Elk River/Salmon Creek Watershed Analysis Scotia, California

Cumulative Watershed Effects Assessment

Prepared for Pacific Lumber Company (PALCO) Scotia, California

16020-00

NOTES ON THE ELK RIVER/SALMON CREEK (ERSC) WATERSHED ANALYSIS AND PRESCRIPTIONS

The enclosed package contains the following documents related to the watershed analysis completed for the Elk River and Salmon Creek (ERSC) watershed analysis units containing lands owned by the Pacific Lumber Company (PALCO) in northern California: (a) Final ERSC Watershed Analysis Report, (b) Prescriptions, and (c) Justification for Prescriptions.

This watershed analysis was initiated by a Signatory Review Team (SRT) composed of scientists from PALCO and several state and federal agencies, including the National Marine Fisheries Service (now NOAA Fisheries), U.S. Fish and Wildlife Service, California Department of Forestry and Fire Protection, California Department of Fish and Game, California Department of Mines and Geology (now California Geological Survey), and the North Coast Regional Water Quality Control Board. The watershed analysis was completed in fulfillment of obligations contained within the company's Habitat Conservation Plan or HCP (PALCO 1999). Most of the actual analysis and assessment was conducted by a resource assessment team composed of private sector scientists with extensive experience in watershed analysis, especially with development of the guidelines for and completion of watershed studies within Washington State as this "DNR Approach" is required, by the HCP, to be the template for watershed studies on PALCO's lands.

The watershed analysis is aimed at identifying existing conditions and the physical and biological processes at work within the Elk River and Salmon Creek watershed analysis units. The analysis is particularly concerned with land management practices that could impact aquatic resources, and the specific portions of the watershed that are sensitive to those management practices. The attached document is a compilation of the technical studies that were completed as part of that analysis.

The enclosed watershed analysis was completed using approaches contained within "Watershed Assessment Methods for PALCO Lands" (PALCO 2000). This methods manual was developed by a joint PALCO-Agency-Consultant team, with significant public input and outside scientific peer review, over a period of approximately 10 months. In some cases, individual methods or analyses differ from those in PALCO (2000). Such instances are noted in the text of the watershed analysis. Interested parties may wish to review section 6.3.2 of the HCP ("Watershed Analysis") and/or examine the watershed analysis methods contained within the Washington DNR manual ("Standard Methodology for Conducting Watershed Analysis," Washington Forest Practices Board 1997).

The watershed analysis process itself is science-driven and often technically complex. This attached report attempts to explain the analysis in enough detail to allow most readers to understand what work was done, and what it means. However, some knowledge of watershed science and terminology would be helpful, and for some portions of the analysis, likely required for a better understanding. This is probably inevitable in a document of this length and technical complexity.

PALCO and its consultant team at Hart Crowser would like to thank the agency representatives who contributed their time and effort to this watershed analysis. PALCO also wishes to thank the agency representatives involved in utilizing the watershed analysis data in the prescriptions process.

We believe that this analysis has significantly increased our scientific understanding of the ERSC watershed analysis units, which, in turn, will allow the company and the state and federal agencies involved in its HCP to implement management approaches that will allow PALCO to economically utilize its lands while protecting the environment.

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ACRONYMS AND ABBREVIATIONS

APFC	Aquatic Properly Functioning Conditions
ASTM	American Standards for Testing Materials
BLM	US Bureau of Land Management
C	Centigrade
CDF	California Department of Forestry
CG	Consolidated Geology
CG0	Consolidated Geology, 0 to 1.5 percent gradient
CG1.5	Consolidated Geology, 1.5 to 3 percent gradient
CG3	Consolidated Geology, 3 to 6.5 percent gradient
CG6.5	Consolidated Geology, 6.5 to 20 percent gradient
CG20	Consolidated Geology, greater than 20 percent gradient
CGU	channel geomorphic unit
CWE	cumulative watershed effects
DI	disturbance index
EKA	Eureka weather station
ERSC	Elk River and Salmon Creek
F	Fahrenheit
GIS	geographic information system
HCP	Habitat Conservation Plan
LEED	Lower Eel and Eel Delta
LWD	large woody debris
MSF	Mainstem, Fine Bed
MSG	Mainstem, Gravel Bed
MWAT	mean weekly average temperature
NMFS	National Marine and Fisheries Service (now NOAA Fisheries)
NRCS	Natural Resource Conservation Service
NRM	Natural Resources Management
OEI	O'Connor Environmental, Inc.
PALCO	Pacific Lumber Company
PFC Matrix	Interagency Properly Functioning Conditions Matrix
PWA	Pacific Watershed Associates
SRT	Signatory Review Team
THPs	Timber Harvest Plans
TMDL	Total Maximum Daily Load
UG	Unconsolidated Geology
UG0	Unconsolidated Geology, 0 to 1.5 percent gradient
UG1.5	Unconsolidated Geology, 1.5 to 3 percent gradient

ACRONYMS AND ABBREVIATIONS (Continued)

UG3	Unconsolidated Geology, 3 to 6.5 percent gradient
UG6.5	Unconsolidated Geology, 6.5 to 20 percent gradient
UG20	Unconsolidated Geology, greater than 20 percent gradient
USCS	Unified Soil Classification System
USGS	United States Geological Survey
WAU	Watershed Analysis Unit

ELK RIVER/SALMON CREEK WATERSHED ANALYSIS
SCOTIA, CALIFORNIA

INTRODUCTION

The Pacific Lumber Company (PALCO) initiated watershed analyses on the Elk River, Salmon Creek, and Fields Landing Watershed Analysis Units (WAUs) in Humboldt County, California (Figure 1), following the requirements in its Habitat Conservation Plan (HCP; PALCO 1999a). We combined these three WAUs into one large study area we refer to collectively as the ERSC to expedite the watershed analysis process on PALCO ownership blocks in these adjacent WAUs. This report incorporates water quality information within the Fish Habitat (Appendix F) and Amphibian and Reptile Habitat (Appendix G) modules.

WATERSHED OVERVIEW

Watershed Characteristics

Geographic Setting and Study Area Definition

The Elk River flows eastward along the west side of the northern California Coast Range into Humboldt Bay south of Eureka (Figures 1 and 5). The Elk River drainage has a basin area of approximately 33,700 acres, 22,200 acres of which are owned by PALCO (Map 1, Table 1). The Headwaters Reserve is an approximately 7,500-acre area (PALCO 1999a), mostly in the Elk River Basin, in the ERSC that was previously owned by PALCO but is now owned by the United States and is managed by the US Bureau of Land Management (BLM). The main Elk River study area includes the PALCO-owned land in the watershed as well as tributaries that are hydrologically connected with PALCO property. The Elk River Basin is bordered in its upper portion by the Freshwater Creek Basin to the north, with which it shares many common characteristics and similar geology (See PALCO 2001a). The King Salmon and sewage treatment plant peninsulas are excluded from the watershed analysis area (PALCO 2002b).

