remote-sensing.

Research Recommendations

Current and comprehensive sources for riparian information are lacking for this subbasin. This assessment relied on detailed information from USFS analyses that cover only a portion of the subbasin. There are very little data available summarizing riparian conditions on private lands. In addition, much of the available data are from the mid 1990's and may be out-dated. The data and reports that are available rarely include the multiple restoration and fencing projects that are currently underway.

Because little existing information is available, it is recommended that studies on representative, functioning streams in the watershed be conducted to help eliminate data gaps and improve understanding of proper riparian function and performance. In addition, streams that are undergoing restoration should also be studied, in order to evaluate the impact of projects, such as riparian fencing, on species composition, shading and wood recruitment.

Restoration and Management Opportunities

Thoughtful implementation of riparian community recovery efforts can have dramatic benefits to water quality, water temperature, sediment loading, aquatic habitat, time of concentration, discharge, and property protection. Restoration planning, however, should be approached in the most cost effective and strategic manner. Cost-benefit analyses, as a balance of opportunity and strategy, are important to the success of any given project. Therefore, based on the understanding that upper-elevation riparian vegetation policies are in place, and that lower elevation areas would most benefit from riparian vegetation enhancements, the following recommendations are made.

1. Concentrate riparian recovery initiatives on private property. Some of the best candidates for riparian restoration in the Upper Klamath Lake Subbasin occur on private lands. There are many incentives to private landowners to encourage restoration and proper management and not everyone needs to participate in order to have an impact. Restoration projects on private lands have more funding available and are generally implemented more quickly than on public lands. Involving landowners helps build a sense of community and helps ensure benefits to both the people and the resource. Work coordinated by KBRT in the Wood River Watershed has resulted in several successful riparian projects on private property. Important strategies for private land include the following:

- Grazing management has evolved to be more mindful of riparian impacts; however, it is still important to continue efforts to identify and implement grazing management strategies that meet riparian habitat objectives. As part of these efforts, riparian areas should be evaluated as to the potential for replanting and species selection. Grazing management should evaluate the benefit of livestock exclusion or managed grazing through timing, duration, and frequency. This would allow the streams to begin to restore channel form naturally by reducing stream bank erosion processes. Riparian restoration would also provide future imports of coarse organic matter and large wood, which would improve food chain support function and habitat complexity, respectively.

- Providing stock watering areas away from waterways would reduce direct release of animal excrement into stream systems and reduce trampling of riverbanks and associated vegetation.

While restoration on public lands is important to the subbasin, much of it is already being implemented, or is planned for implementation in the near term. These efforts should be encouraged and monitored for important lessons that could be applied to projects on private land.

2. Concentrate riparian recovery initiatives near areas that are already functioning or have key habitat value. Build restoration efforts out from areas that already contain important resources into adjacent regions with degraded riparian vegetative conditions. The larger the vegetative stand (i.e., a patch of trees or willows) along a riparian reach, the more resilient it becomes, and the greater its contributions to the surrounding area. It is also likely that areas with functioning, yet vulnerable, riparian systems have other resource assets including functioning fish habitat, low water temperature, and stable channels to build on.

The lower reaches of streams, where they meet Upper Klamath or Agency lakes, are ecologically significant areas that provide key habitat for aquatic species. These streams can provide essential refugia habitat, especially during summer months when water quality is limited within the lakes. In addition, the connectivity between the lakes and streams is essential for fish to access and utilize spawning areas in higher stream reaches. Historically significant fish-bearing streams, such as Sevenmile Creek/Canal, should be prioritized for habitat improvements.

3. Consider restoration management projects as well as restoration design projects. Not every riparian community needs riparian plantings to improve. Often, changes in management strategy will allow the existing communities to recover and provide riparian benefit. Examples include rotational grazing to allow cattle in areas when stubble height is adequate, and coordination of water diversion between landowners to maintain stable water levels so plants can adapt. Often, a combination of management and design can provide more significant benefits to riparian vegetation. For example, construction of a water gap to water cattle shifts grazing pressure away from streambanks, allowing those areas to recover and thrive.

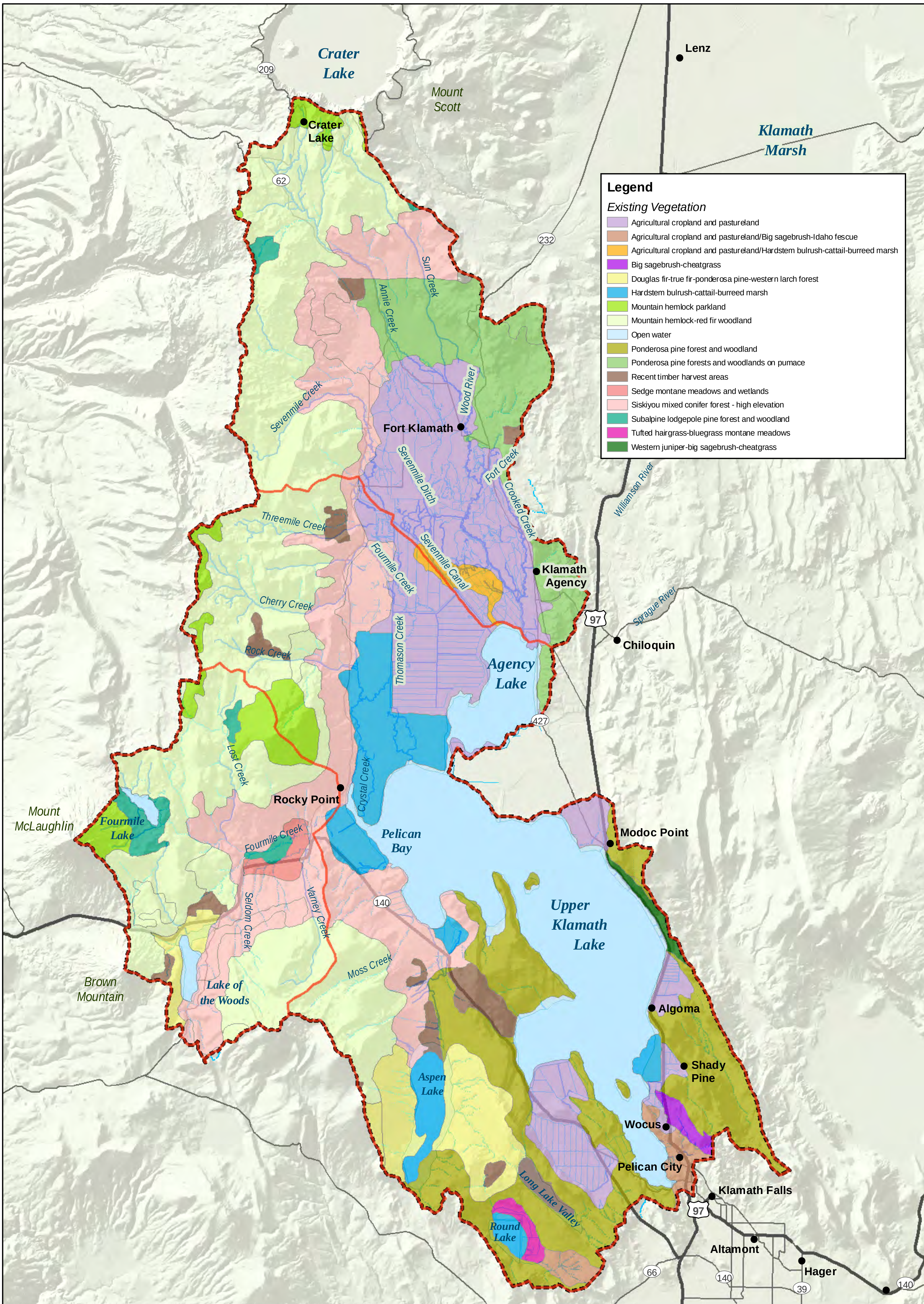
It is also important to protect investments by making sure areas that are restored are compatible with management strategies. For example, willows may need to be fenced for the first few years in order to ensure that they are not consumed by grazing cattle.

Another management issue within the subbasin is water use for irrigation. Streams have been re-located and/or de-watered for irrigation purposes, resulting in some streams losing their connection to Upper Klamath and Agency lakes. The combination of channel restoration and water conservation efforts by private landowners can help increase the amount of water that stays in-stream, increasing streams flows and re-establishing the historic channel connection to the lakes.

4. Choose the right types of vegetation for the right places. On a site-by-site basis, consider adjacent vegetation, historical vegetation, slope, successional patterns, and annual moisture cycles when choosing plant communities to restore. In some places, especially small streams, willows may be the best choice over taller canopy. In other areas, canopy cover will provide the greatest benefit to the riparian area and its associated assets.

5. Prevent and remove conifer encroachment into wet meadows. Where historic fire suppression or grazing has led to conditions where conifers are overtopping native hardwoods, such as aspen/cottonwood and changing wet meadows, prioritize removal of conifer to favor hardwoods and meadow restoration.

List of Maps



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Source Data:
ESRI, Klamath County, Oregon GEO

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Stream/River: Perennial
- Stream/River: Intermittent
- Stream/River: Ephemeral
- Canal Ditch

Map 6-1:
Existing Riparian Conditions

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CHAPTER 7:

WETLANDS ASSESSMENT

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7 WETLANDS ASSESSMENT

Introduction

The purpose of this section is to identify the location, class and quality of existing wetlands and determine how these wetland characteristics have changed over time in order to identify potential restoration or enhancement actions at a subbasin scale.

Critical questions that are addressed in this part of the assessment are as follows:

- Where are the wetlands in the subbasin?
- What are the general characteristics of wetlands within the subbasin?
- What opportunities exist to restore wetlands in the subbasin?

Methods

The locations and conditions of the wetlands in the subbasin were evaluated using the most current digital National Wetland Inventory (NWI) data generated by USFWS (USFWS 1981). However, due to the size of the assessment area, it was not practical to address each wetland polygon. Therefore, wetlands of similar class were grouped and evaluated in the results and discussion below. Identified wetlands were evaluated based on the Cowardin Classification Code (Cowardin 1992). According to this classification code, wetlands in the subbasin were distinguished by the System, Subsystem, and Class modifiers in the database and then characterized by watershed.

In addition, landowner and agency interviews were used to supplement the technical data described above.

Results

Wetlands are defined by Cowardin (1992) as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water." In order to be defined as a wetland, the area in question "must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Cowardin 1992). All of the wetlands discussed in the following sections meet the Cowardin definition of a wetland. However, it is important to note that the definition used to determine state or federal jurisdictional wetlands is different from the Cowardin definition. Therefore, the information in this chapter should not be used to delineate or identify jurisdictional wetlands or waters.

In summary, there are twelve types of wetlands occurring in the subbasin (as shown in Map 7-1, Existing Wetlands and Figure 7-1, Types and Prevalence of Wetlands in the Watershed); however, of these twelve, two wetland types – lacustrine limnetic and palustrine emergent - comprise the vast majority of the wetlands in the subbasin. Lacustrine limnetic wetlands and palustrine emergent wetlands combined make up 96 percent of the total wetland area within the subbasin while all other wetland types (see the legend in Figure 7-1 for specific wetland types) combined make up the remaining 4 percent of the total wetland area.

Lacustrine limnetic wetlands are a subsystem of the lacustrine wetland system. Lacustrine wetlands consist of at least 20 acre-large deep-water habitats lacking vegetation over 30 percent of its area (Cowardin 1992). Examples of lacustrine wetlands include permanently flooded lakes and reservoirs. Water depth further categorizes a lacustrine wetland as limnetic or littoral - lacustrine limnetic wetlands are deepwater habitat (Cowardin 1992) and lacustrine littoral wetlands are located from the shore to a depth of 6.6 feet below water, or to the maximum extent of nonpersistent emergent vegetation (Cowardin 1992). Lacustrine limnetic wetlands make up an average of 48 percent of the total wetlands within the subbasin whereas lacustrine littoral wetlands make up just 1 percent.

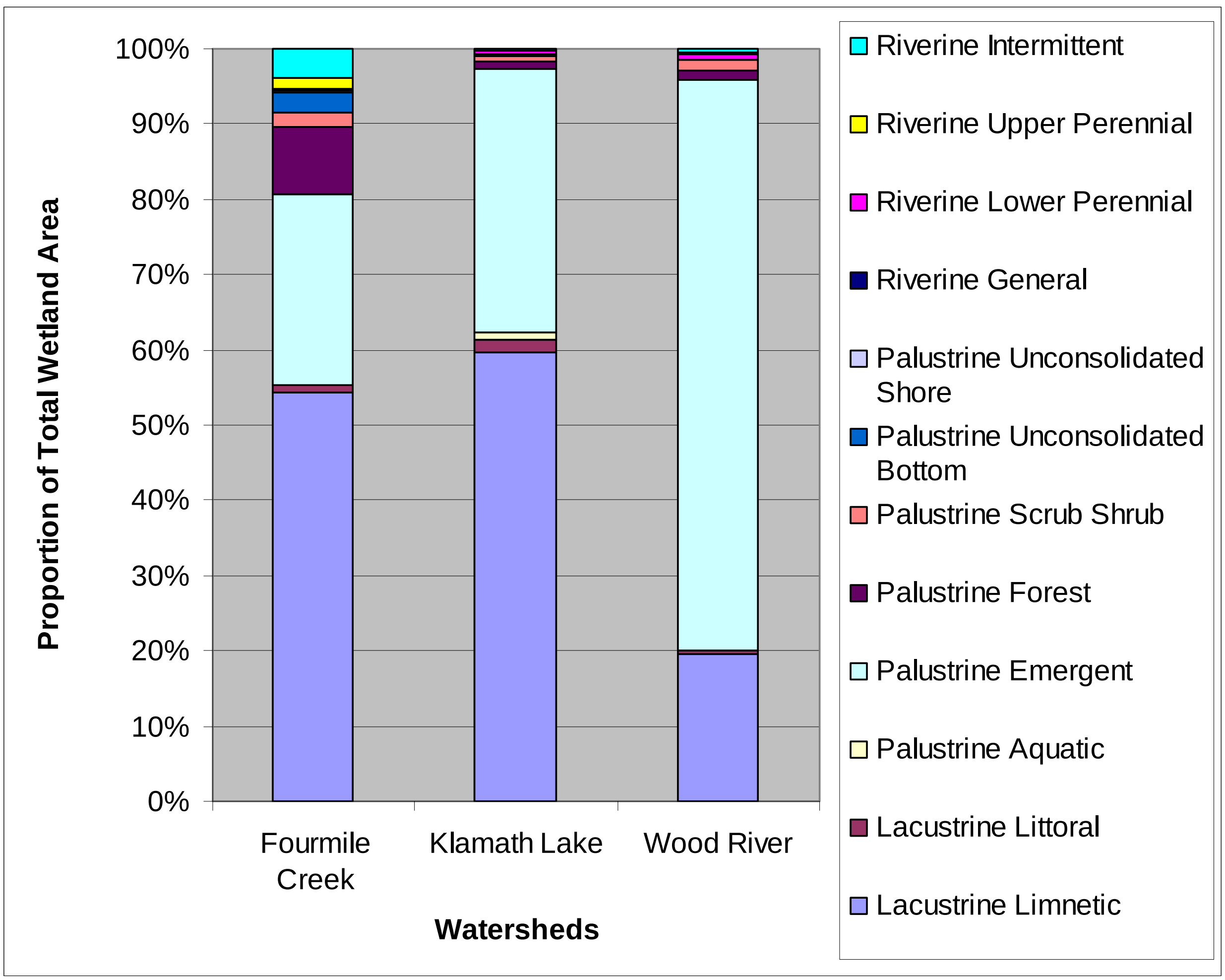


Figure 7-1. Types and Prevalence of Wetlands in the Watersheds

The other dominant wetland type within the subbasin, palustrine emergent wetlands, is a class within the larger system of palustrine wetlands. Palustrine wetlands are a group of wetlands traditionally referred to as a marsh, swamp, bog, fen, or prairie (Cowardin, 1992). Palustrine wetlands are shallow in comparison to limnetic wetlands and typically have a water depth of less than approximately 6.5 feet at low water (Cowardin 1992).

Palustrine wetlands can be further defined by class, based on vegetation types and substrate. The class of palustrine *emergent* wetlands contains emergent vegetation, which includes sedges, rushes, and grasses typically found in wet areas. In most years, this vegetation is present throughout the growing season (Cowardin 1992). The class of palustrine *scrub shrub* wetlands is dominated by woody vegetation less than approximately 20 feet tall, including shrubs and small trees. Palustrine *forested* wetlands are dominated by trees greater than 20 feet tall. These three types of wetlands are sometimes referred to as "swamps" or "bottomland hardwoods" (Cowardin 1992).

While there are small occurrences of various classes of palustrine wetlands within the subbasin, including palustrine forested (1 percent), palustrine scrub shrub (1 percent), palustrine unconsolidated bottom (<1 percent) and palustrine unconsolidated shore (<1 percent), palustrine emergent wetlands are the most common (48 percent) throughout the subbasin. The characteristics of specific wetland types are discussed in further detail at the watershed level in the following sections.

Wetlands Condition by Watershed

Wood River

Most of the 45,700 acres of wetlands in this watershed are found along the valley bottom, starting in the mid to lower reaches of Annie and Sun Creeks, continuing south to Agency Lake (Figure 7-2, Aerial Photo of the Lower Wood River and Wood River Wetland, Adjacent to Agency Lake).

Nearly 76 percent of all wetlands in this watershed are classified as palustrine emergent wetlands. Most of these areas (Map 7-1) are low gradient, spring fed meadows and irrigated pastures leading down to Agency Lake. Based upon historic descriptions of the area, it is likely that much of the area currently identified as palustrine emergent wetland was at one time palustrine forest or palustrine scrub shrub wetland. Throughout the watershed, woody vegetation was removed for agricultural use (USFS 1994).

Palustrine forest and palustrine scrub shrub wetlands are currently confined to areas immediately adjacent to major stream channels, including Wood River, Annie, Sun, Crooked, and Fort Creeks. Palustrine forested wetlands, making up just over 1 percent of wetlands found in this watershed, are found along low gradient channels. Locations include the western edge of the valley, in the transition zone between the Cascades and valley floor, along Annie Creek, where the channel gradient changes from the steep southern slopes of Crater Lake, and the more gradual slopes of the Wood River Valley. Palustrine scrub shrub wetlands, 1.5 percent of wetlands in this watershed, are often found in mid-elevations adjacent to palustrine forested wetlands; however, they can also be found in lower elevations within the watershed. The Wood River has almost a continuous band of palustrine scrub shrub wetlands along its mid to lower reach.

Lacustrine limnetic wetlands total 20 percent of the wetlands in this watershed. The largest expanse of lacustrine limnetic wetlands occurs near Agency Lake, at Wood River Marsh.

Figure 7-2. Aerial photo of the lower Wood River and Wood River Wetland, adjacent to Agency Lake (DEA 2009).

Klamath Lake

Of the three watersheds present in the subbasin, the Klamath Lake watershed has the greatest number of wetlands, totaling nearly 100,000 acres (USFWS 1981). Many former shoreline wetlands have been separated from Upper Klamath and Agency lakes by dikes which were built to increase the amount of land available for grazing (Haluska and Snyder 2007). However, one of the largest undrained wetlands, the Upper Klamath National Wildlife Refuge, exists in this watershed.

Almost 60 percent of the wetlands in this watershed are lacustrine limnetic wetlands (Map 7-1). These wetlands include Upper Klamath and Agency lakes, but also flat areas near the headwaters of Rock and Cherry Creeks. Lacustrine littoral wetlands, another class of lacustrine wetlands, make up less than 2 percent of the wetlands in the watershed. Upper Klamath National Wildlife Refuge has the largest concentration of lacustrine littoral wetlands, where pockets of water are surrounded by palustrine emergent wetlands.

Palustrine emergent wetlands are the second most common type of wetland in the watershed, totaling 35 percent. In the southern portion of the watershed, Aspen Lake, Round Lake, and

Long Lake Valley are palustrine emergent wetlands, created by depressions that collect water from springs and runoff from adjacent hillsides. Like the Wood River watershed, palustrine emergent wetlands in this watershed are found in abundance at lower elevations of the valley on land that has been drained and grazed and abuts Upper Klamath and Agency lakes. Barnes Ranch and Agency Lake Ranch, located on the edges of the lakes, were purchased in the mid-1990s by the Bureau of Reclamation, in order to restore the wetlands that had been degraded by agricultural activities (Shapiro 2000). Large palustrine emergent wetlands that have not been drained include Upper Klamath National Wildlife Refuge, Sesti Tgawaals Wildlife Area, Shoalwater Bay Wildlife Area, and Hank's Marsh (Lindenberg and Wood 2009).

An important wetland that was drained, but has been partially restored, Caledonia Marsh, has not been identified by GIS data as a wetland (Figure 7-3, Aerial Photo of Caledonia Marsh, Adjacent to Upper Klamath Lake). In 2006, the dike separating a portion of Caledonia Marsh from Upper Klamath Lake was unexpectedly breached, causing the marsh to flood (Lindenberg and Wood 2009). Prior to 2006, two parcels at Caledonia Marsh were already out of agricultural production and in the process of being restored (Lindenberg and Wood 2009).

Fourmile Creek

Of the three watersheds present in the subbasin, Fourmile Creek watershed has the least amount of wetland area, containing 3,400 acres, just 2 percent of all the wetlands found in the subbasin. Highly permeable soils and steep topography limit the amount of wetlands found in this watershed. However, depressions in the landscape, including high elevation lakes and low gradient portions of stream channels, provide for some wetland formation.

Figure 7-3. Aerial photo of Caledonia Marsh, adjacent to Upper Klamath Lake (DEA 2009).

Fourmile Lake and Lake of the Woods, identified as lacustrine limnetic wetlands, account for 54 percent, or 1800 acres, of the total wetland area in the watershed (Map 7-1). The remaining wetlands in the watershed are palustrine emergent (25 percent), palustrine forested (9 percent), riverine intermittent (4 percent), palustrine unconsolidated bottom (3 percent), palustrine scrub shrub (2 percent), lacustrine littoral (1 percent), and riverine upper perennial (1 percent) (a description of these wetland class characteristics is provided below). Three other wetland types occur: palustrine aquatic, palustrine unconsolidated shore, and riverine lower perennial, but total less than 1 percent combined and therefore will not be discussed further.

Palustrine emergent wetlands are interspersed with palustrine forested wetlands and are concentrated at the edges of Fourmile Lake, Lake of the Woods, the upper reaches of Lost Creek, and in the bottom of the Fourmile Creek drainage. Riverine intermittent wetlands can be found scattered throughout the upper reaches of the watershed, in areas where topographical relief has collected snowmelt and soils are highly permeable. Palustrine unconsolidated bottom wetlands are mainly located in small depressions upslope from Fourmile Lake and on the east slope of Mount McLoughlin. Palustrine scrub shrub wetlands are present in the upper elevations of the watershed, along perennial and intermittent streams, most commonly alongside palustrine emergent and palustrine forested wetlands. Minor instances of lacustrine littoral wetlands are found in shallow water at the periphery of both Fourmile Lake and Lake of the Woods. And finally, riverine upper perennial wetlands are located on the eastern slopes of the Cascades, mainly fed by snowpack and draining into Fourmile Lake.

Discussion

Upper Klamath and Agency lakes, which lie at the bottom of the subbasin, are the largest wetland features of the subbasin. These lakes, and the wetlands surrounding them, were formed by a glacial lake, Modoc Lake, and the deposition of clay soils that confine groundwater movement (Snyder and Morace 1997). Presently, through a combination of surface and subsurface flow, water in the subbasin collects to create one of the largest wetland features in the region. Surveys from the United States General Land Office (GLO) performed in the late 1800’s reveal that a diverse matrix of palustrine forested, scrub shrub and emergent wetlands once surrounded the lakes (OIT 2006). The arrival of settlers in the late 1800’s led to some significant changes to these wetlands. Some historians estimate that since the late 1800’s, nearly 65 percent of the area’s wetlands were drained for agricultural use (NRCS 2003). Further modifications were required when, in the 1920’s, the Bureau of Reclamation constructed the Link River Dam and raised water levels in the lake by two feet. Following dam construction, dikes were built to separate the wetlands from the lake, and then drainage ditches and pumps were used to regulate the water table (USFS 1994).

The loss of wetlands in the subbasin has led to reduced water quality, a reduction in available wetland habitat, and a reduction in water storage capacity. The increase in algal blooms and the decline in native species in the lakes and streams, coupled with the reduced availability of water for agriculture and habitat, has motivated private landowners and public agencies to restore wetlands within the subbasin.

Restoration project types include dike removal, riparian fencing, native planting and changes in land management, including dryland pasture, rotational grazing or farming, and enrollment in the NRCS Wetlands Reserve Program (WRP). It is important to note that almost all restoration projects are collaboration between private landowners and various public agencies. Projects at Barnes Ranch and Agency Ranch included dike removal and seasonal flooding with 700 acres of Agency Ranch being enrolled in the WRP (Peterson, pers. comm. 2009). Bureau of Land Management has also restored Wood River Wetland, shown in Figure 7-4 (Aerial Photo of the Wood River Wetland, Currently Being Restored), by controlling the hydrology to create permanent and semi-permanent wetlands (NRCS 2003). Extensive fencing along Sevenmile Creek/Canal and its tributaries have managed access of cattle and allowed hydric vegetation to regenerate (Peterson, pers. comm. 2009). Currently, USFWS is leading efforts to restore lower Fourmile Creek. Work is planned to begin in the fall of 2010; channelized reaches will be restored to a more natural condition, resulting in extended periods of inundation and restoration of wet meadow habitat. In addition, the Running Y Ranch has restored portions of Caledonia Marsh and there are plans to reconnect 7,000 acres of federally owned Agency Lake Ranch to Agency Lake and designate this land part of the Klamath Refuge system.

Monitoring of restoration projects provides valuable insight about the results of different types of restoration and management activities. Monitoring results show that fencing projects have allowed willow and aspen to regenerate, increasing the amount of palustrine scrub shrub and forested wetlands (Peterson, pers. comm. 2009).

Figure 7-4. Aerial photo of the Wood River Wetland, currently being restored (DEA 2009).

In order to explore the future wetland restoration needs within the subbasin, issues regarding water quality, habitat and water storage will be addressed individually, in the following paragraphs:

WATER QUALITY: Despite the significant restoration work that has been accomplished within the subbasin, water quality within Upper Klamath and Agency lakes continues to be a concern. This is due to a combination of the area's geology and current land use. High levels of naturally occurring phosphorous are found in spring fed streams, particularly Wood River and Annie Creek, and within the lake where nutrient rich sediments are constantly stirred up by wave action (Shapiro 2000 and DEQ 2002). Historic lake-fringe wetlands likely buffered this phosphorous loading to the lakes (Snyder and Morace 1997). When elevated levels of nutrients in the streams combine with nutrients from agricultural runoff, Upper Klamath and Agency lakes experience severe algal blooms for several months in the summer (DEQ 2002). Algal blooms disrupt pH and dissolved oxygen levels in the lakes, creating conditions that are harmful to fish (DEQ 2002).

Wetland restoration and monitoring efforts suggest short term negative impacts can result from restoration activities such as flooding previously drained wetlands. Examples include the recent restoration of the Wood River Wetland where inundation of previously drained wetlands had initial negative impacts on water quality. These negative impacts to water quality are a result of subsidence. Subsidence occurs when wetland soils are drained and exposed to oxygen and organic material stored in the soils quickly decomposes, releasing nutrients and minerals. Subsiding wetlands release carbon, nitrogen and phosphorous into the water when they are flooded (Carpenter et al. 2009).

USGS and Oregon State University conducted another study looking at water quality at restoration sites, focusing on phosphorous dynamics in restored wetlands around Upper Klamath Lake (USGS 2006). These studies along with future research will help to understand the short and long term effects of restoring once-drained wetlands, and how to minimize those effects.

HABITAT: Reduction of wetlands has reduced the amount of available wetland habitat and impacted several species. Specifically, Lost River (*Deltistes luxatus*) and Shortnose suckers (*Chasmistes brevirostrus*), once abundant in the subbasin, have declined in numbers so significantly that they were listed as endangered in 1988 (USFWS 2007a and 2007b). In addition to the degraded water quality within the lakes, they do not have adequate access to streams or springs for spawning, or palustrine emergent wetland habitat for larval and juvenile life stages (USFWS 2007a and 2007b). Suckers and other aquatic species have also been affected by the channelization and vegetation removal at lower stream reaches, where streams join Upper Klamath and Agency lakes. Prior to channelization, these locations would have been a diverse interface between lake and stream, with shifting sediments, variable water depths and a variety of vegetation and wetland habitats.

STORAGE CAPACITY: There have been several recent dry years in the Upper Klamath Lake Subbasin. Potential impacts from increased drought frequency become increasingly important in the context of climate change. In an effort to understand how drought will play a role in the future, it is important to reference the climate change studies that are occurring within the region. The results of the draft Klamath Basin Climate Futures Forum Report determine that climate change will lead to more severe weather patterns, an example of which may include extensive droughts. Several strategies mentioned in this report that may help buffer against such events include increasing groundwater aquifer recharge through the restoration of wetlands and floodplains, and providing incentives for water conservation (NCCSP and CLI 2010). In addition, restoring wetland and riparian systems will make them more resilient to extreme weather events.

Topographical features, geology, wetland size, and position in the landscape relative to other wetlands help determine the degree to which wetlands and subbasin wetland complexes contribute to, subtract from, and seasonally mediate the overall hydrology of a subbasin. An extensive amount of historic wetlands have been modified in the Upper Klamath Lake Subbasin; however, both large- and small-scale wetland restoration projects have been successfully implemented. The monitoring results of these projects with regards to the effects on water quality and species recovery will help to guide future efforts.

Confidence Evaluation

The overall confidence in the wetland assessment is moderate. National Wetlands Inventory (NWI) data were used extensively to determine present-day wetland conditions. NWI data are a nationally utilized data source generated by USFWS to identify sites across the country with wetland characteristics. NWI data were generated via aerial photo interpretation, and attempted to document all photo interpretable wetlands within their spatial database (USFWS 1981). It is likely that not all wetlands were mapped during this process. Most farmed wetlands are not mapped, and partially drained wetlands have been conservatively mapped given the limits of aerial photo interpretation (USFWS 1981). Therefore NWI data do not represent exact wetland boundaries to the level of precision that formal, on-the-ground wetland surveys and delineations do. As such, NWI boundaries should be considered generalized interpretations of wetland locations and sizes and should in no way be used to make jurisdictional determinations.

