FINAL

Upper Klamath Lake Watershed Assessment

June 2010

Prepared for

Klamath Watershed Partnership

Prepared by

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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.

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Funding

Major funding was made available from the Oregon Watershed Enhancement Board (OWEB). For assistance with this funding we are very grateful to Rick Craiger of OWEB.

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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

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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.

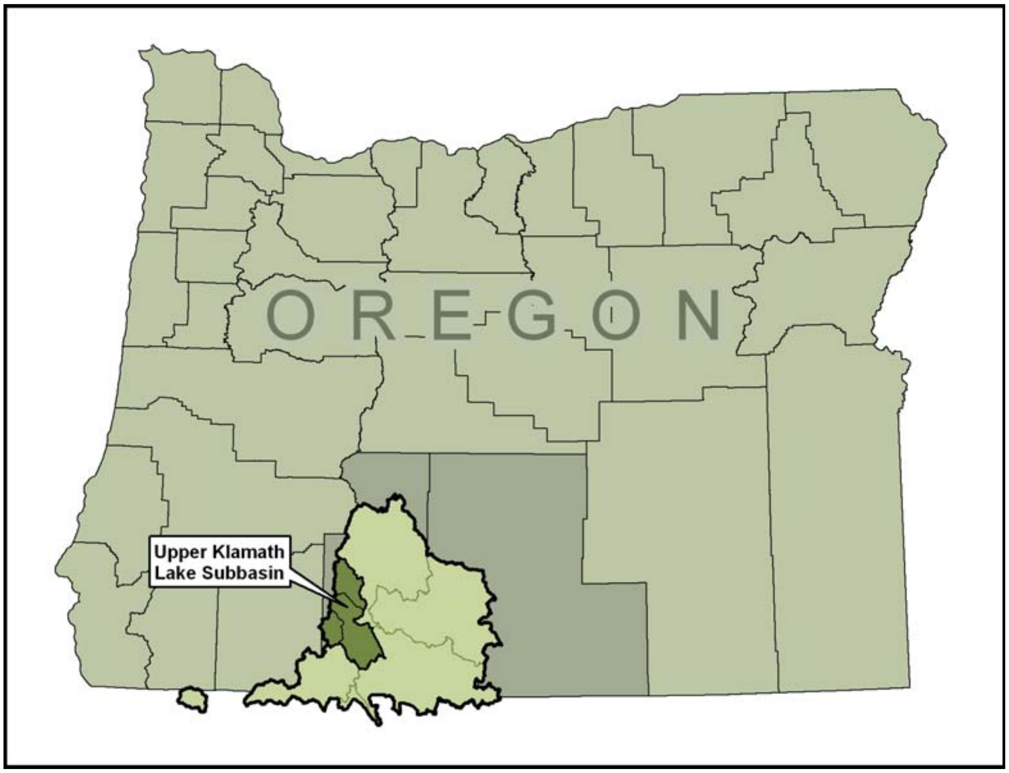

Figure 1-1. Location of the Upper Klamath Lake Subbasin

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.

		Elevation (feet)		
Watershed	**Area (mi^2)**	**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 14^{th} 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 15^{th} 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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Map 1-2. Land Ownership

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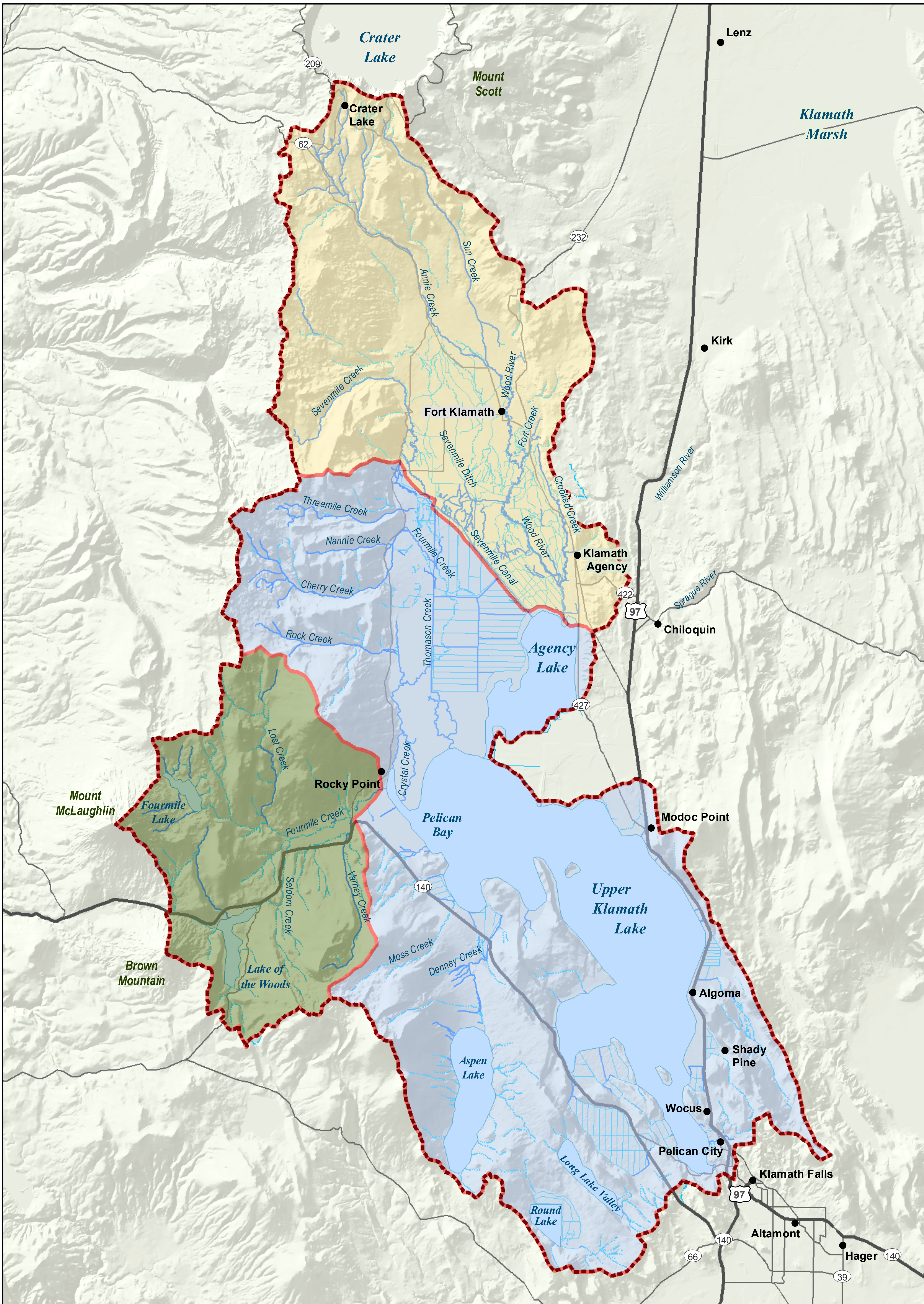