The Salmon Creek drainage is adjacent to the southern ridge of the Elk River drainage and is bounded on the south by the Eel Delta WAU (PALCO 2002a). The Salmon Creek WAU has a basin area of approximately 13,000 acres, of which PALCO owns 620 acres. Most of the PALCO ownership is located at the head of Little Salmon Creek. Two small parcels (approximately 63 acres) are contiguous with the Elk River ownership along the north ridge of the Salmon

Creek Watershed, and 25 acres are contiguous with the Eel Delta ownership along the south ridge.

The Fields Landing WAU is a small 3,765-acre area draining directly into Humboldt Bay between the Elk River and Salmon Creek (ERSC) WAUs. PALCO owns 71 acres of land in the Fields Landing WAU, which lie along the eastern edge, contiguous with the Elk River ownership block. There is about 0.3 mile of delineated Class II and III stream channel on the PALCO ownership. Because of the extremely small PALCO ownership area, its location in a narrow strip along the ridge top, and the general lack of stream channels on it, analyses in this report will usually incorporate the PALCO-owned land in the Fields Landing WAU with the Elk River analyses.

Topography

The Elk River and Salmon Creek Basins drain to the northwest and have well developed alluvial floodplain valleys that extend from Humboldt Bay several miles upstream. These streams drain low (at elevations of about 2,000 feet) hills in the upper parts of the basins and lower (800-foot elevation) ridges on their northern and southern margins.

The Elk River meanders across a well defined floodplain in the lower half of the basin. Tributaries to the Elk River are deeply incised into the landscape with low-gradient mainstem channels that typically transition sharply to moderately steep headwater tributaries (see Map A-5). The PALCO ownership is limited to upland areas of this WAU. The Elk River WAU has approximately 438 miles of delineated stream channels (Table 2); 330 miles (77 percent) of the stream network is on PALCO land. The Class I and II stream density on PALCO land, measured from the more detailed PALCO Hydro layer, is 3.4 miles/square mile.

The Fields Landing WAU contains several small streams, including Willow Brook, that drain the southwest side of Humboldt Hill and some wetland regime channels that drain the Salmon Creek delta. The streams in the Fields Landing WAU drain directly to Humboldt Bay. The land area is approximately evenly divided between the steep area draining the Humboldt Hill terrace and the flat delta lands between Humboldt Hill, Salmon Creek, and the bay. There are approximately 15 miles of delineated stream channels in the Fields Landing WAU. Less than 0.6 mile (3 percent) of the stream network is on PALCO land.

Little Salmon Creek drains into Salmon Creek, which flows into the southern end of Humboldt Bay. Little Salmon Creek flows through a low-gradient, moderately broad valley for the first 3 miles above its confluence with the mainstem.

Upstream, hills pinch the channel and form a narrow valley with moderately steep slopes on either side. The PALCO ownership is located in the middle to upper portion of Little Salmon Creek and spans the transition from low-gradient Class I channel to the moderately steep Class II channel reach. There are approximately 109 miles of delineated stream channels in the Salmon Creek WAU. There are a total of 9.4 stream miles (9 percent of the Salmon Creek stream network) on the 1 square mile of PALCO land; 4 miles are Class I and Class II.

Geology

The regional geology of the coastal area in Northern California is shaped and influenced by a relatively active tectonic regime. Three plates join at the Mendocino Triple Junction offshore to the southwest of Humboldt Bay, and the coastal area is subject to combinations of transverse-right lateral motion along one plate boundary and subduction/uplift acting in regional compression to the northeast along the other boundary. Relatively high rates of uplift on the order of 0.24 to 0.40 inch per year (Carver and Burke 1992) have resulted in relatively extensive folding, faulting, and associated seismic activity. This activity has pushed the geologic units up at relatively high angles and, therefore, induces dip angles and dip directions that shape the generally northeast- and southwest-facing slopes of the ERSC.

The geology of the PALCO ownership in the Elk River and Salmon Creek WAUs is mostly comprised of rock units from the Quaternary/Tertiary Wildcat Group (QTw) (Map 2; McLaughlin et al. 2000). The Wildcat Group consists of poorly compacted sandstones, siltstones, and mudstones that are highly susceptible to erosion where exposed. Due to the tendency of these rocks to break down quickly to fine materials, we have classified the Wildcat Group as an "unconsolidated geology" (UG) for the purposes of watershed analysis. Stream channels draining areas underlain by Wildcat geology are often dominated by silts and sands, and can have a relatively high potential for suspended sediment loads. Wildcat dominates the north side of Little Salmon Creek; all but the lower 3 or 4 miles of Salmon Creek; Clapp, Railroad, and Tom Gulches; and most of the Elk River Basin above Tom Gulch to the contact with the Franciscan Complex to the east.

Rock units of the Late Cretaceous Yager terrane (y1) appear in the upper watershed and in valleys where the channels have cut down through the rock units of the Wildcat to expose the underlying Yager (upper portions of Salmon Creek, South Fork Elk River, North Fork Elk River, the lower portions of the North and South Branches of the North Fork Elk River). The Yager terrane consists of dark gray indurated (i.e., well consolidated) mudstones, shales, graywackes, siltstones, and conglomerates, with interbedded limey siltstones. Rocks from the Yager terrane are much more resistant to weathering than are the Wildcat and generate larger clasts of gravel- and cobble-sized materials. For the purposes of watershed analysis, we have classified the Yager terrane as a "consolidated geology" (CG).

The easternmost portion of the Elk River Basin contains the Late Jurassic to Late Cretaceous Franciscan Complex, Central Belt (mélange) rock units (cm2), which consist of metasandstone and metaargillite. The relatively indurated nature of these rocks contributes to a lower erosion potential and competence of the rock clasts derived from them compared to that of the other rock units in the watershed. Therefore, we have classified this as CG.

The lower elevations of the watershed are typically mantled with relatively thick, undifferentiated, Pleistocene/Holocene (Quaternary) river terrace (Qt) deposits comprised of poorly indurated, inter-fingering lenses of gravel, sand, silt, and clay. These deposits are frequently exposed along the margins of the Elk River and its tributaries (McLaughlin et al. 2000). The terrace deposits overlie a sandstone subunit (Hookton Formation) of the Wildcat that has a relatively high susceptibility to surface erosion and landsliding. The Hookton and terrace deposits are classified as UG for watershed analysis.

The coastal zones, deltas, and floodplain areas of the three WAUs contain Quaternary alluvial deposits (Qal). The watershed areas proportioned by geologic units are provided in Table 3.