Available NWI data are appropriate for understanding large scale patterns, rather than fine scale details. The available NWI data allowed the identification of clear patterns that exist at a large scale, such as general wetland type and relative size. The data were not appropriate for evaluating individual wetland characteristics.

Research Recommendations

Many studies have been done, or are currently underway, to understand the impacts of wetland restoration activities. Thorough monitoring activities at wetland restoration sites have provided valuable information that can be used to improve future restoration activities. Existing restoration projects should continue to include monitoring to increase the volume and breadth of available data.

A large component of most wetland restoration projects includes deliberate changes in inundation. Continued studies of restored wetlands are needed in order to understand how water-level management affects soil conditions, plant species, biogeochemical processing, and nutrient losses and storage over time (Carpenter et al. 2009). In addition, research should address how multiple, completed projects throughout the subbasin work to collectively increase water storage.

Restoration and Management Opportunities

1. Continue to increase the proportion of palustrine emergent communities surrounding Upper Klamath and Agency lakes. Palustrine emergent communities were historically one of the dominant wetland types within the subbasin, but have been significantly altered by agriculture. Wetlands adjacent to Upper Klamath and Agency lakes have the ability to filter incoming sediments, moderate flood events, and absorb nutrients, thereby improving water quality within the lakes. The recovery and return of aquatic species such as endangered Lost River and Shortnose suckers and salmonids is contingent upon increased availability of palustrine emergent wetland habitat and improved water quality within Upper Klamath and Agency lakes.

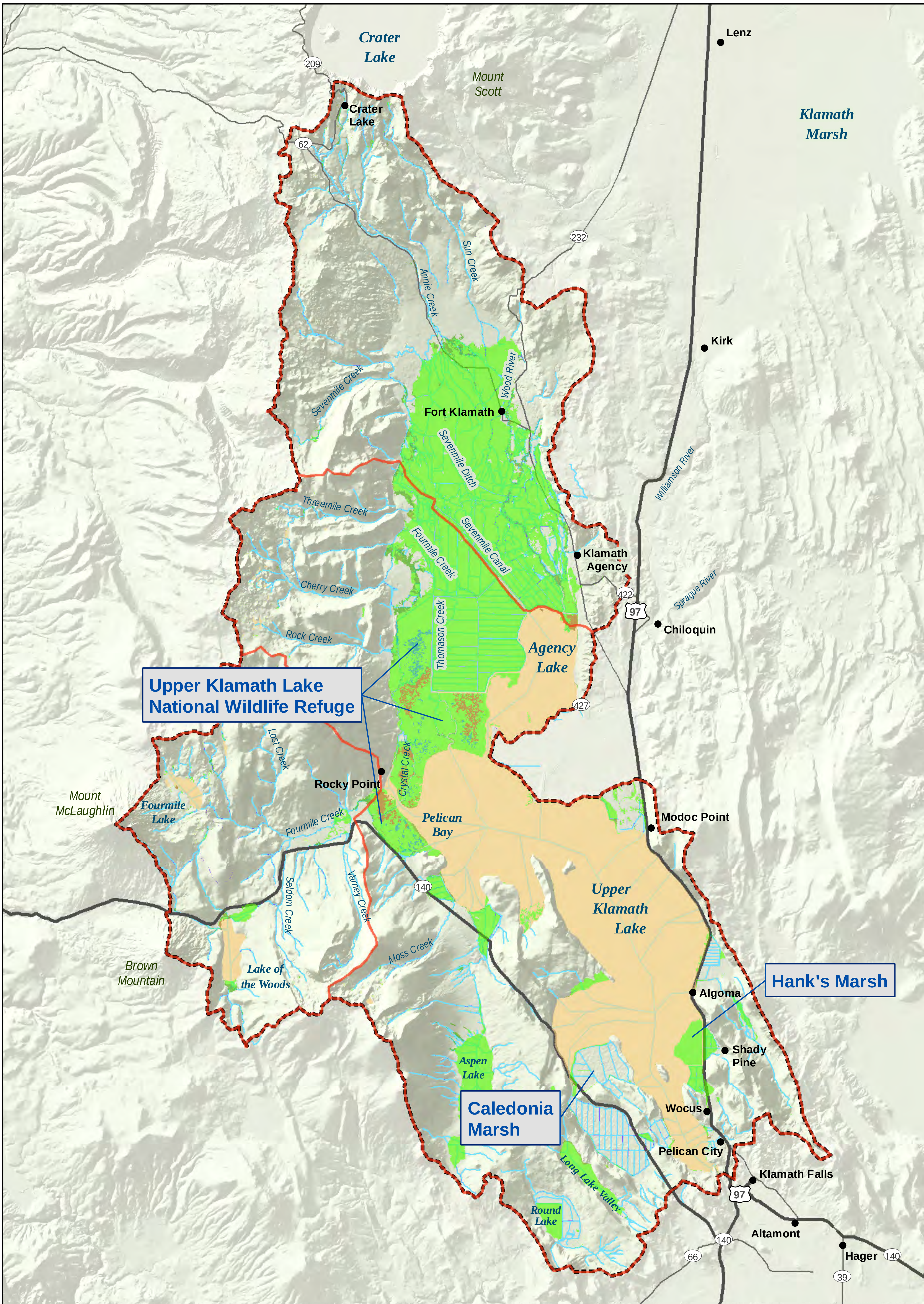
In addition to large-scale wetland restoration projects, management activities that balance both wetlands and agricultural use are recommended for implementation. Opportunities to manage previously drained wetlands as seasonal and permanent have been addressed by NRCS (NRCS 2003). Such efforts would include working with landowners who have significant wetland areas to restore them in a manner compatible with their land use efforts (i.e., grazing, agriculture, etc.). Prioritization of restoration project sites should be based on proximity to functioning wetland systems and existing restoration sites.

2. Increase the proportion of palustrine scrub shrub and forested wetlands throughout the subbasin. The historic proportion of palustrine scrub shrub and forested wetlands have been severely reduced by farming, grazing, and channelization. Only small pockets of scrub shrub and forested wetlands remain; however, they provide valuable ecological services in the subbasin such as habitat structure and forage for wildlife, bank stability, and improved conditions for aquatic species.

In recent years, fencing projects have successfully managed cattle access to riparian habitats allowing trees and shrubs to regenerate. As such, the quantity of riparian habitat in the subbasin has increased in the last decade. Locations where the land is farmed, rather than grazed, may provide opportunities for buffers (not requiring fences) between farming and streams, allowing scrub shrub communities to re-establish. Using cooperative management agreements that improve wetland structure and function between adjacent areas managed by the Fremont-Winema National Forest and private landowners, restoration actions could be targeted to expand on functioning scrub shrub forested wetlands in the Cascade foothills.

3. Enhance wetlands that are contributing to, or could contribute to, subbasin late season hydrological flows. Some wetland complexes, by virtue of their individual characteristics and position on the landscape, have the potential to mediate peak flows and contribute to late-season flows in the subbasin. Identification of these wetlands, and the specific conditions that are limiting their potential contributions, will help guide restoration efforts to enhance wetland systems and overall subbasin health. Wetland enhancement efforts that elevate water levels, reduce evapo-transpiration, and improve long-term storage would likely enhance late-season flows.

List of Maps



0 4 8
Miles

Source Data:
ESRI, Klamath County, Oregon GEO

Legend

- Subbasin Boundary
- Watershed Boundary - 5th Field
- Other Highway
- Major Road
- Lakes and Reservoirs
- Swamp or Marsh
- River/Stream/Canal

Cowardin Class

- Lacustrine Limnetic
- Lacustrine Littoral
- Palustrine Aquatic
- Palustrine Emergent
- Palustrine Forest
- Palustrine Scrub-Shrub
- Palustrine Unconsolidated Bottom
- Palustrine Unconsolidated Shore
- Riverine (General)
- Riverine Lower Perennial Aquatic Bed
- Riverine Lower Perennial Unconsolidated Bottom
- Riverine Upper Perennial
- Riverine Intermittent

Map 7-1: Existing Wetlands

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CHAPTER 8:

WATER QUALITY ASSESSMENT

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8 WATER QUALITY ASSESSMENT

Introduction

The purpose of the water quality assessment is to compile and evaluate available information about water quality within the subbasin, with the purpose of identifying areas of water quality impairment and where restoration efforts have the potential to improve water quality. The Oregon Department of Environmental Quality (DEQ) completed a Total Maximum Daily Load (TMDL) analysis for the Upper Klamath Lake Subbasin in 2002 (DEQ 2002a), the results of which were of particular value for this chapter of the assessment. Critical questions addressed in this section are as follows:

- What are the designated beneficial uses of water within the subbasin?
- What are the water quality criteria that apply to the subbasin?
- Are there stream reaches identified as water quality limited segments on the 303(d) list by the state?
- Are any stream reaches identified as high-quality waters or Outstanding Resource Waters?
- Do water quality studies or evaluations indicate that water quality has been degraded or is limiting the beneficial uses?

Methods

Information regarding designated beneficial uses, water quality criteria, and 303(d) listed waters were obtained from the DEQ website, which provides links to relevant Oregon Administrative Rules and to DEQ 303(d) databases. The DEQ 303(d) 2004/2006 Integrated Report Database was reviewed to identify water quality limited water bodies.

The Klamath Watershed Institute (KWI) at Humboldt State University has been compiling water quality monitoring station location information from federal, state, and tribal agencies, and other organizations for the entire Klamath River basin. KWI provided their data for the Upper Klamath Lake Subbasin in an excel spreadsheet format (KWI 2009), which includes latitude and longitude coordinates for water quality monitoring stations. KWI data were converted into a GIS shapefile (shown in Map 8-1, Water Quality). Tabular data providing a summary of data collected at each station are provided in Appendix A Water Quality Monitoring Database. However, this data set only contains information that was provided to KWI by participating entities and therefore may not be comprehensive. In the project area this includes data from: U.S. Geological Survey, Bureau of Reclamation, U.S. Bureau of Land Management, Klamath Tribes, and The Nature Conservancy. Data for the USFS lands are not included in the KWI data set; however, USFS data have been provided separately. In addition, Oregon DEQ station locations are provided in the KWI dataset; however, no DEQ monitoring stations are present within the Upper Klamath Lake Subbasin. KBRT has been conducting water quality monitoring, often times coupled with flow measurements, since 2002. These data are provided in annual monitoring reports from 2002 through 2006. Data collected since 2007 will be compiled into a single report at the end of 2010. Currently, there is not a single compiled data set of all monitoring stations.

Oregon DEQ conducted intensive riparian corridor mapping and stream temperature analysis for the Williamson and Sprague Rivers, which flow into Upper Klamath Lake but are outside of the assessment area. Unfortunately, similar studies were not performed for streams within the Upper Klamath Lake Subbasin.

Results

Designated Beneficial Uses

In-stream water quality requirements are based on the protection of recognized water uses, referred to as "designated beneficial uses" (OWEB 1999). The State of Oregon designates these uses for each basin within the state. Designated beneficial uses have been designated for the Upper Klamath Basin, which includes the Upper Klamath Lake Subbasin. Designated beneficial uses particular to the Upper Klamath Lake Subbasin are provided in Table 8-1, Designated Beneficial Uses for the Upper Klamath Lake Basin, Particular to the Upper Klamath Lake Subbasin and are discussed further in Chapter 4, Hydrology and Water Use.

Table 8-1. Designated Beneficial Uses for the Upper Klamath Lake Basin, Particular to the Upper Klamath Lake Subbasin

Public Domestic Water Supply	Boating	Wildlife and Hunting
Private Domestic Water Supply	Salmonid Fish Spawning (Trout)	Fishing
Industrial Water Supply	Salmonid Fish Rearing (Trout)	Water Contact Recreation
Irrigation	Resident Fish and Aquatic Life	Aesthetic Quality
Livestock Watering	Commercial Navigation	Hydro Power

Data Source: OAR 340-41-0180

Water Quality Criteria

Water quality rules contain both narrative and numeric standards. The following OARs provide general statewide narrative standards germane to this assessment. Numeric water quality criteria are provided in Table 8-2, General and Upper Klamath Basin-Specific Water Quality Criteria and Standards.

OAR 340-041-0007(1): "Notwithstanding the water quality standards contained in this Division, the highest and best practicable treatment and/or control of wastes, activities, and flows must in every case be provided so as to maintain dissolved oxygen and overall water quality at the highest possible levels and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor, and other deleterious factors at the lowest possible levels."

OAR 340-041-0007(2): "Where a less stringent natural condition of a water of the State exceeds the numeric criteria set out in this Division, the natural condition supersedes the numeric criteria and becomes the standard for that water body."

OAR 340-041-0007(9): "In order to improve controls over nonpoint sources of pollution, federal, State, and local resource management agencies will be encouraged and assisted to coordinate planning and implementation of programs to regulate or control runoff, erosion, turbidity, stream temperature, stream flow, and the withdrawal and use of irrigation water on a basin-wide approach so as to protect the quality and beneficial uses of water and related resources."

Table 8-2. General and Upper Klamath Basin-Specific Water Quality Criteria and Standards

(Basin-specific criteria are shown in italics, where such criteria have been developed)

Water Quality Attribute	Water Quality Criteria and Standards
Temperature	**Designated Core Cold Water Streams:** The seven-day-average maximum temperature may not exceed 16.0 degrees Celsius (60.8 degrees Fahrenheit)
	Designated Salmon and Trout Rearing and Migration Use Streams: The seven-day-average maximum temperature may not exceed 18.0 degrees Celsius (64.4 degrees Fahrenheit)
	Designated Redband Trout Use: The seven-day-average maximum temperature may not exceed 20.0 degrees Celsius (68.0 degrees Fahrenheit)
	Designated Bull Trout Use: The seven-day-average maximum temperature of a stream may not exceed 12.0 degrees Celsius (53.6 degrees Fahrenheit).
	Non-Designated/Unidentified Tributaries: For waters that are not identified on the DEQ "Fish Use Designations" maps the applicable criteria for these waters are the same criteria as is applicable to the nearest downstream water body depicted on the applicable map.
	Natural Lakes. Natural lakes may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the natural condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.
pH	**Fresh waters except Cascade lakes:** *pH may not fall outside the range of 6.5 to 9.0. When greater than 25 percent of ambient measurements taken between June and September are greater than pH 8.7, DEQ will determine whether the values higher than 8.7 are anthropogenic or natural in origin*.
	Cascade lakes above 5,000 feet altitude: *pH values may not fall outside the range of 6.0 to 8.5.*
Dissolved Oxygen	**Spawning areas used by native trout (applicable during spawning through fry emergence period):** Dissolved oxygen (DO) may not be less than 11.0 mg/l. However, if the minimum intergravel DO measured as a spatial median, is 8.0 mg/l or greater, then the DO criterion is 9.0 mg/l. Where conditions of barometric pressure, altititude, and termperature preclude attainment of the 11.0 mg/l criteria, DO levels must not be less than 95 percent saturation. The spatial median intergravel dissolved oxygen concentration must not fall below 8.0 mg/l.
	Cold-water aquatic life: DO may not be less than 8.0 mg/l as an absolute minimum. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/l, dissolved oxygen may not be less than 90 percent of saturation. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen may not fall below 8.0 mg/l as a 30-day mean minimum, 6.5 mg/l as a seven-day minimum mean, and may not fall below 6.0 mg/l as an absolute minimum.

Water Quality Attribute	Water Quality Criteria and Standards
Bacteria	The 30-day log mean of 126 E. coli organisms per 100 milliliters (minimum of 5 samples); No single sample may exceed 406 E. coli organisms per 100 milliliters.
Nuisance Phytoplankton Growth	**Lakes, reservoirs, and streams (excludes ponds and reservoirs less than ten acres in surface area, and marshes and saline lakes):** In natural lakes that thermally stratify, average Chlorophyll a concentrations must not exceed 0.01 mg/l. In natural lakes that do not thermally stratify, reservoirs, and rivers, average Chlorophyll a concentrations must not exceed 0.015 mg/l.

Data Source: General Water Quality Criteria, OAR 340-041-0001 through -0061;
Basin-Specific Water Quality Criteria, OAR 340-041-0185

Water Quality Limited Streams and the TMDL Process

Section 303(d) of the Federal Clean Water Act requires states to compile a list of waters suffering from water quality impairment. These water bodies are referred to as "water quality limited." States are required to establish TMDLs for all water quality limited water bodies, with the exception of those that are impaired by natural causes or where pollutants can not be defined (DEQ 2002a). The purpose of the TMDL is to analyze causes of water quality impairment and then establish the measures by which water quality standards will be met in the future. A Water Quality Management Plan (WQMP) is developed to implement these measures. Completion of the written WQMP results in delisting of 303(d) listed waters which fall under the plan, even if measures provided in the plan still need to be implemented. Therefore, while 303(d) listings provide a way to identify water quality impaired streams, they are limited in the sense that they do not identify streams that do not provide quality habitat or which are impaired by pollutants that are not considered for 303(d) listings or where there are not enough available data to make a determination.

Table 8-3, 1998 303(d) Listing Information for Upper Klamath Lake Subbasin Waterbodies, provides a list of waters within the Upper Klamath Lake Subbasin that were previously listed on the 303(d) list as impaired waters (water bodies shown on Map 8-1). These water bodies have been removed from the list, not necessarily because water quality has improved, but because a WQMP was prepared to address the area. In 2002, a TMDL and WQMP were completed for the Upper Klamath Lake Subbasin, which included the three fifth-field watersheds discussed in this assessment. This resulted in water quality impaired waters within the subbasin being delisted. Additionally, water bodies that did not meet habitat and flow conditions, although considered impaired, were removed from the 303(d) list because the parameter of concern was not considered to be a pollutant (DEQ 2002).

Table 8-3. 1998 303(d) Listing Information for Upper Klamath Lake Subbasin Waterbodies

River Segment	303(d) Listing Information (from 1998 list)
Upper Klamath and Agency lakes	**Parameter:** Chlorophyll a **Criteria:** Thermally stratified lake, 0.01 mg/l **Season:** Summer **Basis for Listing Consideration and Supporting Data:** Delisted in 2002 with approval of TMDL.
	Parameter: Dissolved Oxygen **Criteria:** Cool water: Not less than 6.5 mg/l **Season:** Summer **Basis for Listing Consideration and Supporting Data:** Delisted in 2002 with approval of TMDL.
	Parameter: pH **Criteria:** pH 6.5 to 8.5 **Season:** Summer
	Basis for Listing Consideration and Supporting Data: Delisted in 2002 with approval of TMDL.
Annie Creek	**Parameter:** Flow modification **River Miles:** 0 to 6.1 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined
	Basis for Listing Consideration and Supporting Data: Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.
	Parameter: Habitat modification **River Miles:** 0 to 6.1 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined
	Basis for Listing Consideration and Supporting Data: Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.
Cherry Creek	**Parameter:** Flow modification **River Miles:** 0 to 9.7 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined
	Basis for Listing Consideration and Supporting Data: Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.
Fourmile Creek	**Parameter:** Temperature **River Miles:** 0 to 1.0 **Criteria:** 17.8^{o} C (64.0^{o} F) **Season:** Summer
	Basis for Listing Consideration and Supporting Data: Delisted in 2002 with approval of TMDL.
	Parameter: Flow modification **River Miles:** 0 to 10.2 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined
	Basis for Listing Consideration and Supporting Data: Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.
Rock Creek	**Parameter:** Temperature **River Miles:** 0 to 5.7 **Criteria:** 17.8^{o} C (64.0^{o} F) **Season:** Summer
	Basis for Listing Consideration and Supporting Data: Delisted in 2002 with approval of TMDL.
	Parameter: Habitat modification **River Miles:** 0 to 5.7 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined
	Basis for Listing Consideration and Supporting Data: Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.
Sevenmile Canal	**Parameter:** Flow modification **River Miles:** 0 to 1.8 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined
	Basis for Listing Consideration and Supporting Data: Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.
	Parameter: Habitat modification **River Miles:** 0 to 1.8 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined
	Basis for Listing Consideration and Supporting Data: Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.

River Segment	303(d) Listing Information (from 1998 list)
Threemile Creek	**Parameter:** Habitat modification **River Miles:** 0 to 7.6 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined **Basis for Listing Consideration and Supporting Data:** Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.
Wood River	**Parameter:** Flow modification **River Miles:** 0 to 17.8 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined **Basis for Listing Consideration and Supporting Data:** Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed. **Parameter:** Habitat modification **River Miles:** 0 to 17.8 **Criteria:** conditions that are deleterious to fish or other aquatic life **Season:** Undefined **Basis for Listing Consideration and Supporting Data:** Delisted in 2002. Water quality limited but not a pollutant. No TMDL needed.

Data Source: DEQ 2006

Since completion of the Upper Klamath Lake Drainage TMDL and WQMP, a new water temperature standard was adopted for redband trout. The new standard came about as a result of improved understanding of redband trout's ability to tolerate warmer water temperatures compared to most other salmonid species. The new standard is 20.0^o C (68.0^o F).

Discussion of Water Quality Limited Water Bodies

This section provides a characterization of water quality conditions based on water bodies and water quality issues identified during the TMDL process.

Upper Klamath and Agency Lakes (Chlorophyll a, pH, and Dissolved Oxygen)

Upper Klamath and Agency lakes are large (90.9 and 13.7 square miles, respectively), shallow (mean depth approximately 6.6 feet), hypereutrophic (i.e., very high biological productivity and nutrient levels) lake systems (DEQ 2002). Low dissolved oxygen and pH water quality violations led to the 1998 303(d) listing of both Upper Klamath and Agency lakes. The Upper Klamath Lake TMDL was developed in 2002 to address the dissolved oxygen and pH problems. Development of the TMDL used a large database of lake and upland information that has been, and continues to be, collected by multiple academic efforts, government agencies and the Klamath Tribes.

Water quality standards are established to protect the beneficial uses of Upper Klamath and Agency lakes. The most sensitive beneficial uses are protected aquatic resources, including the shortnose sucker, Lost River sucker, and interior redband trout. Based on monitored levels of dissolved oxygen, pH and chlorophyll a, both Upper Klamath and Agency lakes were designated as water quality limited for resident fish and aquatic life.

Historical accounts indicate that Upper Klamath and Agency lakes were considered eutrophic (i.e., high biological productivity and nutrient levels) 100 years ago (DEQ 2002) as opposed to the current day hypereutrophic state. However, over that time period there have been numerous land and water use changes that have impacted watershed hydrologic regimes and nutrient export characteristics of the drainage. Land use practices have also affected nutrient cycling and leaching through the loss of wetlands (DEQ 2002, USGS 2009). The hydrology of both lakes has been changed by 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 the construction of the Link River Dam at the lake's outlet in the 1920's that allowed the lake to be operated as a storage reservoir. As a result, both the timing and quantity of lake flushing flows and nutrient retention dynamics have been altered, and lake surface elevation and volume are seasonally reduced below historic levels (DEQ 2002). Considerable changes in land management have also occurred relative to pre-settlement times, including a shift from native vegetation to forage production crops for grazing, and the conversion of 35,000 acres of wetlands to pasture and cropland on the lake periphery itself (Gearheart et al. 1995; Risley and Laenen 1999 as cited in DEQ 2002). These watershed land use and management changes are consistent with the types of activities that would cause altered hydraulic regimes (Poff et al. 1997 as cited in DEQ 2002) and increased nutrient loading to tributaries and Upper Klamath and Agency lakes (Carpenter and Cottingham 1997 as cited in DEQ 2002).

A study on nutrient concentrations of irrigation runoff in the Wood River system showed that dissolved phosphorus concentrations were consistently lower in headwater source areas such as upper Annie Creek and Sevenmile Creek than they were in irrigation water (Ciotti et al. 2009). While headwater concentrations of phosphorus may be considered high background compared to other watersheds it is lower than phosphorus found in most irrigation surface flows in the Wood River Valley (Ciotti et al. 2009). This study was performed in the upper Wood River Valley in upland mineral soils. Nutrient concentrations were low relative to those found by USGS and Reclamation at drained agricultural wetlands further down in the system (Ciotti pers. comm. 2009). The lower end of the valley and most of the agricultural lands around the lakes are peat soils where nutrient export potential is much greater during annual cycles of drainage followed by reflooding (Ciotti pers. comm. 2009). Additionally, the peat areas are also closer to the lake where export potential is greatest. This study also noted that the type of grazing and irrigation practices can have a considerable influence on the amount of nutrients entering waterways and eventually the lakes (Ciotti et al. 2009). The maintenance of healthy pasture (e.g., minimizing bare spots) and reducing concentrations of livestock near canals or other watering areas should reduce nutrient transport during flood irrigation events (Ciotti pers. comm. 2009).

Additionally, KBRT commissioned a test of water quality return flows in the Wood River Valley, to identify the main areas of poor quality and opportunities for addressing them through constructed wetlands (Graham Matthews and Associates 2010). The following conclusions were developed:

1. There are a wide range of nutrient concentrations present in irrigation ditches and drains within the Wood River Valley, most of which are elevated in TP and TN from background conditions.

2. Potential treatment wetland sites should be located where existing ditches are relatively shallow, currently convey a substantial percentage of the net export from West Canal, and have low to moderate discharge.

3. Since many of the ditches gain nutrients as they travel down-gradient, the most effective locations are in the middle of the valley (around Sevenmile Road), but before the drains become so deep that it would be difficult to move the water out of the ditch into a treatment wetland.

Both internal (i.e., lake-generated, typically bottom sediment nutrient release into the water column) and external (i.e., watershed generated) sources of total phosphorus were considered in DEQ's loading analysis. Lake outflow total phosphorus loads tended to increase during high runoff events in the spring (DEQ 2002). High outflow rates of phosphorus continue into the summer period when external load into the lake is low, indicating that phosphorus is internally loaded to the lake from the nutrient rich sediments (DEQ 2002). Internal loading of phosphorus from the lake sediments is a large source, producing roughly two thirds of the yearly average total load to the lake water column (DEQ 2002). Rykbost and Charlton (2001 as cited in DEQ 2002) and Kann and Walker (2001 as cited in DEQ 2002) documented elevated lake average total phosphorus concentrations in June, July, August, September and October. These seasonal increases in lake mean total phosphorus concentrations are the result of internal loading during this period. Large net internal loading events are generally followed by a substantial decline, indicating a sedimentation event. Such events coincide with algal bloom crashes where the cause is simply dead algae falling out of the water column and onto the lake sediment (Kann 1998 as cited in DEQ 2002).

Sediment cores were collected from Upper Klamath Lake to determine historic sedimentation rates and algal compositions deposited over the last 150 years (Eilers et al. 2001 as cited in DEQ 2002). Results obtained from this investigation indicate that water quality conditions within the lake have changed dramatically as development of the surrounding watershed progressed. The study showed that sediment accumulation rates have substantially increased in the 20th century. Mineral tracer analysis revealed strong evidence of increased sediment inputs to the lake associated with erosion and land use disturbance occurring within the watershed during the 20th century (DEQ 2002). In conclusion, the current day internal load of phosphorous within the lake bottom sediments has been highly influenced by actions within the watershed that occurred in the last century.

External sources represent the remaining one third of loading to the lake, largely coming from adjacent reclaimed wetlands and traditional upland sources of nutrients such as erosion, increased water yields (e.g., drainage improvements), riparian/wetland disturbance and natural sources such as springs (DEQ 2002). Table 8-4 (Distributions – External phosphorous loading, drainage area, and flow input to Upper Klamath and Agency lakes) provides the percent contribution of phosphorous by all sources to Upper Klamath and Agency lakes, including sources outside of the Upper Klamath Lake Subbasin (i.e., the Williamson and Sprague Rivers) (DEQ 2002). DEQ modeling efforts have shown that reductions in total phosphorus loading to the lakes will improve water quality to levels that comply with water quality standards (DEQ 2002).

Table 8-4. Distributions – External phosphorous loading, drainage area, and flow input to Upper Klamath and Agency lakes (Kann and Walker 2001 as cited in DEQ 2002).

Source Area/Type	Portion of Total Phosphorus Load	Portion of External Phosphorus Load	Portion of Drainage Area	Portion of Inflow Volume to Lake
Williamson River	8.0%	20.5%	35.9%	17.9%
Sprague River	10.3%	26.5%	43.4%	33.2%
Wood River	7.4%	19.1%	4.0%	16.4%
SevenMile Creek	3.5%	9.0%	1.1%	6.5%
Ag. Pumps Directly to Lake	4.4%	11.2%	1.1%	2.9%
Miscellaneous Sources	3.8%	9.8%	11.7%	16.1%
Precipitation	1.1%	2.7%	2.8%	7.0%
Chiloquin STP	0.1%	0.3%	n/a	~0.0%
Crooked Creek Hatchery	0.4%	1.0%	n/a	~0.0%
Internal Loading	61.0%	n/a	n/a	n/a

A statistical correlation between lake-mean total phosphorus, chlorophyll a and pH was realized from analysis of the data used in the TMDL and WQMP document and this was used to support the use of total phosphorus as a controlling parameter for addressing adverse pH and dissolved oxygen levels in the lakes (DEQ 2002). A lake-mean total phosphorus concentration of approximately 100 µg /l corresponds to a mean chlorophyll a concentration of approximately 66 µg/l and a mean pH of 9.0 in June and July (DEQ 2002). Thus, the nutrient phosphorus helps to fertilize algal blooms within the lake.

Low dissolved oxygen and high pH levels have been linked to high algal productivity in both lakes (Kann and Walker 2001 and Walker 2001 as cited in DEQ 2002). Chlorophyll a concentrations exceeding 200 µg/l are frequently observed in the summer months (Kann and Smith 1999 as cited in DEQ 2002). This is far greater than the water quality criteria of no more than 10 µg/l. Algal blooms are accompanied or followed by deviations from Oregon's water quality standards for pH, dissolved oxygen and free ammonia.