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Miles

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

Watershed Boundary - 5th Field

Fourmile Creek

Klamath Lake

Wood River

Map 1-1:
Base Map

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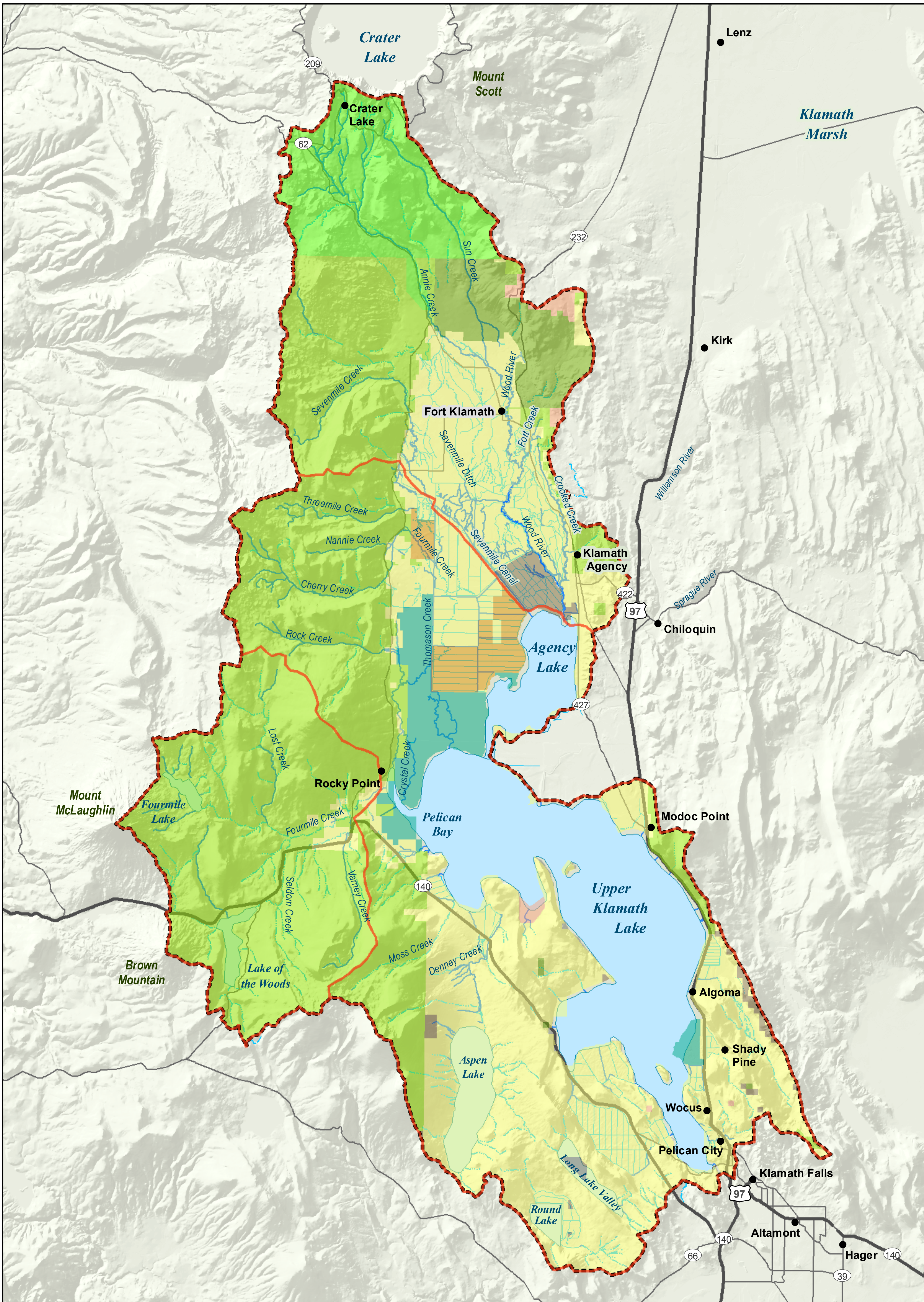

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Source Data:
ESRI, Klamath County, Oregon GEO,
US Department of Forestry,
USGS (National Hydrography Dataset)

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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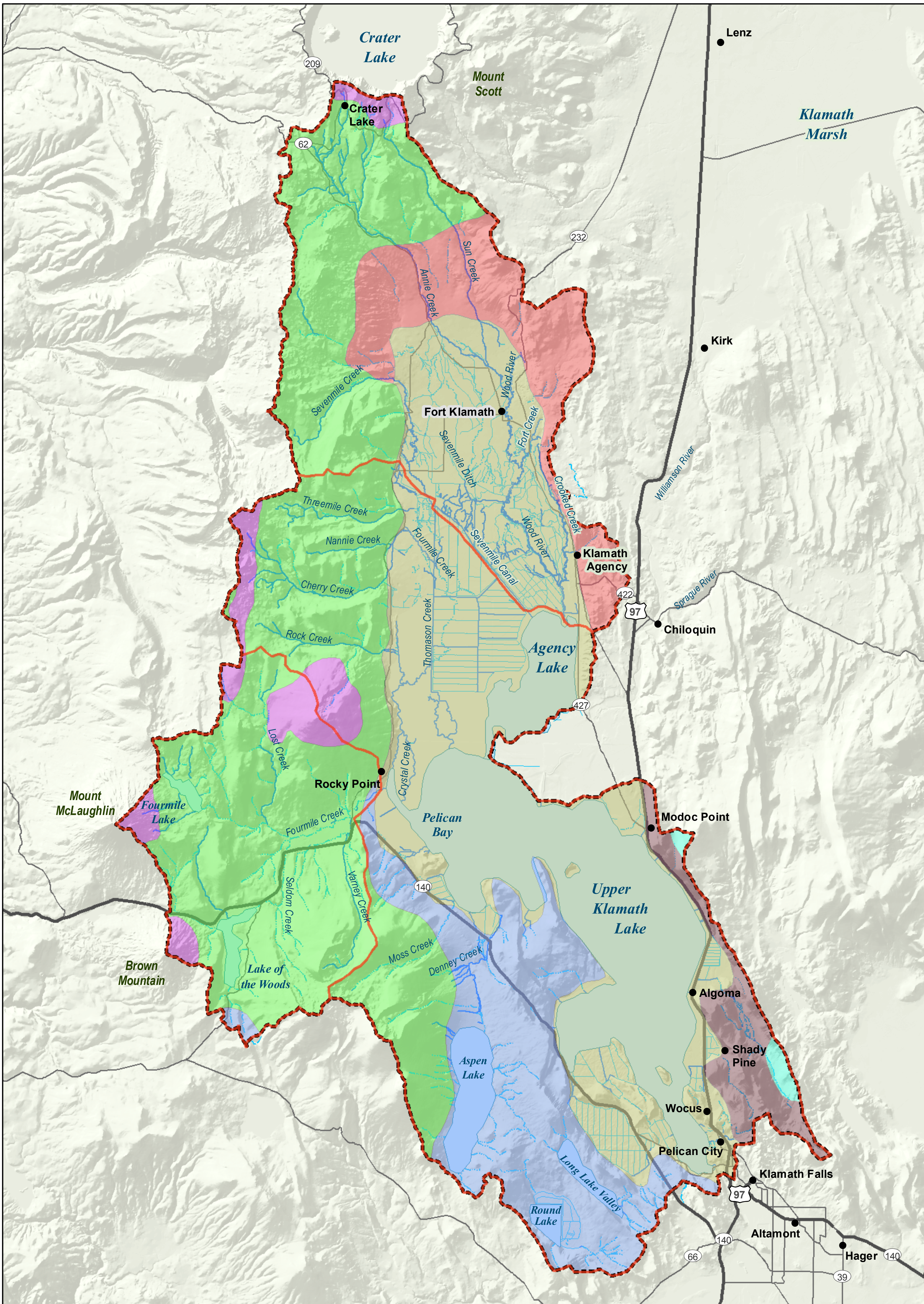

Legend		Ecoregion Name
Subbasin Boundary		Klamath Juniper/Ponderosa Pine Woodland
Watershed Boundary - 5th Field		Pumice Plateau Forest
Stream/River: Perennial		Southern Cascade Slope
Stream/River: Intermittent		Cascade Subalpine/Alpine
Stream/River: Ephemeral		Fremont Pine/Fir Forest
Canal Ditch		High Southern Cascades Montane Forest
		Klamath/Goose Lake Warm Wet Basins

N

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Miles

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

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).