Seismic Regime

The North Coast of California lies within a seismically active region of North America (HEEC 1999) and the seismic hazard for Humboldt County is considered high (OES 1975). The shaking (cyclic loading) that occurs during earthquakes has the potential to initiate or accelerate landsliding. Water pressure in the soil can increase significantly under cyclic loading such as that induced during an earthquake. These pressure increases can, depending on many physical parameters, provide a potential mechanism for loss of shear strength in earth materials leading to landsliding. Several seismic events and resulting effects are well documented in the region (Youd and Hoose 1978, Kilbourne and Saucedo 1981, Rust 1984, Dengler et al. 1992, Dunklin 1992, McPherson and Dengler 1992, and Dengler 1997). It has been observed locally (McPherson and Dengler 1992) that stream flow and turbidity increase soon after earthquake-induced liquefaction of stream sediments in the region. It has also been noted (McPherson and Dengler 1992) that landslides are a subsequent source of sediment as observed after the Honeydew Earthquake in 1991. Numerous authors document earthquake frequencies and magnitudes (Dengler et al. 1992, and Dengler 1997). Large earthquakes have likely influenced conditions in the ERSC. A few examples of such earthquakes include the Trinidad (1980), Cape Mendocino (1992), and Eureka (1994) earthquakes. It is unclear how these events may have had an impact in the ERSC Watersheds. Engineers and geologists that analyze potential seismic hazards typically use either deterministic or empirical methods to investigate hazards from future surface rupture (Abramson et al. 1996, and Hull and Shuri 2002).

Faults in and near the ERSC Watersheds include the Freshwater Fault, the Mad River Fault Zone, and the Little Salmon Fault. The Freshwater Fault is mapped within the watershed along the eastern boundary and exhibits no known evidence of activity since the late Quaternary (Falls 1999). Located north of the Elk River Watershed, the active Mad River Fault Zone is comprised of five principal thrust faults (Trinidad, Blue Lake, McKinleyville, Mad River, and Fickle Hill faults) and numerous minor thrust faults (Kelsey and Carver 1988). Kelsey and Carver (1988) propose a net slip rate along the Mad River Fault Zone of at least 0.25 inch/year (measured horizontally) since the late Pleistocene. The Little Salmon Fault is located within the watershed along the southwest boundary where traces are mapped near the College of the Redwoods, in Holocene terrace deposits, and east of Tompkins Hill. The Little Salmon Fault has produced a minimum of three seismic events within the last 2,000 years (Dengler et. al. 1992). The Little Salmon Fault is an active constituent of the Goose Lake Fault Zone. Measurements of trench observations reported in Wills (1990) indicate the main strand accumulated slip is about 0.22 inch/year.

Soil

Soils in the ERSC are roughly correlated with underlying geology. Two different types of soil data are available for the watershed. The first type of soil data was developed by the USDA Natural Resource Conservation Service (NRCS; formerly the US Soil Conservation Service) as part of county-wide soil mapping and study. This effort produced a soil map with units that are based on agricultural needs. The second type of soil data was collected by Hart Crowser as part of a study of engineering soil index properties and strength parameters. These data include information on soil texture, soil depth, unit weight, gradation, and plasticity, and are useful for slope stability assessments. These two sources of soil information and map units do not always directly correlate with each other or mapped geologic units. The NRCS classification is typically used as an index for the work done in estimating surface erosion (Appendix B). The engineering characteristics are typically used with empirical correlations for estimates of soil strength parameters important in slope stability analyses (Appendix A).

NRCS Soil Mapping. Soil mapped by the NRCS indicates Larabee soil developed in areas of Wildcat Formation and Hugo and small areas of other soil on Franciscan rocks (Map 3). Bottomland and Farmland soil developed on the Quaternary alluvium in the lower mainstem. The Surface Erosion Assessment (Appendix B) provides detailed descriptions of these soil map units in terms of potential erodibility or vulnerability to surface erosion based on the NRCS soil mapping data.

Soil Engineering Data

Soil samples that overlie the different geologic units in the watershed were taken as part of a previous study by Hart Crowser. Soil engineering characteristics are described in relation to the soil developed on different geologic units (e.g., Wildcat, Franciscan, Hookton). These data and the relationship to mass wasting are discussed below and in Appendix A.

Soil of colluvial and residual origin cover the majority of the landscape in the watershed, except where bedrock is exposed. Residual soil forms from the mechanical breakdown and chemical weathering of the underlying rock units and geologic or organic materials. Colluvium is defined as weathered material that has moved downslope by gravity-induced movement and accumulated on the hillside. Most of the shallow landslide mechanisms for failure rely in part on the strength parameters associated with these soil units. These deposits are generally relatively thin on ridgetops and steep upper slopes and increase in thickness down hillsides toward the bottom of slopes where they can form thick (10 or more feet) accumulations. We have observed that colluvial deposits in the ERSC are generally about 2 feet in depth. In general, soil associated with the Hookton, and to a lesser degree the Wildcat formations, is correlated with the highest rates of shallow landslides.

Soil Physical Parameters. Many of the soil types present in the ERSC have previously been investigated and described on other portions of PALCO's ownership. For example, a summary of typical soil physical parameters for the watershed is presented in the LEED Watershed Analysis (PALCO 2002a). Our analyses indicate that soil throughout the ERSC are mostly non-plastic silt, clay, sand, and gravel (Unified Soil Classification System [USCS]). Soil depths were, on average, slightly less than about 8 feet. Soil associated with the Wildcat Group generally is consistent with material having moderate to high moist unit weights, moderate friction angles, and moderate cohesion. Clayey soil units associated with the Franciscan are consistent with soil having relatively low unit weights, low friction angles, and relatively high cohesion.

Consistency and Particle Size. Average grain size data from the soil samples were used to divide the calculated erosion rates from all erosion processes into grain size components by the soil that covers the geologic units (Table 4). We used American Standard for Testing Materials (ASTM) grain size classes when analyzing soil samples for slope stability analyses. They are approximately consistent with those relevant to fish and amphibian habitat conditions, with the exception that gravel content is broken out at 4.75 mm rather than at 8 mm. Therefore, when reporting on fines in relation to biological habitat, we are referring to all sediment less than 4.75 mm.

The soil consistency influences the erodibility of the soil (how easily the soil particles are eroded). Large gravel and cobble-sized particles are more difficult to erode via surface erosion processes and are left behind as a protective lag deposit on eroding surfaces. Sand and silt-sized particles are very easy to erode; soils with a high sand/silt fraction are generally very erodible. Clay-sized particles, while very small and easily carried once in suspension, are actually more difficult to erode because clay soils have stronger inter-particle attraction.

The consistency of the soil also determines their effect on the stream channels and fish habitat once they are delivered to the stream channels. The particle size classes that affect biota differ from those that affect the structural properties. The term “fines” in the study of fish and amphibian habitat generally refers to material less than 8 mm. Very fine sediments (silt and clay sizes less than 0.075 mm) are entrained by even fairly low flows and raise turbidity, but are not largely responsible for gravel infilling (PALCO 2000). Sand-sized particles (0.075 to 2 mm) are the ones most responsible for the filling of gravel interstitial spaces (infilling) that can prevent flow of water and oxygen to fish eggs and fry, thereby smothering them. Large sand and small gravel, can also contribute to redd (fish nest) and large substrate burial, although they are less likely than smaller sands to cause egg and alevin suffocation. Such burial of larger gravel and cobbles reduces the availability of spawning-sized gravels and can prevent juvenile fish from using the interstitial spaces for refuge.