Chlorophyll a is a measure of the amount of algae in the water column. When algal growth (a.k.a. chlorophyll a) becomes excessive it can have considerable adverse effects on water chemistry, including large swings in pH and dissolved oxygen concentrations. The cyanobacterium *Aphanizomenon flos-aqaue* (AFA) is the primary species of algae that causes large, deleterious blooms within Upper Klamath and Agency lakes (Figure 8-1, Photo of algae bloom [Aphanizomenon flos-aquae] in Upper Klamath Lake) (Hoilman and others et al. 2008 as cited in USGS 2009). These blooms result in significant water quality deterioration due to photosynthetically elevated pH (Kann and Smith 1993 as cited in DEQ 2002) and to both supersaturated and low DO concentrations (Kann 1993a, 1993b as cited in DEQ 2002). Adverse effects that detract from native fish survival and viability occur during periods of both high pH and low DO. These blooms are seasonally and spatially variable throughout the lake systems (DEQ 2002). Year to year variations in the timing and development of algal blooms during late spring and early summer are largely temperature dependent (DEQ 2002, USGS 2009). The more general seasonal pattern of the algal bloom boom and bust cycle, along with the relationship to phosphorous concentrations and pH levels, is displayed in Figure 8-2 (Observed total phosphorous, Chlorophyll a, and pH values).

Figure 8-1. Photo of algal bloom (Aphanizomenon flos-aquae) in Upper Klamath Lake (DEQ 2002).

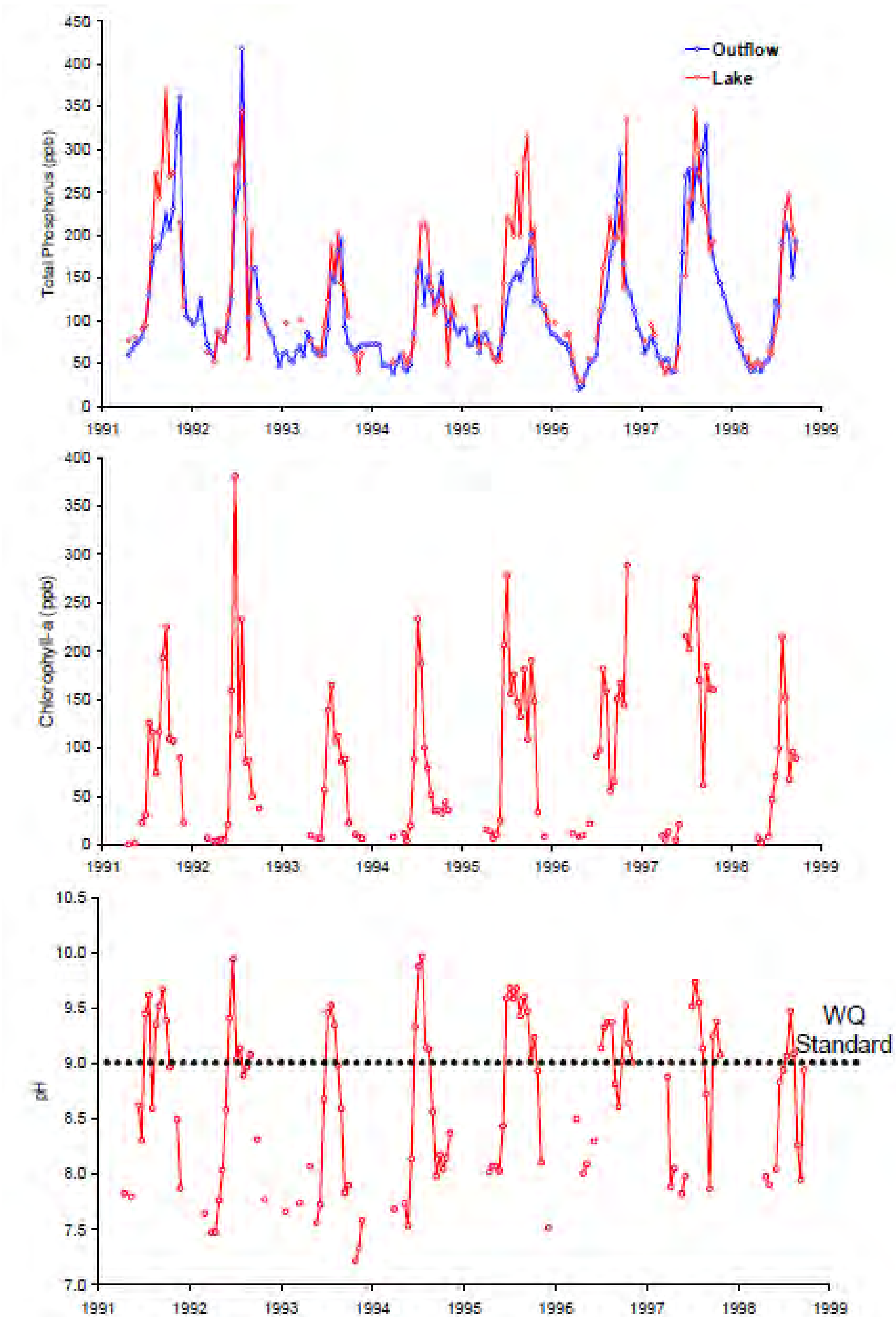


Figure 8-2. Observed total phosphorous, Chlorophyll a, and pH values (DEQ 2002 citing data from Kann 2000).

Agency Lake was determined to have a seasonal cycle of AFA bloom and decline similar to, but independent from, that of Upper Klamath Lake (USGS 2009). Circulation patterns in Upper Klamath Lake have been explored with measurements and modeling (Gartner et al. 2007 and Wood et al. 2008 as cited in USGS 2009). These studies have confirmed that during periods of prevailing northwesterly winds, circulation is clockwise around the lake, consisting of a broad and shallow southward flow through most of the lake and along the northern and eastern shorelines, and a narrow, deep, northward flow through the trench along the western shoreline (USGS 2009). This description of the wind-driven currents indicates that poor water quality conditions, particularly low dissolved oxygen, that are observed in the northern part of the lake do not primarily originate locally. Instead, the circulation pattern could allow transportation of poor water quality conditions originating in the southern part of the lake through the trench west of Bare Island into the northern part of the lake (USGS 2009). In addition to the above measured and modeled water quality/circulation patterns, anecdotal evidence suggests that algae tends to collect in Howards Bay due to eddie/lake circulation patterns and may result in poorer water quality in this area relative to the rest of the lake (Curtis pers. comm. 2009).

It is important to note that considerable efforts have been made, and continue to be made, to reverse many of the land use and management impacts on water quality, while still allowing for sustainable economic use of natural resources. For example, although continued work is still needed to improve the water quality of Upper Klamath and Agency lakes, a considerable amount of wetland adjacent to the lakes has been restored and reconnected to the lake. In addition, significant riparian improvements have taken place on both private and public lands. Figure 8-3 (Reclaimed wetland acreage and restoration) shows the trend in wetland loss and subsequent restoration that has taken place in wetlands surrounding the lakes. However, Figure 8-3 only accounts for restoration projects completed through the year 2000 and several thousand acres more have been restored since this time period (e.g., Williamson River Delta south).

It is also important to highlight management actions on some reclaimed lands that help to minimize adverse effects to water quality. For example, irrigation practices at the Running Y Ranch (reclaimed Wocus Marsh) pull water into the irrigation system during periods of high lake levels and then recirculate the tail water through their agricultural fields until after the end of the growing season. Tail water is not pumped back into the lake until January through April and thus minimizes the amount of nutrient rich irrigation return water flowing into Upper Klamath Lake during the period of highest water quality concern (i.e., the late spring through summer months) (Curtis pers. comm. 2009).

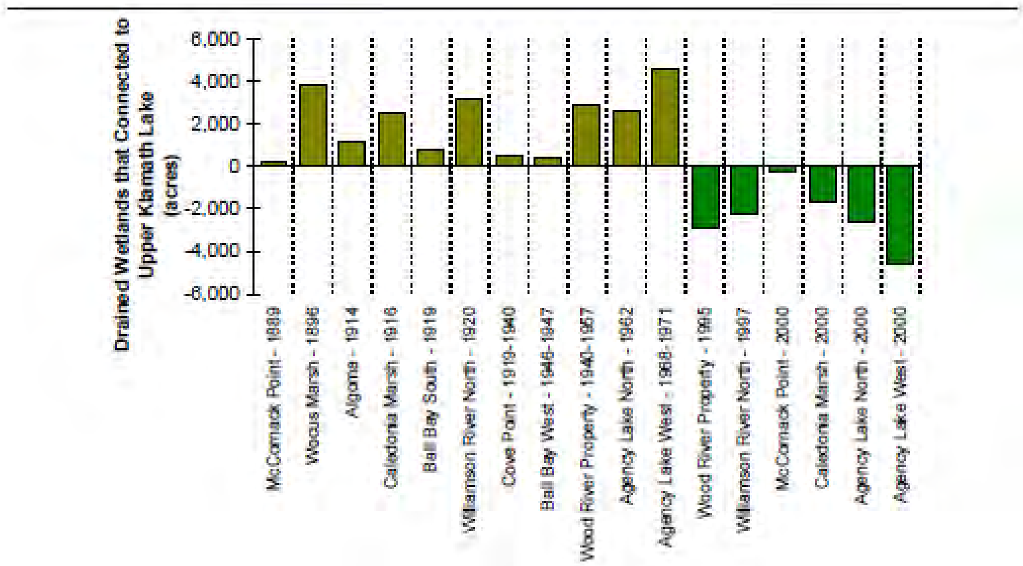


Figure 8-3. Reclaimed wetland acreage and restoration. (Snyder and Morace 1997 and Snyder 2001 as cited in DEQ 2002).

Fourmile Creek and Rock Creek (Temperature)

Many of the tributary streams, particularly the perennial streams, within the Upper Klamath Lake Subbasin contain cool to very cold water, as a result of groundwater inputs such as springs. Table 8-5, Temperature of springs contributing flows to Upper Klamath Lake Subbasin streams provides a partial list of springs that provide consistent cool water inflows to various tributaries within the Wood River watershed. These springs provide a critical source of cool water, with even the warmest spring flows (i.e., Tecumseh Spring) being below the lowest water temperature criteria for Upper Klamath Lake Subbasin streams (i.e., bull trout use criteria of no more than 53.6^{o} F).

Table 8-5. Temperature of springs contributing flows to Upper Klamath Lake Subbasin streams, August 18-28, 1989

Spring Name	Flows To	Elevation (ft)	Temp ^{o}F
Annie Spring	Annie Creek	6,040	37.2
Blue Springs	Sevenmile Creek	4,180	39.7
Mares Egg Spring	Crane Creek	4,154	41.4
Fourmile Spring	Fourmile Creek	4,153	41.4
Wood River source	Wood River	4,199	42.3
Tecumseh Spring	Crooked Creek	4,199	51.3
Reservation Spring	Fort Creek	4,179	46.8
Crooked Creek source	Crooked Creek	4,177	45.0
Fish Hatchery Springs	Fort Creek	4160	44.6 – 47.1

Data Source: (USGS 1990)

Despite the cool water inputs described above, Fourmile Creek and Rock Creek were previously listed on the 303(d) list for temperature and included in the temperature TMDL for the Upper Klamath Lake Subbasin. The TMDL documentation does not provide specifics for the listing of these two streams. The temperature TMDL focused on conducting riparian shading data collection and modeling for the Williamson River and Sprague River, but did not include as intensive efforts on most of the tributaries of these rivers and Upper Klamath and Agency lakes. Nevertheless, it can be inferred from the TMDL document (DEQ 2002) that the listing of Fourmile and Rock Creeks was a function of poor streamside shading, as there are no point sources of heat load to these creeks. Figure 8-4 (Temperature graphs for Fourmile and Rock Creeks) provides temperature graphs for Fourmile and Rock Creeks. As displayed in these graphs, the temperature criteria are met within the perennial reaches of these creeks. However, within the lower reaches that go dry every summer, temperature exceeds specified criteria (Anderson pers. comm. 2009). Information regarding riparian conditions and the benefits of shading are provided in Chapter 6, Riparian Assessment.

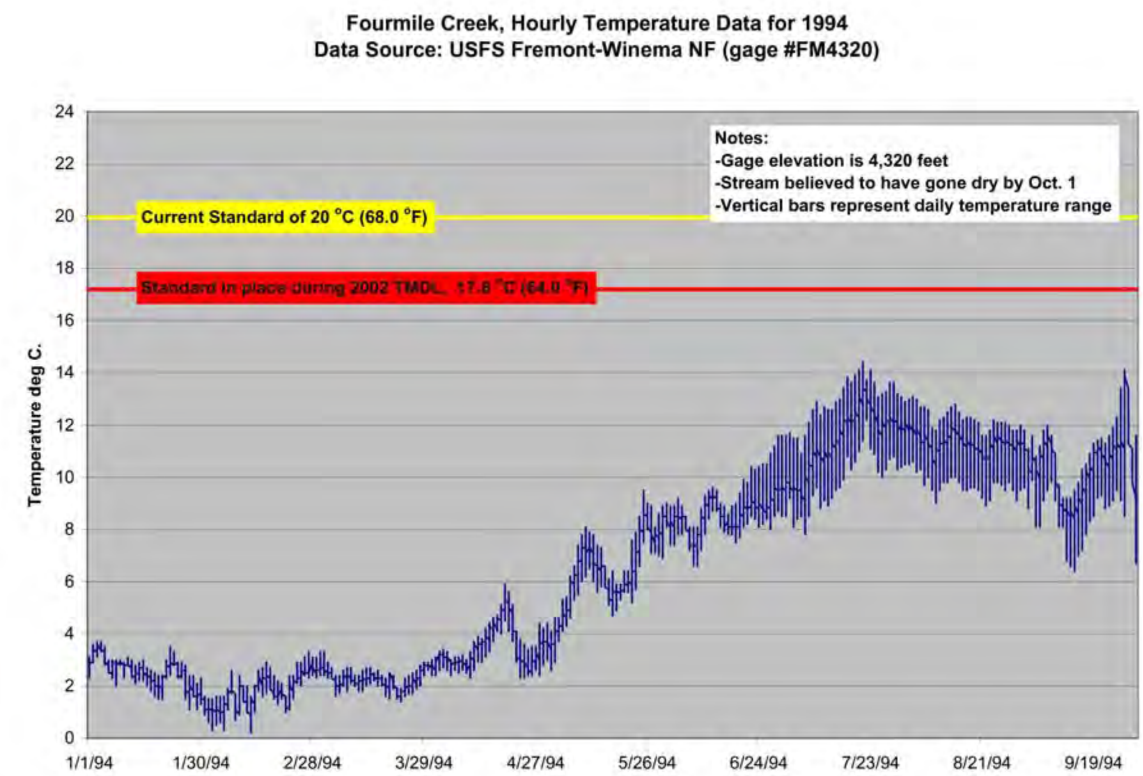
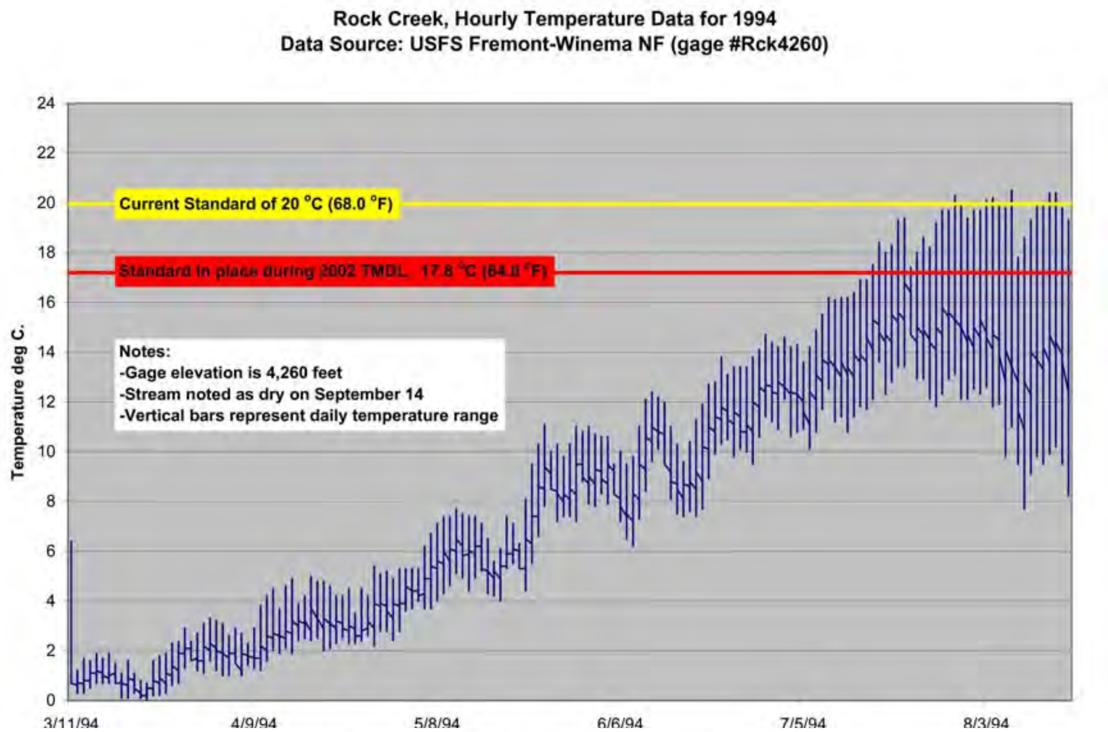


Figure 8-4. Temperature graphs for Fourmile and Rock Creeks (prepared by DEA from USFS 2009).



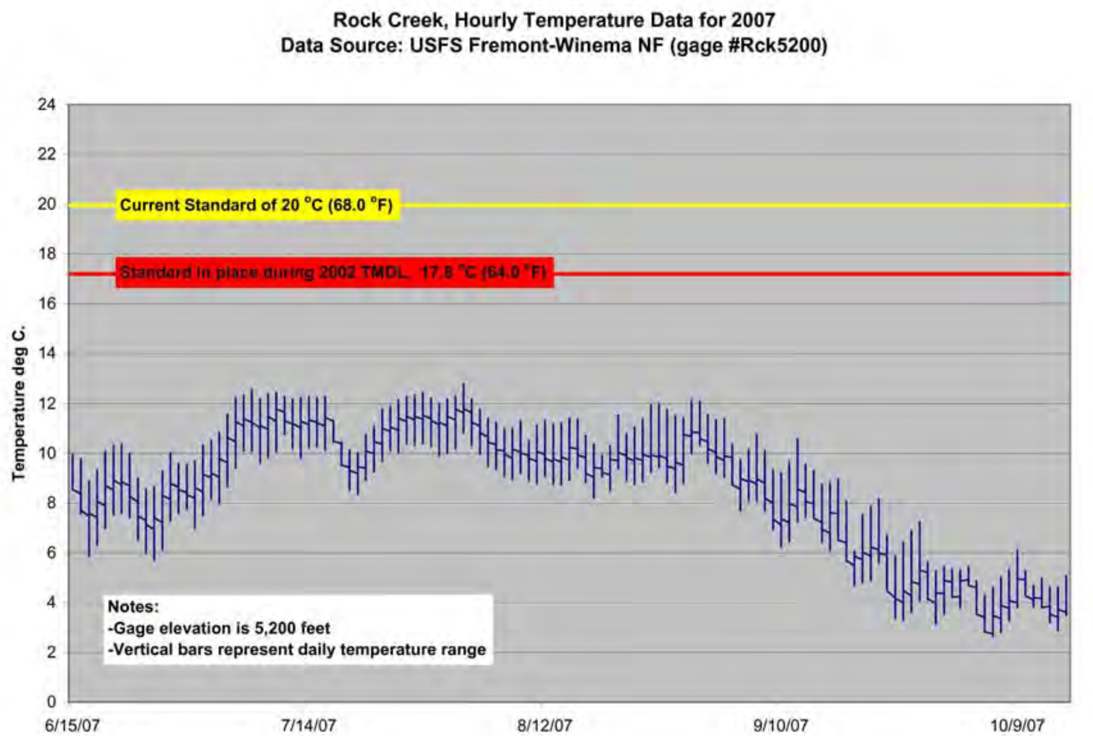


Figure 8-4.Continue - Temperature graphs for Fourmile and Rock Creeks (prepared by DEA from USFS 2009).

Habitat and Flow Modified Streams

The following streams were previously 303(d) listed due to poor habitat quality and/or adverse flow modifications: Annie Creek, Cherry Creek, Fourmile Creek, Rock Creek, Sevenmile Creek, Threemile Creek, and the Wood River. A TMDL was not prepared for these streams with respect to habitat and flow modifications because these types of impairments are not considered to be pollutants. A discussion of habitat and flow modifications to these various streams is provided in other chapters of this assessment.

Outstanding Resource Waters

The Outstanding Resource Waters policy is carried out by DEQ. This policy is governed under OAR 340-041-0004. This OAR states that "where existing high quality waters constitute an outstanding State or national resource such as those waters designated as extraordinary resource waters, or as critical habitat areas, the existing water quality and water quality values must be maintained and protected, and classified as Outstanding Resource Waters of Oregon." There have been no Outstanding Resource Waters designated for the Upper Klamath Lake Subbasin (Wigal pers. comm. 2009).

Confidence Evaluation

Confidence in the water quality evaluation is moderate to high with respect to the parameters of concern (i.e., water temperature, pH, chlorophyll a, and dissolved oxygen). Extensive monitoring, modeling, and other research was conducted on Agency Lake, Upper Klamath Lake, and their tributary streams by DEQ and other agencies, including the Klamath Tribes, as part of the development of the TMDL and WQMP for the Upper Klamath drainage basin. The water quality data that were collected in preparation for the 2002 TMDL are still being collected; however, analysis of this newer data has not occurred in a formal manner and thus represents a data gap (i.e., data are available but have not been interpreted) (Kirk pers. comm. 2009).

This water quality assessment, combined with the depth of local knowledge, is more than sufficient for a general understanding of water quality conditions within the subbasin to determine general and specific protective and restorative measures. As part of the TMDL process, water quality management plans have been prepared by the USFS and the U.S. Department of Agriculture-Natural Resource Conservation Service. The USFS directs land management activities on the largest block of public land in the watershed (i.e., Fremont-Winema National Forest). The USDA-NRCS direct water quality outreach programs to private land owners (i.e., programs funded through USDA-NRCS). Additionally, public agencies, non-profits, private landowners, and the Klamath Tribes continue to work together to address many of the habitat and flow related water quality impairments within the subbasin. The Bureau of Reclamation has not prepared a water quality management plan for lands managed at the north end of Agency Lake because these properties were intended to be reconnected to the lake and transferred to the USFWS refuge system (Kirk and Cameron pers. comm. 2009). These efforts have taken longer than originally anticipated. The lack of an approved water quality management plan from the Bureau of Reclamation may be considered a data gap with respect to the TMDL process.

The USGS is currently conducting nutrient studies of bed sediments and pore water in Upper Klamath and Agency lakes, with published results anticipated in June of 2010 (Cameron pers. comm. 2009). This information, combined with past lake nutrient studies, should provide a moderate to high level of understanding of the magnitude and mechanisms of nutrient loading within the lakes from internal sources.

A great deal of work has been accomplished and continues to be conducted by public agencies, private landowners, non-profits, and the Klamath Tribes to reduce external sources of nutrients to the lakes. It is likely the issue of internal loads of nutrients to the lake causing hypereutrophic conditions will be of greater concern than that of external sources. Although some conversations have been had on how to address internal lake nutrient loads, a formal evaluation has not been conducted and therefore represents an important data gap (Cameron pers. comm. 2009).

Research Recommendations

The following studies are proposed to address the data gaps described above.

1. Evaluate water quality data recorded after the 2002 TMDL process to assess more recent trends and compare with previously evaluated data.

2. Conduct an opportunities and constraints analysis for lowering in-lake stores of nutrients (i.e., internal loading of nutrients from bottom sediments to water column) from Upper Klamath and Agency lakes with the goal of returning the lakes to a eutrophic rather than a hypereutrophic condition. Opportunities should focus on public and private sectors and potential collaboration between the two (Cameron pers. comm. 2009). Constraints should focus on economic, ecological, logistical, and cultural/social factors.

Restoration and Management Opportunities

The following restoration actions are proposed to improve water quality conditions within the Upper Klamath Lake Subbasin:

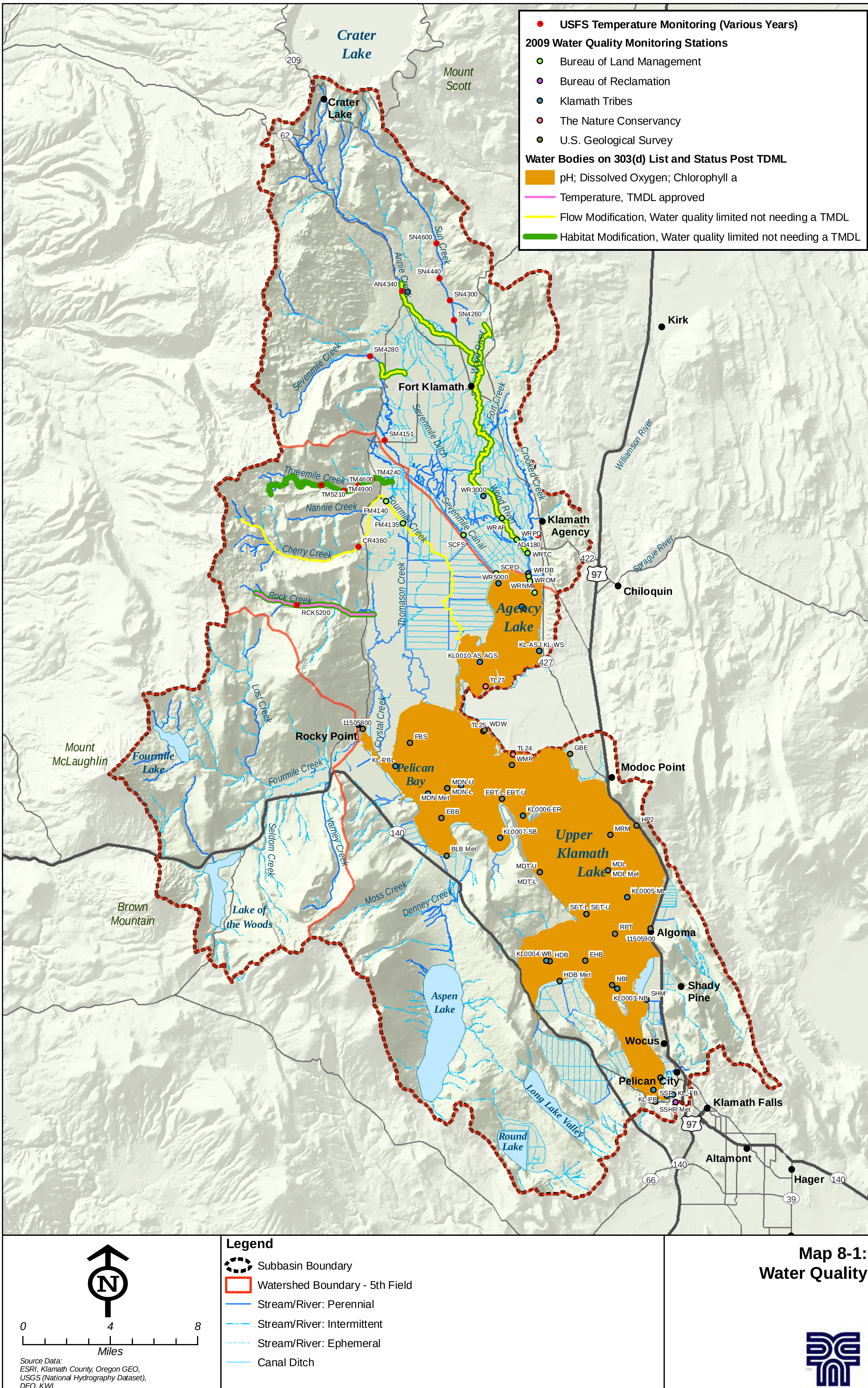
1. Conduct a pilot project to investigate removal of in-lake stores of nutrients (see research recommendation above).

2. Develop flow management and critical springs site protection plan(s) to protect important cold water flows to Upper Klamath and Agency lakes, and their tributaries. Emphasis should entail protection of these flows during critical periods (i.e., summer and early fall months).

3. Continue efforts to identify and implement grazing management strategies that meet water quality objectives. As part of this effort, riparian areas should be evaluated as to the potential for replanting and species selection. Grazing management should evaluate the benefit of livestock exclusion or managed grazing through timing, duration, and frequency. This would allow the streams to begin to restore channel form naturally by reducing stream bank erosion processes. In areas where exclusion fencing is used, it may be preferable to replant in some areas so that riparian shrub and tree species can reestablish more successfully. While vegetated riparian areas do reduce nutrient loading during the growing season, when plants are dormant they can act as nutrient sources, releasing accumulated nutrients to adjacent streams. Periodic harvesting (e.g., managed grazing) of plant biomass may be useful to reduce dormant season loading of P (USGS 2007). Riparian restoration would also provide future imports of coarse organic matter and large wood, which would improve food chain support function and habitat complexity respectively (also mentioned in Chapter 6, Riparian Assessment).

4. Provide stock watering areas away from waterways to reduce direct release of animal excrement into stream systems and reduce trampling of riverbanks and associated vegetation (also mentioned in Chapter 6, Riparian Assessment).

List of Maps



Map 8-1: Water Quality

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CHAPTER 9:

FISH AND FISH HABITAT ASSESSMENT

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9 FISH AND FISH HABITAT ASSESSMENT

Introduction

The purpose of the fish and fish habitat assessment is to compile and evaluate available information about fish populations, distribution, habitat, and migration barriers. This section addresses the following critical questions:

- What fish species are documented in the subbasin? Are any of these currently state or federally listed as endangered or candidate species? Are there any fish species that historically occurred in the watershed which no longer occur there?
- What are the distribution, relative abundance, and population status of salmonid and other key species in the subbasin?
- Which salmonid and key species are native to the subbasin, and which have been introduced?
- Are there potential interactions between native and introduced species?
- What is the condition of fish habitat in the subbasin according to existing habitat data?
- Where are potential barriers to fish migration?

Methods

The following data sources were reviewed to determine fish species presence and distribution within the study area and were used to prepare the fish distribution map (Map 9-1, Fish Distribution).