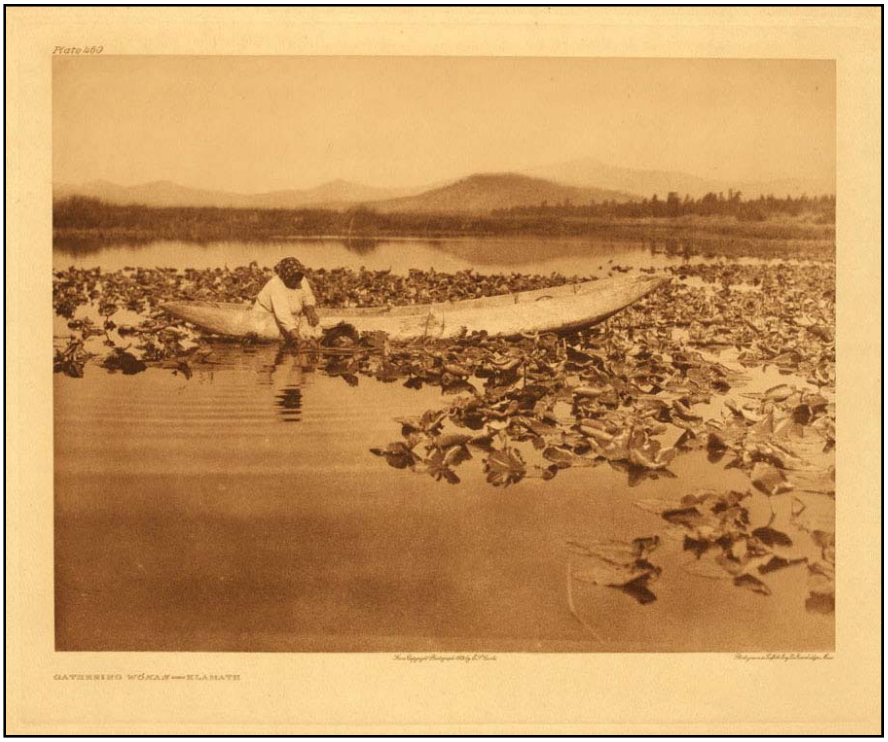


Figure 2-1. Wocus Harvest

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

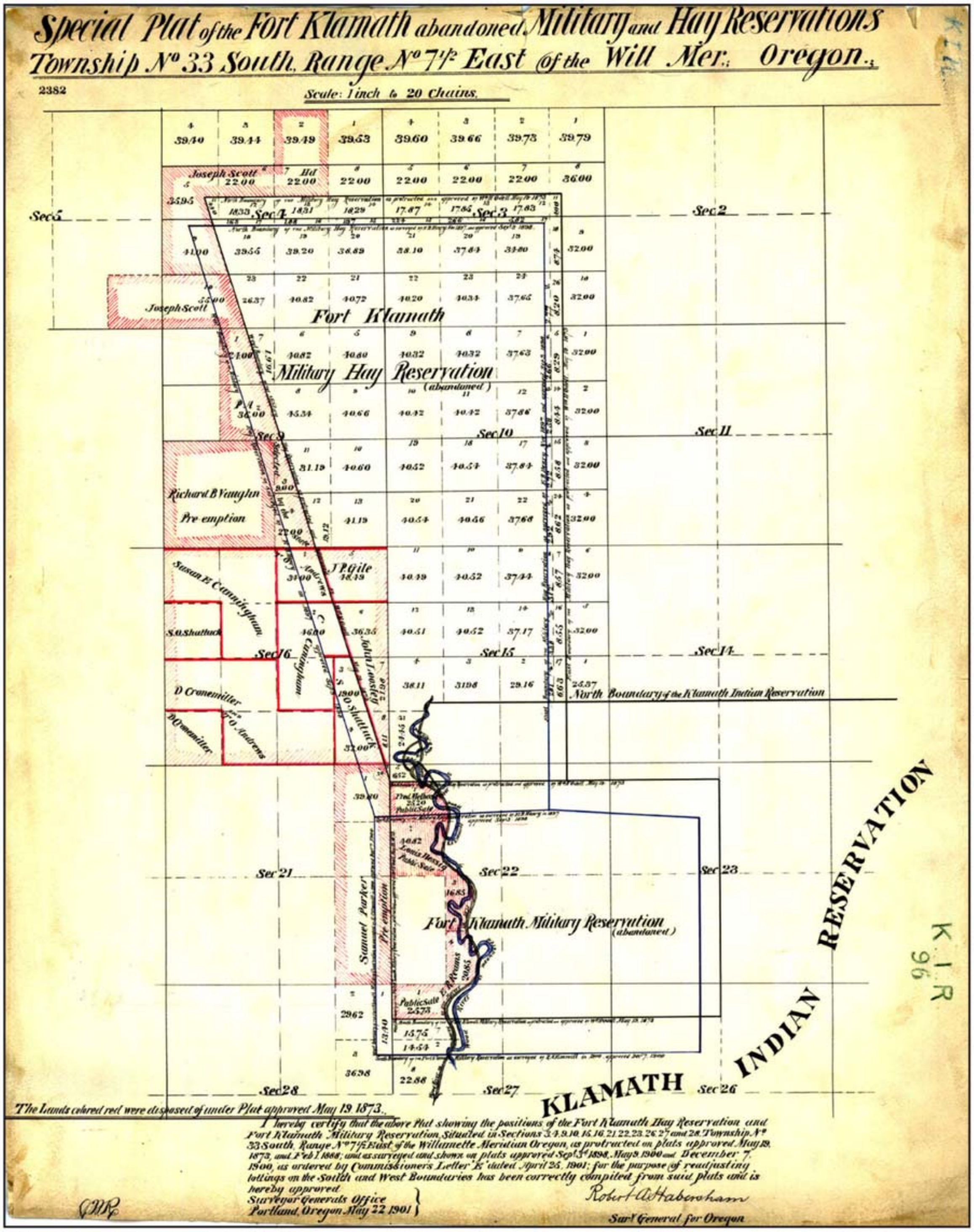
European settlement of the Klamath Basin began in the early nineteenth century (USDA 1985). One of the first documented journeys to the basin was that of Peter Skene Ogden who came to "Clammitte" camp, or what is now know as the Williamson River. Ogden came to the area with Hudson's Bay Company to trap 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).

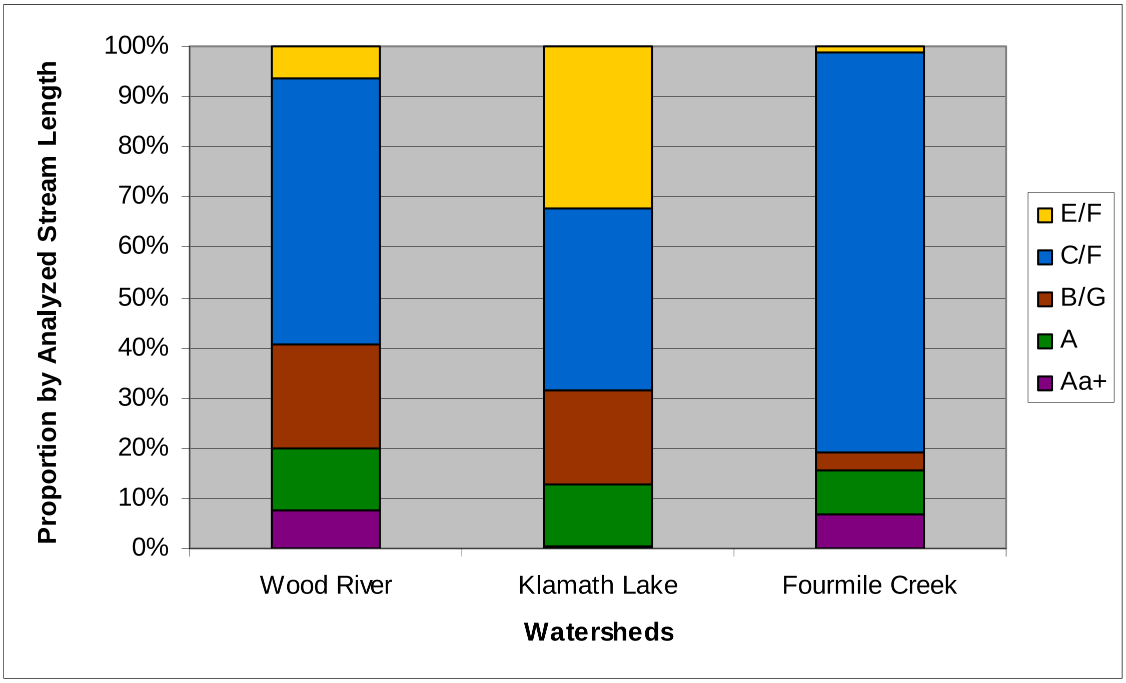

Figure 3-1. Summary of Rosgen Channel Types in the Upper Klamath Lake Subbasin

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.

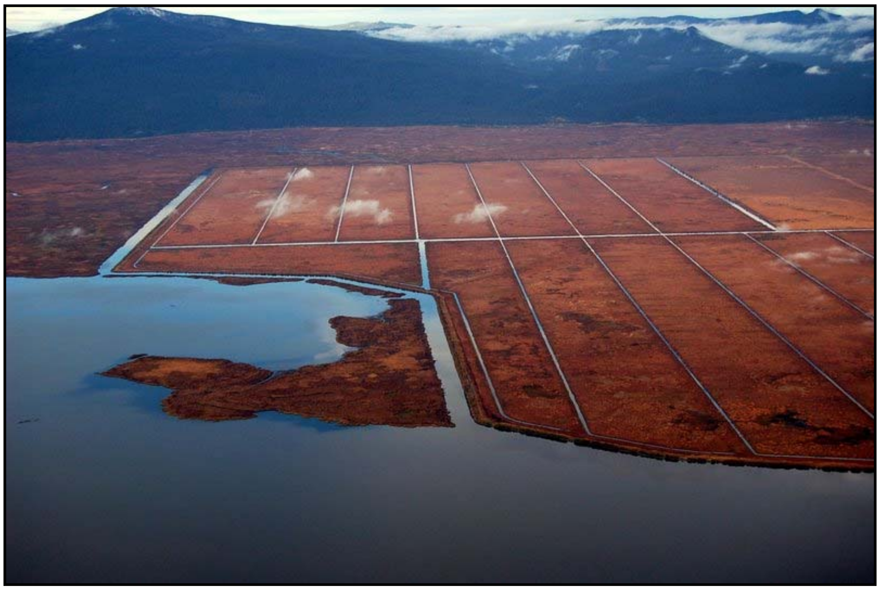

Figure 3-6. Aerial photo of an example of channelization adjacent to Agency Lake (DEA 2009).

