Clackamas Basin Summary

Watershed Overview

Prepared For

Clackamas River Basin Council

Clackamas, Oregon

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WPN WATERSHED PROFESSIONALS NETWORK

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1.0 INTRODUCTION

This summary document is one of four background documents prepared to summarize and synthesize the relevant information needed to produce the Clackamas River Basin Action Plan. The other three companion documents provide a: 1) summary of fish and fish habitat issues, 2) summary of wildlife issues, and 3) summary of water quality and water quantity issues. The purpose of these documents is to provide the Council and the public with a general understanding of conditions, trends, and key issues affecting fish, wildlife and water quality/quantity throughout the Clackamas Basin.

Summarizing these topics for a river basin is a potentially large task and can be done at various levels of effort. Our scope of work was focused at communicating to the CRBC members and general public without overburdening the reader with technical information. The process relied primarily on existing reports and where needed supplementing these reports with additional compilation of data. Technical information that may be needed to support the summaries are incorporated into appendices that are geared toward water resource professionals and are not intended for general distribution.

2.0 PHYSICAL AND BIOLOGICAL SETTING

2.1 GENERAL CHARACTERISTICS

The Clackamas River Basin is located in Clackamas and Marion Counties, Oregon, east and south of the Portland Metropolitan area (Figure 1). The Clackamas River is tributary to the Willamette River, entering the Willamette at approximately river mile (RM) 25. The Clackamas River is the last major tributary stream downstream of Willamette Falls. Portions of the cities of Sandy, Gladstone, Oregon City, Estacada, Happy Valley, and Damascus are located within the Basin. Important transportation routes passing through the Basin include State Highways 211, 212, 213, and 224; US Highway 26, Interstate Highway 205, and the north-south mainline of the Union Pacific Railroad. The Clackamas River Basin is approximately 941 square miles in area.

For the purposes of this summary, the Clackamas Basin has been subdivided into 34 Geographic Areas (Figure 1). Geographic area characteristics are given in Table 1. Elevations in the watershed range from approximately 10 feet at the confluence with the Willamette River, to over 7,200 feet at Olallie Butte located along the southeast boundary of the basin. Mean elevation and slopes generally increase from the mouth of the Clackamas River upstream to the headwater areas (Table 1).

Figure 1. Geographic areas within the Clackamas Basin. Data sources: Clackamas County (2003), ODFW (2004), USGS (1999).

Table 1. Characteristics of geographic areas within the Clackamas Basin. Data source: USGS (1999).

Geographic area	Area: Square miles	Area: Acres	Elevation (ft) Mean (range)	Mean slope (%)
1. Lower Clackamas	21.7	13,897	273 (10 - 985)	8
2. NF Reservoir/Estacada Lake	18.4	11,801	981 (309 - 2134)	20
3. Middle Clackamas Mainstem	18.4	11,746	1771 (666 - 4059)	44
4. Upper Clackamas Mainstem	20.8	13,307	2477 (1339 - 5614)	26
5a. Cow Creek	1.2	781	160 (35 - 469)	6
5b. Sieben Creek	1.9	1,231	389 (67 - 871)	10
5c. Edna/Johnson Creeks	2.4	1,531	354 (37 - 800)	12
5d. Foster Creek	3.5	2,223	352 (131 - 556)	5
5e. Goose Creek	4.8	3,102	474 (183 - 826)	5
6a. Rock Creek	9.4	6,025	488 (72 - 1129)	12
6b. Richardson Creek	4.2	2,673	546 (98 - 885)	11
7a. Lower Clear Creek	19.6	12,530	434 (83 - 888)	10
7b. Little Clear Creek	9.1	5,800	885 (331 - 1489)	14
7c. Middle Clear Creek	17.3	11,062	896 (332 - 1489)	12
7d. Upper Clear Creek	27.0	17,289	1809 (698 - 4229)	20
8a. Lower Deep Creek	7.1	4,557	488 (141 - 998)	10
8b. Upper Deep Creek	13.9	8,927	966 (299 - 1645)	13
8c. North Fork Deep Creek	14.2	9,105	617 (194 - 1015)	6
8d. Tickle Creek	13.7	8,774	821 (299 - 1606)	10
9a. Lower Eagle Creek	35.0	22,413	1142 (196 - 2989)	15
9b. Upper Eagle Creek	27.1	17,325	2961 (1209 - 4643)	45
10. North Fork Eagle Creek	28.0	17,907	1634 (508 - 3970)	18
11a. North Fork Clackamas River	33.0	21,146	2516 (667 - 4783)	25
11b. South Fork Clackamas River	30.1	19,257	2981 (666 - 4856)	35
11c. Pup/Cat/Whale/Sandstone/Big Cks	12.3	7,845	3064 (983 - 5075)	44
11d. Dinner/3 Lynx/Cripple/Bull Cks	12.8	8,187	3656 (1038 - 5055)	28
12. Fish Creek	46.6	29,794	3106 (865 - 5297)	48
13. Roaring River	42.5	27,184	3510 (949 - 5180)	39
14. Oak Grove Fork	141.5	90,572	3610 (1346 - 5585)	19
15a. Tag/Switch Creeks	8.1	5,163	2841 (1361 - 4613)	30
15b. Trout Creek	6.7	4,303	3033 (1442 - 5292)	44
15c. Headwaters tributaries	136.8	87,579	3891 (1490 - 7217)	21
16. Collawash River	91.3	58,440	3498 (1460 - 5733)	37
17. Hot Springs Fork	61.0	39,013	3317 (1686 - 5543)	37
Entire Basin	**941.4**	**602,489**	**2723 (10 - 7217)**	**26**

Information on public land ownership was available from the Oregon Department of Forestry (ODF, 2004). Land ownership within the assessment area is shown in Figure 2 and summarized in Table 2. The majority of lands upstream of the Portland General Electric (PGE) dams are in Federal ownership (Table 2).

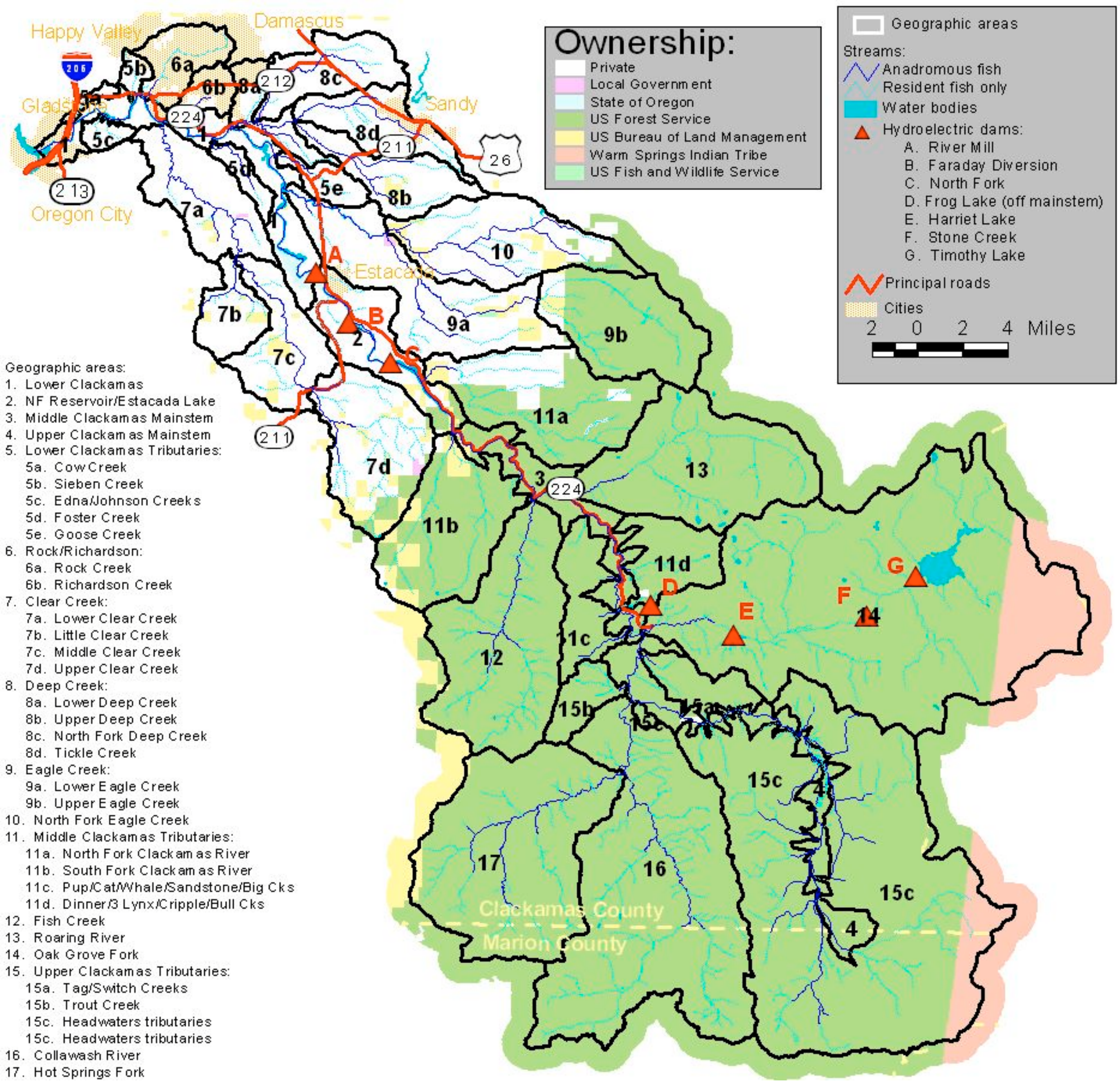

Figure 2. Major landownership groups within the Clackamas Basin. Data source: ODF (2004).

Table 2. Summary of landownership (acres) within the Clackamas Basin. Data source: ODF (2004).

Geographic area	Private	Local Gov't.	State of Oregon	Warm Springs	BLM	USFS	USFWS
01. Lower Clackamas	12,870	86	869	-	71	-	-
02. NF Reservoir/Estacada Lake	9,975	-	122	-	754	950	-
03. Middle Clackamas Mainstem	25	-	-	-	195	11,525	-
04. Upper Clackamas Mainstem	121	-	-	-	-	13,187	-
05a. Cow Creek	781	-	-	-	-	-	-
05b. Sieben Creek	1,230	-	-	-	-	-	-
05c. Edna/Johnson Creeks	1,531	-	-	-	-	-	-
05d. Foster Creek	2,223	-	-	-	-	-	-
05e. Goose Creek	3,102	-	-	-	-	-	-
06a. Rock Creek	6,024	-	-	-	-	-	-
06b. Richardson Creek	2,673	-	-	-	-	-	-
07a. Lower Clear Creek	12,209	44	1	-	276	-	-
07b. Little Clear Creek	5,186	-	-	-	613	-	-
07c. Middle Clear Creek	10,135	-	5	-	921	-	-
07d. Upper Clear Creek	12,897	189	-	-	2,580	1,623	-
08a. Lower Deep Creek	4,532	25	-	-	-	-	-
08b. Upper Deep Creek	8,449	-	-	-	477	-	-
08c. North Fork Deep Creek	9,046	58	-	-	-	-	-
08d. Tickle Creek	8,774	-	-	-	-	-	-
09a. Lower Eagle Creek	20,689	163	26	-	1,335	75	124
09b. Upper Eagle Creek	1,171	-	-	-	595	15,559	-
10. North Fork Eagle Creek	15,072	18	-	-	1,530	1,285	-
11a. North Fork Clackamas River	6,260	-	-	-	605	14,280	-
11b. South Fork Clackamas River	527	20	-	-	3,016	15,694	-
11c. Pup/Cat/Whale/Sandstone/Big Cks	-	-	-	-	-	7,846	-
11d. Dinner/3 Lynx/Cripple/Bull Cks	52	-	-	-	-	8,135	-
12. Fish Creek	-	-	-	-	280	29,515	-
13. Roaring River	-	-	-	-	-	27,184	-
14. Oak Grove Fork	-	-	-	11,298	-	79,277	-
15a. Tag/Switch Creeks	-	-	-	-	-	5,164	-
15b. Trout Creek	-	-	-	-	-	4,304	-
15c. Headwaters tributaries	16	-	-	5,581	-	81,996	-
16. Collawash River	-	-	-	-	-	58,449	-
17. Hot Springs Fork	-	-	-	-	862	38,156	-
Entire Basin	**155,570**	**603**	**1,023**	**16,879**	**14,110**	**414,205**	**124**