Investigation of Subsurface Soil Conditions. Specific soil descriptions for engineering applications as previously described are located in Appendix A of the LEED Watershed Analysis (PALCO 2002a). The locations of our subsurface soil sample sites are shown on Map 9. We assume for this analysis that the soil sampled at a site is directly related to the geologic units (parent material) from which they are derived. This would not necessarily be a correct assumption where colluvium has developed from geologic units higher on the slope.

Climate and Hydrology

Temperature and Precipitation Patterns

The ERSC is dominated by a maritime climate with moderate temperatures and high humidity prevailing the entire year. The rainy season begins in October and continues through April, accounting for about 90 percent of the annual precipitation. The dry season runs from May through September and is marked by considerable fog or low cloudiness.

Average annual temperatures at the Eureka weather station (EKA) hover around the low 50 degrees Fahrenheit (F) with cooler temperatures occurring from November through April, and the warmest occurring from June through September (Figure 2). Minimum annual temperatures at Eureka are typically in the low 30s (F) and occur during December and January. Annual maxima are typically in the high 70s (F) and occur in August or September. Winter temperatures at higher elevations in the hills would tend to be somewhat cooler than those at Eureka, and summer temperatures tend to be significantly warmer.

The annual precipitation at the EKA from 1948 to 2002 ranged between 16 and 67 inches with a long-term annual average of 38 inches (Figure 6). Precipitation varies with distance from the ocean, elevation, slope steepness, and orientation. In the ERSC, the average annual precipitation varies from a high of 70 inches in the high elevations in the northeast and southeast corners to a low of 40 inches at the river mouths (Map 4). Monthly average precipitation at Eureka ranges from 0.1 inch in July to 6.9 inches in January. A precipitation gauge at Kneeland (2,400 feet elevation; data from 1954 to present) in the Freshwater drainage north of Elk River and another at Bridgeville (2,100 feet elevation; 1954 to present) provide precipitation information more representative of the higher headwater elevations of the ERSC. The relationships among Kneeland, Bridgeville, and Eureka precipitation are evident on Figure 3. Average snowfall in Eureka is negligible (Figure 4), but snow does typically fall in Bridgeville between November and April (PALCO 2001a). Actual precipitation and snowfall in the ERSC should range between those measured at Eureka and Bridgeville. Although the ridges of the ERSC likely receive occasional snow, the elevation overall is so low that the snow would never be deep or widespread enough for rain-on-snow events to be significant in these watersheds.

Another weather station located at Fernbridge (Figure 5; Table 5) is likely to be more representative of conditions in the Salmon Creek and Fields Landing drainages than the Eureka gauge. However, no data from that station could be located.

Major Storm Events and Flood History

The general storm patterns and history in Humboldt County have been described in the Freshwater Creek, Van Duzen River, and LEED Watershed Analyses (PALCO 2001a, 2001b, and 2002a, respectively). Harden (1995), Coghlan (1984), and Helley and LaMarche (1973) describe flood histories applicable to the Humboldt County area. In the 20th century, flood events recorded in 1907, 1915, 1927, and 1937 were locally significant (Coghlan 1984); however, flood events of 1953, 1955, 1964, 1972, 1975, 1986, and 1996-1997 appear to have been higher and produced greater watershed response than those of the first half of the century. A number of large flood-producing storms occurred in the late 19th century that may have been comparable to, or larger than those recorded from 1953 to 1975. These include the floods of 1861-1862, 1867, 1879, 1881, and 1888. North of the Eel River, the 1890 flood is thought to have exceeded the magnitude of the 1964 flood (PWA 1999).

At the EKA, the years 1995 through 1998 were consistently some of the wettest years in the previous 50-year record and even some of the wettest in the entire 111-year precipitation record for Eureka (PALCO 1999b). This wet period was preceded by a very dry period (Figure 6). Recent flooding occurred in the Elk River drainage in January and March 1974; March 1975; December 1982; January and December 1983; December 1996; January 1997; and November 1998 (PALCO 1999b). Localized flooding, particularly near the junction of the North and South Forks, is reported by residents to occur yearly since about 1995. PALCO's 1999 report on the Analysis of Flooding in Elk River and Freshwater Creek Watersheds (PALCO 1999b) contains more extensive information on the storm history of the Elk River.

Discharge data for the Elk River are limited (Figure 7). The USGS monitored a gauge near the confluence of the North and South Forks from 1959 to 1967. Bill Conroy installed a gauge near the old USGS gauge location and recorded data from 1997 through 1999 as part of his master's thesis project. Conroy (1999), PALCO (1999b), and Reid (2000) discuss the relationships among data from these two monitoring periods. No hydrographs for Salmon Creek could be located, although a study gauge was recently installed near the mouth at the wildlife refuge (Personal communication with Mike Love, private consultant, Eureka, CA; October 2002).

Daily rainfall at the EKA and daily discharge in the Elk River are displayed on Figure 7. These records show that the highest precipitation spikes do not necessarily translate into the highest flood peaks. Rather, the highest flood peaks occur during periods of steady high rainfall (note especially water years 1958 and 1998). This suggests that antecedent moisture conditions heavily influence river discharge in the Elk River drainage. Another feature of the hyetograph is that large storms (3 inches per day) occurred frequently during the periods 1950-1959, 1981-1984, and 1995-1999, and that the periods of 1977-1980 and 1985-1994 had no storms that dropped more than 2 inches of rain in one day. The fact that the famous 1964 flood (a rain-on-snow event) was not the largest flood of that period in the Elk River is consistent with the assumption that rain-on-snow events are not driving factors in the ERSC. PALCO (1999b) contains an in-depth discussion of the relationship between rainfall patterns and flooding in Elk River.

Dams and Flow Diversions

A mill pond existed on the South Fork Elk River at the old mill town of Falk from probably 1884, when the mill was built, until the dam was removed with the aid of explosives in 1952 (Decker 1971 in Milliman 1995). Conroy (1999) reports anecdotal evidence that other splash dams existed throughout the Elk River Basin but does not note specific locations.

ERSC Forest Ecology

The ERSC is part of the Redwood Forest ecosystem, and the stands are dominated by redwood from the mainstem rivers to the ridges due to the low elevation and proximity to the coast. (Please refer to the LEED Watershed Analysis [PALCO 2002a] for a description of the coastal Redwood Forest ecosystem.) Current vegetative conditions in the ERSC are primarily second growth redwood forests of varying ages (Map 5). In general, the stands to the north of the North Fork Elk River are maturing redwood forest (approximately 50 to 60 years in age). The eastern portions of the watershed (Upper North Fork Elk River) were harvested more recently and are vegetated with regenerating plantations of young redwood forest with patches of alder vegetation. The Headwaters Reserve, located in the Upper South Fork Elk River drainage basin, is a combination of late-seral and mid-mature redwood forest. Forests within the PALCO-owned lands in the South Fork Elk are younger stands of primarily 30 to

60 years in age. Hardwood-dominated stands are mainly present in the riparian areas along the lower portions of the South Fork and the North Fork Elk River.