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

Map 3-1. Rosgen Level 1 Channel Types

Map 3-2. Channel Modifications

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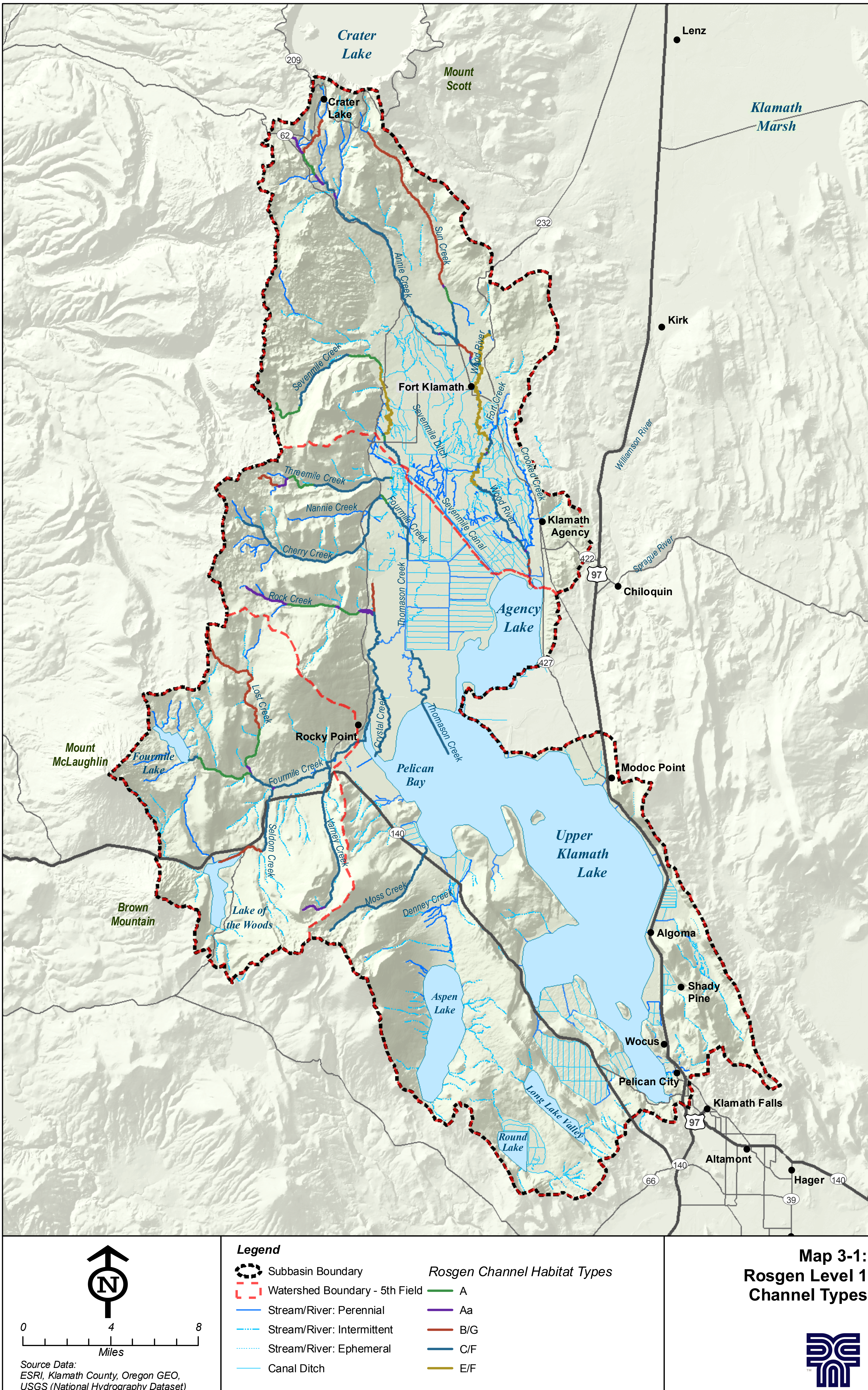

Map 3-1: Rosgen Level 1 Channel Types

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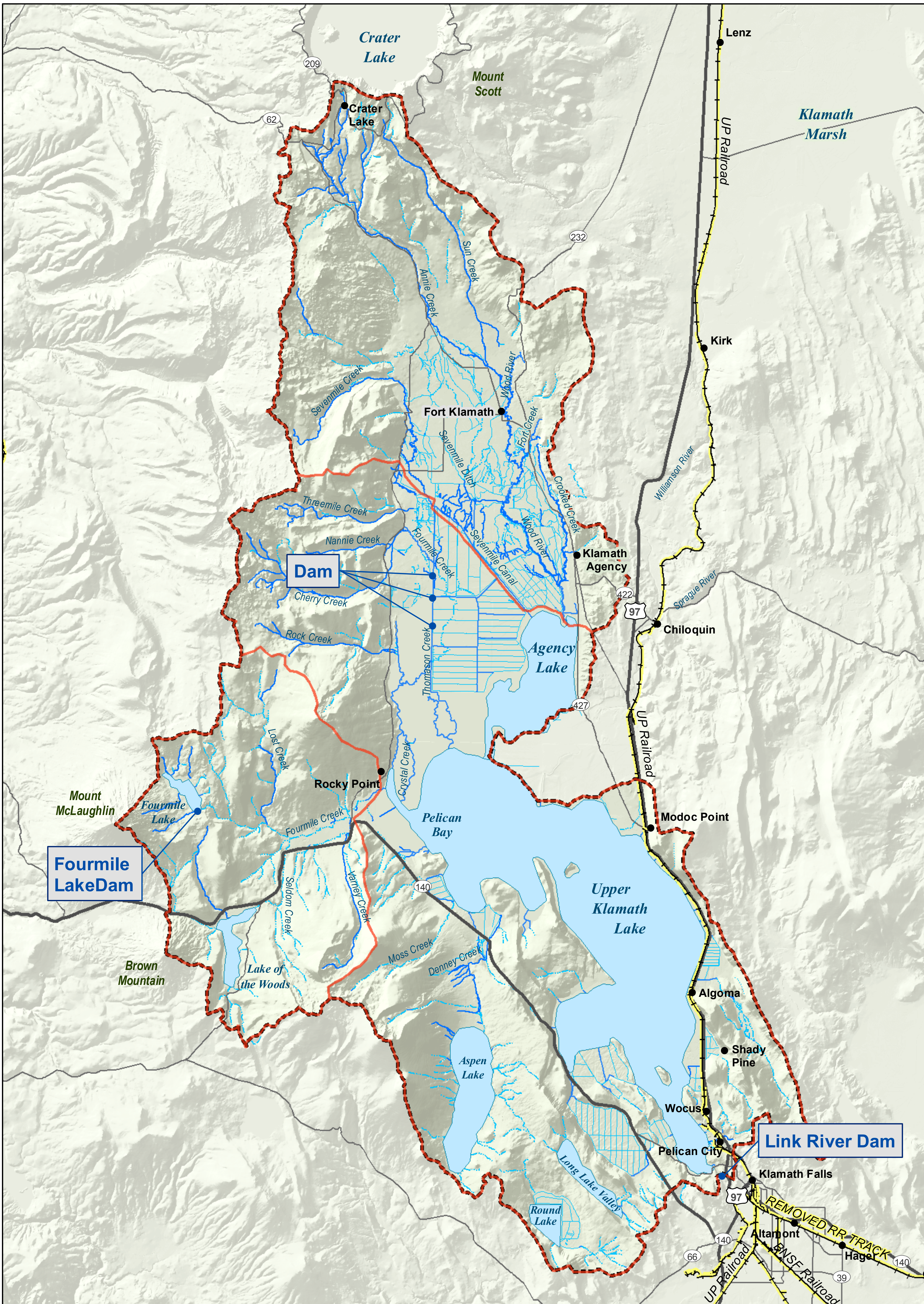

0 4 8

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

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.