2.2 ECOREGIONS

Oregon is ecologically very diverse. In order to structure and make sense of that ecological diversity the US Environmental Protection Agency (EPA) has developed the concept of ecoregions. Ecoregions can be thought of as areas within which conditions are relatively similar with respect to geology, physiography, vegetation, climate, soils, land use, wildlife distributions, and hydrology. The ecoregion approach is set up at varying scales across the landscape. At the coarsest level North America has been divided into 15 **level I** ecoregions, within which are 52 **level II** ecoregions. There are 9 **level III** ecoregions within Oregon. Two of these level III ecoregions are represented within the Clackamas Basin; the Willamette Valley and Cascades ecoregions (Figure 3). The Willamette Valley level III ecoregion was historically characterized by rolling prairies, deciduous/coniferous forests, and extensive wetlands across the broad valley (EPA, 2003a). It differs from the adjacent Cascades level III ecoregion by having lower precipitation, less relief, a more temperate climate, and a different mosaic of vegetation. Landforms consist of terraces and floodplains interlaced with and surrounded by rolling hills. The Cascades level III ecoregion is a mountainous terrain underlain by recent volcanics, with areas of alpine glaciation at the higher elevations (EPA, 2003a). The Cascades level III ecoregion is characterized by relatively steep ridges and river valleys, active and dormant volcanoes, a moist and temperate climate supporting extensive coniferous forests, with subalpine meadows at the higher elevations.

The 9 level III ecoregions found in Oregon have been further divided into 65 **level IV** ecoregions (Thorson and others, 2003; Figure 3). Level IV is the finest-scale ecoregions that have been defined. The following is a brief overview of each of the five level IV ecoregions that are represented within the Clackamas Basin (Thorson and others, 2003). Subsequent discussions of geology, soils and vegetation will follow the level IV ecoregion organization.

Prairie Terraces (3c)

This area is located along the Clackamas River approximately downstream of River Mill dam, and consists primarily of the Lower Clackamas and Lower Clackamas Tributaries Geographic areas (Figure 3). This area is characterized as nearly level, slightly depressional, or undulating fluvial terraces with sluggish, meandering tributary streams. Historically, seasonal wetlands and ponds were common. Many streams are now channelized (examples being portions of Goose and Foster Creeks).

Valley Foothills (3d)

This area includes the headwaters portions of the Lower Clackamas Tributaries; the Rock/Richardson; and lower portions of the Clear Creek, Deep Creek, and Eagle Creek Geographic areas (Figure 3). This area is characterized as rolling foothills with medium gradient, sinuous streams deeply incised in some areas. The areas of greatest relief often occur in the lower to mid-portions of these watersheds, where the largest streams have incised into the underlying geology, with the headwater areas having relatively flat or rolling topography. A few buttes (such as the Boring lava domes) occur in this area.

Western Cascades Lowlands and Valleys (4a)

This area includes most of the mainstem Clackamas River and floodplain upstream of the River Mill Dam (the NF Reservoir/Estacada Lake, Middle Clackamas Mainstem, and Upper Clackamas Mainstem Geographic areas); the upper extent of the Deep, Clear and Eagle Creek Geographic areas; the entire North fork Eagle Geographic area; and the lower elevation portions of the Middle Clackamas Tributaries, Fish Creek, Roaring River, Oak Grove Fork, Upper Clackamas Tributaries, Collawash River, and Hot Springs Fork geographic areas (Figure 3). Low mountain ridges, buttes, and valleys and medium gradient rivers and streams characterize this area.

Western Cascades Montane Highlands (4b)

This area includes the headwaters portions of the Middle Clackamas Tribs, Fish Creek, Roaring River, Upper Clackamas Tributaries, Collawash River, and Hot Springs Fork geographic areas; and the middle elevation portions of the Oak Grove Fork geographic area (Figure 3). This area was partly glaciated, and is characterized by mountainous areas that are steeply sloping and highly dissected with buttes, ridges, and scattered lakes in glacial rock-basins. Medium to high gradient streams occur.

Cascade Crest Montane Forest (4c)

This area includes the headwaters portions of the Clackamas River and Oak Grove Fork geographic area (Figure 3). The area was glaciated in the past, and is characterized as an undulating plateau punctuated by buttes, volcanic cones, lava flows, and mountains. Meandering, medium gradient streams cross the subdued, glaciated terrain. Many lakes occupy glacial rock-basins.

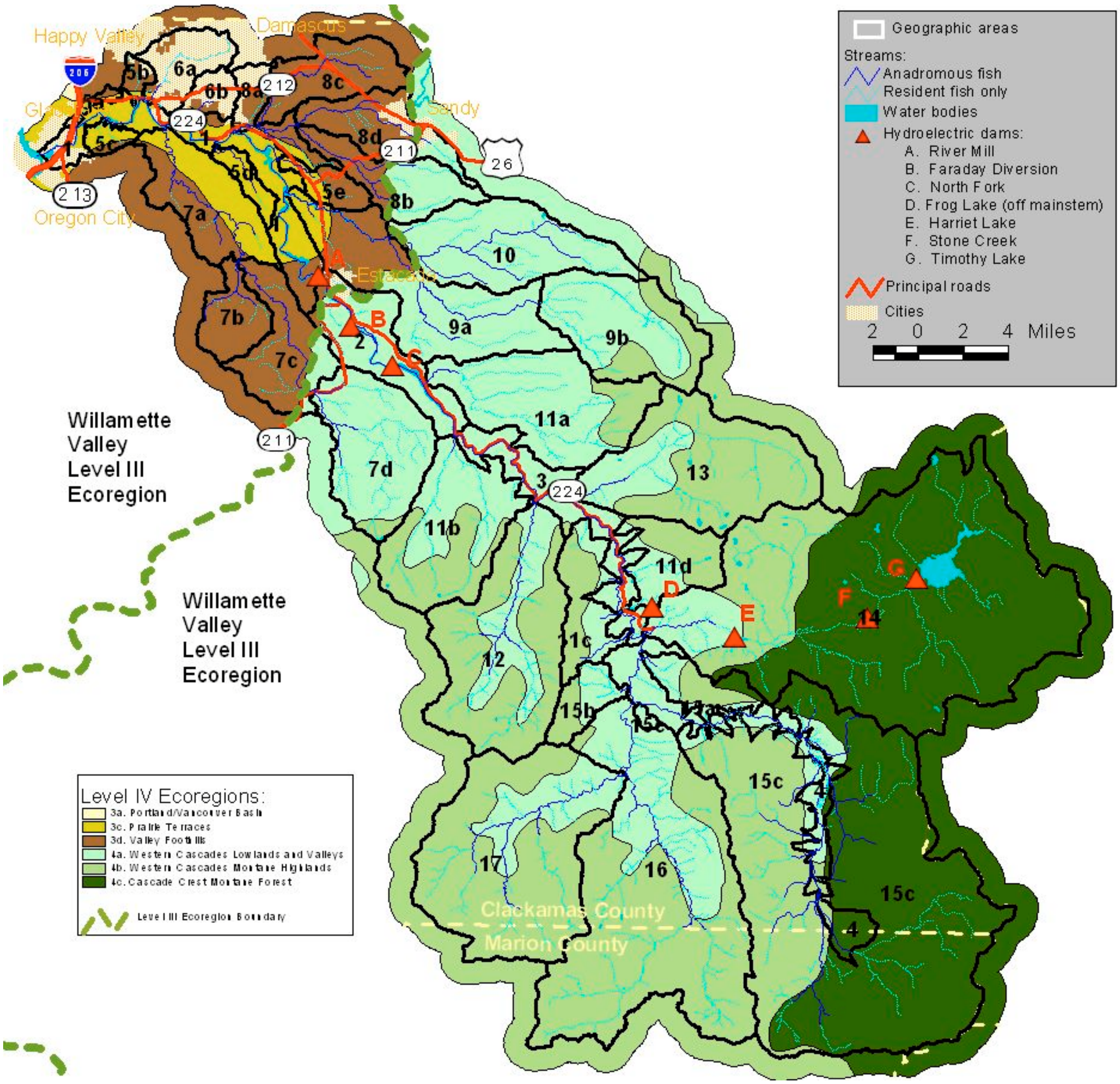

Figure 3. Level III and level IV ecoregions within the Clackamas Basin. Data source: EPA (2003b).

2.3 GEOLOGY AND SOILS

The underlying geology is one of the primary factors used to differentiate the various level III and level IV ecoregions, and one of the primary determinants of present-day stream channel morphology. The geology of the Clackamas River basin consists primarily of Tertiary and Quaternary age (45 million to 10,000 years old) volcanics and alluvial deposits (McBain and others, 2001). The volcanic rocks include tephras (i.e., material ejected from volcanoes, like ash and pumice), pyroclastic flows (i.e. material that originated as rapidly moving, highly heated mixtures of volcanic gasses, ash, and larger pieces of rock), and lahars (volcanic mudflows). Following their initial deposition, these materials have been modified structurally by folding and faulting; and geomorphically by glaciation, stream erosion, and mass wasting (McBain and others, 2001).

The Clackamas Basin can be divided into four primary areas, which generally follow the level III and level IV boundaries shown in Figure 3. The High Cascades roughly corresponds to the Cascade Crest Montane Forest level IV ecoregion (4c on Figure 3). This areas is made up of recent volcanoes (some less than 1,500 years old; such as Mount Hood) and surrounding lava and ash deposits (McBain and others, 2001). The geology of the High Cascades is quite young. The Western Cascades includes all of the Cascades level III ecoregion, with the exception of the Cascade Crest Montane Forest level IV ecoregion (4c on Figure 3). This is an older volcanic chain that is no longer active (approximately 45 to 10 million years old; McBain and others, 2001). Underlying the Western Cascades area are the Columbia River Basalts. The Columbia River Basalts are exposed in areas where the Clackamas River and tributaries have incised through the overlying strata. The Willamette Valley area, which corresponds with the Willamette Valley level III ecoregion (Figure 3), occupies the remainder of the Basin. The following descriptions of each of these four groups are taken from McBain and others (2001). Additional information on soil characteristics are summarized from EPA (2003a) and WPN (2001):

High Cascades (includes level IV ecoregion 4c)

The volcanics of the High Cascades cap the older volcanic units of the Western Cascades. Within the Clackamas River basin, the High Cascades generally consists of Quaternary-age (< 2 million years old) basalt and andesite lava flows. High Cascades topography is mountainous; slopes are relatively moderate, ranging from locally steep where incised by streams to relatively flat (generally less than 30 percent) in higher elevation meadows and on top of volcanic flows. Elevations of the High Cascades are generally above 3,500 feet, where precipitation falls primarily as snow. Slope instability tends to be manifested as large slump blocks and rock falls rather than debris flows and earthflows.