Aquatic Resources

The ERSC has a diverse aquatic community that includes the HCP-designated aquatic species of concern (PALCO 2000). Coho, chinook, steelhead, and cutthroat trout use the mainstem of the Elk River as well as many of its sub-basins for adult and juvenile migration, rearing, and spawning (Map F-1). Coho generally spawn during October to mid-February, peaking in December (Fukushima and Lesh 1998). The fall chinook run generally occurs from October through late November, peaking in early November (Fukushima and Lesh 1998), and the winter-run steelhead trout (anadromous rainbow trout) migration usually occurs from December through May, peaking in late January and February (Fukushima and Lesh 1998). Although little is known about the distribution of resident and anadromous coastal cutthroat trout, they are likely to inhabit many of the Class I streams within the ERSC study area. Resident coastal cutthroat trout are most likely to occur in the Class I streams upstream of anadromous fish barriers.

No salmonids have been identified in Little Salmon Creek (see Appendix F) within the PALCO ownership. There are no Class I (fish-bearing) streams on the PALCO ownership in the Fields Landing WAU.

Torrent salamanders and immature tailed frogs have been observed in the steep, rocky stream reaches in many headwater channels of the ERSC (Map G-1a). Adult tailed frogs have also been observed frequently in lower gradient, often fish-bearing, streams. Red- and yellow-legged frogs are present in low-gradient waterbodies throughout the ERSC (Map G-1b). Northwestern pond turtles are only believed to use the floodplain areas of the Elk River and may occur around the mouths of some of the tributary streams where they flow across the Elk River floodplain (Map G-1b).

Land Use and Forest Management

Land Use

Land use within the ERSC is dominated by timber management (Map 5). The remainder of the watershed is occupied by agricultural interests, primarily dairy and feeder cattle, with a small area of residential/urban property. Most of the forestry occurs in the uplands in the eastern portions of the ERSC WAUs. Nearly 100 percent of the PALCO-owned land in the three WAUs is forest land (Table

6). Agriculture lands are confined to the floodplain areas adjacent to the Elk River and Salmon Creek. Most of the urban lands occur in association with the Town of Fields Landing. The nearby King Salmon industrial/residential area is outside of the WAU boundaries.

The Elk River WAU contains the old unincorporated town area of Elk River, the northern portion of the Humboldt Hill settlement, and most of the Headwaters Reserve. The abandoned mill site of Falk is in the South Fork Elk River Watershed, on land now included in the Headwaters Reserve. Another abandoned and dismantled mill site, "Mill C," lies adjacent to the North Fork Elk River near the confluence of the South Branch. An archery club range and a church camp lie along the main North Fork Elk River Road at the lower end of PALCO's property. A Girl Scout camp and a Boy Scout camp are situated adjacent to the confluence of Browns Gulch with the North Fork Elk River. Cattle grazing is not a significant land use in the forestry portions of the Elk River WAU, but is common in other portions of the basin. A trailhead parking lot and walking trail along the old road adjacent to the South Fork Elk River see heavy pedestrian, but no bicycle, horse, or vehicular use.

The Salmon Creek WAU contains the farming settlements of Hookton, Indianola, Beatrice, and Table Bluff and part of the Headwaters Reserve. A system of natural gas wells and pipelines is distributed throughout the timber area of Salmon Creek on PALCO and non-PALCO property. The Fields Landing WAU contains the southern portion of the Humboldt Hill settlement and the Town of Fields Landing.

Forest Management History

Pacific Watershed Associates (PWA) has done an extensive historical analysis of logging and road construction in the North Fork Elk River Basin (PWA 1998), based primarily on harvest records and aerial photo investigations. We combined the PWA work with results from work done by Conroy (1999) and ourselves to generate the following history of forest management in the ERSC. Table 8 lists the aerial photos available for the ERSC by photo year.

Spatial Distribution of Initial Land Management

Elk River was settled in the late 1800s. Soon afterward, the lowlands were cleared of timber for pastures (Conroy 1999). Logging in the Elk River Watershed began in the 1880s. The first major mill was established during this period at Falk in 1884.

The history of initial logging on lands currently owned by PALCO is depicted on Map 6. Logging initially took place along the main stream channels in the lower North Fork Watershed (PWA 1998). In the 1920s, steam donkey and railroad logging in the adjacent Freshwater Creek Watershed spilled over into the northern ridge tops and slopes of the North Fork Elk River (PWA 1998). Logging spread from these areas to the lower watershed during the 1930s with the onset of railroad logging. In the 1930s and early 1940s, railroad logging and early tractor logging spread south along the main stem of the North Fork as well as along the entire North Branch of the North Fork Elk River (PWA 1998). Very little logging occurred during the 1950s. The 1960s saw the first entries into the high reaches of the North Fork, and the surrounding ridgetops were not harvested until the 1970s. A large block of the South Branch of the North Fork and Corrigan Creek was also first logged in the 1970s. The initial harvesting of timber in the headwaters south of the upper North Fork and the South Fork occurred during the 1990s. Subsequent harvests of second- and third-growth timber have occurred throughout the North Fork Elk River Basin and continue to the present (Map 7). For example, extensive logging has occurred since the late 1980s.

The first-cycle harvest history along the South Fork Elk River is not known, because we have no records. However, the overstory canopy age (Map 7) provides information about the overstory stand initiation date in the South Fork Basin. It would appear that there was a significant round of harvesting along the main stem of the South Fork during the 1950s and 1960s. Since the mill at Falk was established in the late 1800s, and they probably harvested first along the main stem river to float the logs to the mill (see photos at Headwaters Trail trailhead), we assume that the 1950s and 1960s harvesting was the second round of harvesting. Smaller units in this basin were harvested in the 1940s, 1970s, and 1980s.

Most of the first round of harvesting on PALCO land in Little Salmon Creek occurred around the turn of the twentieth century. One unit in the northwest corner of the ownership block was not cut until the 1950s (Map 6). What is probably the second cycle of harvesting occurred in the 1960s in the southern half of the block. Judging from the initiation year of the overstory trees in this block (Map 7), the early harvests tended to be partial or thinning cuts rather than clearcuts.

Timber Harvest, Yarding, and Hauling Methods and Locations

The density and placement of roads in the ERSC reflect the history and sequence of logging activities in different parts of the basin and the types of yarding and transportation systems that were constructed to service those activities (Table 9). PWA's North Fork Elk River Sediment Source Investigation (PWA 1998) provides an extensive description of the road-building history developed from aerial photo analyses. Road building in the South Fork Elk River and Salmon Creek Basins is assumed to be similar to that in the North Fork, with the possible exception of the early ridgetop railroad grade construction that came from harvesting in the adjacent Freshwater Basin.