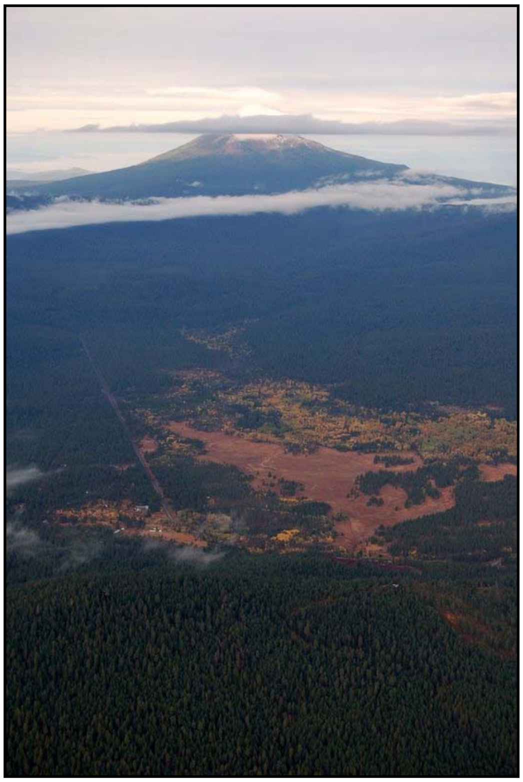


Figure 4-3. Aerial Photo of the east slope of Mount McLoughlin, Fourmile Creek watershed (DEA 2009).

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

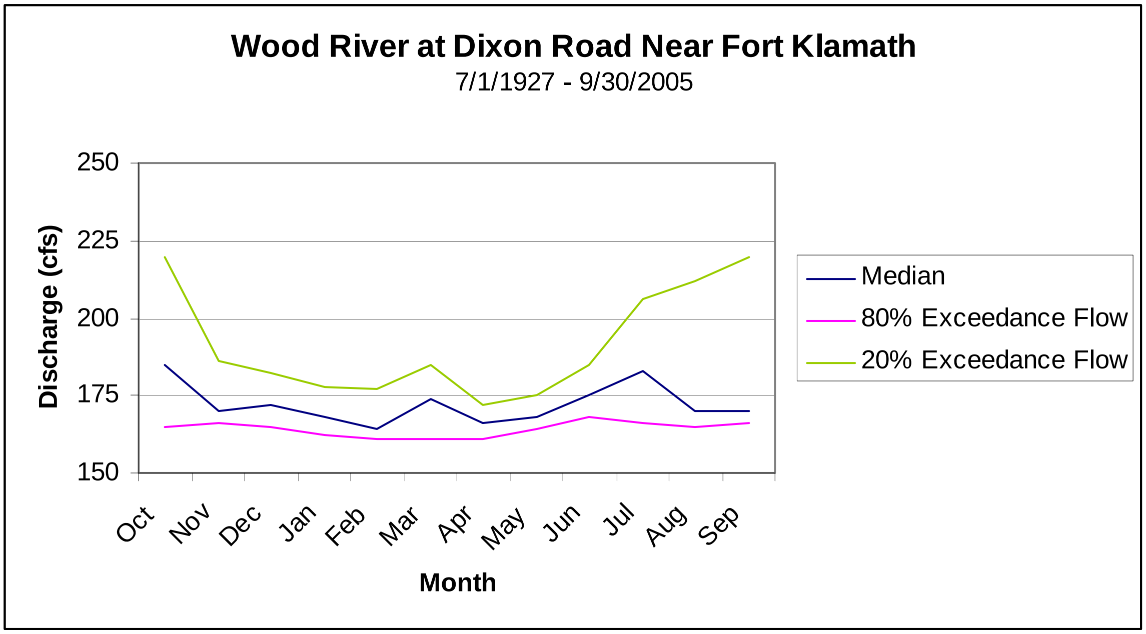
Map #	ID #	Hydrologic Unit	Description	Drainage Area (mi^2)	Gage Elev. (ft)	Period of record: Mean daily flow	Period of record: Peak flows (water years)	Current status/ responsible agency
16	11504170	18010203	Crane Div to Sevenmile Creek Near Fort Klamath					Discontinued
17	11504200	18010203	Crooked 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

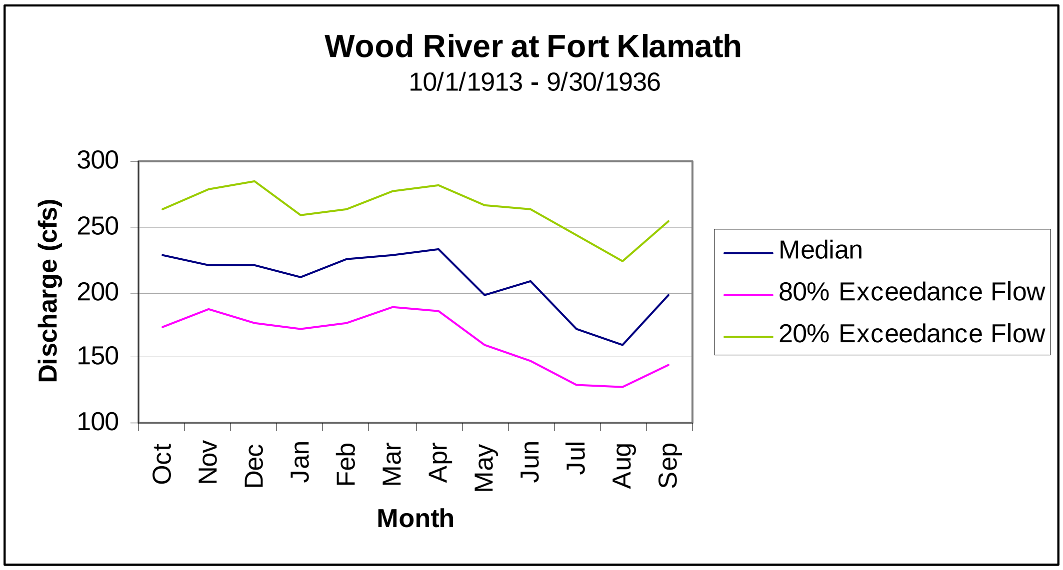
Gage #11502940 (Gage #1 on Map 4-1); Table 4-1

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.

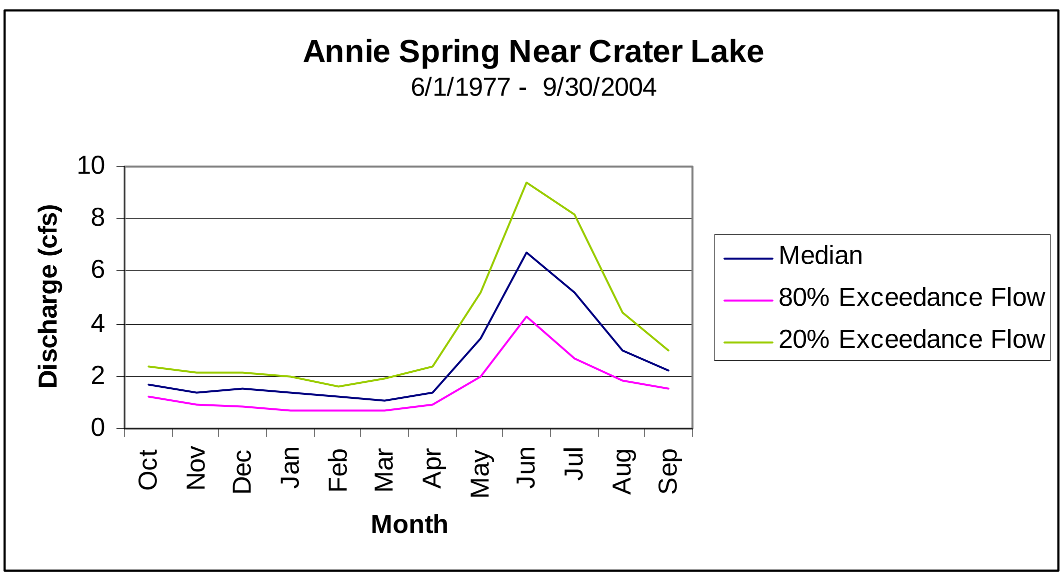
The gage for Wood River at Fort Klamath, shown in Figure 4-5, reveals higher baseflows than those at the Dixon Road gage (Figure 4-4). This additional input can be attributed to groundwater and surface water associated with Annie and Sun Creeks. The reduction in flows during the summer, seen in Figure 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.