- ODF fish presence/absence maps GIS layer.
- ODFW Native Fish Status Report (ODFW 2005)
- ODFW bull trout distribution GIS data.
- Upper Klamath Lake Drainage TMDL and WQMP (DEQ 2002)
- Business Plan for the Upper Klamath Basin Keystone Initiative, a 10-Year Initiative to Secure Upper Klamath Basin Native Fish Populations: Lost River Sucker, Shortnose Sucker, and Klamath Redband Rainbow Trout (Version 1.0). (USFWS et al. 2008)
- Draft-fish species presence in forest streams, west zone Fremont-Winema National Forests, relative to the operations of water diversions and absence of fish screening (USFS 2003).
- Winema National Forest Fish Distribution Database (USFS 2010)

Mapped distribution of bull trout in this watershed assessment is based solely on ODFW GIS data. In contrast, a compiled GIS dataset for redband and sucker species was not available and therefore a compilation of the data sources listed above were used to map their distribution.

The analysis of fish habitat conditions relied on existing data and reports, data produced by other sections of this watershed assessment, several brief site visits, and communications with resource agency staff. Due to the scope of this assessment most streams have not been visually surveyed and none of the streams were physically surveyed (i.e., extensive measurements taken).

Additional methodology is provided as needed in the following “Results” subsections.

Results

Map 9-1 shows fish presence/absence and known species distribution within the study area. Table 9-1, Streams/Waterbodies Mapped as Containing Fish, provides a list of streams for each fifth-field watershed identified on Map 9-1 as containing fish. Only streams with known fish presence are listed – creeks of unknown fish presence are not included in Table 9-1. Table 9-2, Documented Fish Species within the Upper Klamath Lake Subbasin provides a list of documented fish species for the Upper Klamath Lake Subbasin.

Table 9-1. Streams/Waterbodies Mapped as Containing Fish (Native and/or Non-Native Species)

Fifth-Field	Stream/Water Body
Klamath Lake	Agency Lake
	Upper Klamath Lake
	Threemile Creek
	Fourmile Creek
	Crane Creek
	Cherry Creek
	Rock Creek
	Crystal Creek
	Thomason Creek
	Denny Creek
	Crane Creek
	Lajeunesse Creek
	Moss Creek
	Recreation Creek
Fourmile Creek	Fourmile Creek
	Long Creek
	Seldom Creek
	Billie Creek
	Swan Creek
	Fourmile Lake
	Lake of the Woods

Fifth-Field	Stream/Water Body
Wood River	Wood River
	Sun Creek
	Annie Creek
	Fort Creek
	Crooked Creek
	Agency Creek
	Sevenmile Creek
	Short Creek

Data Source: ODF GIS fish presence data

Table 9-2. Documented Fish Species within the Upper Klamath Lake Subbasin

Native Species		Non-Native Species	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Blue Chub	*Gila coerulea*	Alligator gar	*Atractosteus spatula*
Bull Trout	*Salvelinus confluentus*	Brook Trout	*Salvelinus fontinalis*
Klamath Lake Sculpin	*Cottus princeps*	Brown Bullhead	*Ameirus nebulosus*
Klamath Lamprey	*Lampetra similis*	Brown Trout	*Salmo trutta*
Klamath Largescale Sucker	*Catostomus snyderi*	Channel catfish	*Ictalurus punctatus.*
Lost River Sucker	*Deltistes luxatus*	Cut throat trout	*Oncorhynchus clarki*
Marbled Sculpin	*Cottus klamathensis*	Fathead Minnow	*Pimephales promelas*
Redband Trout	*Oncorhynchus mykiss*	Goldfish	*Carassius auratus*
Shortnose Sucker	*Chasmistes brevirostris*	Guppies	*Poecilia spp.*
Slender Sculpin	*Cottus tenuis*	Introduced Rainbow Trout	*Oncorhynchus mykiss irideus*
Speckled Dace	*Rhinichthys osculus klamathensis*	Kokanee Salmon	*Oncorhynchus nerka kennerlyi*
Tui Chub	*Gila bicolor*	Largemouth Bass	*Micropterus salmoides*
		Mollies	*Poecilia spp.*
		Pumpkinseed	*Lepomis gibbosus*
		Sacramento perch	*Archoplites interruptus*
		White sturgeon	*Acipenser transmontanus*
		Yellow Perch	*Perca flavescens*

Data Source: DEQ 2002

Threatened, and Endangered Fish Species

Under the federal Endangered Species Act (ESA), the term "threatened species" means any species (or subspecies or distinct population segment for vertebrate organisms) that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. The term "endangered species" means any species that is in danger of extinction throughout all or a significant portion of its range. The principal considerations in the determination of whether a species warrants listing are the threats that currently confront the species and the likelihood that the species will persist in the foreseeable future. Thus, listing of a species as either threatened or endangered may be warranted when the species still occupies much of its historic range but currently confronts significant, widespread threats. In contrast, if not currently confronted by significant threats, a species occupying only a small portion of its historic range may be considered to be neither threatened nor endangered. Table 9-3, Proposed, Candidate, and Listed Fish within the Upper Klamath Lake Basin provides a list of fish within the Upper Klamath Lake Subbasin that are proposed, candidate, or listed threatened or endangered.

Table 9-3. Proposed, Candidate, and Listed Fish within the Upper Klamath Lake Basin

Species	Federal Status	State Status
Bull Trout	Threatened	Threatened
Shortnose Sucker	Endangered	Endangered
Lost River Sucker	Endangered	Endangered

Fish Species Historically Present

Historically, three species of anadromous fish migrated from the Pacific Ocean up the Klamath River and into Upper Klamath Lake: steelhead trout (*Oncorhynchus mykiss*), Chinook salmon (*Oncorhynchus tshawytscha*), and Pacific lamprey (*Entosphenus tridentatus*) (ODFW 2008). These migrations occurred until construction of Copco Dam in 1917 (ODFW 2005).

While these species are no longer present in the region because of dams, many state and federal agencies, tribes and stakeholders have prepared and adopted a plan for the reintroduction of these anadromous species to the Upper Klamath Basin (ODFW 2008). The impetus for this plan revolves around new fish passage requirements being imposed on the four mainstem dams of the Klamath River Hydroelectic Project, owned and operated by PacifiCorp, as part of the Federal Energy Regulatory Commission (FERC) relicensing process (ODFW 2008). Additionally, negotiations have been underway regarding future fish and water management in the Klamath River basin that could potentially result in the removal of all four dams (ODFW 2008). All of these actions suggest that anadromous fish will, once again, be present within Upper Klamath Lake and its tributaries.

Species Profiles

Focal Species

Redband Trout

Oregon basin redband trout occupy remnant streams in seven Pleistocene lake beds in Oregon, including the Klamath basin (i.e., Lake Modoc) (ODFW 2004b). Desiccation of the prehistoric lakes resulted in the formation of stream/marsh/lake systems, which redband trout adapted to by establishing adfluvial life histories; meaning the fish would migrate from the highly productive rearing areas in the lakes and marshes to spawning areas in streams (ODFW 2004b). During severe drought episodes, which could cause complete desiccation of the lakes and marshes, streams provided refuge for populations that would later return to the lakes and marshes when they refilled (ODFW 2004b). The Klamath basin is the only one of the seven former Pleistocene lake bed systems that has an outlet to the ocean. The other six systems are closed basins. Redband within these closed basins are referred to as “Great Basin redband trout.”

“The Upper Klamath Lake Basin supports the largest and most functional adfluvial redband trout populations of Oregon interior basins.” (ODFW 2005). Redband trout of the Upper Klamath Lake Subbasin are part of the Upper Klamath Lake group. The Upper Klamath Lake group is distinguished from redband trout found in the Upper Williamson River group, as the Upper Klamath Lake group is resistant to the disease *Ceratomyxa shasta*, which is found in Upper Klamath Lake and the lower Williamson River (ODFW 2004b). The upper Williamson River group, however, lacks this resistance.

Within the Upper Klamath Lake Subbasin, the Upper Klamath Lake group consists of the Lower Williamson River, Wood River, and Cascade Complex populations. The Cascade Complex population of redband trout refers to the population that utilizes the streams flowing off of the eastern slopes of the Cascade mountains and into the west side of Upper Klamath Lake, excluding the Wood River watershed that contains the Wood River population of redband trout. Redband trout in individual streams of the Cascade Complex population may prove to be separate populations (ODFW 2005). Table 9-4, ODFW Fish Status Report Findings for Redband Trout, (ODFW 2005) provides pass/fail ratings for these three populations as rated by ODFW. Irrigation diversions and habitat degradation in the lower reaches likely prevent movement among streams, limiting the ability of fish in these streams to function as a single population. However, until additional information proves otherwise, redband trout in streams of the Cascade Complex are treated as a single population.

Table 9-4. ODFW Fish Status Report Findings for Redband Trout

Population	Existence	Distribution	Abundance	Productivity	Reproductive Independence	Hybrid
Cascade Complex	Pass	Fail	Fail	Fail	Pass	Pass
Wood River	Pass	Pass	Pass	Pass	Pass	Pass
Lower Williamson River	Pass	Pass	Pass	Pass	Pass	Pass

Data Source: ODFW 2005

The Cascade Complex received failing scores for distribution, abundance, and productivity. Distribution failed due to extremely limited distribution throughout this complex (i.e., less than six stream miles) (ODFW 2005). Abundance failed; however, this failure can be partly attributed to a lack of a sufficient quantity of data. Nevertheless, available data do suggest that redband trout density is low (i.e., <0.06 fish/m^2) in the Cascade Complex system with the exception of

Cherry Creek, which had moderate densities (i.e., 0.06 – 0.19 fish/m^2) (ODFW 2005). Productivity data are not available; therefore, this criterion was assessed based on qualitative aspects of productivity. Productivity failed in the Cascade Complex due to a combination of degraded habitat, presence of brown trout and/or brook trout, or limited expression of a migratory life history (i.e., ability to move from streams to the lakes) due to irrigation diversions and withdrawals (ODFW 2005).

While the Cascades Complex received many failing scores, the Wood River and Lower Williamson River populations received passing scores for all measured parameters. Distribution passed because populations in these two systems occupy greater than six miles of habitat within their respective populations and have connections to other populations (ODFW 2005). Abundance passed in these two populations due to extremely high abundance, possibly the largest of Oregon's interior basins (ODFW 2005). Productivity passed, with long term redd (trout spawning nests) counts in both populations showing stable or increasing trends in abundance. Redd counts in Fort Creek, a tributary of the Wood River, exceed 80 redds annually and typically are much greater (ODFW 2005). Redd counts for the Wood River have been greater than 200 each year since 2001 (ODFW 2005). Despite these high redd counts and passing score for productivity, habitat in the Wood River system is impacted by water diversion and withdrawal (ODFW 2005). The Wood and Lower Williamson populations are both able to express an adfluvial life history.

Redband trout females typically select redd sites in gravel substrates at the head of a riffle or downstream edge of a pool (Orcutt et al. 1968 as cited in Weyerhaeuser Company 1996). Hatching of fry occurs within 30 to 40 days and is partly dependent on water temperature (Scott and Crossman 1973 as cited in Weyerhaeuser Company 1996). The fry emerge from the gravels within approximately two weeks, where they then stay near stream margins through the summer and over winter in shallow areas with good cover (Weyerhaeuser Company 1996). Following the first winter, juveniles move to deeper and faster water as they grow (Everest and Chapman 1969 as cited in Weyerhaeuser Company 1996). Following the second winter they seek larger pools and are typically reproductively mature by the following spring (Holton 1953 as cited in Weyerhaeuser Company 1996). Adult redband prefer water temperatures between 12.8 and 18.3^{o} C (55 and 65^{o} F) (Cherry et al. 1977 as cited in Weyerhaeuser Company 1996). Growth rate slows above 20.0^{o} C (68^{o} F) (i.e., current water quality standard for redband trout) and is believed to stop at 25.0^{o} C (77^{o} F) (Hokanson et al 1977 as cited in Weyerhaeuser Company 1996).

Bull Trout

The following description is provided by USFWS, 2009b, except where noted.

Bull trout were listed as threatened under the ESA in June 1998 and critical habitat was designated in 2005. A Recovery Plan was drafted in 2005 and has not been finalized. On January 13, 2010, the USFWS proposed to revise its 2005 designation of critical habitat for bull trout. The proposed revision is the result of review of earlier bull trout critical habitat proposals and the 2005 designation, public comments and new information. The USFWS voluntarily embarked on this re-examination to ensure that the best science was used to identify the features and areas essential to the conservation of the species.

Current presence of bull trout in the Upper Klamath Lake Subbasin has only been documented in Sun Creek and Threemile Creek (ODFW 2005). Sevenmile Creek contained a population of bull trout, but this population is now considered extinct (ODFW 2005). Table 9-5, ODFW Fish Status Report Findings for Bull Trout, provides pass/fail ratings for these populations (ODFW 2005).

Table 9-5. ODFW Fish Status Report Findings for Bull Trout

Population	Existence	Distribution	Abundance	Productivity	Reproductive Independence	Hybrid
Sun Creek	Pass	Fail	Pass	Pass	Pass	Pass
Threemile Creek	Pass	Fail	Fail	Fail	Pass	Pass
Sevenmile Creek	Fail	Not applicable, population is extinct				

Data Source: ODFW 2005

Current spawning and distribution of bull trout in the Klamath Basin is highly fragmented and limited to a few headwater streams (ODFW 2005). Poor water quality and irrigation diversions have isolated populations, minimizing opportunities for bull trout to express a migratory life history, mix among other populations, and colonize unoccupied habitats (ODFW 2005). The Sun Creek population is estimated to contain greater than 100 adults, which enabled it to pass the abundance criterion. In contrast, the Threemile Creek population failed this criterion due to there being fewer than 100 adults leading to a risk of inbreeding. ODFW has been working in cooperation with USFS, NPS, and the Bull Trout Working Group, undertaking efforts to prevent competition and hybridization of bull trout with non-native brook trout since 1992 (see section “Interactions Between Native and Non-Native Species” below).

Bull trout are native throughout the Pacific Northwest. In Oregon, bull trout were historically found in the Willamette River and major tributaries on the west side of the Oregon Cascades; the Columbia and Snake Rivers and major tributaries east of the Cascades; and in streams of the Klamath basin. Currently, most bull trout populations are confined to headwater areas of tributaries to the Columbia, Snake, and Klamath Rivers.

Bull trout are vulnerable to many of the same threats that have reduced salmon populations. Due to their need for very cold waters and a long incubation time, bull trout are more sensitive to increased water temperatures, poor water quality and degraded stream habitat than many other salmonids. Further threats to bull trout include hybridization and competition with non-native brook trout, brown trout and lake trout, overfishing, poaching, and man-made structures that block migration.

The bull trout population in Threemile Creek is particularly vulnerable because it is in a very small sixth field watershed with very heavy fuel loadings. As such, this population is at high risk of loss due to a catastrophic wildfire. A well designed fuel reduction project in this watershed could greatly reduce the risk of a stand-replacement fire burning out this isolated, small population of bull trout.

Bull trout are seldom found in waters where temperatures are warmer than 59º to 64º F. Besides very cold water, bull trout require stable stream channels, clean spawning gravel, complex and diverse cover, and unblocked migration routes. Small bull trout eat terrestrial and aquatic insects but shift to preying on other fish as they grow larger. Large bull trout are primarily fish predators. Bull trout evolved with sculpins and other trout, and use all of them as food sources. Resident adult bull trout can reach up to 10 inches long, while adult migratory bull trout can grow to 36 inches in length and weigh up to 32 pounds. Bull trout reach sexual maturity at between four and seven years of age and are known to live as long as 12 years. They spawn in the fall after temperatures drop below 48º F, in streams with abundant cold, unpolluted water, clean gravel and cobble substrate, and gentle stream slopes. Many spawning areas are associated with cold water springs or areas where stream flow is influenced by groundwater. Bull trout eggs require a long incubation period compared to other salmon and trout, hatching in late winter or early spring. Fry may remain in the stream gravels for up to three weeks before emerging. Bull trout less than 200 mm in length have been observed swallowing brook trout and brook trout and bull trout hybrids over 100 mm by night divers involved in removal efforts on Threemile Creek (Smith and Anderson pers. comm. 2010).

Bull trout may be either resident or migratory. Resident fish live their entire lives near areas where they were spawned. Migratory fish are usually spawned in small headwater streams, and then migrate to larger streams, rivers, lakes, or reservoirs where they grow to maturity. Smaller resident fish remain near the areas where they were spawned while larger, migratory, fish will move considerable distances to spawn when habitat conditions allow. For instance, bull trout in Montana's Flathead Lake have been known to migrate up to 250 kilometers (150 miles) to spawn. Bull trout in the Upper Klamath Subbasin currently only show a resident life history due to their very limited distribution in the headwaters of Sun Creek and Threemile Creek. Historically, they are believed to have shown a migratory life history, with range expansion and population exchange available via migration through Upper Klamath and Agency lakes.

Shortnose Sucker

The following description is provided by USFWS, 2008a, except where noted.

The shortnose sucker was listed as endangered in 1988, a Recovery Plan was published in 1993, critical habitat was proposed in 1994, but not finalized, and a five-year status review was conducted in 2007 (USFWS, 2007b). Extensive research since 1993 has provided a substantial amount of new scientific information for the shortnose sucker. The USFWS is in the process of revising the Recovery Plan to incorporate this knowledge and refine the recovery strategies accordingly. The process began in fall of 2008 and will continue through early 2010. The Desert Research Institute has been contracted by USFWS to facilitate the review. The Recovery Plan review will be an open process, with opportunity for stakeholder engagement that will be focused through the Recovery Implementation Committee (RIC). The RIC consists of representatives from various interest groups in the Upper Klamath Basin including watershed councils, tribes, non-profits, resource agencies, local governments, and other interest groups.

Shortnose suckers were once widespread and abundant in the Upper Klamath Basin where wetlands protected sucker habitats by reducing erosion forces, removing organic and inorganic nutrients, and maintaining water quality. Agricultural development and associated water and land use changes in the basin have contributed to the significant loss of these wetlands. The resulting reduction and degradation of shortnose sucker lake and stream habitats have led to a significant decline in population. Although over-harvesting and pollution may have played a role in the species decline, it is believed that the construction of dams, the draining or dredging of lakes, and other alterations of natural stream flow have reduced the reproductive success of shortnose suckers by as much as 95 percent through the loss of suitable spawning habitat. At the time the shortnose sucker was listed as endangered, it was noted that there had been no significant addition of young into the population in 18 years. Currently, the shortnose sucker occupies only a fraction of its former range and is restricted to a few areas in the Upper Klamath Basin, including Upper Klamath Lake and its tributaries. Poor water quality, reduced suitable habitat for all size and age classes, and the impacts of non-native fishes continue to threaten remaining shortnose sucker populations.

Shortnose suckers are distinguished by their large heads with oblique, terminal mouths with thin but fleshy lips. The shortnose sucker can live up to 33 years and is usually less than 50 centimeters (20 inches) in length. The diet of this bottom-feeding species consists of detritus (decomposing organic matter), zooplankton (tiny floating aquatic animals), algae, and aquatic insects. Shortnose suckers reach sexual maturity around six or seven years and then participate in spawning migration. Adult suckers migrate from the quiet waters of lakes, such as Upper Klamath and Agency lakes, into fast moving streams from March through May in order to spawn; they may also spawn in springs from February to late April when water temperatures are a constant 15^0 C (60^0 F). Thousands of eggs (from 18,000 for smaller fish to 46,000 for larger fish) are typically laid near the stream bottom in areas where gravel or cobble is available. Once the larvae hatch, they begin migrating back to calmer waters.

The shortnose sucker dwells in the deeper water of lakes and spawns in springs or tributary streams upstream from its home lake. Areas with gravel or close-set stone (cobble) bottoms are generally preferred for spawning habitat. In addition, spawning streams have a fairly shallow shoreline with an abundance of aquatic vegetation; these areas provide a safe haven for the young larvae during their journey back downstream to their home lakes or the deep, quiet waters of rivers. Shoreline vegetation in both lake and river habitats is important for the rearing of larval and juvenile suckers.

Suckers that reside in Upper Klamath and Agency lakes utilize spawning habitat in the Williamson River, Wood River, Sprague River, and a number of cold water springs that flow directly into the lakes. Historically, sucker spawning occurred in other Upper Klamath Lake tributaries including Crooked Creek, Fort Creek, Sevenmile Creek, Fourmile Creek, Odessa Creek and Crystal Creek, (Stine 1982 as cited in USBR 2001) in addition to springs surrounding

Upper Klamath Lake including Barkley Springs, Harriman Springs, four unnamed springs on the eastside of Upper Klamath Lake, Odessa Springs, and Bare Island Springs (Cascade Quality Solutions 2005). Although no rigorous spawning run surveys have been conducted in these locations, infrequent visual, electrofishing, trap and trammel net surveys have been conducted by Reclamation, Klamath Tribes, ODFW, Cell Tech, and Oregon State University (OSU) over the last decade. As of 2001 there was no documented evidence of sucker spawning runs in these streams or springs (USBR 2001).

Although a number of factors have contributed to the decline of the shortnose sucker, habitat degradation is considered the primary cause. Streams, rivers, and lakes have been modified by channelization and dams. Appropriate management of the timing and duration of grazing within the riparian zone is critical in maintaining proper streambank vegetation and streambank integrity. Improperly functioning riparian zones reduce the efficiency of sediment transport, increasing suspended sediment and nutrients within the river system. Lack of aquatic vegetation and high sediment content in streams results in eggs and larvae either being suffocated or dried out and consumed by other fish. In addition, loss of streambank vegetation due to overgrazing, logging activities, agricultural practices, and road construction has also led to increases in stream temperatures, high levels of nutrients (which encourages the buildup of excess algae and bacteria), and serious erosion and sedimentation problems in streams. Such water quality problems have reduced the availability of suitable shortnose sucker habitat and have resulted in high rates of fish mortality. Entire age classes of young suckers are routinely lost due to poor water quality conditions. As a result, few young suckers survive to sexual maturity, and therefore, do not increase the population size. Other factors affecting the decline of the shortnose sucker include previous over-harvesting, chemical pollution from pesticides, herbicides, and forestry practices, and predation and competition from native and non-native fishes such as largemouth bass, blue chub, yellow perch, fathead minnows, and rainbow trout.

Lost River Sucker

The following description is provided by USFWS, 2008b, except where noted.

The Lost River sucker was federally listed as endangered in 1988, a Recovery Plan was published in 1993, critical habitat was proposed in 1994, but not designated, a status review was conducted in 2004, and a five-year review was done in 2007 (USFWS 2007a). Extensive research since 1993 has provided a substantial amount of new scientific information for the Lost River sucker. The USFWS is in the process of revising the Recovery Plan to incorporate this knowledge and refine the recovery strategies accordingly. The process began in fall of 2008 and will continue through early 2010. The Desert Research Institute has been contracted by USFWS to facilitate the review. The Recovery Plan review will be an open process, with opportunity for stakeholder engagement that will be focused through the Recovery Implementation Committee (RIC). The RIC consists of representatives from various interest groups in the Upper Klamath Basin including watershed councils, tribes, non-profits, resource agencies, local government, and other interest groups.

Reasons for decline of the Lost River sucker are similar to those described above for the shortnose sucker, which include extensive loss of wetland habitats, pollution, past overharvesting, dam construction, draining and/or dredging of lakes, and other alterations to natural stream flows. Also similar to the shortnose sucker, the Lost River sucker reproductive success has been diminished by up to 95 percent through the degradation of suitable breeding habitat and, at the time of listing, there had been no significant addition of young into the population in 18 years.

Locally known as mullet, the Lost River sucker is a large, long-lived sucker that can reach 43 years of age. It has unique triangular-shaped gill structures which are used to strain a diet of detritus (decomposing organic matter), zooplankton (tiny floating aquatic animals), algae, and aquatic insects from the water. Lost River suckers typically begin to reproduce at nine years, when they first participate in spawning migration. Adult suckers migrate from the quiet waters of lakes into fast moving streams from March through May in order to spawn. They may also spawn in lakeshore springs from February to mid-April when the water temperature is a constant 15° C (60° F). Thousands of eggs (from 44,000 for smaller fish to 218,000 for larger suckers) are typically laid near the stream bottom in areas where gravel or cobble is available. Once the eggs hatch, the larval fish begin their migration back to calmer waters. They generally migrate at night and stay in shallow, shoreline areas and in aquatic vegetation during the day. Upon their return to the lake, larvae may be preyed upon by largemouth bass, yellow perch, or other non-native predatory fish, and larger juveniles may compete for food with non-native fishes such as fathead minnows, yellow perch, and others.

The Lost River sucker dwells in the deeper water of lakes and spawns in springs or tributary streams upstream of the home lake. Areas with gravel or close-set stone ("cobble") bottoms in springs or in moderate to fast-flowing streams are preferred for spawning. In addition, the spawning streams should have a fairly shallow shoreline with abundant aquatic vegetation; these areas provide a safe haven for the young larvae during their journey back downstream to their home lakes or the deep, quiet waters of rivers.

Currently, the Lost River sucker occupies only a fraction of its former range and is restricted to a few areas in the Upper Klamath Basin, such as Upper Klamath Lake and its tributaries. Suckers that reside in Upper Klamath and Agency lakes utilize spawning habitat in the Williamson River, Wood River, Sprague River, and a number of cold water springs that flow directly into the lakes. Historically, sucker spawning occurred in other Upper Klamath Lake tributaries including Crooked Creek, Fort Creek, Sevenmile Creek, Fourmile Creek, Odessa Creek, and Crystal Creek (Stine 1982 as cited in USBR 2001) in addition to springs surrounding Upper Klamath Lake including Barkley Springs, Harriman Springs, four unnamed springs on the eastside of Upper Klamath Lake, Odessa Springs, and Bare Island Springs (Cascade Quality Solutions 2005). Similar to the shortnose sucker, there is no recent documented evidence of sucker spawning runs in these streams or springs (USBR 2001).

A number of factors, similar to those discussed above for shortnose sucker, have contributed to the decline of the Lost River sucker. Poor water quality, reduced suitable habitat for all sizes and ages, and the impacts of non-native fishes continue to threaten remaining Lost River sucker populations.

Non-Native Trout Species

Brook Trout

Brook trout prefer clear, cool, well-oxygenated water. They are found in creeks, lakes, and small- to medium-size rivers. Brook trout feed on a wide range of organisms, including worms, leeches, crustaceans, insects, mollusks, fishes, and amphibians (Fishbase 2004). Introduced fish in California have been documented to reach 15 years of age (Fishbase 2004). Importantly, brook trout reach sexual maturity at an earlier age than bull trout and therefore can out reproduce them. Additionally, brook trout can hybridize with native bull trout which, as mentioned previously, is seen as a large threat to existing bull trout populations (Anderson pers. comm. 2009).

Brown Trout

Brown trout prefer cold, well-oxygenated waters. Their temperature and water quality tolerance limits are lower than that of rainbow trout. Brown trout favor large streams in mountainous areas with adequate cover in the form of submerged rocks, undercut banks, and overhanging vegetation. They feed on aquatic and terrestrial insects, mollusks, crustaceans, and small fish. Brown trout mature in 3 to 4 years. Reproduction takes place in rivers, with the female producing approximately 10,000 eggs (Fishbase 2004).

Rainbow Trout

Rainbow trout prefer moderate- to fast-flowing, well-oxygenated water for breeding, but are also found in cold lakes (Fishbase 2004). Adults feed on aquatic and terrestrial insects, mollusks, crustaceans, fish eggs, minnows, and other small fishes (including other trout). The young feed primarily on zooplankton (Fishbase 2004). Due to the prevalence of *C. Shasta* non-native rainbow trout cannot survive unless in the headwaters above Upper Klamath Lake. They are no longer stocked by ODFW, except in Spring Creek (Anderson pers. comm. 2009).

Interactions Between Native and Non-Native Trout Species

Interactions between native redband trout and bull trout and non-native trout species can potentially occur through competition for resources, predation between species (particularly adult predation of juveniles), and interbreeding between native and non-native stocks. These potential interactions are discussed in further detail below.

In the Upper Klamath Lake Subbasin it appears that brook trout do adversely affect populations of native redband and bull trout species (Anderson and Buktenica pers. comm. 2009). Although adult native trout can fare well against adult non-native brook trout, juvenile native trout have a harder time competing. As mentioned previously, interbreeding of non-native brook trout with native bull trout is also a problem (Anderson pers. comm. 2009). Non-native brown trout pose a significant threat to native trout species, but not through hybridization (Smith pers. comm. 2010).

Efforts have been underway by ODFW and the Bull Trout Working Group to remove brook trout from streams containing bull trout within the Upper Klamath Lake Subbasin (Anderson and Buktenica pers. comm. 2009). These efforts have focused on the middle to upper reaches of Sun Creek and Threemile Creek. Electrofishing and other methods (e.g., antimycin) have been used to remove brook trout and bull trout hybrids in the creek reaches containing bull trout located above manmade fish passage barriers. In the case of Sun Creek, the NPS installed two log and rock migration barriers specifically to prevent upstream migration of brook trout into upstream creek reaches where brook trout were being removed (Bucktenica 1993). The USFS installed a barrier on Threemile Creek. In addition, a downstream barrier was installed by ODFW with assistance from KBRT. Figure 9-1 (Fish Observed and Removed at Threemile Creek Above 3413-110 Culvert Crossing, 1997 through 2008) shows a small but improving bull trout population on Threemile Creek resulting from brook trout and brook-bull trout hybrid removal efforts (USFS 2009).