Early Logging. Prior to the 1940s, logging was done with steam-driven cable and winch systems ("steam donkeys") and/or oxen (PWA 1998). Harvesting with this method typically removed all of what were considered at that time merchantable trees, leaving only cull and broken trees. During this period, stream channels were themselves often the primary transportation corridor. Steam donkeys worked their way up smaller streambeds by attaching the yarding cable to a standing tree upstream and hauling in the line, dragging the steam donkey apparatus up the channel bed. They then proceeded to haul cut timber down hillslopes to the valley bottom where the logs could be loaded or hauled with oxen to a rail line or to a larger river channel for floating. Alternatively, oxen and railroad haul roads were built straight up the tributary channels by covering the streams with a "road bed" of logs laid across the channel, referred to as corduroying. Corduroy roads were built both for oxen teams and for railroads. Railroad beds tend to use large logs spaced apart and placed high on the confined valley walls, to support the great weight of the machinery operating on them and because the rails spanned the gaps. Oxen team roads used smaller logs very densely packed and right down on the streambed grade (Robert Darby, PALCO, personal communication, October 19, 2003). Many channels, especially the smaller ones that were not subject to stream clearing in the 1980s, still have remnants of these log roads.

Once yarded down from the hillslopes and out of tributary valleys, logs were transported to mills by rivers and railroads. The first roads in the ERSC were the railroads built beginning in the late 1800s up the North Fork Elk River approximately as far as Bridge Creek. Additional ridge-top railroads came over the northern watershed boundary from the Freshwater Creek Basin in the 1920s. Railroads extended up into Doe, McWhinney, and Bridge Creeks and Browns Gulch in the 1930s. Interestingly, the early railroads often had lower impact on streams at crossings than later truck roads, because they tended to use trestles over the streams rather than fill construction in them as later roads did. In the 1930s and 40s, railroads, truck haul roads, and tractor skid trails associated with early tractor yarding spread to the entire North Branch Elk River and farther up the mainstem North Fork (PWA 1998).

Splash-damming and general river-driving of logs were also prevalent methods of log transport and were sometimes used in conjunction with railroad hauling. Splash-damming involves construction of a dam with a releasable gate. The river and logs are ponded behind the dam until there is enough volume to release the gate and "splash" the log mass in a flood down the channel. During this process, the channel experienced intense scour and degradation from the flow and logs, as well as the channel clearing that occurred prior to the splash to facilitate conveyance of the logs. Splash-damming is anecdotally reported to have occurred in the ERSC although no information on specific dam sites is available (Conroy 1999). This could only have occurred on the larger channels in the ERSC due to the large size of redwood timber. Log driving did not necessarily require splash-damming, but the channels would still have been cleared of obstructions and experienced scour, bank erosion, and subsequent channelization from the logs themselves.

Modern Logging. Between 1940 and 1987, the watershed was logged primarily using tractors on a dense network of skid trails, with hauling changing to trucks. Prior to 1974, timber harvesting typically removed 70 percent of the merchantable trees (following the ad velorum taxation rules) and did not typically leave riparian buffers. Since 1974, silvicultural methods followed the California Forest Practice Rules, which were adopted with the Z'berg-Nejedley Forest Practices Act (Conroy 1999).

Roads constructed from the 1940s through the late 1980s were truck roads built to service primarily tractor yarding systems. By 1954, aerial photo analysis shows there were 29 miles of logging (truck) roads in the North Fork Elk River Basin (PWA 1998). Between 1954 and 1966, 22 miles of truck haul roads were constructed, along with additional temporary tractor skid trails. Most of this occurred in the Middle and Upper North Fork Elk River Watersheds and in the South Branch North Fork Watershed. Another 25 road miles were built in the 1966 to 1974 period, concentrated in the Lake Creek and South Branch North Fork Watersheds. Between 1974 and 1987, only 9 new miles of road were constructed to support the similarly reduced logging of that period.

The earliest truck roads in the ERSC followed railroad grades and were often adjacent to major streams ("stream-adjacent" roads) to take advantage of the gentle gradients. Some roads were also constructed on ridgetops (especially along the northern boundary from Freshwater Creek) and on mid-slope railroad grades. Stream-adjacent and mid-slope road systems have numerous stream crossings and opportunities for eroded sediment to be delivered to the streams. Clapp Gulch and Railroad Gulch and portions of the Upper North Fork and South Fork Basins provide good examples of this type of road layout, with corresponding high road densities. These two sub-basins have the highest road densities in the watershed, with 10 mi/mi^2 in the Clapp Gulch sub-basin and 8.8 mi/mi^2 in Railroad Gulch sub-basin. The channel infilling that began with corduroying for oxen and train tracks continued during the tractor logging era of the 1940s to 1970s. Many low-order stream channels were filled in with soil and organic debris to form tractor yarding corridors (PWA 1998).

Although large portions of PALCO's land in the Elk River Watershed were harvested in the late 1980s and 1990s (Maps 7 and 8), very little of this area was clearcut (PALCO 1999b, Figure 2). Partial cutting and thinning have been the dominant harvest methods in these areas, and more than 50 percent of the canopy cover typically remains after harvest. Because of this, reported canopy age is not always directly correlated with the harvest history (Maps 7 and 8). During this period, clearcut logging was done with modern partial- or full-suspension cable yarding systems, but thinning and other partial cuts still relied on tractor yarding (Figure B-5).

The 22 miles of roads built between 1987 and 1994 include many mid-slope roads in the northeastern and southeastern headwaters of the North Fork, but began to be dominated by the now prevalent ridgetop roads that service various modern suspension cable yarding systems. Ridgetop road systems dominate the sub-basins on the northern part of the watershed, including Dunlap, Bridge, and McWhinney sub-basins. Ridgetop road systems generally have few, if any, stream crossings and are much less likely to result in delivery of eroded sediment to streams. The 1994 to 1997 period saw 28 miles of new, primarily ridgetop, road construction (PWA 1998).

Recent Logging. No new logging plans were approved in Elk River from 1999 to 2002, resulting in little to no harvesting in the watershed over that period. Although annual harvest since 1999 has been low (Table 9), it has increasingly utilized clearcut harvest methods, often in areas that were previously thinned. Current timber harvesting is subject to new HCP interim rules, and future harvesting will be subject to watershed-specific prescriptions developed from this Watershed Analysis. Also during this period, helicopter yarding has become prevalent in this watershed (Figure B-5, Table 9).

The length of road constructed between 1997 and 2000 has not been calculated; this was prior to the tracking instituted with the HCP implementation. Little or no road building took place between 1999 and 2002. In addition, a policy of allowing no road traffic during wet conditions was implemented on PALCO lands after 1998 to reduce what was believed to be the greatest source of road sediment generation and delivery to streams. Although the actual wording of the HCP is slightly more liberal (PALCO 1999a), PALCO's actual implementation is such that when there is any significant rain, all traffic ceases except for light pickups used for monitoring and emergency repair work (Jeff Barrett, personal communication, January 2004). Road stormproofing, reconstruction, and upgrading have occurred on a significant portion of PALCO's roads in Elk River to reduce sediment inputs to streams and to support harvesting. Much of this work have involved improving roads to levels that exceed the current forest practice standards, as required by PALCO's agreed-upon HCP maintenance objectives.