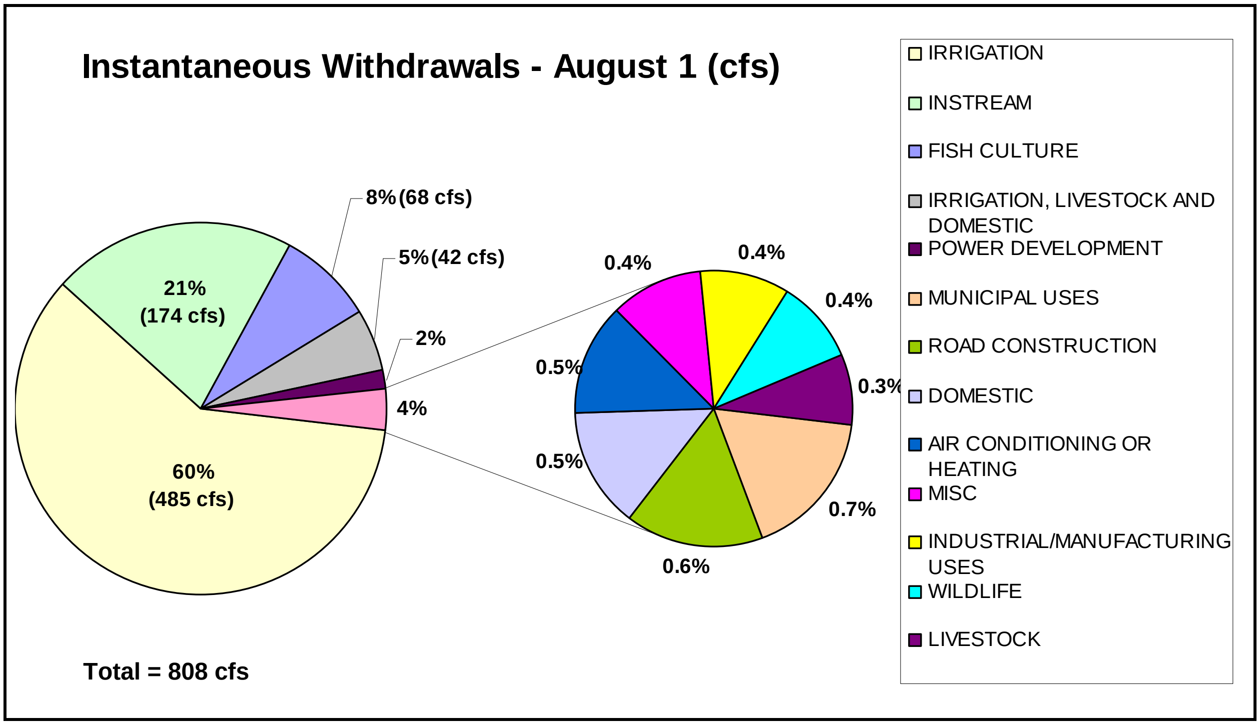


Figure 4-7. Summary of Instantaneous Withdrawal Rates Within the Upper Klamath Lake Subbasin

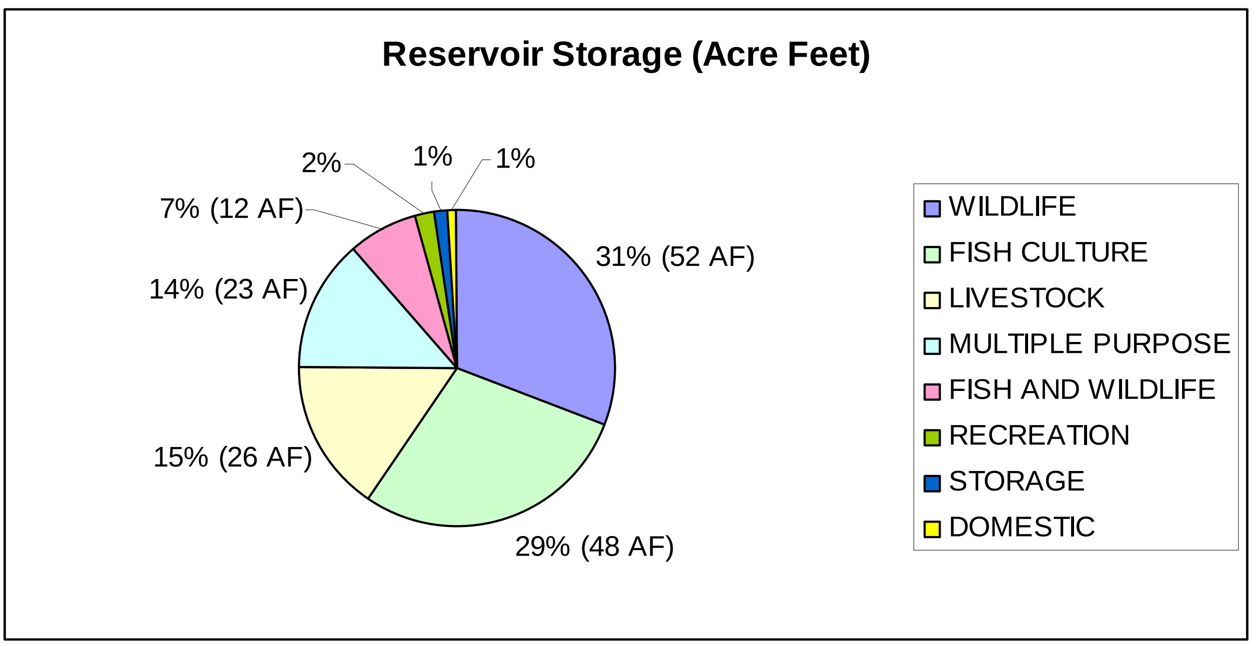


Figure 4-8. Summary of Reservoir Storage Within the Upper Klamath Lake Subbasin

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).

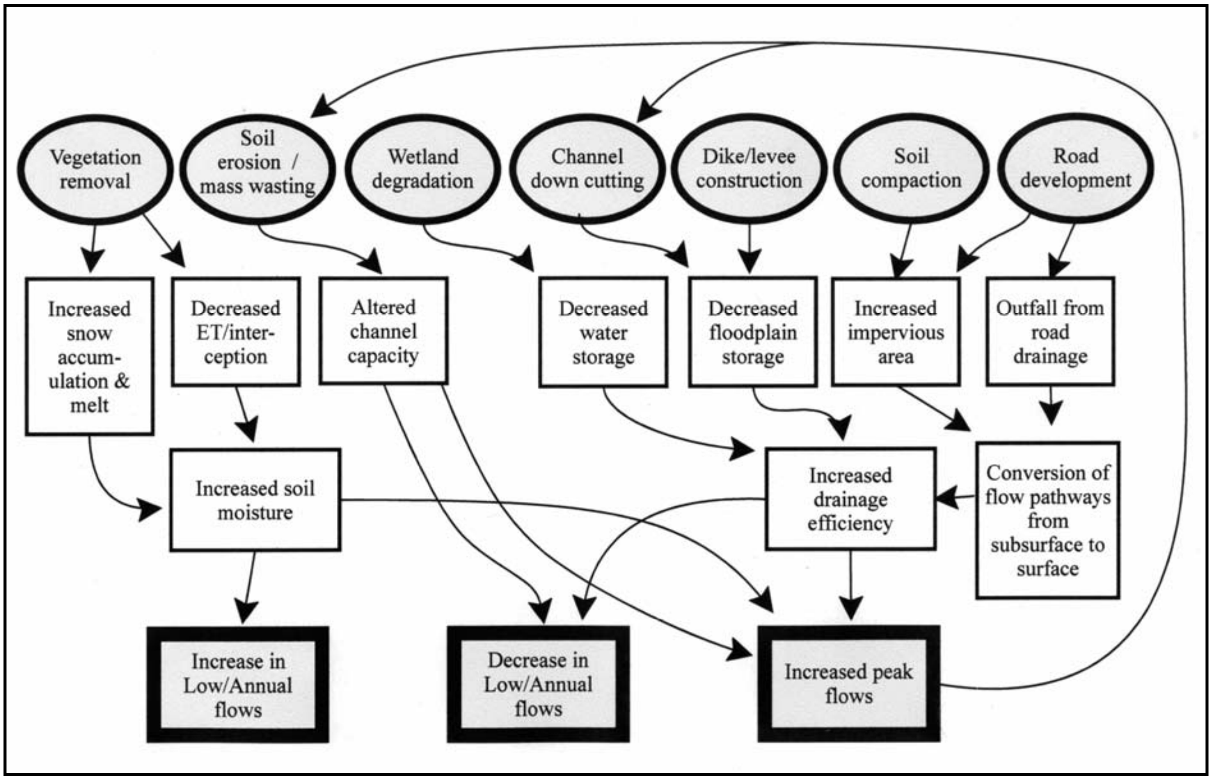
Land Use Effects on Flow Regime – Other Land Uses

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.