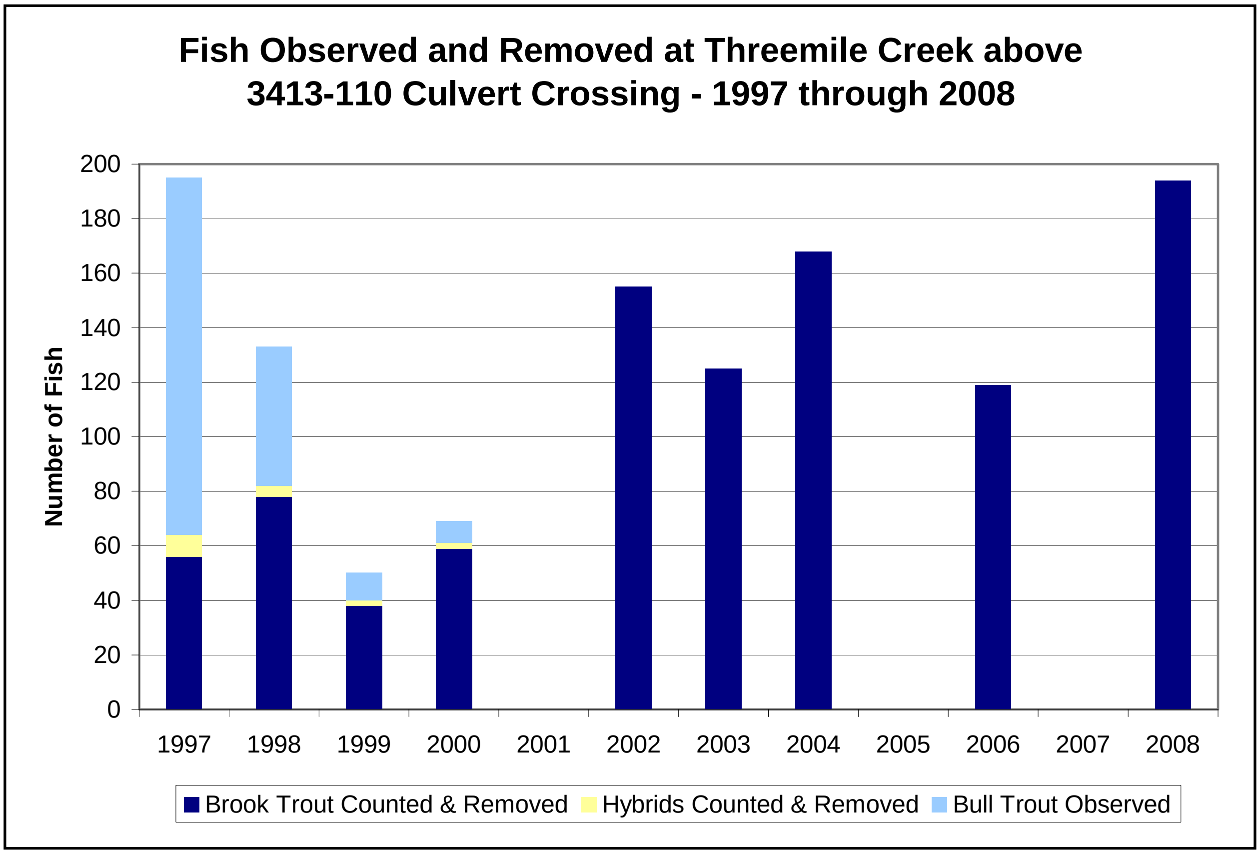


Figure 9-1. Fish observed and removed at Threemile Creek above 3413-110 culvert crossing, 1997 through 2008 (USFS 2009).

Fish Habitat Conditions

Wood River Watershed

The primary tributaries included in this discussion are: the Wood River, Sun Creek, Annie Creek, Fort Creek, Crooked Creek, and Sevenmile Creek/Canal.

Wood River

A spring emanating from the escarpment at Kimball State Park is the source of the Wood River (ODF 1995) (Figure 9-2, Aerial Photo of source spring for the Wood River). It flows for slightly more than 15 miles before entering Agency Lake. Tributaries to the river include Annie Creek, Fort Creek, and Crooked Creek. Sun Creek is a tributary to Annie Creek, with the two creeks combining roughly 1.75 miles prior to Annie Creek's confluence with the Wood River (Figure 9-3, Aerial Photo showing Annie Creek). There are several diversions located along the river, some of which may require screening to prevent entrainment of fish.

Figure 9-2. Aerial Photo of source spring for the Wood River (DEA 2009).

Figure 9-3. Aerial Photo showing Annie Creek flowing from right side of photo east to its confluence with the Wood River. Several water diversions flow westward from the Wood River (DEA 2009).

The Wood River has been altered to varying degrees by management practices primarily associated with past logging and subsequent grazing/pasture management. As fishing guides Chris Engel and Ed Miranda put it, "The Wood River Valley didn't get its name due to the lack of trees…" (interview with Ranch and Range Consulting 2009). During the late 1800's through the 1950's much of the tree cover was removed within the Wood River Valley. The trees provided a natural source of LWD to the streams, creating deep pools and trapping sediment and gravels as they moved through the system, which led to great fish habitat (Chris Engel and Ed Miranda interview with Ranch and Range Consulting 2009).

A cursory review of aerial photography shows that native woody riparian vegetation has decreased and the land has been converted to pasture; however, there are still portions of the river that contain adjacent intact native riparian communities that help to support in-stream functions. Hydrology of the Wood River is primarily a function of direct inputs from groundwater, groundwater fed springs, and tributaries. According to local landowner observations this leads to relatively little fluctuation in stream flows and the maintenance of cold water temperatures throughout the year (Kerns pers. comm. 2009), which benefits native trout species.

Landowner Martin Kerns noted that in the 1940's it was common to find 15 to 18 pound trout (up to 3 feet long) spawning in the Wood River. About 30 years ago trout stopped coming up the river. Until recently, in the past few years, there were no trout observed along the Kerns Ranch. The trout that come up river today are considerably smaller; although, they can still reach up to 24 inches in length (Martin Kerns, interview with Ranch and Range Consulting 2009).

In the mid-90's there were a series of restoration projects along the Wood River and its mouth. These projects were intended to restore the original meanders of the river and improve instream and riparian habitat conditions. Although the projects are generally viewed as favorable, there are varying points of view regarding how the projects were conducted and resulting effects.

According to fishing guides Chris Engel and Ed Miranda (interview with Ranch and Range Consulting 2009), the entire Wood River historically supported a great redband trout fishery. Prior to these restoration projects there were two runs of redband, during the summer and late fall; however, the guides suggest the restoration projects may have resulted in eliminating the summer runs. It is believed the projects themselves were not deleterious to habitat, but the construction work, particularly pile driving during the summer migration, may have caused redband to find spawning areas outside of the Wood River (Chris Engel and Ed Miranda interview with Ranch and Range Consulting 2009). These observations are contrasted by those of ODFW as described below.

According to ODFW there is no evidence to date that indicates the restoration efforts negatively impacted the summer redband population (Smith pers. comm. 2009). Genetic work on the redband trout of the Wood River and Williamson River show that these are two distinct stocks of fish, meaning that the fish in these two rivers do not and have not exchanged genes in many generations (Smith pers. comm. 2009). The pile driving scaring the fish to spawn elsewhere would have diluted that unique genetic resource and ODFW has found no evidence to support this (Smith pers. comm. 2009). Movements of some individual fish may have been affected during construction, but ODFW suggests that the redband trout population in the Wood River as a whole was not adversely affected by the construction work. Based on current genetic understanding there is just one stock of redband trout in the Wood River, with individual fish migrating into the Wood River nearly throughout the year although numbers vary seasonally (Smith pers. comm. 2009). Fish numbers entering the river begin to decrease in March and April, with only the months of May and June showing very low numbers (Smith pers. comm. 2009). Multiple factors influence the timing of when fish enter the river and swim up to their spawning grounds, including flow, temperature, freshets, and other factors.

ODFW believes the restoration work conducted in the 1990's had a positive effect on the Wood River system (Smith pers. comm. 2009). The re-opening of Tecumseh Springs, a tributary to the Wood River, attracted fish from the Wood River just weeks following the completion of the restoration work (Smith pers. comm. 2009). Redband are known for exploring new available habitat and ODFW believes that completing this restoration work created new habitat that redband trout were able to explore. Therefore, redband were not lost from the Wood River system but instead have redistributed themselves to fill in previously vacant habitat (Smith pers. comm. 2009). Further evidence of this occurred with removal of the British Petroleum Dam on Fort Creek, a tributary of the Wood River (see discussion of Fort Creek below). The expansion of redband trout into the areas made available by the dam removal lowered the number of fish observed at the "caddis hole," a well-known fishing location, because the fish now had more suitable habitat available to them (Smith pers. comm. 2009).

In 1996, the Bureau of Land Management (BLM) began major restoration of the floodplain, delta and river channel of the lower Wood River (BLM 2009) (Figure 9-4, Aerial Photo of Wood River). The project intent was to restore the functionality of the Wood River and adjacent floodplains to increase channel complexity, increase floodplain connectivity, and restore wetland and riparian habitat (BLM 2009). When the project was completed there were concerns that it was not functioning at desired levels. For example, cold water from a distributary channel was being released to a very shallow portion of Agency Lake that may not have been accessible to fish attempting to migrate up into the Wood River. Additionally, sediments, washed out of the river channel after excavation of the historic delta channel, have accumulated near the current river mouth, exacerbating shallow conditions for boating and fish migrations in late summer and fall (BLM 2009). A Record of Decision to remedy the problem was signed in June of 2009 by BLM. BLM and partners are looking to remedy the problem by restoring one of the historic channels of the Wood River delta which enters a deeper area of Agency Lake. It is expected this will provide a deep, high quality holding area for migratory fish staging or over-summering in Agency Lake. As a separate project, BLM began channel narrowing and floodplain restoration between the confluence of Crooked Creek and the bridge at the Wood River Dike Road in 1998 but was unable to complete this work due to funding shortfalls (BLM 2009). BLM now plans to complete this work, which will cover the lower 200 yards of the Wood River stream channel.

Narrowing of the channel is expected to allow the river to better transport the sediment load from upstream sources (BLM 2009).

Figure 9-4. Aerial Photo looking south towards mouth of Wood River entering into Agency Lake (DEA 2009).

Fort Creek

Fort Creek flows from Reservation Spring and runs for roughly four miles before its confluence with the Wood River. The upper half of the creek meanders through mostly mature, mixed conifer/deciduous forestland before emerging into pastureland (ODFW 1996 as cited in Shapiro and Associates, Inc. 2000). In the early 1990's a diversion dam on Fort Creek, located east of the town of Fort Klamath along the eastern ridge of the valley, washed out and opened up one mile of additional spawning habitat (Chris Engel and Ed Miranda, interview with Ranch and Range Consulting 2009).

Crooked Creek

Crooked Creek originates from a spring at the base of Sugar Hill, on the eastern edge of the Wood River valley. It flows for approximately seven miles to its confluence with the Wood River. Several springs, including Tecumseh Springs, add flows to the creek, which help to maintain flows and cold water temperatures. The majority of the creek flows through private pasture land; however, there are patches of riparian forest along the creek.

The effects of the 2002 KBRT land and water management plan for the Wood River Valley have been fairly substantial for the Crooked Creek study reaches (GMA 2008). These effects include decreased channel width and width to depth ratios and decreased bank erosion. The areas of Crooked Creek Reach 4 that have undergone restoration in the form of channel narrowing and LWD enhancement showed an increase in adult trout usage (GMA 2008).

Annie Creek

Annie Creek, a tributary of the Wood River, originates in Crater Lake National Park. It is a perennial stream, fed by the park's snowpack as well as groundwater (ODF 1995). After leaving the park, it crosses 0.5 miles of Fremont-Winema National Forest and 0.75 miles of Sun Pass State Forest. In its highest reaches, the creek flows through a steep and narrow canyon carved through the Mazama ash deposits. Further down, Annie Creek eventually becomes less confined. Generally speaking, the upper and middle reaches are bordered by well-timbered riparian corridors and are likely similar to historic conditions. The 0.75 mile stretch across the state forest is protected by the Department of Forestry's "Protective Conservancy - Critical Wildlife Habitat" land use classification.

Where the creek eventually leaves the forested hill slopes and enters the broader Wood River valley, it crosses onto private livestock pastures and is eventually joined by Sun Creek before meeting the Wood River, about four miles from the state forest (ODF 1995). These lower reaches of Annie Creek have been altered to varying degrees by management practices and likely have reduced in-stream habitat complexity; however, patches of forested riparian vegetation remain, particularly in areas close to the state forest border.

Sun Creek

Sun Creek, a tributary of Annie Creek, also originates in Crater Lake National Park. After leaving the park, it flows across Sun Pass State Forest for three miles, then across private livestock pastures for one mile before joining Annie Creek (ODF 1995). Its year-round stream flow is generated by mountain snowpack and groundwater. Sun Creek has been greatly altered by agricultural water uses (ODF 1995). Its water is diverted into irrigation canals at two points: the first is one mile upstream from where Sun Creek crosses the state forest boundary, and the second is at the state forest boundary where the stream enters private land. Irrigation return flow then enters Annie Creek and the Wood River. Once it enters private land, Sun Creek meanders for 0.5 miles before becoming an irrigation ditch. Sun Creek enters Annie Creek through a 24-inch culvert near the intersection of Highway 62 and Dixon Road (ODF 1995).

On the state forest, Sun Creek's lower reach appears to have been channelized many years ago (ODF 1995). Riparian vegetation grows only on the stream banks, and the water runs at high velocity. The Oregon State Department of Forestry protects the upper reach with a "Protective Conservancy - Critical Wildlife Habitat" land use classification. The lower reach of Sun Creek has a wide, natural riparian area with multiple channels and an active beaver population (ODF 1995).

As discussed previously, Sun Creek supports a population of bull trout within the boundaries of Crater Lake National Park and efforts are underway to restore bull trout habitat and eliminate competition and interbreeding with brook trout in this area (ODF 1995). The NPS installed two log and rock migration barriers on Sun Creek specifically to prevent upstream migration of brook trout into upstream creek reaches where brook trout were being removed (Buktenica 1993, Buktenica pers. comm. 2009).

Sevenmile Creek

Historically, redband and bull trout both occurred within Sevenmile Creek (USFS 2003); however, there is a large series of cascades and waterfalls in the higher reaches of Sevenmile Creek, that most likely prevents the upstream movement of all fish (see Map 9-2, Potential Fish Barriers). Only non-native brook trout, previously introduced by humans in the system, currently inhabit Sevenmile Creek above this natural barrier (Anderson pers. comm. 2009).

Relative to many other creeks on National Forest land, the roughly eight mile stretch of Sevenmile Creek (within National Forest land) has been less adversely impacted. In contrast, on private property, Sevenmile Creek runs roughly six miles as a meandering valley floor creek where it is used for irrigation and has been considerably modified relative to natural conditions (Anderson pers. comm. 2009). The remaining lower six miles of this water course have been confined to the Sevenmile Canal that outlets to Agency Lake (Shapiro and Associates, Inc. 2000). Adfluvial fish migration to National Forest reaches has been greatly impaired, if not completely eliminated, by the irrigation systems (i.e., diversions and withdrawals) and aquatic habitat has been significantly reduced throughout these modified reaches (Anderson pers. comm. 2009). Figure 9-5 (Sevenmile Creek System Impediments to Fish Passage) shows various barriers currently impeding fish passage.

With the exception of two small fish tentatively identified as redband trout, electrofishing surveys conducted by ODFW and USFS in 2002 revealed only a low density of brook trout residing within the National Forest boundary (Anderson pers. comm. 2009). Redband trout have been reported downstream of the National Forest boundary on private lands but not on National Forest land.

While bull trout are believed to have been extirpated from Sevenmile Creek since the 1970s at the latest, the Klamath Basin Bull Trout Working Group (BTWG) has identified Sevenmile Creek as important to long-term efforts to stabilize and restore local populations of bull trout in the Klamath Basin (USFS 2002). Forest Road (FR) 3334 closely approaches Sevenmile Creek along much of its length. As described in Chapter 5, Sediment Sources Assessment, the road had previously been directing sediment-laden runoff into the creek, but has since been storm proofed to alleviate this problem. This work was conducted in association with bull trout recovery efforts (Anderson pers. comm. 2009). Additionally, changes in irrigation and grazing management practices implemented through a KBRT program have had several positive effects on the channel morphology and fish habitat for Sevenmile Creek (GMA 2008). Sevenmile Creek, the uppermost section studied, showed the most improvement in fish habitat with increases in pool numbers, depth, LWD, and a decrease in deleterious fine sediment. The two uppermost reaches have more stable banks and narrower, deeper channels (GMA 2008).

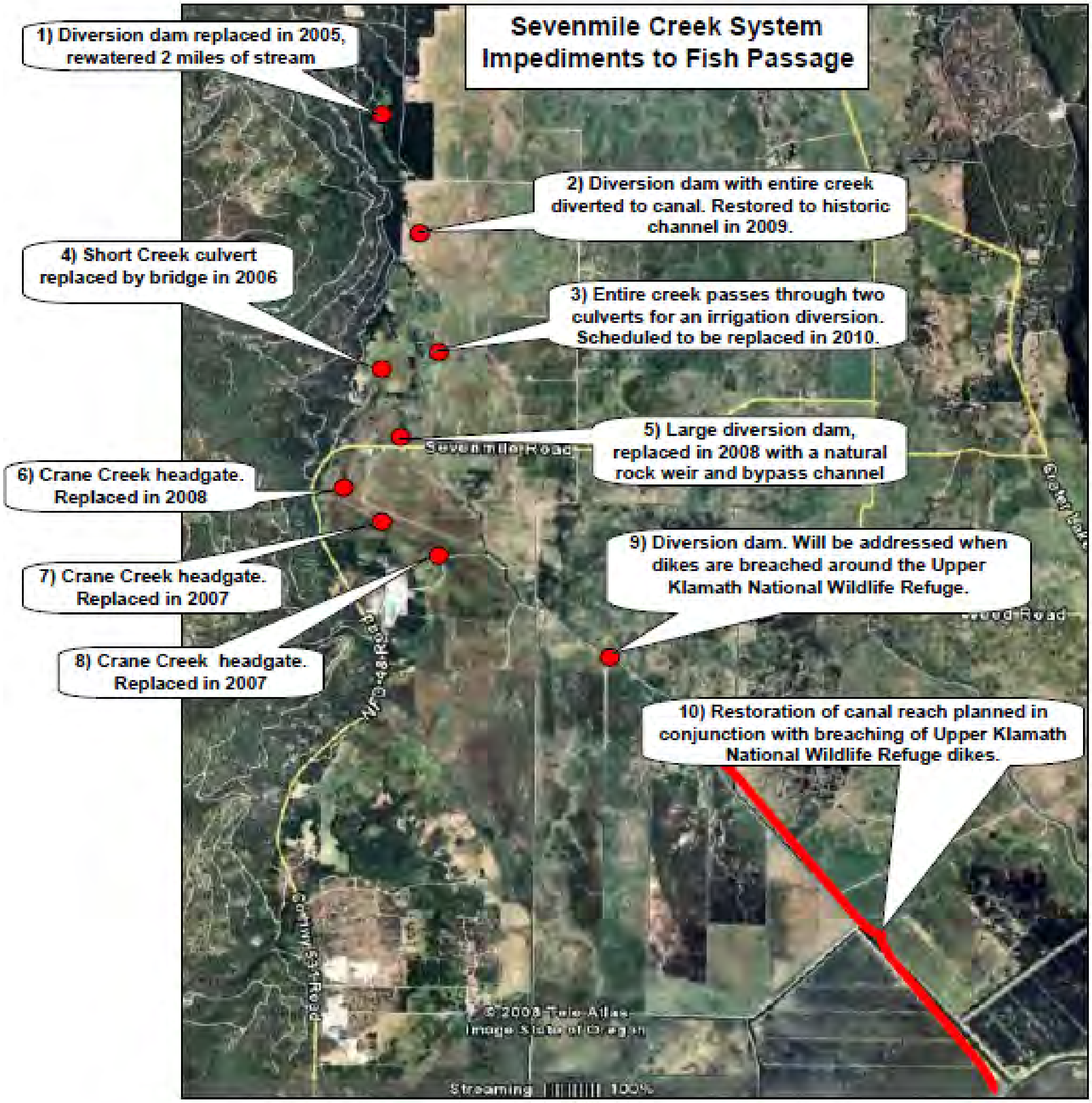


Figure 9-5. Sevenmile Creek System Impediments to Fish Passage (KBRT date unknown).

Habitat conditions within the mid to upper reaches of Sevenmile Creek (below natural fish barrier) are similar to but slightly below the quality of historical conditions. The most recent stream survey (USFS 2002) shows that large wood frequency and pool depths are below desired conditions (Anderson pers. comm. 2009). Four reaches were surveyed in 2002. The highest and lowest reaches showed an abundance of pool habitats due to the presence of beaver ponding and marsh habitat. The middle two reaches are comprised of roughly one-third pool habitat and two-thirds riffle habitat and contain a considerable amount of side channel habitat. These middle reaches are slightly deficient in large wood numbers, which is adversely affecting overall pool depths (Anderson pers. comm. 2009). There are minimal suitable spawning-sized substrates to provide full seeding if redband trout were able to access this former habitat, particularly in the highest and lowest reaches (Anderson pers. comm. 2009).

The lower reaches of Sevenmile Creek within National Forest lands provide a unique type of habitat. Within these reaches, gradient is low and the stream meanders through a wide valley floor. Current riparian conditions are similar to historic conditions. Wood and lateral scour are the primary sources of deep pool habitat in some areas, with beaver activity providing this in others. Undercut banks and vegetation play a more significant role as forms of cover than in upper reaches. Hardwoods dominate the dense canopy cover of the riparian area, with some late seral conifers on the outer edges. There is still a fairly active beaver population in this area. Beaver activity improves fish habitat by creating pond and side channel rearing habitat, but degrades spawning substrates by trapping sediments.

The Sevenmile Creek channel downstream of the National Forest boundary has been altered for irrigation and and adjacent riparian areas converted to pasture, substantially lowering fish habitat functions. The creek is used for irrigation and is eventually diverted into Sevenmile Canal. Fish passage is impaired because of head gates on irrigation canals, but is most likely not blocked year round. In recent years, KBRT has been conducting considerable work to improve conditions along this reach.

For example, the Upper Sevenmile Ditch diversion had historically reduced flow and fish habitat function along Sevenmile Creek for decades (Anderson pers. comm. 2009). Although numerous springs entering the reach below the diversion helped increase in-stream flows, they did not entirely mitigate for the loss of flows. Recently, KBRT worked with the property owners to develop a water leasing program, which has returned approximately 40 percent of the baseflow back to the creek (Anderson pers. comm. 2009). Beaver dams have turned the reach into a series of glides, three to five feet in depth, creating excellent rearing habitat and hiding cover. Spawning, however, is limited by sediments, resulting from erosion along Dry Creek, being trapped by the numerous (22 recorded in 1995) beaver dams and covering spawning gravels.

Dry Creek is an intermittent tributary of Sevenmile Creek. Historically, it may have provided seasonal forage habitat for fish; however, fish surveys in 1992 did not locate any fish in the perennial section of the creek. Currently, Dry Creek provides minimal habitat for fish.

Fourmile Creek Watershed

The following descriptions of Fourmile, Seldom and Varney Creeks are provided by USFS 2008, except where noted.

Fourmile Creek

Fourmile Creek flows eastward from Fourmile Lake along the boundary of the Sky Lakes Wilderness Area until it enters Pelican Bay/Upper Klamath Lake at Harriman Springs. Fourmile Creek supports redband and brook trout. Historically, the upper reaches of Fourmile Creek functioned as a perennial stream, maintained by flows from Fourmile Lake, but are now mostly intermittent as a result of irrigation and water supply diversions. In 1890 flow patterns in Fourmile Creek were completely altered by construction of a dam across the outlet of Fourmile Lake and the diversion of flows from Fourmile Creek to the west side of the Cascades (a trans-basin transfer of flows). In the early 1900's, channelization of the lower two miles of Fourmile Creek affected flows by lowering the local water table. This has impacted the timing of peak flows and the duration/magnitude of base and bankfull flows. The lower reaches of Fourmile Creek were most likely historically intermittent due to evaporation and percolation.

Loss of water from the headwaters (due to the trans-basin diversion of water from Fourmile Lake to the Rogue River drainage) has caused a reduction in channel-forming, bankfull flows. Additional details about the affects of this diversion on channel conditions are provided in Chapter 3, Channel Habitat Typing and Modifications. In general, this has resulted in a decrease in the amount of perennial stream habitat in Fourmile Creek (above Seldom Creek). Today, lower Fourmile Creek does not provide suitable fish habitat.

When water is present, water temperature for native fish in Fourmile Creek remains well within State standards for redband trout which largely has to do with the runoff being snowmelt influenced and occurring early in the runoff season. The State standard is 20°C for the seven-day average of daily maximum temperatures. Fourmile Creek has only limited data for temperature monitoring due to the fact that its flows are largely diverted to the Rogue Basin once the irrigation season begins. The highest daily maximum recorded was 14.4°C, and the seven-day average of daily maximum would be somewhat less.

Seldom Creek

Seldom Creek originates from Lake of the Woods when high water in the spring flows over and into the Great Meadow along Highway 140. Spring runoff from Great Meadow flows north under the highway, entering Fourmile Creek. Seldom Creek is an intermittent tributary to the intermittent portions of Fourmile Creek. Seldom Creek does not contain habitat suitable for fish and experiences flows only during the short period of rapid snowmelt from the upper watershed.

Varney Creek

The headwaters of Varney Creek originate high in the Mountain Lakes Wilderness Area. Spring runoff flows downhill and north under Highway 140 then enters Fourmile Creek. Like Seldom Creek, Varney Creek is an intermittent tributary to the intermittent portions of Fourmile Creek. Varney Creek offers only limited fish habitat for a small population of non-native brook trout.

Klamath Lake Watershed Tributaries

The primary drainage systems on the west side of the Klamath Lake watershed include Rock Creek, Lost Creek, Cherry Creek, Nannie Creek, Threemile Creek and Recreation/Crystal Creeks. Information provided in this section is primarily derived from the “Watershed Analysis Report for the Threemile, Sevenmile, and Dry Creek Watersheds” (USFS 1995), “Rock, Cherry, and Nannie Creeks Watershed Analysis” (USFS date unknown, written prior to 1994), and the Westside Fuels Reduction Project Biological Assessment (USFS 2008). The Fremont-Winema

National Forest has conducted considerable habitat restoration actions since preparing their watershed analyses; therefore, the Westside Fuels report (USFS 2008) summarized and provided updates to descriptions in the watershed analyses. Edits and updates have been incorporated into the discussions below based on conversations with USFS staff. Additional citations are noted within the discussion.

Rock Creek

The following description is taken from USFS 2008.

Rock Creek is best characterized as a step-pool system. Its headwaters originate within the Sky Lakes Wilderness. It flows approximately 2.5 miles through a narrow U-shaped valley before the valley narrows to a V-shaped form where stream gradient increases. Only the mid-reaches of Rock Creek are perennial. They provide year-round habitat for native redband and non-native brook trout. Rock Creek is hydrologically connected to Crystal Creek and Upper Klamath Marsh on an intermittent basis. Flows generally subside in the extensive alluvial fan by late-June or early July, but may become continuous later in the year, when winter snow pack begins to accumulate in the mountains and frequent winter rains or rain-on-snow events cause peak stream flows. Widespread flooding across the alluvial fan is most prevalent during November and December rain-on-snow events when historical peak flows occur. There is an extended period of hydrologic connectivity in the late spring (April – June) that provides fish passage back to the stream from Upper Klamath Lake. USFS has received oral accounts by a person with a long history in the area of observing large redband trout (migrating and carcasses) in Rock Creek near the 3419 bridge crossing during the months of May and June. The large size of the fish suggests that they had migrated into the creek from Upper Klamath Lake, as resident fish do not grow as large as migratory fish.

Stream surveys (USDA 2004, 2003, 1994, 1990, 1979) completed on Rock Creek all reveal that, in its current condition, the stream provides marginal fish habitat overall. Although there have been several timber sales in the Rock Creek watershed, a sanitation sale which took place in 1971 had the greatest impacts on aquatic habitat in Rock Creek. This sale occurred along an approximately two-mile long section of Rock Creek and was designed to remove instream LWD and adjacent large trees in the riparian zone. Trees were harvested on both sides of the bank, and skidded from the creek. In association with this timber sale, numerous roads and skid trails were constructed that paralleled the creek throughout the lower two reaches. Large berms of boulders, trees, and soil were placed along portions of the creek to protect road fill slopes from the creek.

As a result of these actions, Rock Creek currently has low habitat complexity and is dominated by the presence of shallow riffles with few primary pools. Available pool habitat is predominately small pocket pools created by the geology of this step-pool system. Spawning substrates are sporadically located throughout this boulder-dominated system, but rarely accumulate in quantities large enough to qualify as quality spawning habitat. Hiding cover is limited in the lower half of the creek, and is provided predominately by boulders and turbulence. Areas of reduced flow velocities that are ideal for juvenile rearing habitat are limited throughout the system, with most suitable rearing habitat occurring in the middle to upper reaches. The volume of large woody material in the lower reaches is extremely low, and does not meet regional USFS recommendations.

To address low habitat complexity, large wood replenishment was begun in 2004 when 38 large pieces were flown into the lower two reaches. In the fall of 2007 an additional 250-300 pieces of large wood were placed in the active stream channel by helicopter. Most of the transport of water, sediments, and organic materials needed for fish habitat in Rock Creek comes from the stream banks and adjacent riparian areas of Rock Creek itself (as opposed to tributaries). The intent of the LWD placement efforts of 2004 and 2007 was to restore the step-pool stream channel configuration, trap spawning-sized substrates, and increase pool numbers and pool depths for the benefit of native fish.

Currently, Rock Creek has intermittent connection to Crystal Creek through a shallow sedge/marsh meadow. A partnership has been formed between the USFS, the private landowner, USFWS, and the NRCS to improve fish passage across the alluvial fan to help promote the adfluvial population of redband trout in Rock Creek. Implementation of designed activities began on private lands in 2008 and the project was completed in 2009.

The USFS watershed analysis concluded that roads were having the greatest effect on increased sediment input to Rock Creek. Details of road/sediment issues and work conducted to alleviate this problem are provided in Chapter 5, Sediment Sources Assessment.

Water temperature for native fish in Rock Creek is well within State standards for redband trout. The standard is 20°C for the seven-day average of daily maximum temperatures. Rock Creek averages approximately 12.8°C, and no single recorded daily high has exceeded 20°C. Current shading is provided by the topography, as well as large trees and shrubs.