Soils range widely from sandy loam to very cobbly loam. Soil erosion rate is generally low due to competent geology and gentle slopes on the plateaus. Shallow landslides occur on the slopes of steep buttes and cones. Soils have a *Cryic* temperature regime, meaning that these soils have a mean annual temperature higher than 0°C but lower than 8°C. The soil moisture regime is *Udic* meaning that, in most years, the amount of stored moisture plus rainfall is approximately equal to, or exceeds, the amount of evapotranspiration.

Western Cascades (level IV ecoregions 4a and 4b)

The Western Cascades consist primarily of deeply weathered volcanic rocks (10 to 42 million years old). Although much older than the High Cascades rocks, Western Cascades rocks are thought to have formed in a very similar geologic setting. The age of the Western Cascades rocks generally increases from east to west. Western Cascades topography is defined by forested slopes that become locally steep to near-vertical where incised by streams and at certain bedrock outcrops, but are gentler where they have been modified by other erosional processes (e.g., earthflows). Elevations within the Western Cascades range from approximately 300 to 3,500 feet, and most precipitation in this elevation range falls as a combination of rain and snow. The age, composition, and deep weathering result in Western Cascades rocks being much more prone to debris flow and large scale earthflows.

Soils range widely from deep clay loams to very cobbly loams. Erosion rate is moderate due to abundant precipitation and steep slopes. Competent geology keeps erosion rates from being high. Landslides are usually deep-seated earth flows in lower gradient areas. Shallow landslides (often triggering debris slides) sometimes occur in steep headwater channels. Soil temperature regimes range from *Mesic* (mean annual soil temperature is $\geq$8°C to 15°C) at lower elevations to *Cryic* (0°C to 8°C) at higher elevations. The soil moisture regime is *Udic* meaning that, in most years, the amount of stored moisture plus rainfall is approximately equal to, or exceeds, the amount of evapotranspiration.

Columbia River Basalt (underlying level IV ecoregions 4a and 4b)

The Columbia River Basalt underlies the Western Cascades area, and extensive outcrops of occur in the basin within level IV ecoregions 4a and 4b. Most of these basalt flows are of Miocene age (ranging from 15-16 million years). The Clackamas River and portions of some tributaries have deeply incised into the Columbia River Basalt (for example, Big Bend just upstream of Estacada). Between North Fork Dam and Oak Grove Powerhouse, outcrops of the Columbia River Basalt are exposed in some reaches and may underlie shallow alluvium. Slope instability and runoff characteristics of the Columbia River basalts are most similar to that of the High Cascades.

Willamette Valley (level III ecoregions 3c and 3d)

The geology of the lower Clackamas Basin is characterized by relatively flat-lying sedimentary rocks ranging in age from Pliocene (1.6 - 5.3 million year old) to recent (< 10,000 years old). The Troutdale Formation and the Sandy River Mudstone underlie much of the area. The Troutdale Formation may represent fluvial deposits from the ancestral Columbia River, while the Sandy River Mudstone has been interpreted to be an ancient lacustrine (lake) deposit. Both of these units are prone to slumping and instability, especially where river migration has undercut high terraces.

Over the last two million years, the Clackamas River has been eroding into the underlying sedimentary rocks, creating successively lower floodplains (Figure 4). Sediments carried by the river have been deposited on the floodplains, as the river has cut downward, these former floodplains have been left as high as 600 feet above the present river. These abandoned floodplains are now terraces. Terrace gravel deposits range in thickness from thin veneers tens of feet thick to over 100 feet thick. As the modern river migrates and erodes into these terraces, they are an important source of sediment below River Mill Dam.

Interleaved with the sedimentary rocks are volcanic rocks called the Boring Lavas that erupted from volcanic centers near Boring, Oregon. The Boring Lava flows, located north of Carver and Barton, reached the Clackamas River and may have dammed the river flow for relatively short periods of time. The age of Boring lavas ranges from 3 million to 430,000 years old. The relationship between the Boring Lavas and the Clackamas River terrace history is not well understood. However, the presence of well-dated volcanic rocks may provide some age constraint on the age of the upper terraces.

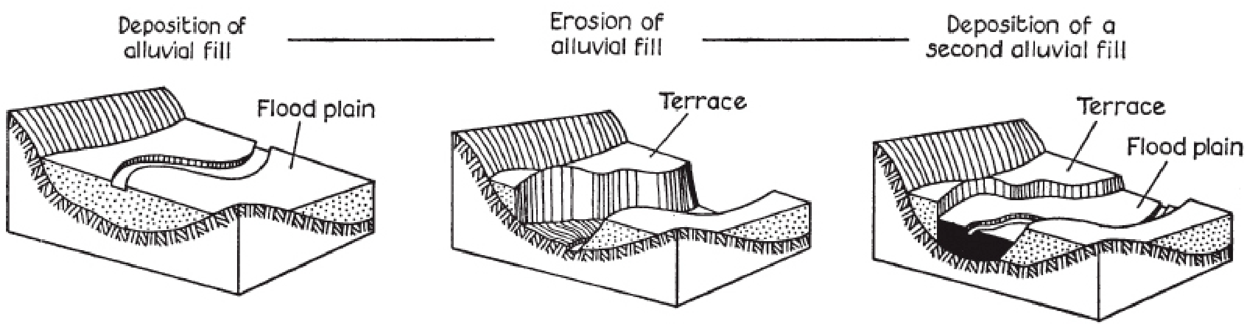

Figure 4. Sequence of incision and aggradation along the lower Clackamas River. From McBain and others (2001).

Soils range from deep silty clay loam to silt loam; well drained to poorly drained. Soils have a *Mesic* temperature regime, meaning that these soils have a mean annual temperature between 8°C and 15°C. The soil moisture regime is *Xeric*, which is typical for Mediterranean climates, where winters are moist and cool and summers are warm and dry. The moisture, coming during the winter when potential evapotranspiration is at a minimum, is particularly effective for leaching.

2.4 CLIMATE

General

The Clackamas Basin is located within two distinct climatic zones, which roughly correspond to the level III ecoregions shown in Figure 3. The portion of the basin that falls within the Willamette Valley level III ecoregion roughly corresponds to Oregon Climate Zone 2 – the Willamette Valley; while the portion of the Basin within the Cascades level III ecoregion corresponds with Oregon Climate Zone 4 – the Northern Cascades (OCS, 2005a).

The climate of the Willamette Valley is relatively mild Mediterranean climate, characterized by cool-wet winters and warm-dry summers (OCS, 2005a). The growing season is long, and moisture is abundant during most of the year, although summer irrigation is common. The Willamette Valley has a predominant winter rainfall climate, with 50% of the annual total typically occurring from December through February, lesser amounts occurring in the spring and fall, and almost no precipitation occurring during the summer months. Rainfall tends to increase with elevation. Extreme temperatures are rare; days with maximum temperature above 90 ^{o}F occur only 5-15 times per year on average, and below zero temperatures occur only about once every 25 years. Mean high temperatures range from the low 80's in the summer to about 40 ^{o}F in the coldest months, while average lows are generally in the low 50's in summer and low 30's in winter. The mean growing season is 150-180 days in the lower portions of the Valley, and 110-130 days in the foothills (above about 800 feet). Snow typically falls every year, however, amounts are generally quite low; valley floor locations averaging 5-10 inches per year, mostly during December through February, with totals increasing with elevation in the foothills. Severe storms are rare; ice storms occurring occasionally as a result of cold air flowing westward through the Columbia Gorge, and high winds occurring several times per year in association with major weather systems.

The climate of the Northern Cascades, and of adjacent climate zones, is strongly influenced by the Cascade Mountain Range. Storms approaching from the west are forced to rise as they encounter the Cascades, resulting in large amounts of orographic (terrain-induced) precipitation on the western slopes (OCS, 2005a). Most of the northern Cascades, receive an excess of 80 inches of rain per year; with the highest peaks collecting more than 150 inches per year, most of it in the form of snow. As in the Willamette Valley, most of the precipitation in the Northern Cascades falls during the winter months with November through March period accounting for more than 75 percent of the total annual precipitation. Spring and fall rain and snow and summer thunderstorms contribute to the annual total, but they are dwarfed by the winter precipitation totals. Total precipitation, and the proportion that occurs as snowfall, increases significantly with elevation. Mean monthly temperatures has a strong inverse correlation with elevation, and growing seasons are typically much shorter then in the Willamette Valley; for example, the growing season is 191 days at the Three Lynx weather station, and 108 days at Government Camp.

Precipitation

The Oregon Climate Service (OCS, 1998) has published digital maps of mean annual and monthly precipitation for the western United States, based on available precipitation records for the period 1961-1990. The OCS maps were produced using a technique that combines point precipitation data and digital elevation model (DEM) data to generate spatial estimates of annual and monthly precipitation. As such, the precipitation maps available from the OCS incorporate precipitation data from the local stations in and around the Clackamas Basin. Mean annual precipitation within the Clackamas Basin is shown in Figure 5. Annual precipitation values are greatest in the mid-portion of the basin. Despite being higher in elevation the easternmost portion of the basin has lower annual precipitation values, likely due to the rain shadow effect of mountains in the mid-portion of the watershed, and the northwest orientation of the Clackamas River valley. Mean annual precipitation ranges from 43 to 109 inches within the Clackamas Basin, and is 71 inches overall (Table 3). The lowest areas of precipitation are within the Lower Clackamas and Lower Clackamas Tributaries geographic areas, and the greatest precipitation occurs in the headwaters of the Fish Creek, Hot Springs Fork, and Eagle Creek geographic areas (Figure 5).

Year-to-year variability in precipitation was assessed using long-term composite precipitation produced by the Oregon Climate Service (2005b) for climate zones #2 (the Willamette Valley) and #4 (the Northern Cascades). The long-term records produced by the OCS use values from all climate stations within the region, and cover the period from 1895 to 2002. Total monthly precipitation data were used to calculate total precipitation by water year[1] (Figure 6).

The two primary patterns of climatic variability that occur in the Pacific Northwest are the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The two climate oscillations have similar spatial climate fingerprints, but very different temporal behavior; PDO events persist for 20-to-30 year periods, while ENSO events typically persist for 6 to 18 months (Mantua, 2001). Changes in Pacific Northeast marine ecosystems have been correlated with PDO phase changes. Warm/dry phases have been correlated with enhanced coastal ocean productivity in Alaska and decreased productivity off the west coast of the lower 48 states, while cold/wet phases have resulted in opposite patterns of ocean productivity (Mantua, 2001). Several studies (Mantua et al., 1997; Minobe, 1997; and Mote et al., 1999) suggest that five distinct PDO cycles have occurred since the late 1800's:

- 1890-1924 (cool/wet)
- 1925-1946 (warm/dry)
- 1947-1976 (cool/wet)
- 1977–1995 (warm/dry)
- 1995–present (cool/wet)

The long-term composite precipitation records produced by the Oregon Climate Service (2005b) for climate zones #2 and #4 were used to evaluate whether or not local trends follow the documented PDO cycles. These data were processed as follows:

1. The mean and standard deviation was calculated for annual precipitation in each zone over the period of record

2. A standardized departure from normal was calculated for each year by subtracting the mean annual precipitation from the annual precipitation for a given year, and dividing by the standard deviation

3. A cumulative standardized departure from normal was then calculated by adding the standardized departure from normal for a given year to the cumulative standardized departure from the previous year (the cumulative standardized departure from normal for the first year in a station record was set to zero).