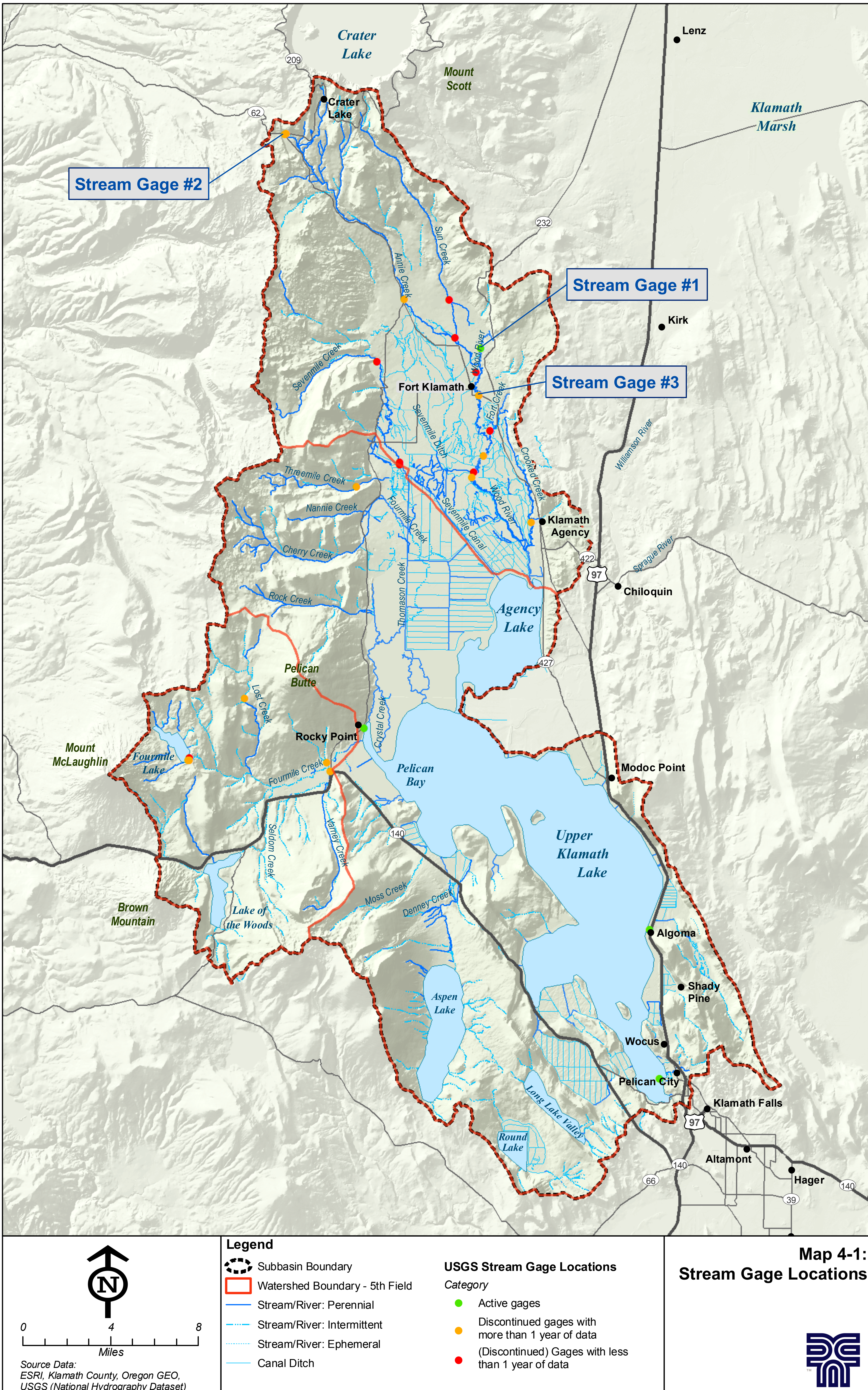
3. Pursue screening on water diversions with insufficient screening or sensitive habitat. Water diversions where threatened, endangered, sensitive or game fish are entrained, or lost due to insufficient screening, especially where bypass flows exist that would guarantee fish survival, should be prioritized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

List of Maps

Map 4-1. Stream Gage Locations

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

Map 4-3. Flood Potential Areas



Map 4-1: Stream Gage Locations

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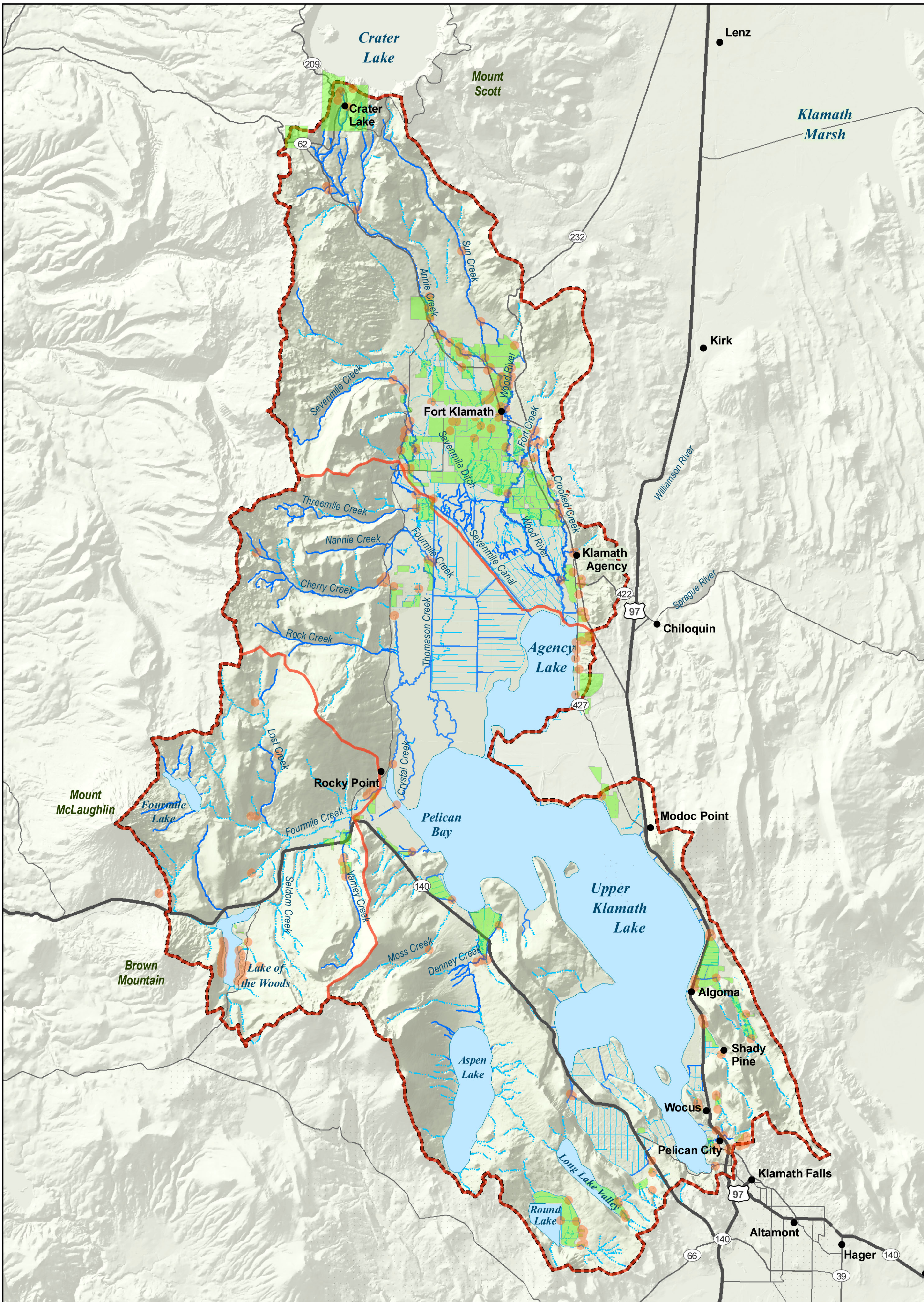