Penn Creek is an intermittent stream that is a major tributary to Rock Creek. Historic timber harvests have reduced its ability to transport water, sediments, and organic materials to Rock Creek. Roading, log skidding, and slash piles have altered the stream channel to such a degree that a defined channel is no longer identifiable in places. There is some debate concerning the importance of Penn Creek as a source of erodible materials to Rock Creek; therefore, no proposals to restore Penn Creek have been developed. Over the past few years, the confluence of Penn Creek has been carefully observed (e.g., layout, implementation, and monitoring of large wood replenishment in the reach of Rock Creek for which Penn Creek is a tributary). Today, the confluence of Penn Creek with Rock Creek remains almost indiscernible.

Lost Creek

The following description is taken from USFS 2008.

The Lost Creek subwatershed extends between the crest of the Cascades on the west and the top of Pelican Butte on the east. It includes Lost Creek and Cold Springs Creek. Lost Creek is an intermittent tributary that originates along the toe of Pelican Butte on its western flank and enters

Fourmile Creek near its crossing of the 3651 road. Lost Creek is predominately a Rosgen B channel type with a narrow valley floor width and a steep valley floor gradient creating a step-pool stream system. This is characteristically a very stable system that has a low-to-moderate sensitivity to disturbance and excellent recovery potential. Overall, B-type channels are in good condition throughout this subwatershed.

Water quality is good and, when it is flowing, Lost Creek's temperatures are within standards for native fish. The historic hydrograph of Lost Creek has remained unchanged overall. The minor site-specific disturbances from woodcutters, timber harvest, and road construction have not altered flow patterns in Lost Creek.

Fish habitat remains similar to the reference (i.e., historic) condition in Lost Creek. Fish habitat is provided through the complex arrangement of large substrate (cobble and boulders) and pools that are primarily small pocket pools. Spawning habitat is available where gravel has accumulated in the interstitial spaces associated with larger substrates, and in the tail-outs of large pools created by woody debris. Cool water temperatures are maintained by the forest canopy and steep topography of the terrain. The area supporting riparian vegetation is narrow, with little floodplain and side channel development. Because it is intermittent, Lost Creek provides only seasonal foraging and spawning habitat. Pools in the downstream reaches of Lost Creek are important to fish that remain in the creek during the summer, after the downstream connection to Fourmile Creek dries up.

Cherry Creek

Cherry Creek flows through a U-shaped valley with a moderate gradient. Two-thirds of this creek lies within the Sky Lakes Wilderness where it provides near natural habitat conditions for fish. Outside of the wilderness area the creek flows through USFS land and private lands. Within the lower reaches, at least five large, seasonal diversions route most of the water away from Cherry Creek across private lands between the USFS boundary and the Fourmile Canal (Anderson pers. comm. 2009). This perennial creek provides habitat for redband and brook trout and contains these species in roughly equal numbers. Historically it also contained bull trout (USFS 2003).

The reaches of Cherry Creek within the Sky Lakes Wilderness are mostly unaffected by land management activities. Within these wilderness reaches, fish habitat is in good-to-excellent condition: LWD is abundant, available hiding cover is excellent, substrate suitable for spawning is ample, and future large wood recruitment is at natural potential. Beaver activity has created large, deep pools and side channels that provide rearing/resting habitat for juvenile and adult fish.

Within the reaches above the diversion below the wilderness area, instream woody material and effective hiding cover for fish are limiting; however, substrates suitable for spawning are available. The majority of substrate provides effective hiding cover for only small fish. Water quality and quantity are not limiting factors in these upper creek reaches.

Just above the diversion canals on Cherry Creek a headgate diverts most of the flows from the creek system. Downstream channels of Cherry Creek can become dewatered when the diversion is active. At the time of the USFS watershed analysis (1995) this diversion was unscreened and believed to pose a risk of entraining fish that would rest in a pool near the headgate, pulling the fish into the diversion canal.

The lower portion of the Cherry Creek system, which includes several water diversions, provides minimal habitat for fish. These downstream creek reaches have been considerably altered, including removal of instream wood, loss of habitat complexity, channelization and routing through a series of irrigation canals before entering Upper Klamath Lake. The USFWS has been working with private landowners for a number of years to restore these lower creek reaches (Anderson pers. comm. 2009).

Nannie Creek

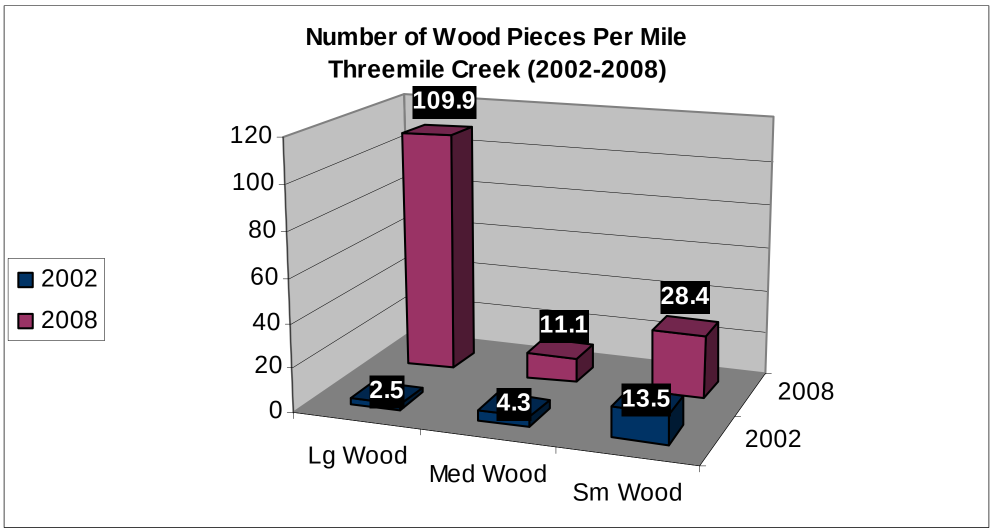
Nannie Creek consists of a spring-fed perennial reach that becomes intermittent before entering lower Cherry Creek (USFS date unknown). An approximately 1/2-mile section maintains perennial flow. An electrofishing survey conducted in 1993 indicated that the perennial section of Nannie Creek was not fish bearing and it is unlikely that fish were ever able to migrate into Nannie Creek from Cherry Creek.

Threemile Creek

Currently Threemile Creek provides habitat for bull trout and brook trout. Historically this stream supported bull trout and redband trout (Anderson pers. comm. 2009). Since 1996 efforts have been undertaken to remove all brook trout and brook trout-bull trout hybrids. This effort has been very successful as displayed in Figure 9-1.

At the time of the 1995 watershed analysis (USFS 1995) conditions in Threemile Creek, relative to historic conditions, showed a decrease in habitat diversity, a decrease of in-stream large wood and future recruitment potential, and an introduction of road fills into the stream. The lower two creek reaches contained near zero in-stream wood, resulting in considerably low habitat diversity. Approximately 85 percent of the habitat had been converted to wide, shallow riffles due to large wood removal. Little primary pool habitat was available, and remaining pools tended to be small and shallow (residual depth estimated to be approximately one foot deep). This reduced resting and rearing, feeding, and overwintering habitat for fish. Retention of spawning substrates was also reduced as a result of removing large wood, which would otherwise act to slow sediment transport through the system. The loss of large wood considerably diminished the quantity of hiding cover in the lower reaches. Stream banks in these reaches had been turned into steep berms that were poorly vegetated, leaving little hanging vegetation cover. Late seral forests have been partially logged and replaced with younger stands, thus diminishing the potential for future recruitment of large wood over the next few decades. Irrigation practices on private property have altered the historic condition of the creek channel, substantially reducing the quantity and quality of fish habitat.

Since 1999, USFS has been heavily engaged in making improvements to water quality and habitat in Threemile Creek (Anderson pers. comm. 2009). These efforts have gone a long way to improving the conditions present during the mid-1990's (as described above). Activities have included road stormproofing, obliteration of spur roads, and instream improvements through large wood replenishment. Figure 9-6 (Threemile Creek wood pieces per mile and pool/riffle counts per mile pre- and post-restoration) shows the change in pool numbers and frequency resulting from the large wood placement into the creek system (USFS 2009). The quantity of large wood, which increased considerably between 2002 and 2008, has led to a substantial increase in the amount of pool habitat - previously the system was closer to 100 percent riffle habitat.



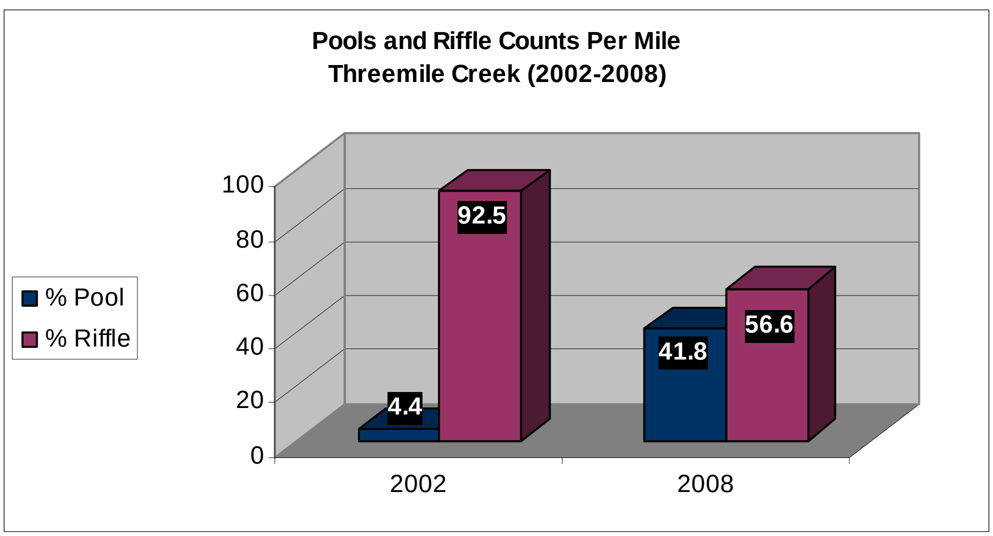


Figure 9-6. Threemile Creek wood pieces per mile and pool/riffle counts per mile pre- and post-restoration (USFS 2009).

An existing fish migration barrier is found at the intersection of FR 3413 and FR 3413/110 roads (Figure 9-7, Photo of Impassable Fish Barrier at Forest Road). This barrier was first observed in

1992 and high flows in 1996 and lack of LWD caused additional downcutting which created a migration barrier (USFS 2007).

Figure 9-7. Photo of Impassable Fish Barrier at Forest Road 3413-110 (USFS 2007)

While barriers are generally perceived as adverse, this barrier has proved to be beneficial, at least for the short-term. It is upstream of this barrier where removal efforts for non-native brook trout and hybrids have occurred (USFS 2007). The presence of this barrier has prevented brook trout from reinvading bull trout habitat upstream of the barrier. This barrier is located on a full fill crossing of the stream and is subject to annual high water events. If this culvert were to plug or otherwise fail, a decade of recovery efforts could be undone (USFS 2007). To mitigate this risk, USFS installed a second barrier downstream in 2008. The installed second barrier will allow another large section of the stream to be cleared of brook trout and thereby be made available to bull trout, potentially expanding their range. When considering possible locations for the new barrier, it was considered desirable to put this new barrier as far downstream as possible, in order to maximize future habitat availability for bull trout (USFS 2007). In order to create as much vertical height as possible, the best location found was on private land in an incised reach of Threemile Creek (USFS 2007). The Forest Service may eventually remove the upstream barrier at Forest Road 3413-110 once brook trout have been removed from the downstream reach.

Recreation Creek and Crystal Creek

The following description is taken from USFS 2008.

Recreation and Crystal Creeks are spring-fed systems. These marsh creeks are better characterized as palustrine wetlands, with little observable gradient or flow (Figure 9-8, Aerial photo of Recreation and Crystal Creeks with Pelican Butte in background. Recreation Creek flows along base of the hillside, while Crystal Creek flows completely through emergent marsh area). Fish use in Recreation and Crystal Creeks appears to be limited to migration, holding, refuge and rearing by redband trout and suckers. The lack of suitable spawning substrate eliminates spawning potential for most species.

Figure 9-8. Aerial photo of Recreation and Crystal creeks with Pelican Butte in background. Recreation Creek flows along base of the hillside, while Crystal Creek flows completely through emergent marsh area (DEA 2009).

Crystal Creek was dredged beginning around 1909 to facilitate steamboat passage for tourist travel to Crater Lake. Evidence suggests Recreation Creek may have also been dredged as it has a channel form similar to Crystal Creek and also is low in woody debris. Prior to dredging and installation of the Link River Dam, these channels historically would have been shallower, held water at elevated levels for a shorter duration, and probably had less of a defined channel than what is found today. Habitat likely was more complex, having less deep, open water, and more LWD and terrestrial and aquatic vegetation for cover.

At summer low flow, Recreation Creek ranges in width from 50 to 200 feet, with a more typical width ranging between 50 to 75 feet. The creek is widest near its confluence with Pelican Bay, tapering off as it proceeds upstream. At high flow, Recreation Creek is contiguous with Upper Klamath Lake and lacks a defined channel. Depths range from 3 to 12 feet, averaging approximately 6 feet. Substrate is almost entirely comprised of silts and organics, with isolated pockets of coarser substrate artificially placed near boat landings and docks.

At summer low flow, Crystal Creek averages approximately 50-70 feet wide. Like Recreation Creek, at high flow, it is also contiguous with Upper Klamath Lake and lacks a defined channel.

Depths range from 2-10 feet, averaging approximately 5.5-6 feet deep. Substrate is entirely comprised of silts and organics.

Streambanks of both creeks are comprised primarily of silts and organics, with fine sediment tightly interwoven around organic root masses (for example, tule and willow). Bank stability is excellent in both systems, with root masses anchored well enough to withstand daily and seasonal wind and wave erosion.

During winter and spring high-flow, fish habitat spreads beyond the active channels of Recreation and Crystal Creeks into the marsh and is actually contiguous with the lake. During summer and fall low-flow, habitat is constrained within the active channel as water levels recede. Under low flow conditions, Recreation and Crystal Creeks both flow through a low gradient, U-shaped channel. Habitat in these channels is glide-like, with uniform depth and a poorly defined thalweg (channel bottom). Fish cover is mainly provided by water depth, aquatic vegetation, and overhanging terrestrial vegetation. Most fish are closely associated with patches of rooted aquatic vegetation, primarily yellow pond lily (*Nuphar polysepalum*) and floating-leaved pondweed (*Potamogeton natans*). Few fish are observed in areas of open water devoid of aquatic vegetation.

Although many pieces of woody debris were present instream, the majority of pieces were small, single pieces partially embedded in fine substrate and providing little cover for fish. All pieces of instream LWD appeared to have cut ends, with no natural pieces observed in the system. It is likely that many pieces of LWD originally found in these systems were removed to facilitate boat passage during dredging activities.

East Side Tributaries to Upper Klamath Lake

There are no perennial streams that flow into the eastern side of Upper Klamath Lake (excluding the Williamson River, which is not part of this assessment). A few mapped intermittent streams appear to flow into irrigation/drainage canals near the communities of Algoma and Shady Pine. No information is available regarding fish presence/absence of these streams; however, they are unlikely to support fish populations due to their intermittent nature and poor connections to Upper Klamath Lake. Several important springs are located along the east side of the lake and are described in the Upper Klamath and Agency lakes section below.

Upper Klamath and Agency Lakes

Upper Klamath and Agency lakes are shallow (average depth approx. 6.5 feet [DEQ 2002]) hypereutrophic lakes that provide habitat for adult redband trout and the endangered Lost River and shortnose suckers. Juvenile suckers also use the adjacent emergent wetlands as rearing habitat. As described in previous chapters, many of the lakeside wetlands were drained and converted to agricultural uses from the early 1900's through the 1970's. This represented a large loss of juvenile rearing habitat in addition to the water quality and food chain support functions these wetlands provided to the lake systems. Since in the mid-1990's efforts have been underway to restore several large tracts back to wetland (Chapter 6, Riparian Assessment, Chapter 7, Wetlands Assessment, and Chapter 8, Water Quality Assessment each provide additional information regarding wetland conversion and restoration).

The lakes suffer from severe water quality problems resulting from nutrient enrichment, particularly phosphorous. This enrichment helps to feed deleterious algal blooms during the late spring through summer months, which in turn lead to large swings in dissolved oxygen concentrations (from anoxic [no oxygen] to supersaturated conditions) and pH. The poor water quality conditions have periodically led to large fish die-offs in the lake, with increased frequency of these die-offs occurring in more recent years (Cascade Quality Solutions 2005). Reported sucker die-offs in Upper Klamath Lake, which appear to be tied to poor water quality, have occurred in 1894, 1928, 1932, 1967, 1968, 1971, 1986, 1994, 1995, 1996, 1997, and 2003 (Cascade Quality Solutions 2005). Since the mid-1980s these die-offs have resulted in changes in size and age structure of Lost River and shortnose sucker populations. The removal of larger, older fish, which have the highest fecundity, may be decreasing the sucker's reproductive productivity, reducing their resiliency and increasing their risk of extinction (Cascade Quality Solutions 2005).

There has been a substantial loss of sucker spawning groups that utilized springs surrounding Upper Klamath Lake, including Barkley Springs, Harriman Springs, Camporee Springs, four unnamed springs on the eastside of Upper Klamath Lake, and Odessa Springs (Cascade Quality Solutions 2005). These spring type spawning grounds have been impacted by a number of factors including lack of access due to presence of man-made fish barriers (i.e., impassable culverts), habitat conversion and water diversion.

Sucker migration/use patterns within the lakes shift as lake levels drop, as observed in Figure 9-9 (Probability of age-1 sucker site occupancy based on depth throughout Upper Klamath Lake, Oregon, in 2007 at six lake levels) (USGS 2009). Particularly, suckers tend to congregate in the deeper trench along the west side of the lake as water elevations subside.

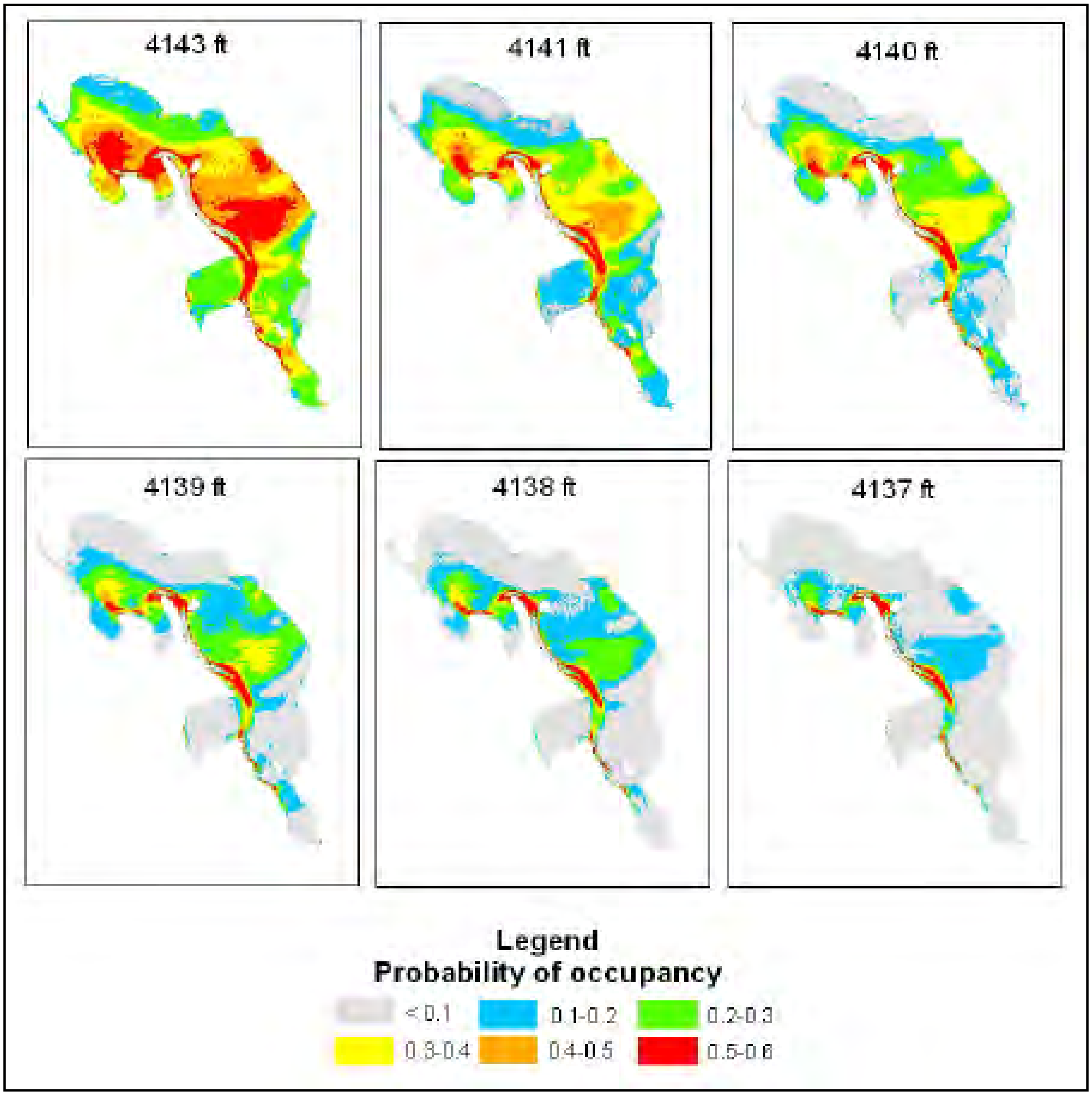


Figure 9-9. Probability of age-1 sucker site occupancy based on depth throughout Upper Klamath Lake, Oregon, in 2007 at six lake levels (USGS 2009)

The following various actions are underway to improve fish habitat conditions within and adjacent to Upper Klamath and Agency lakes:

- Water quality problems are being addressed through the TMDL process, which included preparation of WQMPs.

- Large-scale wetland restoration around the lakes
- Restoration of some of the historic spring spawning areas including Barkley Springs, near Algoma (see Figure 9-10, Aerial photo of Barkley Springs).
- ODFW coordinating with landowners to install fish screens on irrigation water diversion intakes from the lakes. Figure 9-11 (Photo of Fish screen/irrigation diversion under construction at Running Y Ranch, October 2009) provides photos of a fish screening site under construction at the Running Y Ranch (former Wocus Marsh area).

Figure 9-10. Aerial photo of Barkley Springs feeds into irrigation canal on far side of Highway-97. Upper Klamath Lake and Hanks Marsh in foreground, October 2009.

Figure 9-11. Photo of Fish screen/irrigation diversion under construction at Running Y Ranch, October 2009.

Barriers to Fish Passage and Migration

Various barrier types are displayed on Map 9-2 (Potential Fish Barriers), which includes both existing barriers as well as features that typically represent a barrier concern but may not actually act as a barrier (i.e., culverts). The ODFW fish barriers GIS database identifies some culvert crossings as having "unknown" fish passage status within the Wood River watershed and elsewhere in the Upper Klamath Lake Subbasin; however, no culverts or other potential barrier types are listed as impassable by the ODFW GIS database.

This section lists the fish passage barriers that are present within the Upper Klamath Lake Subbasin, as well as the considerable efforts that have been undertaken to remove these barriers.

- USFS conducted an assessment of fish passage at road crossings for all known fish-bearing streams within the Fremont-Winema National Forest (Gorman and Smith 2001). Since this assessment all of the identified fish barriers on National Forest land within the Upper Klamath Lake Subbasin have been replaced with fish passage culverts (Anderson pers. comm. 2009). The only manmade barriers remaining on USFS land within the Upper Klamath Lake Subbasin are those purposely installed or left in place on Threemile Creek in order to prevent brook trout from migrating up into bull trout restored stream reaches (as mentioned previously).
- KBRT and others have been working to remove many of the migration barriers on private lands in the Wood River fifth-field watershed (Peterson pers. comm. 2009).
- Unscreened diversions represent one of the most significant types of barriers to fish passage/migration (Anderson, Smith, and KBRT pers. comm. 2009; Chris Engel and Ed Miranda interview with Ranch and Range Consulting 2009). ODFW commissioned a screen inventory of diversions within the Wood River watershed that showed 66 out of 96 diversions in this system were unscreened (Craven Consulting Group 2004). Summary results are provided in Table 9-6 (Summary of Diversion Screening in the Wood River Fifth-Field Watershed) below. The analysis report done by Craven Consulting Group (2004) also provides details for each diversion that was assessed.
- ODFW does not have a database of screened/unscreened water diversions within the Upper Klamath Lake Subbasin (Richie pers. comm. 2009). Map 9-2 does include water diversions from the OWRD GIS database; however, these data do not specify whether the diversions are screened or not. Craven Consulting Group (2004) performed an inventory of the Wood River watershed that does provide fairly detailed data on most of the diversions within this system. The Craven report also noted that the OWRD GIS database had many duplicate entries and were not always very accurate with respect to geographic positioning (Craven Consulting Group 2004). This should be taken into consideration when viewing diversions shown on Map 9-2.
- Redirection, channelization, and diversion of streams have impacted migration pathways throughout the subbasin, particularly migration pathways across private lands into higher quality stream habitats found on USFS land (Anderson, Smith, and KBRT pers. comm.

2009). Fish passage is blocked, primarily from water diversions (i.e., low flows and unscreened diversions), from Upper Klamath and Agency lakes up to the USFS land reaches of Fourmile Creek, Rock Creek, Cherry Creek, Threemile Creek, and Sevenmile Creek (USFS 2003).

- Two diversion dams on Sevenmile Canal limit redband trout passage (Chris Engel and Ed Miranda interview with Ranch and Range Consulting 2009).
- Low summer flows (i.e., six inch depth or less) and excessively warm water temperatures at the mouth of Sevenmile Canal prevent or limit use by redband trout and bull trout during this time period (Chris Engel and Ed Miranda interview with Ranch and Range Consulting 2009).
- Channelized lower sections of Sevenmile Creek/Canal will not support or provide summer passage of bull trout.
- Diversion of Fourmile Creek at West Canal restricts passage of redband trout (Chris Engel and Ed Miranda interview with Ranch and Range Consulting 2009).

Table 9-6. Summary of Diversion Screening in the Wood River Watershed

	Diversion Type		Headgate		Screened	
Water Body	**Pump**	**Gravity**	**Yes**	**No**	**Yes**	**No**
Wood River	3	19	18	4	13	9
Crooked Creek	4	2	2	4	0	6
Fort Creek	4	3	3	4	4	3
Annie Creek	0	30	30	0	0	30
Sun Creek	0	5	1	4	0	5
Sevenmile Creek/Canal	0	26	26	0	13	13
Total	**11**	**85**	**80**	**16**	**30**	**66**

Data Source: Craven Consulting Group 2004

Confidence Evaluation

The overall confidence in the fish and fish habitat assessment is moderate to high. Existing data and knowledge of local landowners and resource agency personnel are extensive and a great deal of research and implementation of restoration projects has occurred and continues to take place. Information provided in this assessment is meant to provide a broad overview of these efforts in a consolidated form. This fish and fish habitat assessment, combined with the substantive local knowledge, is more than sufficient for a general understanding of fish and fish habitat within the subbasin to determine general and specific protective and restorative measures.

Research Recommendations

The following studies are suggested to address the data gaps listed above.

1. Conduct a survey of water diversions and fish screens and their potential effect on fish passage.

2. Review and update listings for culverts and dams listed as having "unknown" fish passage in ODFW GIS database.

3. Conduct a macroinvertebrate study, particularly in streams of the Wood River watershed, to assess the effects of varying land uses on stream productivity/fisheries support function.

4. Monitor and report on past riparian improvement projects to assess efficacy of various project types (i.e., fencing with complete livestock exclusion; rotational grazing practices, etc.).

Restoration and Management Opportunities

The following restoration actions focus primarily on the key species identified in this report, which include bull trout, redband trout, shortnose sucker, and Lost River sucker; however, other aquatic species would also likely benefit.

1. Screen diversion intakes identified as limiting fish passage (see Research Recommendations, above).

2. Restore historic connections and improve migratory pathways between tributary streams and Upper Klamath and Agency lakes.

3. Protect and restore spring-fed thermal refugia and spawning sites in the lakes and tributaries.

4. Restore stream side riparian/wetland conditions to benefit aquatic habitat.

5. Improve in-stream habitat conditions along altered stream sections.

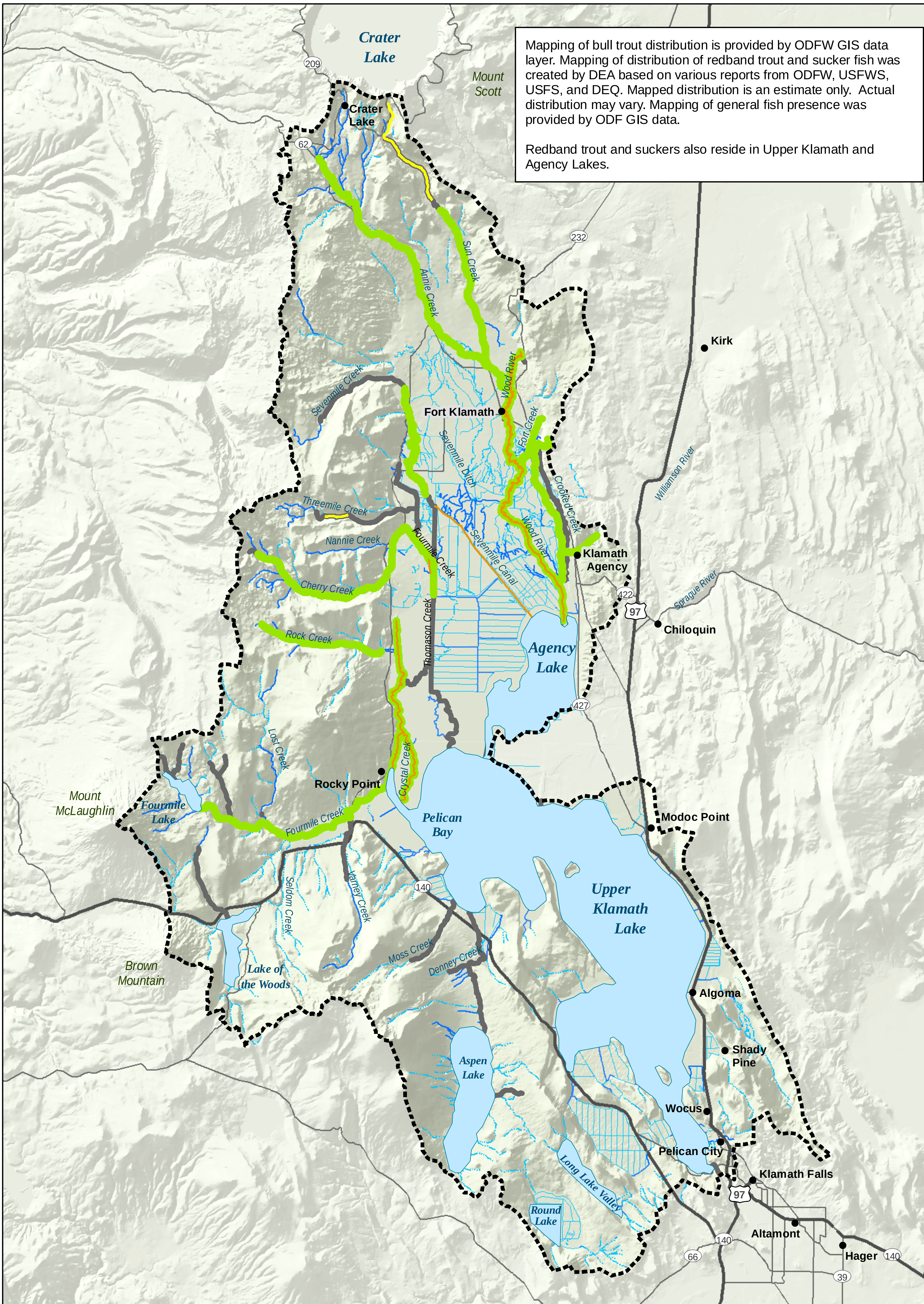
6. Continue to restore and reconnect drained and/or diked off wetlands from Upper Klamath and Agency lakes.