[1] Water year is defined as October 1 through September 30. The water year number comes from the calendar year for the January 1 to September 30 period. For example, Water Year 1990 would begin on October 1, 1989, and continue through September 30, 1990. This definition of water year is recognized by most water resource agencies

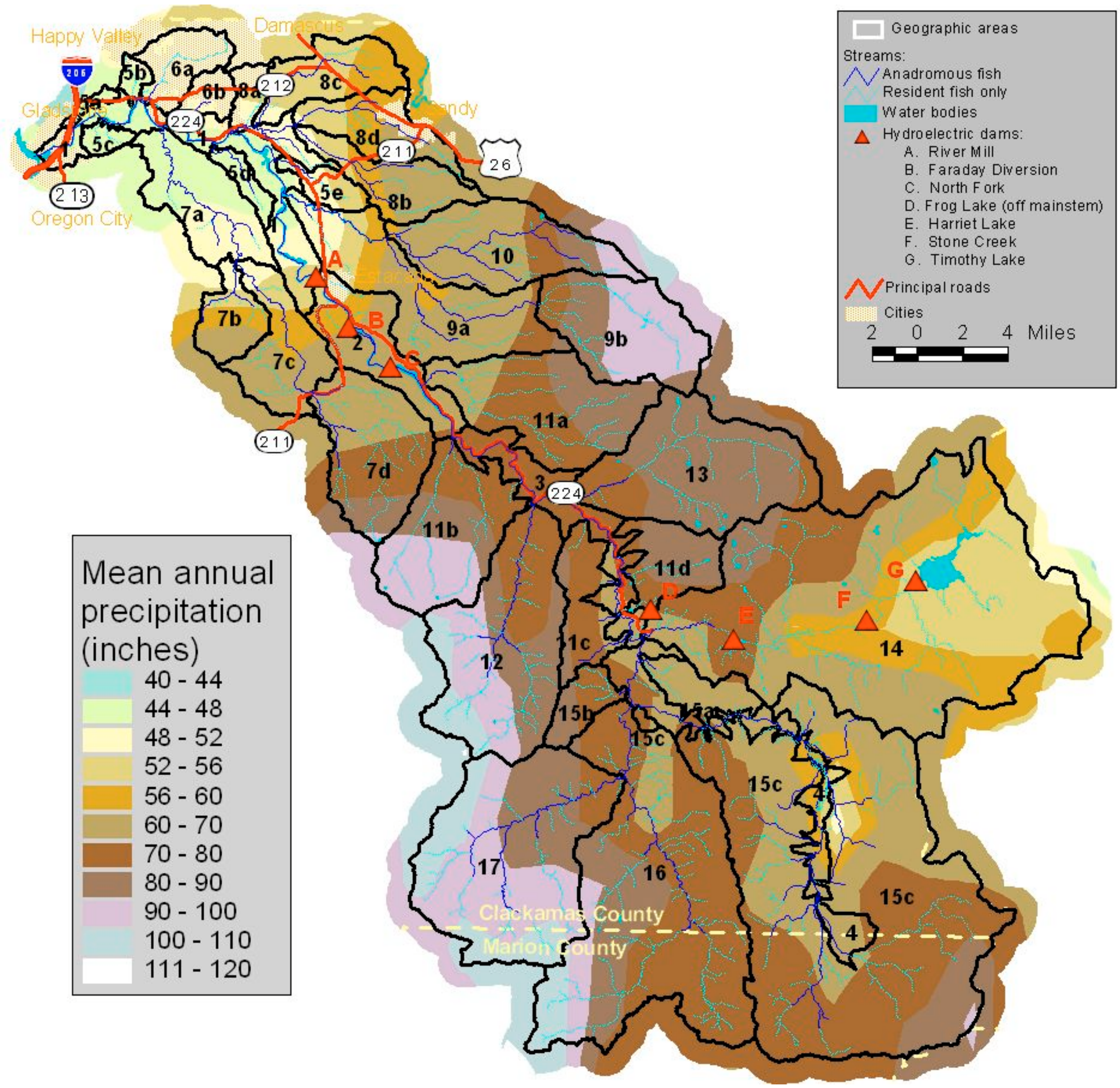

Figure 5. Mean annual precipitation in the Clackamas Basin (OCS, 1998).

Table 3. Mean annual precipitation (inches) in the Clackamas Basin (OCS, 1998).

Geographic area	Area-weighted mean	Min	Max
01. Lower Clackamas	48	43	57
02. NF Reservoir/Estacada Lake	62	53	71
03. Middle Clackamas Mainstem	72	65	83
04. Upper Clackamas Mainstem	66	53	73
05a. Cow Creek	45	43	45
05b. Sieben Creek	47	45	49
05c. Edna/Johnson Creeks	47	45	49
05d. Foster Creek	46	45	49
05e. Goose Creek	52	47	57
06a. Rock Creek	51	45	57
06b. Richardson Creek	51	47	53
07a. Lower Clear Creek	48	45	53
07b. Little Clear Creek	58	51	67
07c. Middle Clear Creek	60	49	67
07d. Upper Clear Creek	72	63	93
08a. Lower Deep Creek	51	47	55
08b. Upper Deep Creek	60	49	67
08c. North Fork Deep Creek	55	49	59
08d. Tickle Creek	59	51	65
09a. Lower Eagle Creek	61	47	85
09b. Upper Eagle Creek	89	71	101
10. North Fork Eagle Creek	70	59	99
11a. North Fork Clackamas River	77	63	91
11b. South Fork Clackamas River	86	71	101
11c. Pup/Cat/Whale/Sandstone/Big Cks	75	67	83
11d. Dinner/3 Lynx/Cripple/Bull Cks	82	67	87
12. Fish Creek	88	71	109
13. Roaring River	81	69	89
14. Oak Grove Fork	63	49	85
15a. Tag/Switch Creeks	69	67	71
15b. Trout Creek	79	71	87
15c. Headwaters tributaries	70	49	93
16. Collawash River	79	65	109
17. Hot Springs Fork	93	73	109
Entire Basin	**71**	**43**	**109**

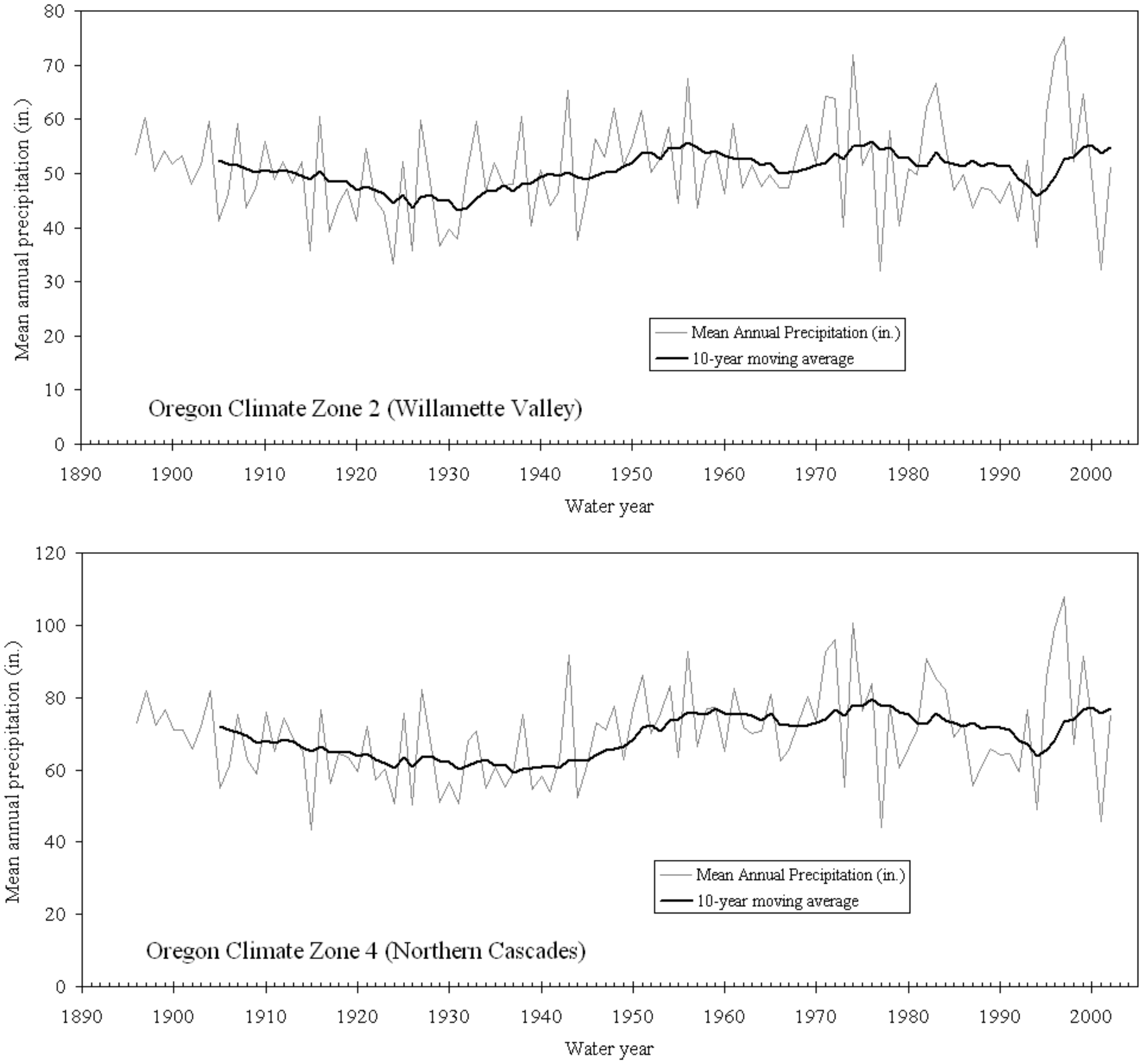

Figure 6. Composite annual precipitation record for Oregon Climate zones #2 (top Graph) and #4 (bottom). (OCS, 2005b).

This approach of using the cumulative standardized departure from normal provides a way to better-illustrate patterns of increasing or decreasing precipitation over time by reducing year-to-year variations in precipitation, thus compensating for the irregular nature of the data set. Values for the cumulative standardized departure from normal increase during wet periods and decrease during dry periods. Results for the two climate zones are given in Figure 7.

Precipitation patterns from the composite records generally follow the regional trends discussed above, and are similar to each other. There appears to have been a cool/wet phase from 1904-1945 in both zones (Figure 7), followed by a warm/dry phase that lasted until at least 1976. The record is more erratic following 1976, however, it appears that there was a warm/dry phase from the mid 1970's to the mid 1990's. There appears to have been a brief cool/wet phase in both zones from the mid to late 1990's after which we appear to be in a warm/dry phase through the end of water year 2002.