Harvest and Road Construction Average Rates

Total harvest area and constructed road lengths were interpreted by PWA from aerial photographs and by Hart Crowser from recent PALCO harvest history data and are reported by photo period in Table 9. Harvest and road construction rates were calculated from data in Table 9. The rate of logging in North Fork Elk River was approximately 161 acres/year between 1934 and 1974 (PWA 1998). During this same period, approximately 2 mi/year of roads were constructed. Between 1974 and 1987, very little harvesting or road construction was conducted in the North Fork Elk River (67 acres/year and 0.6 mi/year, respectively). Between 1987 and 1994, 346 acres/year were harvested, with an average of 3 mi/year of road construction (PWA 1998). Between 1994 and 1997, most harvesting activities were in the North Fork Elk River where about 872 acres/year were harvested, and 8.7 mi/year of roads were built (PWA 1998). Approximately 1,200 acres were harvested in the entire ERSC in 1998 and 150 acres in 1999. Nearly all of these used thinning and other selective harvesting methods (Figure B-4). No Timber Harvest Plans (THPs) were approved, and little harvesting occurred in the Elk River Watershed between 1999 and 2002. Harvesting currently averages 800 acres per year in Elk River (Table 9).

Early harvest and road construction rates for the South Fork Elk River were unavailable, but were assumed similar to the rates in the North Fork Elk River (Conroy 1999). Table 9 shows harvested area for the photo periods between 1987 and 2000. Roads in the Little Salmon and Salmon Creek sub-basins include mid-slope and stream-adjacent roads. Little Salmon Creek has an overall road density of 7.6 mi/mi^2. Approximately 85 percent of these roads are surfaced with native soil materials. The total lengths of roads by surfacing category in the ERSC are provided in Table 7.

Other Stream Channel Disturbance

During the 1970s and 1980s, the Sierra Club, California Conservation Corps, and California Department of Fish and Game maintained a program of woody debris removal from streams (Conroy 1999). This program was intended to remove barriers to fish passage and to allow easier passage of floodwaters. Reacting to the general gain in knowledge about the functions served by wood in streams that was built up in the 1980s, the same groups that removed the large woody debris (LWD) began putting it back into the channels starting in 1987 (Conroy 1999).

Earthquakes in the vicinity have likely caused transient entrainment and movement of otherwise stable sediment deposits in and near streams over the years. Recent Humboldt County earthquakes of 1980, 1992, and 1994 caused significant damage effects in the surrounding area (Dengler 1997) and may have caused pulses in sediment movement in the ERSC.

ISSUES IDENTIFICATION

Issues of concern raised at the public issues identification meeting in April of 2002, and from participating agencies are presented in the Issues Matrix (Attachment 1). Questions and concerns raised during the public meeting held April 22, 2002, along with those received in writing were considered. After review, we categorized and prioritized the comments. The issues are categorized by corresponding module. The response code for Public Issues indicates categorization as a result of the sorting process (See key in Public Issues section of the Issues Matrix). We present the issues in three sections: Critical Questions/Issues, Site-Specific Issues, and Public Issues. In each section we list the issue, our quantitative efforts, the resource assessment task code(s), the module(s) and section(s) where the issue is addressed, and a brief response.

CUMULATIVE WATERSHED EFFECTS

Critical Questions

The Cumulative Watershed Effects (CWE) analysis addresses the following critical questions that were agreed-upon by the SRT on June 11, 2002.

	Question or Need	Where Addressed
Cumulative Watershed Effects		
Critical Questions		
1	How do inferred changes in peak discharge patterns in low-order channels, caused by timber harvest activities, affect aquatic resources?	CWE - Current Conditions, Stream Flow
2	What is the magnitude and distribution (spatial and temporal) of sediment delivery to streams from mass wasting, bank erosion, and other upland sediment sources?	Appendix B; CWE - Sediment Budget
3	What sediment sizes are delivered to the channel system from various input mechanisms?	Appendix B; CWE - Sediment Budget and Sub-basin Group Summaries
4	What percent over background are management-related sediment inputs in each sub-basin?	Appendix B; CWE - Sediment Budget
5	Where are existing and potential future sediment sources in each sub-basin? How could they affect existing and future stream and aquatic habitat conditions?	Appendix B; CWE Sediment Budget and Sub-basin Group Summaries
6	What are the key cause and effect mechanisms in a particular sub-basin and the watershed as a whole?	CWE Sub-basin Group Summaries
7	What is the estimated range of natural variability and relative condition for the aquatic resources [habitat]?	CWE Aquatic Resource Habitat Condition Summary
8	What and where are the past and present timber harvest and other land management activities and what are their impacts?	Watershed Overview – Forest Management History; CWE – Synthesis of Historic Effects and Synthesis of Current Conditions
9	How will the proposed prescriptions influence aquatic resources?	Attachment 3 – Prescription Justifications
10	What are the anticipated impacts from future activities when considered in conjunction with past and current impacts?	Attachment 3 – Prescription Justifications
11	What are the key data gaps and monitoring needs?	Main Report – Monitoring Recommendations

	Question or Need	Where Addressed
Cumulative Watershed Effects (cont'd)		
Informational Needs		
1	Synthesis of available trends monitoring data as well as any other applicable information and monitoring data.	Appendix F; CWE
2	Analysis of impacts on resources of concern, including aquatic-dependent species habitat and riparian stand conditions.	CWE, esp. Sub-basin Group Summaries
3	Assess the cumulative effects of past, present, and anticipated future mechanisms. Does not include impact mechanisms that are small and rare and in combination do not result in a significant impact.	CWE - Syntheses of Historical, Current, and Future Effects
4	Future activities should project at least 5 years in the future and describe the level of confidence in the information applied.	PALCO has been unable to provide information on future activities to assess. Prescriptions as written do not require projection of future conditions; rather, actual conditions are continuously evaluated on an annual basis
5	Do not impose a time limit on the duration of effects. Time series simulations should be run for a duration such that one of the following occurs: environmental effects return to pre-treatment levels, or cannot be distinguished from background levels, or until the threshold of reliable prediction is exceeded for the particular model.	Prescriptions as written do not require projection of future conditions; rather, actual conditions are continuously evaluated on an annual basis
6	Make monitoring recommendations based on uncertainty in results of watershed analysis.	CWE - Monitoring Recommendations

Synthesis of Historical Effects

Pre-1940s

- Stream-adjacent roads
  - Input fine sediment
  - Increase stream-side landslide potential
  - Old roads now form useful trails for recreational and research access

- Large clearcuts
  - Generate significant quantities of sediment with direct overland input to stream network due to lack of stream-side buffers
- No riparian buffering
- Steam donkey dragging up channels
  - Gouging of channels destroys redds, incises channels, disconnects streams from potential off-channel habitat, inputs fine sediment
- Use of large channels for log transport (channel clearing and reaming)
  - Large channels devoid of LWD reduces pool availability, feeding substrate, cover, other LWD benefits
  - Gouging of channels destroys redds, incises channels, disconnects streams from potential off-channel habitat, inputs fine sediment, and disrupts log jams and sediment storage structures.
- Use of tributary channels as haul roads
  - Input of large quantities of sediment and LWD
  - Shade protects from temperature increases
  - Covering reduces salmonid and vertebrate prey production
  - Probably created many warm muddy pools for red-legged frogs
- Flow-concentrating effect of downslope yarding to stream channels
  - Fine sediment input to channel network
  - Risk of stream-side landsliding at concentration points
- Mill pond and dam at Falk
  - Upstream fish migration barrier
  - Prevents access to miles of premier spawning and rearing habitat