7. Consider fuel treatment in the Klamath Lake watershed to reduce the risk of a catastrophic fire that could impact bull trout.

8. Consider riparian thinning immediately adjacent to Threemile Creek to improve chances for long-term LWD sources.

List of Maps

Map 9-1: Fish Distribution



Legend

Subbasin Boundary
Stream/River: Perennial
Stream/River: Intermittent
Stream/River: Ephemeral
Canal Ditch

Current Estimated Fish Presence

Lost River and shortnose suckers
Bull trout
Redband trout
Known general fish presence

N

0 4 8
Miles

Source Data:
ESRI, Klamath County, Oregon GEO, USGS (National Hydrography Dataset), ODF, ODFW, DEA

Map 9-1: Fish Distribution

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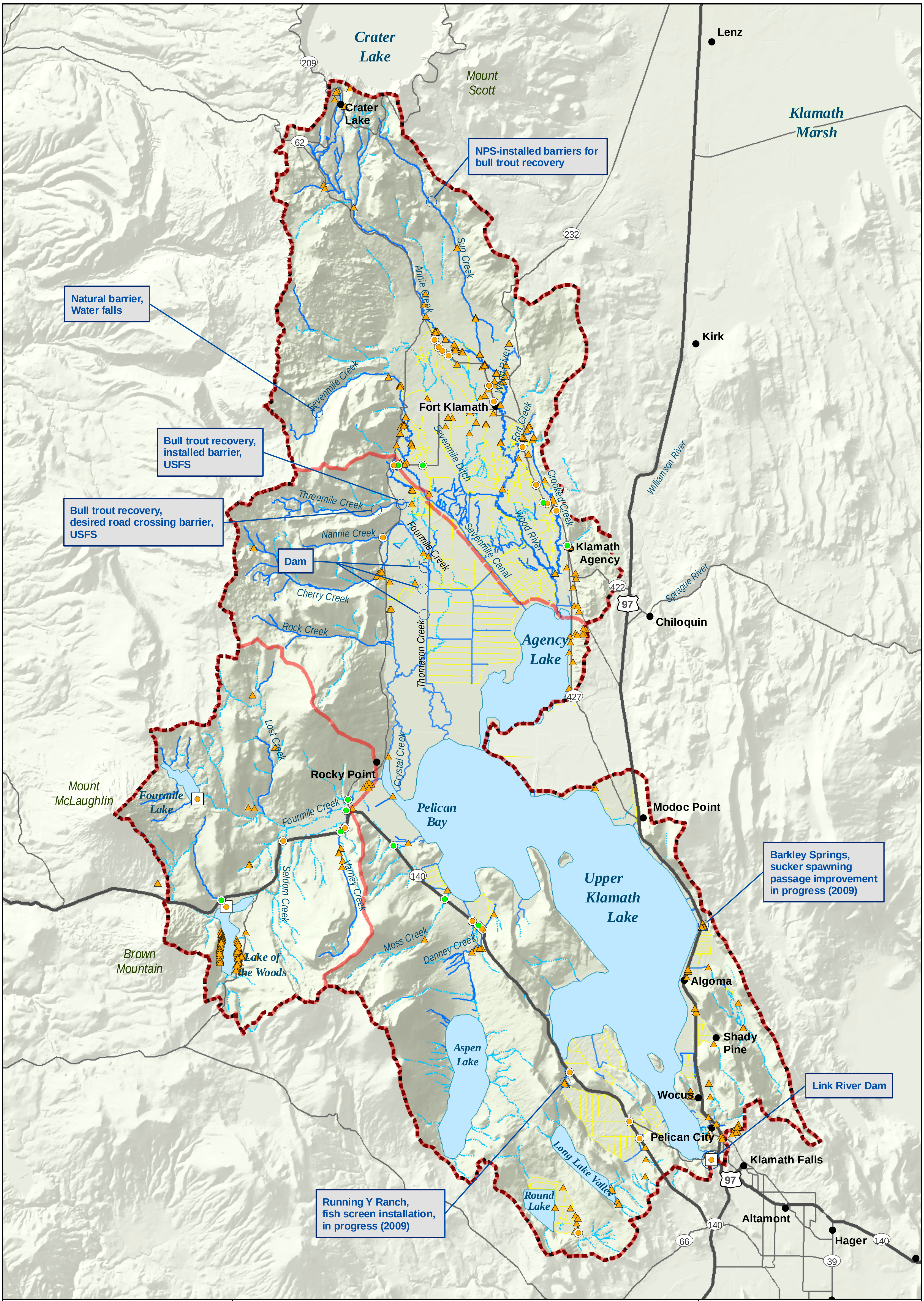

0 4 8
Miles

Source Data:
ESRI, Klamath County, Oregon GEO, USGS (National Hydrography Dataset)

Legend

Subbasin Boundary
Stream/River: Perennial
Stream/River: Intermittent
Stream/River: Ephemeral
Canal Ditch

Potential Barriers

Diversions (OWRD)

ODFW Barriers

Culvert
Dam
Passable
Unknown

Map 9-2: Potential Fish Barriers

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CHAPTER 10:

WATERSHED CONDITION EVALUATION

10 CONDITION EVALUATION, RESEARCH RECOMMENDATIONS AND RESTORATION OPPORTUNITIES

Summary of Watershed Conditions

A fundamental part of the watershed assessment is to provide an understanding of historic conditions, primarily because they serve as an important reference point for proposed restoration and management actions. The Upper Klamath Lake Subbasin has a rich and dynamic history. From the wocus harvest in the extensive marshlands surrounding Upper Klamath and Agency lakes, along the sucker filled waters, through the fertile lowlands, up to the Douglas fir- and yellow pine-rich hillsides – many years have passed since settlers came to the subbasin, but many challenges remain the same. Humans need water to grow their crops, pastureland to feed their livestock, and timber and land to build their communities. These needs remain unchanged; however, increased anthropogenic demands on resources in the subbasin have resulted in dramatic changes to surrounding landscapes, rivers, and lakes.

Prior to Euroamerican settlement, it is estimated that between 1,200 and 2,000 native people inhabited the entire Upper Klamath Basin (DEA, 2005). While these first people prescribed land management activities such as fire for hunting and small dams for trapping fish, it wasn't until the mid to late 1800s that land management techniques, employed by both tribes and settlers, became more large scale. Direct manipulation of the landscape, such as diking and draining wetlands and streams, combined with increased extraction of natural resources such as timber and fish, contributed to the decline of wetland and riparian ecosystem functions and to reductions in fish and beaver populations.

Hydrology, Water Use, and Channel Modifications

Historically, a complex system of springs and snowmelt fed the streams that empty into Upper Klamath and Agency lakes. Flow from springs and snow melt flowed into higher elevation streams, then through a large series of wetlands, and finally into Upper Klamath and Agency lakes. The primary tributaries providing flow into Upper Klamath and Agency lakes included the Williamson River, Wood River, and several streams from the eastern slopes of the Cascade Range. Upper elevation channels were high gradient, fed by snowpack, and well shaded by a combination of trees and topography, all of which helped keep water temperatures relatively cool. Porous soils high in the Cascades allowed snowmelt to infiltrate, which caused some perennial reaches to naturally transition into intermittent reaches. In some cases, such as in lower Fourmile Creek, where the gradient rapidly dissipates, a substantial amount of stream flow naturally disappeared into the porous substrate before reaching the lake.

The basic hydrologic components of snow melt, highly permeable soils leading to infiltration, and spring fed streams still exist today. So too does the forested nature of the upper watershed. However, other components of the watershed's hydrologic system have been modified relative to historic conditions. Around 1920, when the Link River Dam was constructed, dikes were built to protect the pasture and cropland from flooding. In addition, ditches and channel diversions were constructed to manage water demands for surrounding agricultural lands. Water use and diversions within the subbasin have notably reduced stream flow, causing some historically perennial stream reaches to flow intermittently. These human manipulations of the natural hydrologic system led to considerable changes in natural flow and drainage patterns, resulting in adverse impacts to fish and other aquatic-dependent species such as macroinvertebrates and waterfowl.

The channel types that are most sensitive to changes are the low-gradient (<2 percent) reaches with a developed floodplain. These low gradient channels commonly lack geomorphic diversity such as bedrock, boulders, or confining terraces or hillslopes which help control fluctuations in water storage and channel geometry, especially during storm events. For example, diversion and channelization of the channels along Cherry Creek (within the Klamath Lake watershed) has resulted in the development of almost completely vertical banks and disconnection from the natural floodplain. The loss of channel roughness elements has resulted in increased stream velocity, leading to streambank instability, bank erosion, alteration of sediment transport, and a lowered groundwater table. Additionally, diversion of water has caused decreased bankfull flows, which in turn causes aggradation of the streambed as demonstrated by instream bar formation, lateral migration, and stream branching.

A preliminary evaluation of consumptive water use (primarily irrigation) within the subbasin, coupled with instream water rights, indicates that minimum instream flow levels can be maintained during years of average precipitation. However, extreme events such as drought or highly fluctuating climatic patterns creates a burden on a limited resource that may make it difficult to meet the demand of all water rights.

Sediment

According to various studies, sediment accumulation in the Upper Klamath Lake Subbasin has been increasing over the last 100 years. While the high gradient slopes on the east side of the Cascades are generally vulnerable to erosion, the highly permeable nature of the soil and low precipitation typically minimizes large quantities of water and sediment from entering streams. However, ditching and channelizing the low gradient reaches of the subbasin, like those surrounding Upper Klamath and Agency lakes, has reduced channel roughness, which increases water velocities and erosion. Moreover, the reduction in diversity and vigor of vegetation from channel banks for grazing purposes has decreased bank stability and increased erosion potential. Therefore, it is reasonable to conclude that increased sediment within the subbasin is almost entirely the result of anthropogenic activities. The two most significant sources of sediment include bank erosion from unvegetated and/or straightened channels and runoff from roads located adjacent to streams. Elevated sediment levels in streams and Upper Klamath and Agency lakes is just one of the many factors that have substantially impacted fishery resources and water quality.

Riparian Conditions

Historic records and GLO maps indicate upper elevation riparian areas were primarily composed of stands of large, medium density, mature trees, typically ponderosa pine and Douglas-fir. These old growth trees supplied an abundance of LWD to adjacent streams and provided sufficient shading to help cool streams. Lower elevation riparian area vegetation generally included lodgepole pine, aspen, cottonwood, willows, and various native herbaceous species. These low elevation riparian areas transitioned into emergent wetlands surrounding Upper Klamath and Agency lakes.

As mentioned previously, land use and management have altered the upper and lower elevation riparian and wetland areas throughout the subbasin to varying degrees. During the first wave of settlement in the basin, large old growth trees were removed so they could be sold as timber. For example, in Fourmile Lake drainage and the east slopes of the Cascades, nearly all old growth ponderosa pines were cut for timber, resulting in a loss of critical habitat for nesting birds and other riparian habitat dependent species. Additionally, high elevation channels were cleared of large wood in order to move timber to where it could be sold and loaded onto rail cars, resulting in decreased channel complexity and habitat available for aquatic species. Moreover, roads were built to access timber, resulting in increased runoff and sediments in adjacent channels. In summary, logging activities, such as extraction of timber, removal of LWD, and construction of logging roads, severely altered sediment patterns and reduced riparian and aquatic habitat features.

While many upper elevation riparian areas are designated national forest and therefore significant protection and restoration efforts have been employed, the composition of these riparian areas has changed from historic conditions. As mentioned above, these riparian areas generally lack old growth trees. In addition, fire suppression has allowed young shoots to sprout and survive, resulting in overstocked riparian areas with a high proportion of young trees and thus a lack of large wood recruitment opportunities for streams.

Wetland Conditions

Historically, Upper Klamath and Agency lakes were surrounded by an extensive complex of wetlands occupying many thousands of acres. These fringe wetland complexes allowed for adaptation and resiliency to natural variations in water levels resulting from changes in annual precipitation and snow melt, short-term storm events, and longer term climate variation. High water elevations within the lakes were lower than present day due to the absence of the Link River Dam. However, low water elevations were higher than present day. This is because construction of the Link River Dam lowered the bottom elevation of the lake outlet (i.e. natural rock sill was lowered), thereby enabling management of lake water elevations to below historic conditions.

Some historians estimate that since the late 1800’s, nearly 65 percent of the wetlands adjacent to Upper Klamath and Agency lakes have been drained for agricultural use (NRCS 2003). These lower elevation wetland complexes were altered through dredging, diking, and removal of woody vegetation for agricultural purposes, not only reducing total wetland area, but changing the type and quantity of wetland classes from historic conditions. Today, the subbasin is characterized primarily by two wetland classes: palustrine emergent and lacustrine limnetic wetlands. While the proportion of lacustrine littoral wetlands in the subbasin has not changed much over time, the proportion of palustrine emergent wetlands has increased overall. Based upon historic descriptions of the area, it is highly probable that much of the area (particularly in the Wood River watershed) currently identified as palustrine emergent wetland was at one time palustrine forest or palustrine scrub shrub wetland; however, woody vegetation was cleared from these wetland areas for agricultural and pasture use (USFS 1994). The loss of wetlands in the subbasin has contributed to reduced water quality, increased frequency and extent of algal blooms, a reduction in available wetland habitat, a reduction in native species populations, and a reduction in water storage capacity.

Water Quality

Generally speaking, water quality in the tributaries to Upper Klamath and Agency lakes is relatively good (referring to tributaries in Upper Klamath Lake watershed only, does not include Williamson River). Although several tributary streams were previously listed on the 303(d) list as water quality limited, this was primarily due to habitat and/or flow concerns, which are not true water quality parameters. Only two tributaries were listed as water quality impaired for temperature; however, current temperature data, as discussed in Chapter 8 Water Quality, show that the perennial reaches of these streams are in compliance with temperature standards. Generally speaking, the tributary streams within the subbasin, particularly the perennial streams, contain cool to very cold water as a result of groundwater inputs such as springs.

In contrast to the generally good water quality of the subbasin tributaries, Upper Klamath and Agency lakes suffer from poor water quality, which impacts beneficial uses, particularly resident fish and aquatic life. The lakes were previously listed on the 303(d) list for non-compliance with state standards for pH, chlorophyll-a, and dissolved oxygen. A TMDL was issued in 2002 to address these issues, which in turn led to delisting of the water bodies as well as the preparation of water quality management plans by the Forest Service and USDA-NRCS. The water quality problems in the lake are driven by high phosphorous concentrations, which drive deleterious algal blooms that cause low dissolved oxygen and large swings in pH. Phosphorous in the lakes comes from both tributary sources as well as in-lake stores (particularly lake bottom sediments), with nearly two-thirds coming from the in-lake stores. While various restoration efforts have been implemented since 2002, the frequency, extent, and duration of algal blooms (caused by increased phosphorous concentrations) continue to trend upwards. Poor water quality in Upper Klamath and Agency lakes have primarily impacted fish species that use the lake, such as redband trout and Lost River and shortnose suckers.

Fish

Historically, three species of anadromous fish migrated from the Pacific Ocean up the Klamath River and into Upper Klamath Lake: steelhead trout, Chinook salmon, and Pacific lamprey. However, in 1917, after Copco Dam was constructed, these anadromous fish species were no longer able to migrate into Upper Klamath Lake. Currently, twelve native and nine non-native fish species are documented as residing within the Upper Klamath Lake Subbasin. Native focal species described in this watershed assessment (Chapter 9 Fish and Fish Habitat Assessment) include the redband trout, bull trout, shortnose sucker, and Lost River sucker.

The Upper Klamath Lake Subbasin supports the largest and most functional adfluvial redband trout populations of Oregon interior basins. Redband trout of the Upper Klamath Lake Subbasin are part of the Klamath Lake group and are primarily found in streams on the eastern slopes of the Cascade mountains, on the west side of Upper Klamath Lake, and in the Wood River watershed. The principle threats to redband trout within the Upper Klamath Lake watershed are fish passage barriers and the potential for entrainment due to unscreened diversions.

Despite the relative success of redband trout, bull trout populations are listed as threatened. Current spawning and distribution of bull trout in the Upper Klamath Lake Subbasin is highly fragmented and limited to a few headwater streams. Some of the biggest threats to bull trout populations are increased water temperatures, poor water quality, degraded stream habitat, passage/migration barriers and hybridization and competition with non-native brook trout, brown trout, and lake trout.

In addition to the listing of bull trout, the Lost River and shortnose suckers are listed as endangered. Historically, suckers were abundant in the greater Upper Klamath Basin. Currently, the shortnose sucker occupies only a fraction of its former range and is restricted to a few areas in the Upper Klamath Basin, including the Upper Klamath Lake Subbasin and its tributaries. Within the Upper Klamath Lake Subbasin sucker population numbers are severely lower than historic accounts. Suckers that reside in Upper Klamath and Agency lakes utilize spawning habitat in the Williamson River, Wood River, Sprague River, and a number of cold water springs that flow directly into the lakes. Historically, sucker spawning occurred in other Upper Klamath Lake tributaries including Crooked Creek, Fort Creek, Sevenmile Creek, Fourmile Creek, Odessa Creek and Crystal Creek, (Stine 1982 as cited in USBR 2001) in addition to springs surrounding Upper Klamath Lake including Barkley Springs, Harriman Springs, Camporee Springs, four unnamed springs on the eastside of Upper Klamath Lake, Odessa Springs, and Bare Island Springs (Cascade Quality Solutions 2005). Although no rigorous spawning run surveys have been conducted in these locations in recent times, infrequent surveys and observations have revealed no evidence of current day sucker spawning runs in these streams or springs (USBR 2001). The primary threats to current sucker populations are poor water quality, reduced suitable habitat for all size and age classes, and the impacts of non-native fishes (primarily predation of juvenile suckers).

Redirection, channelization, and diversion of streams have impacted fish migration throughout the subbasin, particularly migration across private lands into higher elevation, higher quality stream habitats such as those found on USFS land. Fish passage is blocked, primarily due to water diversions (i.e., low flows and unscreened diversions) from Upper Klamath and Agency lakes up to the USFS land reaches of Fourmile Creek, Rock Creek, Cherry Creek, Threemile Creek, and Sevenmile Creek.

Climate Change

In recent times there has been growing concern about the potential risks posed by predicted changes to the earth's climatic system. Likewise, there has been a growing awareness for the need to plan for and adapt to these potential changes. Looking at the existing watershed conditions through the lens of climate change helps reinforce many of the already identified research needs and restoration and management opportunities. For example, wetland restoration has been identified as a restoration opportunity in the Upper Klamath Lake Subbasin for the purposes of providing benefits to water quality, fish habitat, macroinvertebrate species, etc. Additionally, restoring wetlands will make them more resilient to some of the potential impacts resulting from climate change. Therefore, climate change does not necessarily provide new or unique recommendations for restoration and management opportunities, but rather, helps reinforce and prioritize opportunities that benefit the overall health of the watershed.

The National Center for Conservation Science & Policy (NCCSP) and the University of Oregon's Climate Leadership Initiative (CLI) have been working with stakeholders within the Klamath Basin to address potential effects of predicted climate change to natural, built, and human systems in the basin. This project is known as the Climate Futures Forum. The goal is to take proactive steps to anticipate and prepare for the likely consequences of climate change by building resistance and resilience (i.e., the ability to recover from impacts) to the range of stresses that are expected to occur over the next century (NCCSP and CLI 2010). The Climate Futures Forum project incorporated a range of regionally downscaled climate model predictions, developed by the USDA Forest Service Pacific Northwest Research Station, with local stakeholder group insights to arrive at recommended actions for climate preparedness within the Upper Klamath Basin. A summary of the climate modeling results and recommendations derived from these results is provided below.

Summary of Regional Future Climate Predictions

A range of regional future climate predictions were arrived at using three global climate models (CSIRO, MIROC, and HADCM) and a vegetation model (MC1). These models provided predictions for future temperature, precipitation, vegetation, runoff, and wildfire in the Klamath Basin (NCCSP and CLI 2010). All three climate models projected an increase in annual average temperatures compared to baseline temperatures (2.1 to 3.6° F increase by mid-century and 4.6 to 7.2° F by late century), with summer warming projected to be greater than warming during other seasons (NCCSP and CLI 2010).

Modeled projections for precipitation changes tended to be more varied than temperature. Projections for annual average precipitation ranged from an overall reduction of 11% to an increase of 24% (NCCSP and CLI 2010). However, all three models agreed that future summers are likely to be somewhat drier (a decrease of 3% to 37%) than past summers (NCCSP and CLI 2010).

Based on the modeled projections of climate change, the Climate Future Forums stakeholder group came up with the following management and restoration recommendations:

- "Protect areas with cooler water as air and water temperatures rise. These include stream and lake areas with groundwater-fed springs and well-developed bank vegetation.
- Decommission and re-contour non-essential roads to reduce overall impacts of erosion and sedimentation during severe storm events.
- Reconnect rivers with floodplains, restore wetlands, and restore stream-side areas to hold more water during floods and increase groundwater recharge.
- Protect intact habitats such as roadless areas that provide strongholds for many native species.
- Reseed areas after disturbance with locally collected, native seeds to re-establish plants that occur in the area and limit the spread of invading species.
- Develop new partnerships across agencies, Tribes, and landowners to encourage landscape-scale planning across jurisdictional boundaries.
- Increase reliability of water supply and decrease the likelihood of flooding by restoring wetlands, constructing bioswales, and restoring floodplains and stream-side areas.
- Provide incentives for water conservation to reduce water demand and increase natural water storage.
- Replace undersized culverts to prevent road-stream crossing failures during floods.
- Retain resiliency of natural systems so they continue to provide ecosystem services such as clean water supply, flood buffering, and timber production so that the communities and industries they support are maintained."

Importantly, the management and restoration recommendations provided by the Climate Future Forums stakeholder group are consistent with those made in this watershed assessment.

Potential Future Restoration Efforts in the Subbasin

In synthesizing the results from each of the assessment chapters it is apparent that restoring rivers and wetlands may have the greatest impact on water quality and quantity within the Upper Klamath Lake Subbasin. Restoring rivers, and riparian and wetland communities will lead to the following improvements:

- Enhanced habitat for listed aquatic species
- Reduced sedimentation through increased channel stability
- Increased water storage through reconnection of the channel and floodplain
- Increased water storage and wetland habitat
- Overall improvements to watershed health

Existing Restoration Efforts in the Subbasin

The restoration work that has been taking place in the Upper Klamath Lake Subbasin for the past few decades has taught us many important lessons about the effectiveness of restoration actions. Importantly, people have learned that the results of implementing restoration actions in one area can vary dramatically from the results of implementing the same restoration action in a different area. The following section briefly describes just a few of the historic and ongoing restoration efforts within the subbasin. Knowledge of the types of restoration work that has already been done as well as the successes of this work can help inform future restoration efforts in the subbasin.

Restoration on Public and Private Lands

Table 10-1 provides a list of restoration projects that have taken place within the Upper Klamath Lake Subbasin between 1995 and 2005. Information about several projects was provided by the Oregon Explorer GIS database (Oregon Explorer 2009). This database only covers projects carried out between 1995 and 2005. In addition, information about USFS projects has been provided by USFS GIS data. The locations of these projects are shown in Map 10-1 (Restoration Projects). Additional projects are likely to have occurred within the subbasin that are not listed below or displayed on the maps.

Table 10-1 Restoration Projects Within the Upper Klamath Lake Subbasin, 1995-2005

Project	Stream Name/ Water Body	Project Description	Participant(s)	Landowner	Project Start Year	Project Completion Year	Project Type	Restoration Activities	Total Treated
Riparian Fencing [1]	Wood River	Riparian fencing	ODFW, Private, ODFW, Klamath Guides Association	Private Landowner	2005	2005	Riparian	Riparian: Riparian fencing	Linear Stream Miles: 0.75
Wood River Fish Passage R&E 97-258 [1]	Wood River	Fish passage improvements: fish ladder installed	ODFW, Private, Water-For-Life,	Private Landowner	1998	1999	Fish passage	Fish Passage: Non-culvert improvement	Miles that were previously accessible for both juveniles and adults, where access was improved: 2.00
Wood River Large Woody Debris [1]	Wood River	Instream habitat enhancement: anchored structures	Klamath SWCD, Private, ODFW, OWEB	Private Landowner	2001	2001	Combined	Instream: Instream habitat (anchored): anchored habitat structures Riparian: Riparian fencing	Miles of stream: 0.08 Linear Stream Miles: 0.47
Phil Patti Wood River [1]	Wood River	Instream habitat enhancement: anchored log structures; riparian fencing	Private, OWEB, ODF, Klamath SWCD	Private Landowner	2001	2002	Combined	Instream: Instream habitat (anchored): Structure placement-Anchored habitat structures placed Riparian: Riparian fencing	Miles of stream: 0.08 Linear Stream Miles: 0.47
Annie Creek Slough Fish Ladder [1]	Annie Creek Slough, tributary of Agency Lake	Fish passage improvements: 1 fish ladder installed	ODFW, Rogue River Ranch	Private Landowner	1999	2000	Fish passage	Fish Passage: Non-culvert improvement	Miles that were previously accessible for both juveniles and adults, where access was improved:

Project	Stream Name/ Water Body	Project Description	Participant(s)	Landowner	Project Start Year	Project Completion Year	Project Type	Restoration Activities	Total Treated
									5.00
Sevenmile Creek Fish Passage [1]	Sevenmile Creek, tributary of Agency Lake	Fish passage improvements: 1 fish ladder installed	ODFW, ODFW, Rogue River Ranch	Private Landowner	1998	2000	Fish passage	Fish Passage: Non-culvert improvement	Miles opened that were previously inaccessible for both adults and juveniles: 4.00
Wood River Riparian Fence-Roger Nicholson [1]	Wood River	Riparian fencing	ODFW, Private	Private Landowner	1998	1998	Riparian	Riparian: Riparian fencing	Linear Stream Miles: 1.00
Crooked Creek Spawning Habitat [1]	Crooked Creek, tributary of Wood River	Spawning gravel placement	ODFW, Klamath Flycasters, Eternal Hills Cemetery	ODFW	2005	2005	Instream multiple	Instream: Channel alteration. Spawning gravel placed	Miles of stream: 0.10
Agency Creek Dam Removal and Stream Restoration [1]	Agency Creek, tributary to Crooked Creek	Channel alteration; fish passage improvements: 1 culvert removed and not replaced	OWEB, Fort Klamath Properties, LLC, USFWS	Fort Klamath Properties, LLC	2002	2002	Combined	Instream: channel alteration: main stream channel modified / created Fish Passage: Culvert improvement	Miles of stream: 0.32 Miles opened that were previously inaccessible for both adults and juveniles: 0.30
Peach Bank Improvement [1]	Upper Klamath Lake	Riparian fencing, streambank stabilization	Private, OWEB, Klamath SWCD	Private Landowner	2003	2003	Riparian	Riparian: Bank stabilization, Riparian fencing	Linear Stream Miles: 0.25
South Pasture Levee Breaching [2]	Wetlands adjacent to Upper Klamath Lake	Levee breaching to restore hydrologic connectivity to lake and additional rearing habitat for larval and juvenile suckers that out-migrate from the mouth of the Williamson River	The Nature Conservancy, NRCS, others	The Nature Conservancy	2003	2004	Wetlands	Removed several hundred feet of levee	Acres of wetlands reconnected to lake: approximately 165
Annie Creek Road Relocation and Obliteration	Annie Creek	Road relocation and obliteration	USFS	USFS	2008	2009	Sediment reduction to a fish bearing stream	Road relocation and obliteration	
Crane Creek Stream Restoration	Crane Creek	Fish passage, return water to historic channel	Private, KBRT, USFWS, USFS, NRCS	Private and USFS	2007	2008	Stream restoration	Remove fish barriers, return water to historic channel	Linear Stream Miles: 3.0
Fourmile Creek Road Repair	Fourmile Creek	Road repair	USFS	USFS	2008	2008	Sediment reduction	Road repair	
Lower Rock Creek Stream Enhancement	Rock Creek	Channel reconstruction, riparian planting	USFS	Private and USFS	Unknown	Unknown	Stream enhancement	Channel reconstruction, willow planting	Linear Stream Miles: unknown
Rock Creek Stream Enhancement	Rock Creeks	Large wood placement, habitat enhancement	USFS, ODFW	USFS	2004	2007	Stream enhancement	Instream log placement	Linear Stream Miles: 1.0
Rock Creek Road #3519-060 Obliteration	Rock Creek	Road obliteration	USFS	USFS	2004	2004	Sediment reduction to a fish bearing stream	Road obliteration	
Rainbow Creek Road Obliteration	Rainbow Creek, drains to Lake of the Woods	Road obliteration	USFS	USFS	2006	2006	Sediment reduction to a fish bearing stream	Road obliteration	Linear Stream Miles: 1.0
Sevenmile Creek Road #3334 Improvements	Sevenmile Creek	Road improvements	USFS	USFS	2003	2003	Sediment reduction to a fish bearing stream	Road storm proofing	
Threemile Creek Non-Native Fish Removal	Threemile Creek	Non-native fish removal	USFS	USFS	1996	2009	Reduction in resource competition for native species	Non-native fish removal	