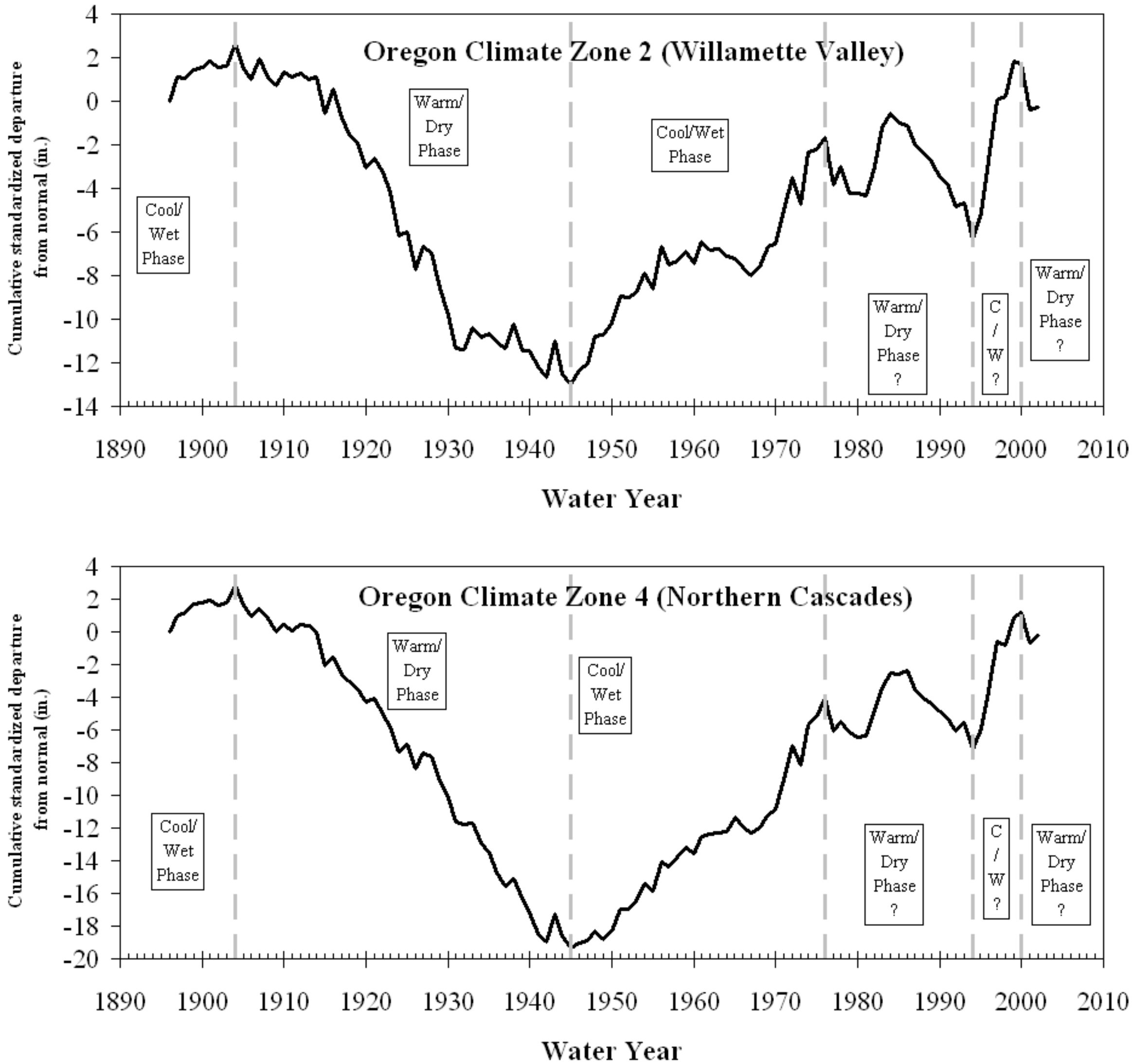

Figure 7. Cumulative standardized departure from normal of annual precipitation for Oregon Climate zones #2 and #4. Local PDO cycles are shown as vertical dashed lines

2.5 LAND USE/ LAND COVER

The following discussion is broken into two sections. The first section outlines the potential natural vegetation of the Clackamas Basin, and the second section outlines present-day land use and land cover.

2.5.1 Potential Natural Vegetation

Information on historic vegetation in the assessment area can be inferred from the level IV ecoregions found within the area (Figure 3). Potential natural vegetation types are summarized below (EPA, 2003b; WPN, 2001):

3c. Prairie Terraces: The potential natural vegetation for this area includes a mosaic of prairies and oak savannah/ and Oregon white oak; with camas, sedges, tufted hairgrass, fescue, and California oatgrass. Occasional groves of Douglas-fir are possible; with ash forests in wet depressions; and ash, oak, maple, and fir riparian forests along sluggish streams with scattered cottonwood groves. Potential understory vegetation includes poison oak, hazel, and Indian plum.

3d. Valley Foothills: A mosaic of oak woodlands and Douglas-fir forests/ Oak savanna and prairies with California oatgrass, fescue, blue wildrye, brodiaea and other prairie forbs. Douglas-fir forests with sword fern, oceanspray, hazel, baldhip rose, and poison oak.

4a. Western Cascades Lowlands and Valleys: Mostly cedar–hemlock–Douglas-fir forest/ Douglas-fir, western hemlock, western redcedar, bigleaf maple, red alder, vine maple, salal, rhododendron, Oregon grape, huckleberry, thimbleberry, swordfern, oxalis, hazel, and blackberry.

4b.Western Cascades Montane Highlands: Mostly silver fir–Douglas-fir forest; some fir–hemlock forest/ Pacific silver fir, western hemlock, mountain hemlock, Douglas-fir, noble fir, bigleaf maple, red alder, and Pacific yew. Understory plants include vine maple, rhododendron, Oregon grape, huckleberry, and thimbleberry

4c.Cascade Crest Montane Forest: Mostly fir-hemlock forest/ Mostly Pacific silver fir, mountain hemlock, and subalpine fir; some noble fir, Douglas-fir, and lodgepole pine. Understory: vine maple, huckleberries, rhododendron, beargrass, twinflower, and wintergreen. Mountain meadows support sedges, dwarf willows, and tufted hairgrass

2.5.2 Current Land Use and Land Cover

Current land cover/land use within the Basin was characterized by combining several available GIS coverages, modified in consultation with members of the CRBC TAC. Recent GAP vegetation data, available from the Oregon Natural Heritage Program (ONHP, 2004) was used as a starting point in compiling the composite coverage. The 40 categories found in the ONHP data set were reduced into 10 categories use in this analysis (described below). Next, agricultural land use classes were extracted from a coverage available from the Pacific Northwest Research Consortium (PNWERC, 1999), and merged with the ONHP data[2]. Finally, information on land use types collected in consultation with members of the TAC was digitized and merged into the above data set. The product of this operation yielded ten land use categories that were used in this analysis (Figure 8). The ten land use categories defined for this analysis are:

[2] The ONHP data did not break out agricultural types, and the PNWERV data set appeared to capture agricultural uses better then other data sets that were reviewed.

1. Parks/Golf Courses
2. Developed (This is all developed areas (industrial, home sites, roads, etc.))
3. Forest
4. Shrubland/Young Forest (Includes some areas that are young forest stands)
5. Nurseries
6. Berries
7. Row Crops
8. Hay/Pasture (Includes pasture land and hay fields (hard to split apart))
9. Christmas Trees
10. Water/wetlands/ channel

At the Basin level, land cover is predominately (90%) forest and shrubland; agricultural activities cover approximately 8% of the basin, other developed areas make up approximately 2% of the total area, and approximately 1% of the total area is covered by water (Figure 8).

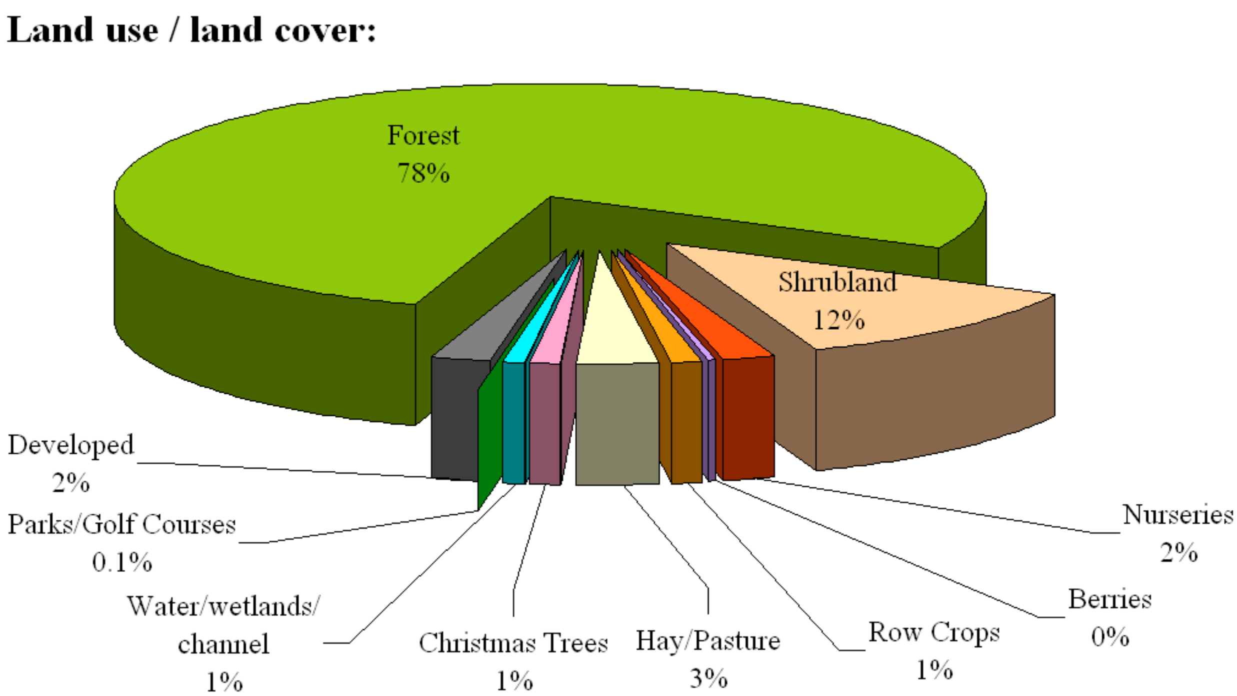

Figure 8. Proportion of total Clackamas Basin area by 10 Land use / land cover classes defined for this assessment.

Land use / land cover in the lower portion of the Clackamas Basin is shown in Figure 9, and summarized by geographic area in Figure 10. The majority of lands classified as "developed are found in the vicinity of the incorporated cities. Agricultural use is widespread throughout the lower portion of the Basin, with nursery crops centered in the North Fork of Deep Creek, and Christmas tree production dominating in the Clear Creek area. Virtually the entire basin upstream of River Mill Dam is in a forested/shrubland condition.