Legend

- 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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0 4 8

Miles

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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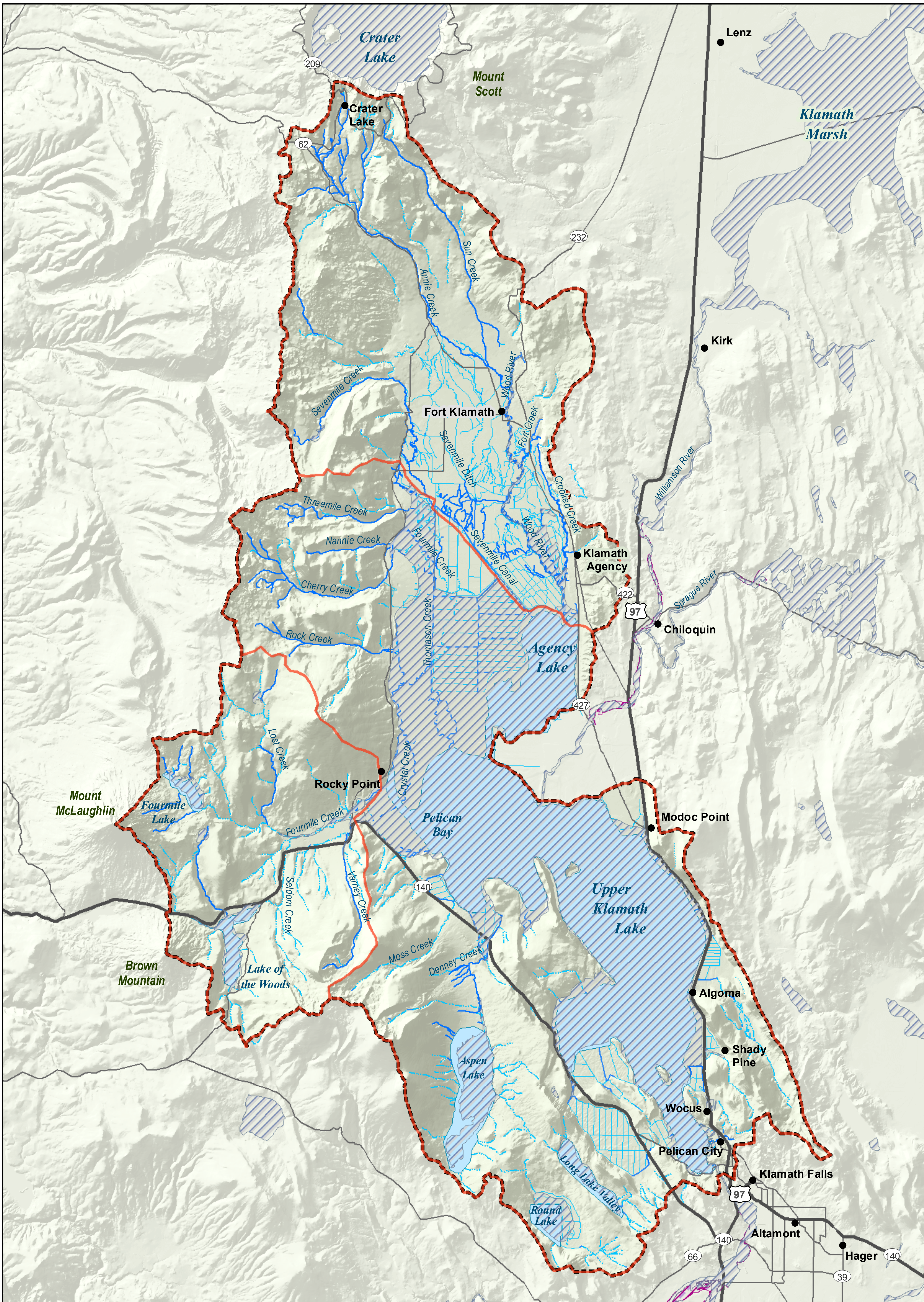

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Source Data:
ESRI, Klamath County, Oregon GEO,
USGS (National Hydrography Dataset)

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

Map 5-1 Erosional Features

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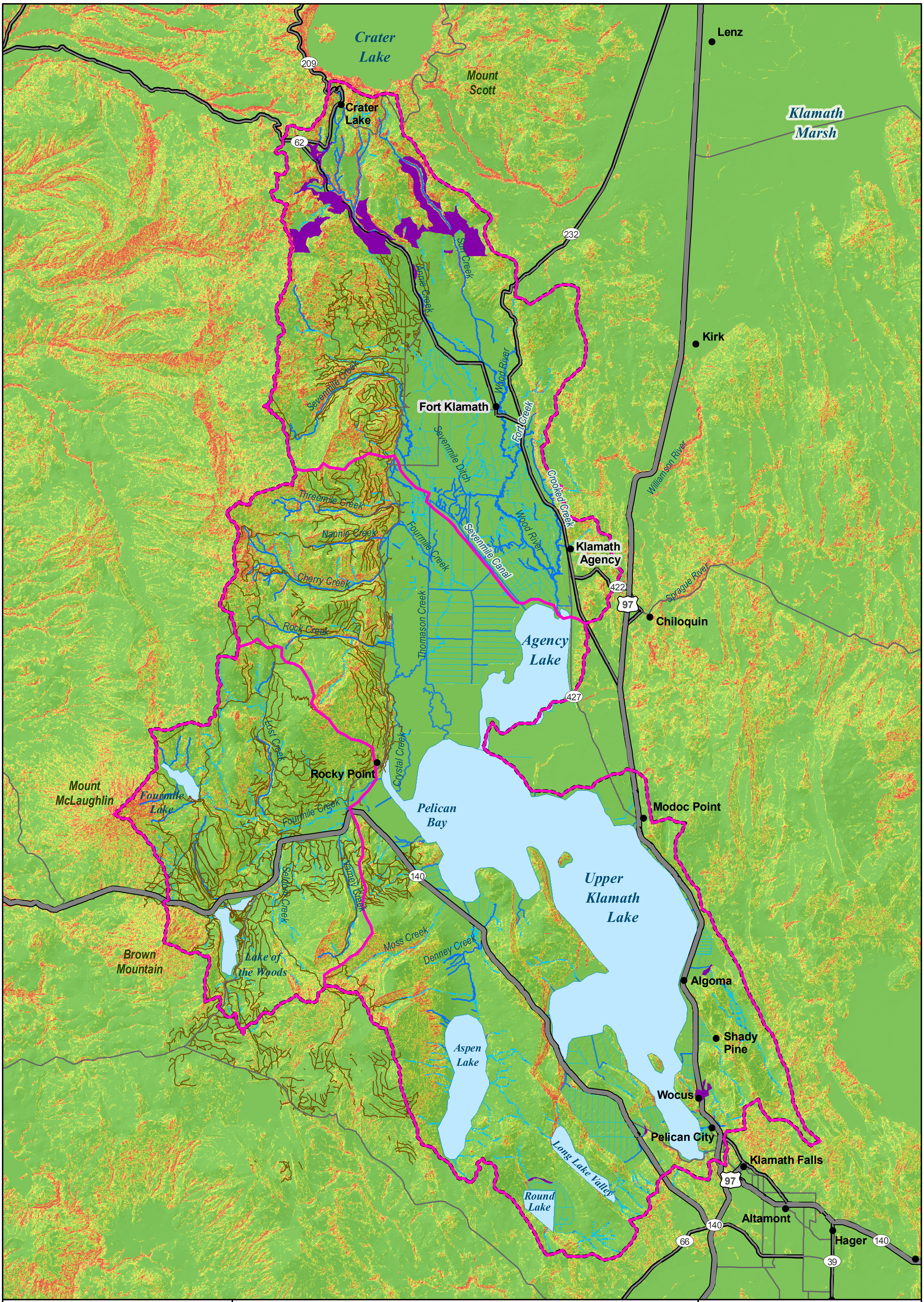

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Source Data:
ESRI, Klamath County, Oregon GEO,
USGS (National Hydrography Dataset)

Legend

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