Project	Stream Name/ Water Body	Project Description	Participant(s)	Landowner	Project Start Year	Project Completion Year	Project Type	Restoration Activities	Total Treated
Threemile Creek Stream Enhancement	Threemile Creek	Large wood placement, habitat enhancement	USFS, ODFW	USFS	2004	2004	Stream enhancement	Instream log placement	
Threemile Creek Fish Barrier Removal	Threemile Creek	Fish barrier removal	USFS	USFS	2007	2008	Fish barrier removal	Weir removal and replacement with log sill	
Threemile Riparian Road Improvements	Threemile Creek	Riparian road improvement	USFS	USFS	2009	2009	Fiparian road improvement	Sediment reduction to stream through road surface treatment and improvements to drainage system	
Crooked Creek riparian fencing [3]	Crooked Creek	Riparian fencing & cattle management	KBRT, NRCS, private landowners	private	2002 (initial area)	2009 (final area)	Riparian	Riparian fencing	4.5 stream miles (9 mi of bank)
Crooked Creek Habitat Restoration I [3]	Crooked Creek	Narrowing stream corridor, restoring habitat features. To be protected in WRP	USFWS, Private landowners	Private	1997	1999	Channel function & habitat	Streambank stabilization, channel restoration, large wood	2.25 miles of stream, 253 ac wetland
Crooked Creek Habitat Restoration II [3]	Crooked Creek	Streambank stabilization, habitat features. To be protected in WRP.	KBRT, USFWS, western native trout initiative, private landowner	Private	2009	2009	Channel function & habitat	Streambank stabilization, spawning gravel addition, large wood	2.25 miles of stream, 98 ac wetland
Agency Creek Dam Removal & Restoration [3]	Agency Creek	Removed dam and restored stream function and connectivity to Crooked	KBRT, USFWS, OWEB, private landowner	Private	2003	2004	Dam removal, riparian, instream	Removed dam, rebuilt historic channel and habitat features	0.75 miles of stream
Agency Ranch lake-fringe wetland restoration [3]	Agency Lake	Breached dike to reconnect to lake, enrolled in WRP	KBRT, USFWS, NRCS, private landowner	Private	2007	2009	wetland	Dike breaching, blocking drainage ditches, wetland habitat features	700 acres
Wood River habitat enhancement I [3]	Wood River	Reconnected stream to riparian wetland, riparian protection, habitat features	KBRT, USFWS, NRCS, private landowner	Private	2009	Continuing	Instream and riparian	Dike breaching, riparian fencing, large wood	0.5 mi stream
Crooked Creek & Wood River System instream flow protection [3]	Crooked Creek, Wood River, tributaries	Short-term (5yr +) transfer of irrigation rights to instream uses	KBRT, ODFW, NRCS, BOR, private landowners	Private & BLM	2004	continuing	Instream	Instream leasing	8 stream miles. 76 cfs
Sevenmile Creek Riparian Fencing [3]	Sevenmile Creek & tributaries	Riparian fencing & cattle management	KBRT, NRCS, private landowners	private	2002 (initial area)	2009 (final area)	Riparian	Riparian fencing	13 stream miles (26 miles bank)
Upper Sevenmile Ditch Dam Removal [3]	Sevenmile creek	Dam replacement with diversion structure that allows fish passage	KBRT, private landowners	USFS, private irrigation diversion	2004	2004	Fish passage	Dam removal	Improved passage to 9 miles of stream
Diversion Dam above Bluesprings [3]	Sevenmile Creek	Return creek to historic channel from canal it had been directed into for irrigation, bypass diversion dam	KBRT, USFWS, private landowner	Private	2009	2009	Fish passage, habitat	Channel restoration, dam removal	0.5 stream miles habitat restored. Improved passage to 10.5 stream miles.
Lower Sevenmile Ditch Diversion Dam [3]	Sevenmile Creek	Remove two culverts placed in the mainstem to facilitate irrigation diversion	KBRT, USFWS, OWEB, private landowner	Private	2009	Continuing	Fish passage	Dam / culvert removal	Improved passage to 13 stream miles
Sevenmile Diversion Dam @ Sevenmile Road [3]	Sevenmile Creek	Remove a large diversion dam, install fish bypass channel. Protected in WRP.	KBRT, USFWS, OWEB, NRCS, private landowner	Private	2008	2009	Fish passage	Dam removal, fish bypass channel	Improved passage to 18 stream miles

Project	Stream Name/ Water Body	Project Description	Participant(s)	Landowner	Project Start Year	Project Completion Year	Project Type	Restoration Activities	Total Treated
Short Creek culvert removal , spring reconnection, and habitat restoration [3]	Short Creek	Remove culvert blocking fish passage, reconnecting spawning channel, habitat features. To be protected in WRP.	KBRT, OWEB, private landowner	Private	2005	2006	Fish passage, instream habitat, riparian fencing	Culvert removal, riparian fencing, large wood, spawning gravel	1.5 stream miles of habitat restored. Improved passage to 0.5 stream miles. 426 ac wetlands to be protected.
Crane Creek restoration to historic channel [3]	Crane Creek	Return Crane Creek to historic channel, from ditch it flowed in year round, restore water table and hydrology to wetlands. Reconnected spring. Removed passage barriers.	KBRT, OWEB, USFWS, USFS, NRCS, private landowner	Private & USFS	2006	2009	Instream, riparian, wetland, passage	Channel restoration, gravel, wood, headgate removal, spring restoration	4 stream miles restored. Passage restored to 5 stream miles. 443 ac wetlands to be protected.
Sevenmile Creek system instream flow protection [3]	Sevenmile Creek and tributaries	Short-term (5yr +) transfer of irrigation rights to instream uses	KBRT, ODFW, NRCS, BOR, private landowners	Private	2004	continuing	Instream	Instream leasing	23 stream miles. 78 cfs
Fourmile Creek system instream flow protection [3]	Fourmile creek and tributaries	Short-term (5yr +) transfer of irrigation rights to instream uses	KBRT, ODFW, NRCS, BOR, private landowners	Private	2004	continuing	Instream	Instream leasing	2 stream miles. 7 cfs

[1]Oregon Explorer 2009
[2]Oregon Explorer 2009 and Oregon.gov 2007
[3]KBRT date unknown

Research Recommendations and Restoration Opportunities

The purpose of a watershed assessment is to gather existing information and draw general conclusions about the general health of the watershed or, in this case, the subbasin. A watershed assessment is not intended to provide site-specific recommendations or target landowners.

This assessment has developed a list of research recommendations and restoration and management opportunities that will generally provide the greatest benefit to the aquatic and riparian resources, and the community members within the Upper Klamath Lake Subbasin. Many of the restoration opportunities identified in this assessment will require additional research, evaluation, or data collection before a site-specific restoration project can be designed and implemented.

Research Recommendations

The research recommendations identified within this Watershed Assessment can be summarized as follows:

1. Riparian/Channel

A. Update information on riparian conditions that is out of date and gather new data on streams located on private property. Conduct a riparian land-cover assessment to 1) identify properly functioning reaches for purposes of protection, 2) identify riparian areas most requiring restoration actions, 3) monitor areas that have received restoration actions or alternative management.

B. Conduct a geomorphic channel assessment on potential restoration sites in order to better understand potential return on investment. Priority should be given to those sites that restore historical connections to Upper Klamath and Agency lakes. Consider the 1) feasibility of removing channel modifications, and 2) the potential impacts upstream and downstream of the restoration site.

C. Consistently monitor the effectiveness of restoration actions. Many landowners and public agencies are implementing restoration projects and gathering monitoring data. There needs to be effective communication and coordination of monitoring efforts in order for the information to be useful.

2. Wetlands

A. Monitor existing restoration sites. Include data on water levels and how they impact soil conditions, plant and animal species, biogeochemical processing, nutrient losses and water storage.

B. Study the effects of grazing management on wetland species composition.

C. As more projects are implemented, assess the impact of multiple wetland restoration projects on water storage and late-season flows. This may reveal places that would be good candidates for restoration based on ability to contribute to overall storage.

3. Hydrology

A. Evaluate gage locations, maintain all currently operational continuous stream flow gages, reestablish discontinued gages and establish additional gages in key locations.

B. Evaluate the effects of land uses and restoration efforts on water storage and late-season flows.

C. Implement subbasin-wide evaluation of land use effects on peak flows. Emphasis should be placed on the possible effects of past activities on current conditions and the possible impacts of future management scenarios.

4. Erosion Control

A. Conduct a comprehensive road inventory in order to prioritize road erosion restoration efforts. Build from the existing USFS inventory to include roads on private land.

B. Conduct a geomorphic analysis on fish-bearing streams that have experienced a change in rate and pattern of sediment transport in order to inform restoration opportunities.

C. Expand upon baseline monitoring efforts (NRCS CEAP Study) to quantify sediment inputs. Monitoring before and after restoration efforts will help guide future restoration actions.

5. Water Quality

A. Evaluate water quality data recorded after 2002 TMDL process to assess more recent trends and comparison with previously evaluated data.

B. Conduct an opportunities and constraints analysis for lowering in-lake stores of nutrients.

6. Fisheries

A. Conduct a survey of water diversions and fish screens and their potential effect on fish passage.

B. Review and update listings for culverts and dams listed as having “unknown” fish passage in ODFW GIS database.

C. Conduct a macroinvertebrate study to assess the effects of varying land uses on stream productivity/fisheries support function. An initial area of focus should be the Wood River fifth-field Watershed.

D. Monitor and report on past riparian improvement projects (and management) to assess the efficacy of various project types. Include sites that utilize cattle management fencing and/or rotational grazing.

Restoration and Management Opportunities

Throughout each chapter, the restoration and management opportunities listed below were developed in response to the issues observed within the subbasin. Implementation of the following restoration and management actions has the potential to make simultaneous and significant improvements to a diversity of resources within the subbasin:

- Restore riparian conditions in those areas identified under 1.A., above.
- Restore floodplain connections in those areas identified under 1.A., above.
- Restore the natural geomorphic processes as identified under 1.B., above.
- Install grazing management fencing in riparian areas identified under 1.A. and 1.B., above.
- Provide stock watering areas away from waterways.
- Increase proportion of palustrine emergent, scrub-shrub and forested wetland communities.

- Enhance wetlands that could contribute to late-season flows as identified under 2.C., above.
- Install additional stream gages at locations identified by 3.A., above.
- Enhance summertime streamflows through voluntary measures such as improving landowner communications regarding water diversion timing and increasing irrigation efficiencies.
- Implement erosion control measures in roadway areas identified under 4.A., above.
- Prepare grazing management plans for private landowners to facilitate improvements to water quality.
- Protect existing redband trout, bull trout, and sucker spawning sites and refugia. This may include the development of spawning site protection plans for private landowners.
- Restore migratory pathways for redband trout, bull trout, and sucker, including restoring historic connections between stream mouths and Agency or Upper Klamath Lake.
- Screen water diversions as identified under 6.A., above.

These restoration and management opportunities can be used as a first step in developing an action plan and monitoring strategies to benefit the Upper Klamath Lake Subbasin. For nearly all of the restoration actions listed above, it is recommended that extensive monitoring of pre- and post-restoration conditions is conducted in order to accurately evaluate success and document learnings. A strategic approach to restoration and management efforts and monitoring will facilitate funding and will ensure those funds are targeted toward the projects that will have the greatest benefit to the overall health of the watershed.

List of Maps

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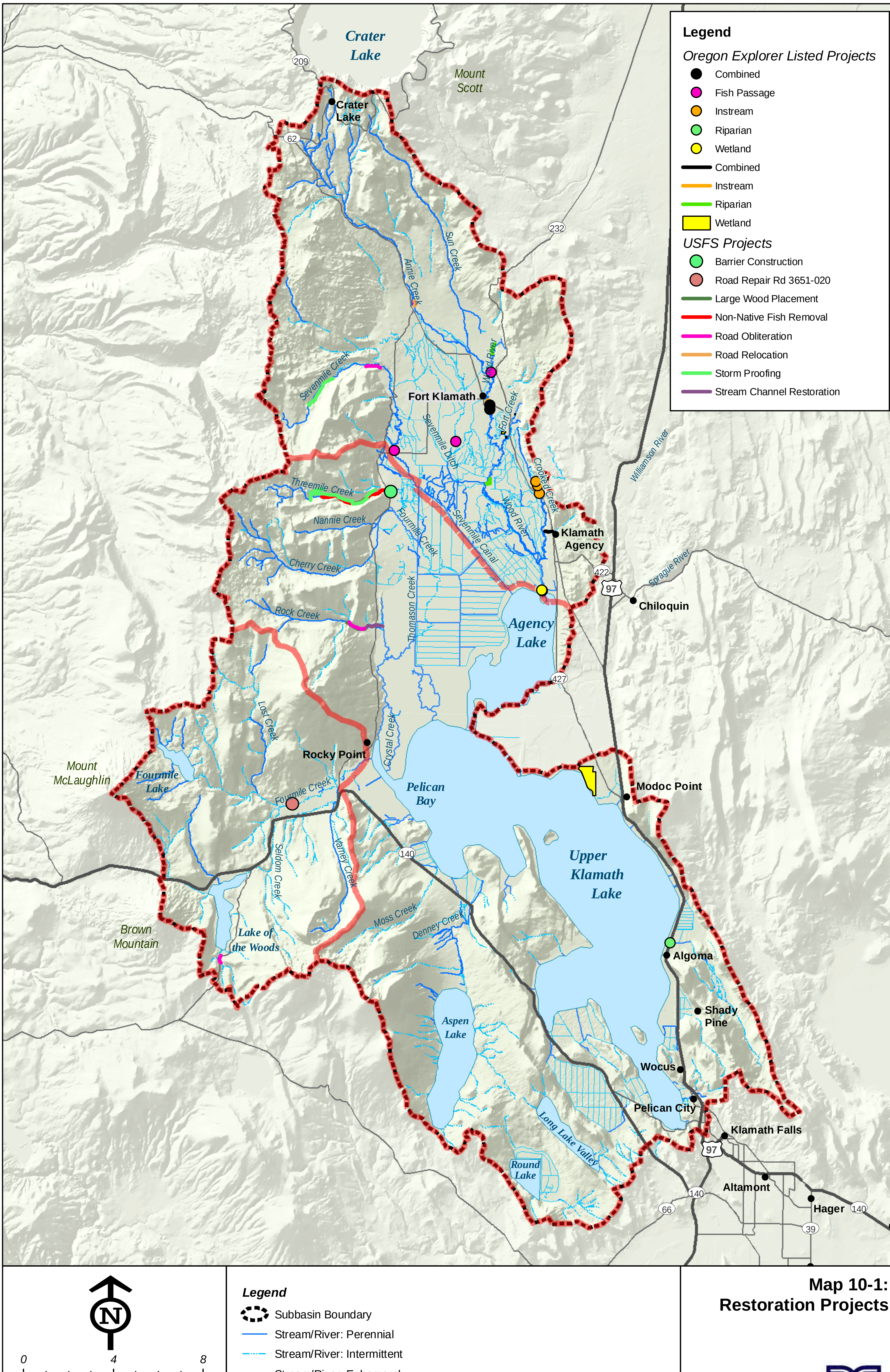

Source Data:
ESRI, Klamath County, Oregon GEO, USGS (National Hydrography Dataset)

Map 10-1: Restoration Projects

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APPENDIX A- WATER QUALITY MONITORING DATABASE

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Metadata for Water Quality Monitoring Stations in the Upper Klamath Lake Subbasin

(source: Klamath Watershed Institute, Humboldt State University 2009)

This is water quality location and frequency information for the Klamath Basin Monitoring Program as of the 2009 sampling season. For more information visit www.KBMP.net. Location information was compiled from a variety of sources including participatory GIS and communication with various agencies.

Lat. and long. Information were requested in WGS 84 datum

Parameter values are as follows:
1= data collected continuously,
2 = data collected 12 or more times per year,
3 = data collected 4-12 times per year,
4 = data collected less than four times per year,
5 = data collected at unknown interval.

Biweek is assumed to be everyother week, unless otherwise stated

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Agency_Site_ID	Agency_N	Lat	Long	Site_Description	Depths_ft	Matrix	Temp_H20	Temp_H20_Seaso	Temp_Air	Temp_Air_Seaso	Rel_Hum	Rel_Hum_Seas	Sonde	Sonde_Seaso	Conductivity	Conductivity_Seas	pH	pH_Season	DO	DO_Season	Total_Phos
FM4140	Bureau of Land Management	42.628875	-122.071189	Fourmile Creek (upper)		surface water	1	June-Oct													
FM4135	Bureau of Land Management	42.614409	-122.055468	Fourmile Creek (lower)		surface water	1	June-Oct													
WRNM	Bureau of Land Management	42.570344	-121.936218	Wood River New Mouth		surface water	1	June-Oct													
WROM	Bureau of Land Management	42.577896	-121.940635	Wood River Old Mouth		surface water	1	June-Oct													
WRDB	Bureau of Land Management	42.580995	-121.941716	Wood River Dike Bridge		surface water	1	June-Oct													
WRTC	Bureau of Land Management	42.596217	-121.942982	Wood River Top Channel		surface water	1	June-Oct													
WRAP	Bureau of Land Management	42.619164	-121.966713	Wood River Above Pump		surface water	1	June-Oct													
WRPD	Bureau of Land Management	42.605155	-121.953242	Wood River Pump Discharge		surface water	1	June-Oct							2	March - Nov	2	March - Nov	2	March - Nov	2
SCPD	Bureau of Land Management	42.582513	-121.97095	Sevenmile Canal Pump Discharge		surface water	1	June-Oct							2	March - Nov	2	March - Nov	2	March - Nov	2
SCFS	Bureau of Land Management	42.607731	-122.000757	Sevenmile Canal Fish Screen		surface water	1	June-Oct							2	March - Nov	2	March - Nov	2	March - Nov	2
421401121480900	Bureau of Reclamation	42.233611	-121.802500	Upper Klamath Lake at Link River Dam		vertical profile	1	all	2	all			1	all	1	all	1	all	1	all	2
KL0010-AS	Klamath Tribes	42.523583	-121.984278	AGENCY SOUTH		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL-ASJ	Klamath Tribes	42.531429	-121.931075	AGENCY JAKE'S		surface water															
KL0006-ER	Klamath Tribes	42.422083	-121.943278	EAGLE RIDGE		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL0005-ML	Klamath Tribes	42.369083	-121.848694	MID LAKE		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL0008- MN	Klamath Tribes	42.441361	-121.998833	MID NORTH		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL0003-NB	Klamath Tribes	42.308389	-121.856222	NORTH BUCK IS.		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL-PB	Klamath Tribes	42.241722	-121.822306	PELCIAN BAY		surface water															
KL0002-PM	Klamath Tribes	42.238026	-121.810373	PELICAN MARINA		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL0007-SB	Klamath Tribes	42.407250	-121.963083	SHOALWATER BAY		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL0004-WB	Klamath Tribes	42.326389	-121.919972	WOCUS BAY		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL-WS	Klamath Tribes	42.531429	-121.931075	WEATHER STATION		surface water															
KL0011-AN	Klamath Tribes	42.560556	-121.947444	AGENCY NORTH		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
KL -FB	Klamath Tribes	42.238725	-121.804673	FREMONT BRIDGE		surface water															
KL-PBL	Klamath Tribes	42.453491	-122.057971	PELICAN BAY INTERFACE		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
UKL0009-CP	Klamath Tribes	42.435722	-122.028194	COON POINT		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
WR2000	Klamath Tribes	42.768433	-122.055366	ANNIE CREEK		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
WR3000	Klamath Tribes	42.633554	-121.983508	WOOD R. @ WEED RD		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
WR4000	Klamath Tribes	42.583000	-121.942000	WOOD R. @ DIKE RD		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
WR5000	Klamath Tribes	42.575966	-121.968600	7-MILE CANAL @ DIKE RD		surface water	1	April - Oct					1	April - Oct	1	April - Oct	1	April - Oct	1	April - Oct	2
TL24	The Nature Conservancy	42.462415	-121.952959	Upper Klamath Lake-West side of WRD from the Williamson River	At mid-depth of water	surface water	2	April-Ice Cover	2	April-Ice Cover			1	April-May	2	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover	2
TL25	The Nature Conservancy	42.477461	-121.980176	Upper Klamath Lake-East side of WRD from the Williamson River	At mid-depth of water	surface water	2	April-Ice Cover	2	April-Ice Cover					2	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover	2
TL27	The Nature Conservancy	42.507214	-121.978672	Agency Lake	At mid-depth of water	surface water	2	April-Ice Cover	2	April-Ice Cover			1	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover	2
AGN	U.S. Geological Survey	42.559722	-121.945278	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
AGS	U.S. Geological Survey	42.523583	-121.984278	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
EPT-L	U.S. Geological Survey	42.433111	-121.962250	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
EPT-U	U.S. Geological Survey	42.433111	-121.962250	Upper Klamath Lake	1 m from surface	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
EBB	U.S. Geological Survey	42.419433	-122.016027	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
EHB	U.S. Geological Survey	42.326500	-121.884972	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
FBS	U.S. Geological Survey	42.469111	-122.045417	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
HDB	U.S. Geological Survey	42.325833	-121.916667	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
MDT-L	U.S. Geological Survey	42.384747	-121.927278	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
MDT-U	U.S. Geological Survey	42.384747	-121.927278	Upper Klamath Lake	1 m from surface	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
MDL	U.S. Geological Survey	42.386667	-121.866417	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
MDN-L	U.S. Geological Survey	42.439306	-122.011111	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
MDN-U	U.S. Geological Survey	42.439306	-122.011111	Upper Klamath Lake	1 m from surface	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
MRM	U.S. Geological Survey	42.410362	-121.864564	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
NBI	U.S. Geological Survey	42.310556	-121.860833	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
RPT	U.S. Geological Survey	42.344889	-121.858971	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
SET-L	U.S. Geological Survey	42.357713	-121.884982	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
SET-U	U.S. Geological Survey	42.357713	-121.884982	Upper Klamath Lake	1 m from surface	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
WMR	U.S. Geological Survey	42.455389	-121.953778	Upper Klamath Lake	1 m from bottom	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
GBE	U.S. Geological Survey	42.463556	-121.902083	Upper Klamath Lake	mid water column	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
HP2	U.S. Geological Survey	42.416699	-121.841099	Upper Klamath Lake	mid water column	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
SHM	U.S. Geological Survey	42.301416	-121.829955	Upper Klamath Lake	mid water column	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
WDW	U.S. Geological Survey	42.478278	-121.978714	Upper Klamath Lake	mid water column	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
SSR	U.S. Geological Survey	42.236078	-121.820661	Upper Klamath Lake	mid water column	surface water	1	May-Oct					1	May-Oct	1	May-Oct	1	May-Oct	1	May-Oct	
BLB Met	U.S. Geological Survey	42.394694	-122.010667	Upper Klamath Lake		atmospheric			1	all year	1	all year									
HDB Met	U.S. Geological Survey	42.312833	-121.907778	Upper Klamath Lake		atmospheric			1	all year	1	all year									
MDL Met	U.S. Geological Survey	42.386667	-121.866417	Upper Klamath Lake		atmospheric			1	May-October	1	May-October									
MDN Met	U.S. Geological Survey	42.439306	-122.011111	Upper Klamath Lake		atmospheric			1	May-October	1	May-October									
SSHR Met	U.S. Geological Survey	42.234100	-121.820661	Upper Klamath Lake		atmospheric			1	all year	1	all year									
11505800	U.S. Geological Survey	42.477635	-122.087797	UPPER KLAMATH LAKE AT ROCKY POINT		surface water															
11505900	U.S. Geological Survey	42.348475	-121.827508	UPPER KLAMATH LAKE AT RATTLESNAKE POINT		surface water															
11507000	U.S. Geological Survey	42.249866	-121.816395	UPPER KLAMATH LAKE NEAR KLAMATH FALLS		surface water															
11507001	U.S. Geological Survey	42.249866	-121.816395	UPPER KLAMATH LAKE NR K.FALLS(WEIGHT/MEAN ELEV) OR		surface water															

Agency_Site_ID	Total_Phos_Seaso	Turbidit	Turbidity_Seaso	BOD	BOD_Seaso	Nutrients	Nutrients_Seaso	TSS	TSS_Season	VSS	VSS_Season	TOC	TOC_Season	Phytoplan	Phytoplank_Season	Chlorophyl	Chlorophyl_Seaso	Phaeophyti	Phaeophytin_Seaso	Microcysti	Microcystis_Seaso	Microcysti	Microcystin_Seaso	SRP	SRP_Season	Total_N
FM4140																										
FM4135																										
WRNM																										
WROM																										
WRDB																										
WRTC																										
WRAP																										
WRPD	March - Nov					2	March - Nov																	2	March - Nov	2
SCPD	March - Nov					2	March - Nov																	2	March - Nov	2
SCFS	March - Nov					2	March - Nov																	2	March - Nov	2
421401121480900	all	2	all	2	May - Dec	2	all	2	May-Dec	2	May-Dec			2	May - Dec	2	May-Dec	2	May-Dec	2	May-Dec	2	May-Dec	2	May-Dec	2
KL0010-AS	April - Oct					2	April - Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL-ASJ																										
KL0006-ER	April - Oct					2	April -Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL0005-ML	April - Oct					2	April -Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL0008- MN	April - Oct					2	April -Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL0003-NB	April - Oct					2	April -Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL-PB																										
KL0002-PM	April - Oct					2	April - Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL0007-SB	April - Oct					2	April - Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL0004-WB	April - Oct					2	April - Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL-WS																										
KL0011-AN	April - Oct					2	April - Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
KL -FB																										
KL-PBL	April - Oct					2	April - Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
UKL0009-CP	April - Oct					2	April - Oct							2	April- Oct	2	April- Oct							2	April- Oct	2
WR2000	all					2	all																	2	all	2
WR3000	all					2	all																	2	all	2
WR4000	all					2	all																	2	all	2
WR5000	all					2	all																	2	all	2
TL24	April-Ice Cover					2	April-Ice Cover					2	April-Ice Cover	3	May-September	3	May-August							2	April-Ice Cover	2
TL25	April-Ice Cover					2	April-Ice Cover					2	April-Ice Cover											2	April-Ice Cover	2
TL27	April-Ice Cover					2	April-Ice Cover					2	April-Ice Cover	3	May-September	3	May-August							2	April-Ice Cover	2
AGN																										
AGS																										
EPT-L																										
EPT-U																										
EBB																										
EHB																										
FBS																										
HDB																										
MDT-L																										
MDT-U																										
MDL																										
MDN-L																										
MDN-U																										
MRM																										
NBI																										
RPT																										
SET-L																										
SET-U																										
WMR																										
GBE																										
HP2																										
SHM																										
WDW																										
SSR																										
BLB Met																										
HDB Met																										
MDL Met																										
MDN Met																										
SSHR Met																										
11505800																										
11505900																										
11507000																										
11507001																										

Agency_Site_ID	Total_N_Seaso	Nitrate	Nitrate_Seaso	Nitrite	Nitrite_Season	Ammonia	Ammonia_Seaso	Alkalinity	Alkalinity_Seaso	Calcium	Calcium_Season	Zooplank	Zooplank_Seaso	Diss_Org_Car	Diss_Org_Carb_Seaso	Particulate_Carb	Particulate_Carbon_Se	Secchi	Secchi_Season	Discharg	Gauge_Heigh	Notes
FM4140																						
FM4135																						
WRNM																						
WROM																						
WRDB																						
WRTC																						
WRAP																						
WRPD	March - Nov	2	March - Nov	2	March - Nov	2	March - Nov															Only collected during discharge
SCPD	March - Nov	2	March - Nov	2	March - Nov	2	March - Nov															Only collected during discharge
SCFS	March - Nov	2	March - Nov	2	March - Nov	2	March - Nov															Only collected during discharge
421401121480900	May-Dec	2	May-Dec	2	May-Dec	2	May-Dec	2	May-Dec	4	Aug			2	May-Dec	2	May-Dec	2	All year			Pacific Corp tracks gauge height
KL0010-AS	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL-ASJ																						
KL0006-ER	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL0005-ML	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL0008- MN	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL0003-NB	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL-PB																						
KL0002-PM	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL0007-SB	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL0004-WB	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL-WS																						
KL0011-AN	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
KL -FB																						
KL-PBL	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
UKL0009-CP	April- Oct	2	April- Oct	2	April- Oct	2	April- Oct					2	April - Oct					2	April - Oct			
WR2000	all	2	all	2	all	2	all													1	1	
WR3000	all	2	all	2	all	2	all													1	1	
WR4000	all	2	all	2	all	2	all													1	1	
WR5000	all	2	all	2	all	2	all													1	1	
TL24	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover															
TL25	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover															
TL27	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover	2	April-Ice Cover															
AGN																						SONDE
AGS																						SONDE
EPT-L																						SONDE
EPT-U																						SONDE
EBB																						SONDE
EHB																						SONDE
FBS																						SONDE
HDB																						SONDE
MDT-L																						SONDE
MDT-U																						SONDE
MDL																						SONDE
MDN-L																						SONDE
MDN-U																						SONDE
MRM																						SONDE
NBI																						SONDE
RPT																						SONDE
SET-L																						SONDE
SET-U																						SONDE
WMR																						SONDE
GBE																						SONDE
HP2																						SONDE
SHM																						SONDE
WDW																						SONDE
SSR																						SONDE
BLB Met																						Meteorological Station
HDB Met																						Meteorological Station
MDL Met																						Meteorological Station
MDN Met																						Meteorological Station
SSHR Met																						Meteorological Station
11505800																					1	
11505900																					1	
11507000																					1	
11507001																					1	Reservior Elevation

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