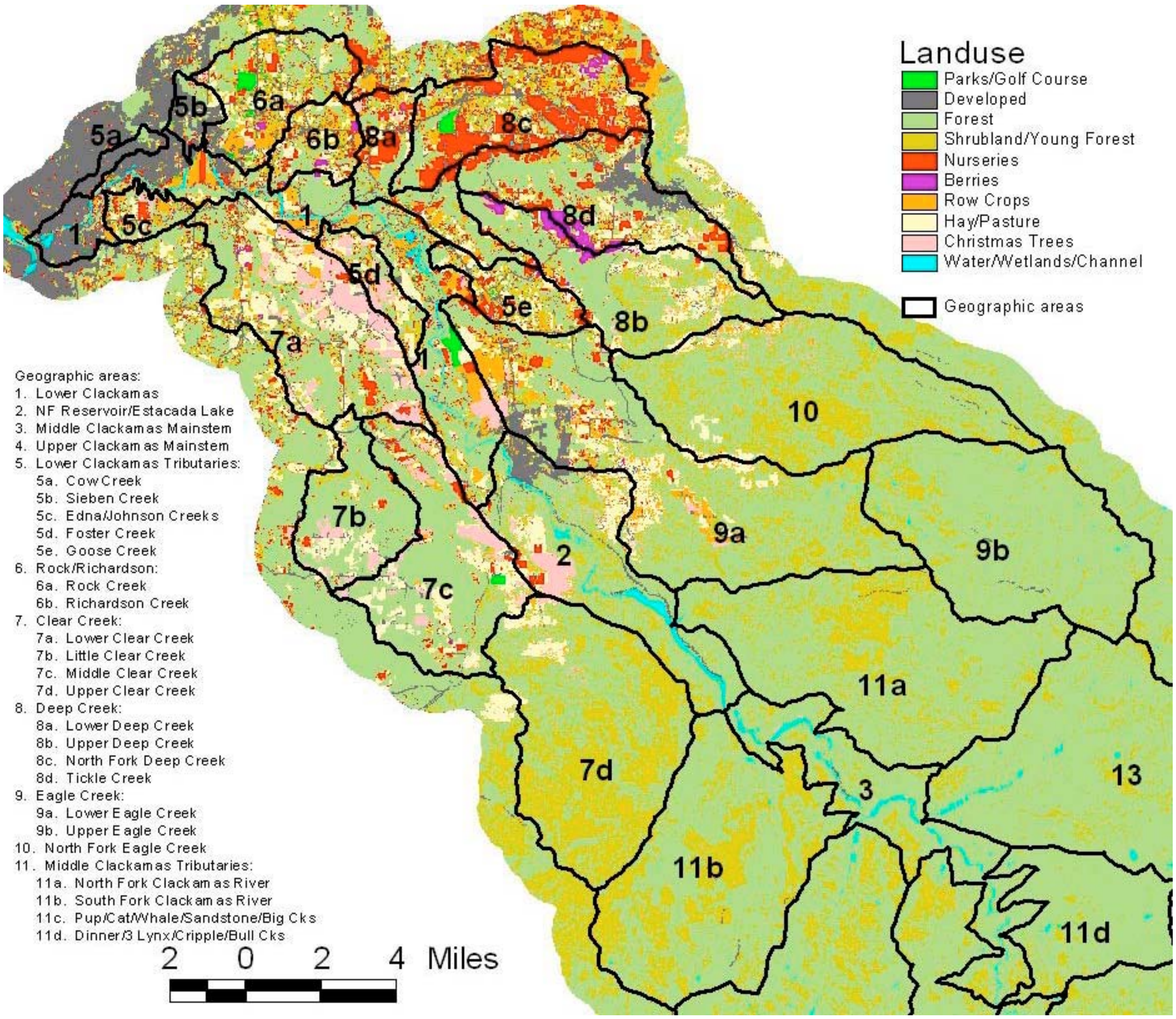

Figure 9. Landuse and land cover within the Clackamas River Basin (areas not shown in the upper basin are predominately forested). Data sources: ONHP (2004), PNWERC (1999).

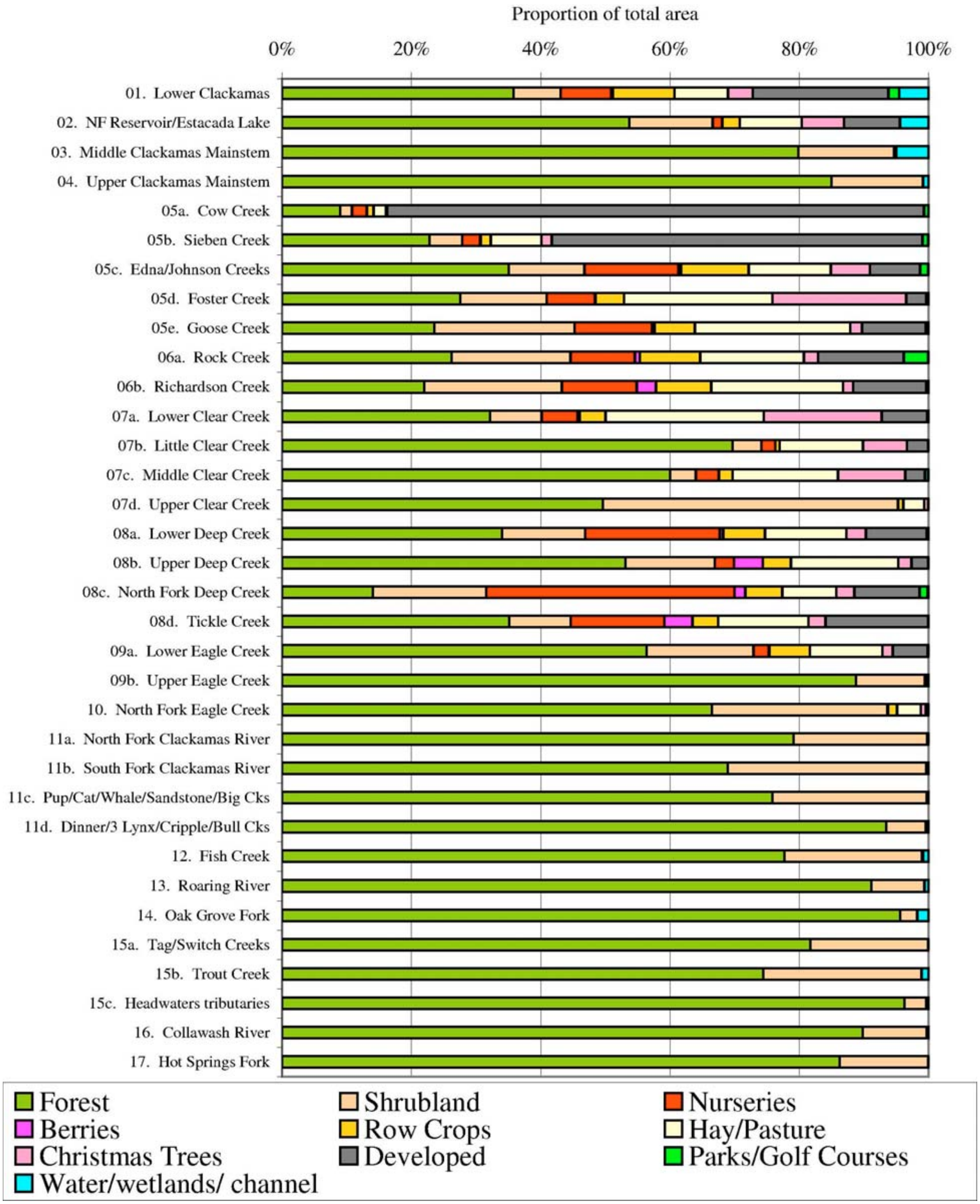

Figure 10. Summary of principal land cover groupings by geographic area and sub-area in the Clackamas Basin.

2.6 CURRENT ZONING

Information on current land zoning within the Clackamas Basin was available from Clackamas County (2005). Current zoning is shown in Figure 11, and summarized in Table 4. Lands designated as "Agriculture/Forest" make up the entire area in all geographic areas in the upper basin; and make up greater then 50% of the total area within all remaining geographic areas with the exception of Rock/Richardson. The primary areas of residential, commercial, and industrial development occur in the Rock/Richardson, Deep Creek, Lower Clackamas Tributaries, Lower Clackamas mainstem, and NF Reservoir/Estacada geographic areas.

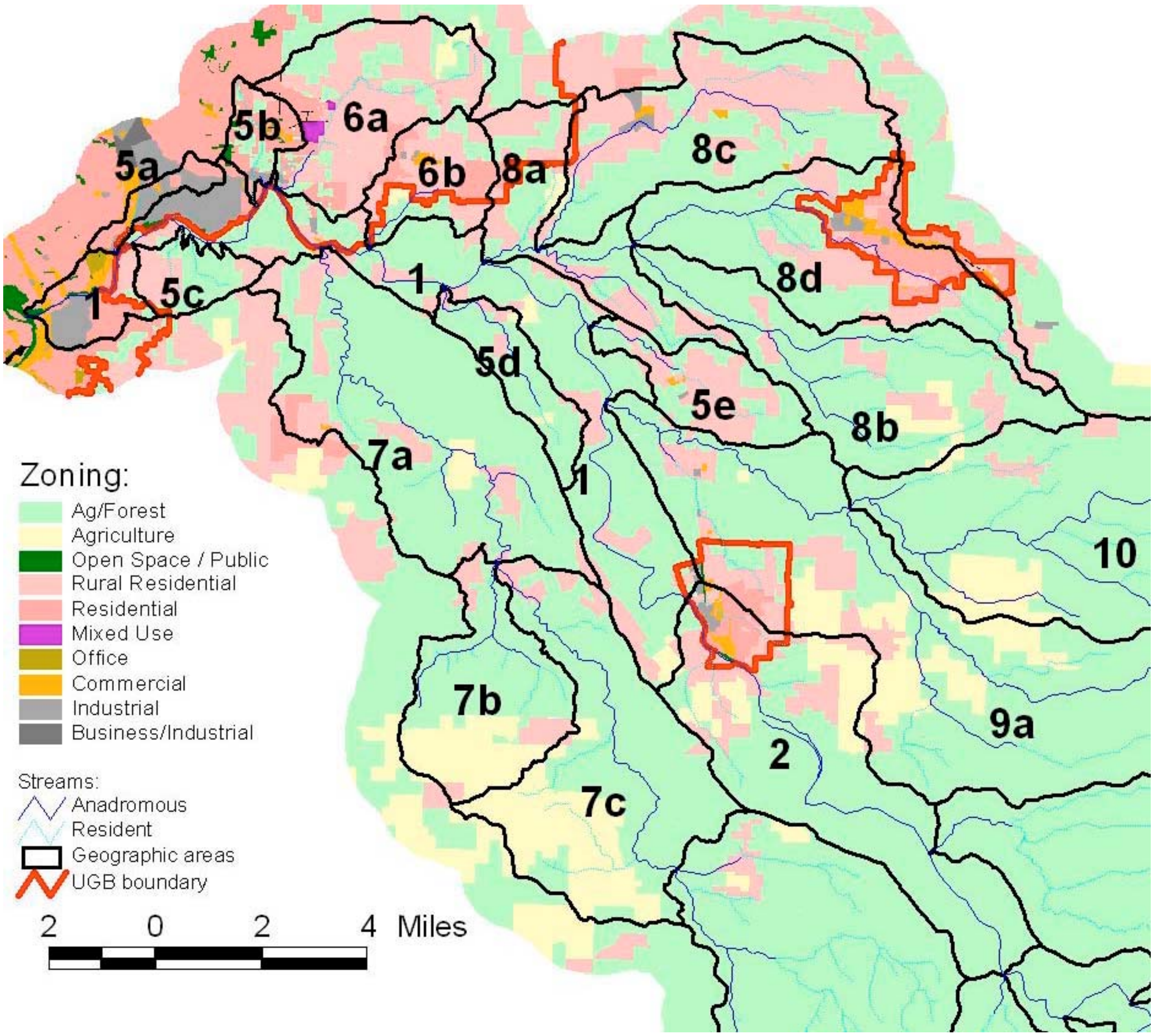

Figure 11. Current zoning within the Clackamas River Basin. Areas not shown are all zoned Ag/Forest. Data source: Clackamas County 2003, 2005.

Table 4. Summary of current zoning within the Clackamas Basin (Clack. Co. 2003).

Geographic area	Ag/Forest	Agri-culture	Open Space/ Public	Rural Resi-dential	Resi-dential	Mixed use	Office	Comm-ercial	Industrial
01. Lower Clackamas	8,818	252	114	2,316	875	-	84	187	1,249
02. NF Reservoir/Estacada Lake	7,924	1,357	50	1,817	433	-	-	119	100
03. Middle Clackamas Mainstem	11,746	-	-	-	-	-	-	-	-
04. Upper Clackamas Mainstem	12,349	-	-	-	-	-	-	-	-
05a. Cow Creek	22	-	-	-	329	-	7	69	353
05b. Sieben Creek	289	-	46	44	741	7	13	30	61
05c. Edna/Johnson Creeks	868	-	-	656	6	-	-	-	-
05d. Foster Creek	1,873	60	-	289	-	-	-	-	-
05e. Goose Creek	1,526	-	-	1,548	-	-	-	18	10
06a. Rock Creek	1,588	186	-	3,351	759	110	-	-	30
06b. Richardson Creek	726	114	-	1,263	492	-	-	56	20
07a. Lower Clear Creek	10,156	307	-	1,873	181	-	-	13	-
07b. Little Clear Creek	3,458	1,760	-	582	-	-	-	-	-
07c. Middle Clear Creek	7,278	3,242	-	542	-	-	-	-	-
07d. Upper Clear Creek	16,712	203	-	374	-	-	-	-	-
08a. Lower Deep Creek	2,475	119	-	1,903	59	-	-	0	-
08b. Upper Deep Creek	7,273	503	-	1,151	-	-	-	-	-
08c. North Fork Deep Creek	4,932	55	-	3,885	27	-	-	64	141
08d. Tickle Creek	5,200	-	-	2,174	1,011	-	-	252	137
09a. Lower Eagle Creek	17,065	2,888	22	2,184	194	-	-	23	36
09b. Upper Eagle Creek	17,324	-	-	-	-	-	-	-	-
10. North Fork Eagle Creek	16,132	1,391	-	383	-	-	-	-	-
11a. North Fork Clackamas River	21,145	-	-	-	-	-	-	-	-
11b. South Fork Clackamas River	19,257	-	-	-	-	-	-	-	-
11c. Pup/Cat/Whale/Sandstone/Big	7,846	-	-	-	-	-	-	-	-
11d. Dinner/3 Lynx/Cripple/Bull	8,188	-	-	-	-	-	-	-	-
12. Fish Creek	29,796	-	-	-	-	-	-	-	-
13. Roaring River	27,184	-	-	-	-	-	-	-	-
14. Oak Grove Fork	90,466	-	-	-	-	-	-	-	-
15a. Tag/Switch Creeks	5,164	-	-	-	-	-	-	-	-
15b. Trout Creek	4,304	-	-	-	-	-	-	-	-
15c. Headwaters tributaries	55,576	-	-	-	-	-	-	-	-
16. Collawash River	33,840	-	-	-	-	-	-	-	-
17. Hot Springs Fork	34,650	-	-	-	-	-	-	-	-
Entire Basin	**493,146**	**12,438**	**232**	**26,337**	**5,107**	**116**	**105**	**831**	**2,138**

2.7 POPULATION DISTRIBUTION, TRENDS, AND PROJECTED GROWTH

Exact population data is not readily available for the Clackamas Basin, however, population patterns and trends can be inferred from several data sources (Oregon Population Research Center, 2005; US Census Bureau, 2005: Oregon Office of Economic Analysis, 2005) available for Clackamas County as a whole, and for the incorporated cities within the Basin. Population values for Clackamas County have steadily increased since the first available records, and are projected to continue increasing at a faster rate (Figure 12). Clackamas County population increased sharply following World War II, with the greatest rate of growth occurring during the period 1960-1980. The rate of growth decreased slightly during the 1980's, but increased rapidly during the 1990's. Data for three cities within the Clackamas Basin indicates that the fastest rates of growth during the period 1990 to present have occurred in the metropolitan area (e.g., Oregon City), with a slower rate of increase in the outlying incorporated areas (e.g., Sandy and Estacada; Figure 12).

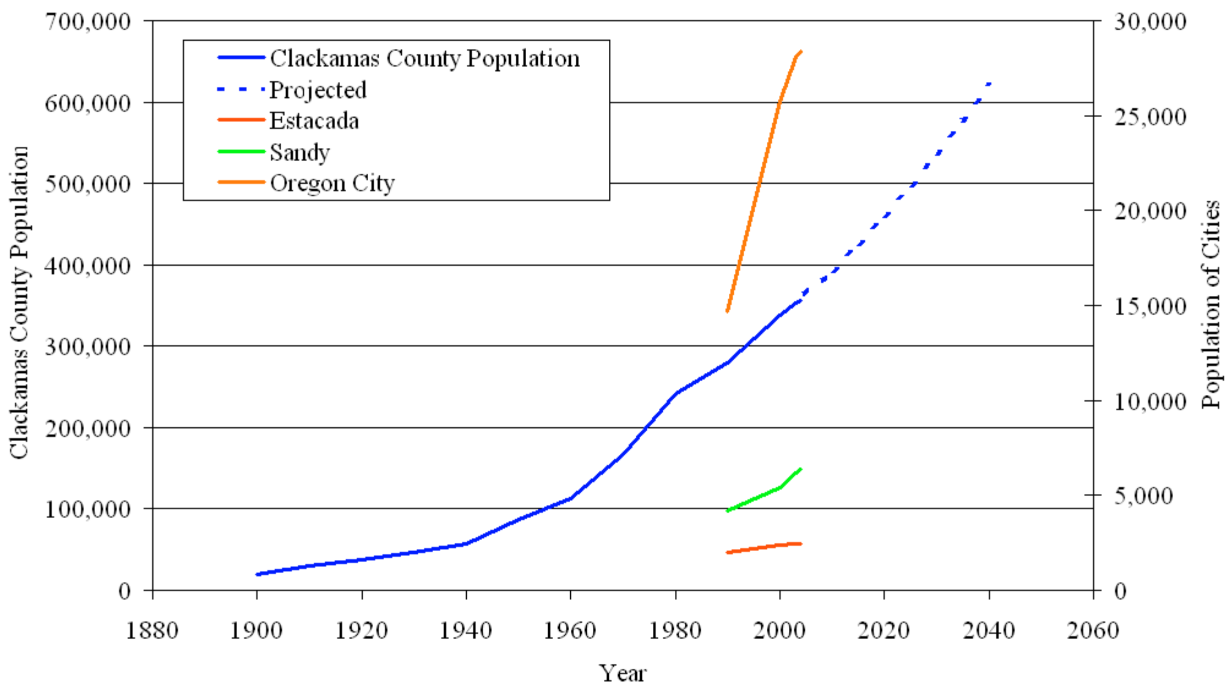

Figure 12. Clackamas County population, 1900 to 2004; projected population growth through 2040; and city populations for Estacada, Sandy and Oregon City (Oregon Population Research Center, 2005; US Census Bureau, 2005: Oregon Office of Economic Analysis, 2005),

The population within the Clackamas is concentrated in and around the incorporated cities and the metropolitan area (Figure 13). The majority of the Basin has population densities less then 1 person per square mile. The forested upper portions of the Basin, primarily on lands managed by the US Forest Service, have no permanent population. Most of the Clackamas River Basin's population is concentrated within the urban growth boundaries (UGBs) of the cities of Sandy, Estacada, and the metropolitan area (Figure 13). UGBs are areas of likely future development. UGB area is summarized by geographic areas in Table 5. Sieben Creek and Rock Creek are located completely within the UGB for the Portland Metropolitan area, as are the majority of the area of Cow Creek and Richardson Creek.

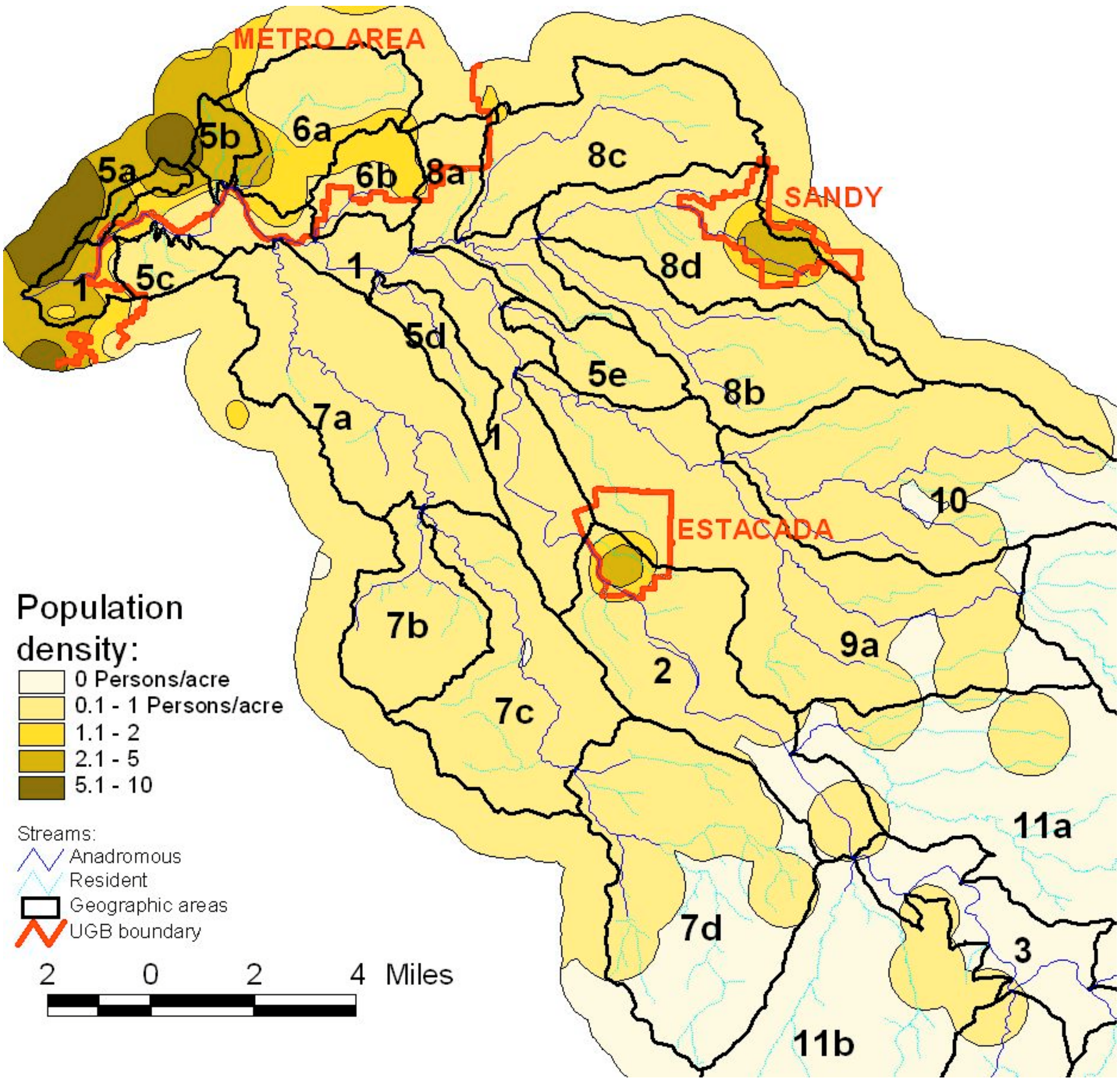

Figure 13. Population density in the lower Clackamas Basin (Oregon Population Research Center, 2005).

Table 5. Urban Growth Boundary area within the Clackamas Basin (Clack. Co. 2003).

Geographic area	Acres within UGB	UGB as % total geographic area
01. Lower Clackamas	3,228	23%
02. NF Reservoir/Estacada Lake	1,021	9%
05a. Cow Creek	763	98%
05b. Sieben Creek	1,230	100%
05c. Edna/Johnson Creeks	14	1%
06a. Rock Creek	6,024	100%
06b. Richardson Creek	1,905	71%
08a. Lower Deep Creek	1,203	26%
08c. North Fork Deep Creek	80	1%
08d. Tickle Creek	1,861	21%
09a. Lower Eagle Creek	1,306	6%

3.0 WATER RESOURCES

3.1 HYDROLOGIC REGIME

The primary peak flow generating processes active in Oregon are rainfall, snowmelt, and rain-on-snow (ROS). Rain-on-snow is the common term used to describe wintertime conditions when relatively warm wind and rain combine to produce rapid snowmelt. The dominant peak flow generating processes can be stratified by EPA level IV ecoregion (Figure 3; WPN, 2001). Within the level IV ecoregions found within the vicinity of the Clackamas Basin the dominant peak flow generating processes are estimated as rainfall in all areas below 2,300 feet elevation (level IV ecoregions 3c, 3d, and 4a; Figure 3), and as ROS in areas above 2,300 feet elevation (level IV ecoregions 4b and 4c; Figure 3). Regardless of the actual location of the ROS zone, it is important to recognize that ROS processes may occur within all elevation ranges; it is just that ROS has the greatest likelihood of significantly affecting peak flows within the ROS zone.

Examination of four representative stream gages within and adjacent to the Clackamas Basin provide further evidence of variation in hydrologic regime in different parts of the watershed. Peak flow records from four USGS stream gages (Table 6) were used to construct peak flow histories. For purposes of comparison, the data are presented as a time series showing the recurrence interval of the annual flow event (Figure 14). This approach allows for a comparison of events from a wide variety of watershed sizes. Recurrence intervals were calculated for the period of record at each station using techniques described by the Interagency Advisory Committee on Water Data (1982). Peak flow magnitude was next plotted against probability (i.e., 1/recurrence interval) on log-probability paper. Recurrence interval was then interpolated for each event from the plotted values.

Table 6. Stream gages used in the flood history summary (USGS, 2005).

Station	Drainage area (mi^2)	Elevation (ft)	Period of record
14209500: Clackamas River Above Three Lynx Creek	479.0	1,092	1909 - Present
14209700: Fish Creek near Three Lynx	45.1	940	1989 - Present
14209900: Dubois Creek at Estacada	2.5	490	1956 - 1977
14211500: Johnson Creek at Sycamore	26.8	228	1940 - Present

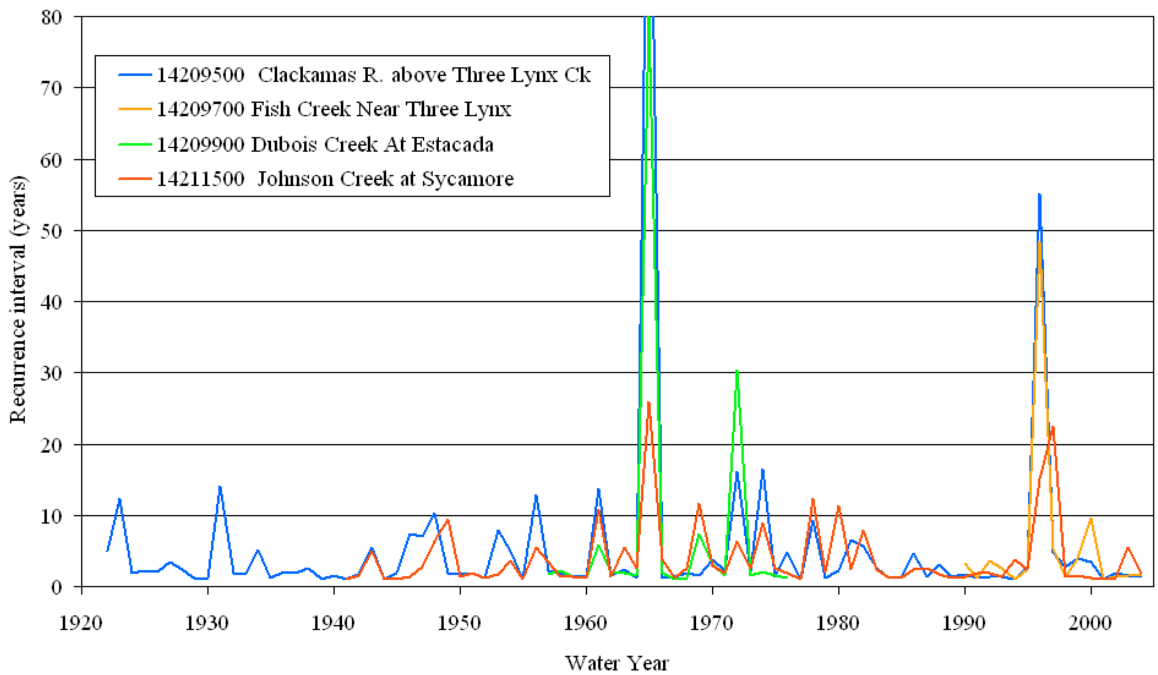

Figure 14. Recurrence interval associated with annual peak flow events at four stream gages in the vicinity of the Clackamas Basin. Data source: USGS (2005).

Several items of interest can be observed from the records plotted in Figure 14. First of all, the period of the 1960s and 1970s saw several large and moderate-sized flood events. In contrast, the 1980s and early 1990s saw relatively few large floods. Consequently, the large flood events in 1996 and 1997 caught many people by surprise, coming after a period of relative calm. The largest event at all four stream gages was the flood that occurred on 12/21/1964 during water year 1965 (i.e., the "'64 flood"). Interestingly, the '64 flood had an estimated recurrence interval of greater then 80 years at the Clackamas River and Dubois Creek gages, but was only estimated to be a ~25 year event at the Johnson Creek gage. This disparity is due no doubt in part to the uncertainty in estimating recurrence intervals from short data records, however, it is probable that the lack of significant snow pack at low elevations probably resulted in much lower magnitude flooding in the lower elevation watersheds.

3.2 STREAMS, LAKES AND WETLANDS

Information on streams within the Clackamas Basin was compiled for this assessment from several available data sources (Table 7, Figure 1). Information on anadromous fish use was taken from a GIS coverage constructed by Clackamas County (2004) for the recent Ecosystem Diagnostics and Treatment (EDT) analysis that was completed for the Basin. Information on streams in the lower basin (i.e., non-federal lands) having resident salmonid use was available from the Oregon Department of Forestry (ODF, 2003). Resident salmonid use in the upper basin (i.e., federal lands) was taken from the US Forest Service (USFS, 2000) stream coverages. Information on Water bodies (lakes, ponds, reservoirs, and large rivers) and wetlands was available from the National Wetlands Inventory (USFWS, 2005). Information on streams, lakes and wetlands within the Clackamas Basin is summarized in Table 7.

Approximately 3,100 miles of streams were identified within the Clackamas Basin (Table 7). Of the total number of stream miles approximately 10% are used by anadromous and resident fish species, another 20% is used by resident salmonid species only, and the remaining 70% has either no salmonid use, or use is unknown. Water bodies make up less then 1% of the total Basin area (Table 7). The geographic areas having the largest area of water bodies are the Oak Grove Fork geographic area, which is dominated by the human-made Timothy Lake; the North Fork Reservoir / Estacada Lake geographic area, which is dominated by the PGE reservoir complex. Wetlands make up approximately 1% of the total Basin area. The largest concentrations of wetlands are in the Oak Grove Fork and Lower Clackamas Geographic areas, and are associated with The Timothy Lake complex, and mainstem Clackamas River areas.

3.3 HYDROELECTRIC FACILITIES ON THE MAINSTEM

The dams and operation of hydroelectric facilities on the mainstem Clackamas River alter the flow regime and create impoundments that influence water quality. The effect of dam operations are being addressed as part of the Federal Energy Regulatory Commission (FERC) relicensing process that is occurring concurrently with development of the CRBC action plan. The information below has been summarized primarily from PGE’s Section 401 application (PGE 2003).

Project Facilities

The Project consists of the Oak Grove Development and the mainstem developments, North Fork Dam, the Faraday Development, and River Mill Dam (Figure 1). The three mainstem developments dams are located in sequence on the Clackamas River between RM 23.3 and RM 30.0. Water released from North Fork Dam is diverted by the Faraday Diversion Dam into Faraday Lake. Water is released from Faraday Lake via the Faraday Powerhouse into Estacada Lake, formed by River Mill Dam. Water released from River Mill Dam flows into the lower Clackamas River.

The Oak Grove Development includes, Timothy Lake and Timothy Lake Dam, Lake Harriet and the Lake Harriet Dam, Frog Lake—an off-stream reservoir that serves as the development’s forebay, pipelines that convey water from Lake Harriet to Frog Lake and from Frog Lake to the

Oak Grove Powerhouse penstocks, and the Oak Grove Powerhouse, which discharges Oak Grove Fork water into the mainstem Clackamas River at RM 48.

Eugene Water and Electric Board's Stone Creek Project, which is not part of this relicensing, diverts the flow of the Oak Grove Fork just below Timothy Lake for power generation. Water is returned to the Oak Grove Fork upstream of Lake Harriet.

Table 7. Summary of stream length by fish use category, area of water bodies, and area of wetlands within the Clackamas Basin (Clackamas Co., 2004; ODF, 2003; USFS, 2000, USFWS, 2005).

	Miles of stream:				Acres of:	
Geographic area	**Anadromous & resident fish use**	**Resident salmonid use only**	**No salmonid use or use unknown**	**Grand Total**	**Water bodies**	**Wetland**
01. Lower Clackamas	22.9	0.5	0.8	24.1	121	1,384
02. NF Reservoir/Estacada Lake	12.6	7.8	4.7	25.1	494	20
03. Middle Clackamas Mainstem	18.7	0.8	54.5	74.0	-	461
04. Upper Clackamas Mainstem	24.8	8.9	44.2	77.9	-	314
05a. Cow Creek	0.3	1.0	1.7	3.0	-	0
05b. Sieben Creek	0.3	2.6	6.7	9.5	-	2
05c. Edna/Johnson Creeks	-	2.9	2.9	5.8	-	2
05d. Foster Creek	3.7	0.9	0.1	4.7	-	16
05e. Goose Creek	2.3	1.9	2.2	6.4	-	25
06a. Rock Creek	1.2	6.4	38.7	46.2	-	12
06b. Richardson Creek	1.9	-	11.3	13.3	-	25
07a. Lower Clear Creek	13.9	2.3	15.9	32.1	-	60
07b. Little Clear Creek	5.0	3.5	11.2	19.7	-	34
07c. Middle Clear Creek	8.9	7.7	8.0	24.6	-	60
07d. Upper Clear Creek	6.1	31.7	23.3	61.0	-	18
08a. Lower Deep Creek	6.0	4.6	3.8	14.5	-	68
08b. Upper Deep Creek	10.1	6.8	11.2	28.1	-	48
08c. North Fork Deep Creek	7.4	4.5	13.8	25.7	-	142
08d. Tickle Creek	8.5	7.0	13.8	29.2	-	48
09a. Lower Eagle Creek	20.2	13.0	15.3	48.5	-	279
09b. Upper Eagle Creek	-	23.6	137.0	160.6	-	3
10. North Fork Eagle Creek	20.6	15.6	12.8	49.1	-	39
11a. North Fork Clackamas River	2.0	37.1	79.2	118.3	12	5
11b. South Fork Clackamas River	0.8	24.4	76.5	101.7	-	15
11c. Pup/Cat/Whale/Sandstone/Big	4.7	2.0	70.3	77.0	-	1
11d. Dinner/3 Lynx/Cripple/Bull	0.7	8.3	43.0	52.0	-	77
12. Fish Creek	11.3	35.1	196.0	242.4	-	15
13. Roaring River	3.0	31.8	183.6	218.4	23	269
14. Oak Grove Fork	4.1	96.7	271.6	372.4	1,454	1,612
15a. Tag/Switch Creeks	0.9	6.3	34.0	41.2	-	17
15b. Trout Creek	0.6	5.1	38.3	44.0	-	1
15c. Headwaters tributaries	36.7	79.5	293.2	409.3	83	562
16. Collawash River	16.7	80.7	328.7	426.0	109	348
17. Hot Springs Fork	17.8	32.8	184.5	235.1	4	131
Grand Total	**294.7**	**593.9**	**2,232.6**	**3,121.2**	**2,300**	**6,113**

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