  - Reduces importance of other effects, because salmon can not get there anyway

- Clearing of main stream channels to facilitate transport of logs

- Few mid-slope roads + use of trestles

  - Prevents some stream damage

  - Avoids road-related mass wasting issues

  - Avoids fish passage issues

  - Trestles provide long-term source of (chemically contaminated) LWD

Net Effects on Aquatic Resources

- Mainstem habitat

  - Large quantities of fine sediment, high turbidity

  - Low LWD for cover, refuge, channel features, and prey substrate in main channel

  - Channel incision

  - Deposition of fine sediment in low-gradient reaches

  - Temperature increases from canopy removal

  - Low habitat diversity in mainstems and little access to off-channel habitats and refugia

  - Grain size coarsening of streambed substrate in moderate and higher gradient areas, but accompanied by high substrate embeddedness

  - Lack of access to smaller tributary channels due to corduroy covering

  - Limited nutrient cycling due to removal of riparian vegetation along long reaches of channel

- Tributary habitat
  - Overabundance of LWD (channel burial) in some tributaries
  - Altered nutrient cycling due to removal of riparian vegetation along long reaches of channel
  - Temperature increases and channel erosion from removal of riparian vegetation
  - Sediment accumulation
- Many of the impacts occurred in the lower portions of the watershed, which overlap the most important fish production and rearing habitat
- Habitats important to salmonids, tailed frogs, and torrent salamanders were generally heavily impacted. Red-legged frogs likely fared well and may have thrived in sunny, warm, muddy puddles and ponds that were created along valley bottom roads.

1940s to Late 1990s

- Extensive road network
- Many mid-slope roads
- Stream crossings become fills with extensive sediment inputs
- Tractoring up low-order channels through 1970s
- Stream cleaning (of LWD) in 1970s and 80s.
  - Do not appear to have cleaned smaller tributaries that were buried
- Change to ridgetop roads and suspension cable yarding in late 1990s
- 1990s predominantly partial harvesting rather than clearcuts
- Essentially no stream buffers until after 1974 when buffers would have been required on the lower mainstems

- Institution of stream-side buffers on fish-bearing streams and most other perennial streams in later years

Net Effects on Aquatic Resources

- Probably increases in landslide rates due to logging on steeper ground, so upper small tributaries affected as well as additional sediment input to lower tributaries and mainstem.
- Additional fine sediment produced by roads and tractor logging causing surface erosion, bank disturbances, and instream impacts.
- More transport of fines out of tributaries and mainstem due to removal of LWD, but added channel incision with floodplains increasingly disconnected.
- Continued temperature problems until time when buffers added.
- Loss of gravel storage structures (LWD) may have reduced spawning areas in 3.0 CGUs; however, increased mass wasting may have increased gravel supply in some areas. Gravel is a limiting factor in this basin.

Post-HCP

- No traffic on roads connected hydrologically to the stream channel network under wet weather conditions
- Enlarged and extended stream-side buffers
- Helicopter yarding
- Extensive road maintenance program using modern sediment-reduction methods
- Three-year moratorium on timber harvest plan approvals

Net Effects on Aquatic Resources

- Reduced both fine and coarse sediment input to streams.
- Increased shading and LWD recruitment potential.

- Response should be declining fines in gravel zones of MSG, CG1.5, and CG3.0 channels. Fines in the beds of UG channels (especially the Gulches) are going to remain unchanged due to natural geology.

- Increased LWD potential will recover first in smaller streams (due to smaller size requirement) and in the middle reaches of the North Fork Elk and the North Branch Elk where riparian stands are reaching large size and stem exclusion stage. LWD potential recovers more slowly on large streams.

- Bank erosion is the dominant LWD input processes in larger streams and in floodplain areas. However, recovery of large trees in Lower North Fork floodplain may or may not occur in some locations as a result of natural flood disturbance next to the channel. Transport of LWD from adjacent non-floodplain reaches just upstream is important.

- New riparian buffer rules and unstable slope rules will help protect LWD recruitment potential. Increased wood will eventually improve spawning by creating gravel storage in the mid-gradient CGUs 3.0 and will improve rearing habitat by creating more pools in the 1.5 and 3.0 CGUs. Also creates habitat complexity including cover and refuge areas in all channels.

- Temperatures should experience a cooling trend, but dramatic changes from present are not expected because most streams in the basin are currently shaded and have low temperatures. There may be some improvement in lower mainstem with the growth of larger trees over time, but this area has natural openings due to flood disturbance, mixed species, and a wider channel. Note that there is also a natural trend of temperature increases with channel size and distance from divide, so lower portions of the river may naturally exceed standards.

Synthesis of Current Conditions

Sediment and Sediment Budget

One watershed process that can be cumulatively affected by management practices is the input and transport of sediment. Sediment plays an important function in the stream ecosystem, forming the stream bed, affecting the shape of the channel, and providing substrate for the organisms that live and reproduce in the stream. Input of more sediment than a stream can transport can result in aggradation and subsequent fining of stream bed substrate; too little sediment input can lead to downcutting, channel incision, and coarsening of the stream bed.

The roles fine-grained sediments (sand, silt, clay) and larger sediments play in a stream ecosystem differ. Larger particles (gravel, cobble, boulder) are generally carried as bedload and influence the form and substrate in a stream. Salmonids lay their eggs in gravel-sized substrate. Fine sediment as used in reference to fish habitat typically refers to sediment smaller than 2 mm in diameter (coarse sand). Other breakdown points that are often used are 0.85 mm (fine sand, silt, and clay) and 4.7, 6.5, or 8 mm (pea gravels). When collecting field data in this study, fines were defined as 2 mm and smaller. These are readily identified in field observations as detriments to fish and amphibian habitat. These are the materials that fill interstitial gravel spaces and would not be used even by small salmonids for spawning, as pea gravels may be. An over-abundance of fine sediment can fill the spaces between larger particles or cloud the water column, and can be harmful to aquatic life. The Interagency Properly Functioning Conditions (PFC) matrix lists a number of sediment targets that help to guide analysis of instream sediment conditions in watershed analyses:

Parameter	Target
• Percent fines <0.85mm	• Class I and II streams <11 to 16%
• Percent particles < 6.5 mm	• <20 to 25% in Class I and II streams
• Pebble counts	• D_{50} of 65 to 95 mm
• Turbidity	• No visible increase due to timber operations in Class I, II, or III streams

Timber harvest activities can increase the input of sediment to streams if care is not taken to minimize erosion of bare ground (primarily roads and burned harvest units) and avoid practices that could increase mass wasting events. Careful harvest practices and road construction and maintenance can minimize sediment inputs.

Sediment Critical Questions

Three critical questions were used to guide the cumulative effects of sediment assessment procedure:

- CQ2. What is magnitude and distribution (spatial and temporal) of sediment delivery to streams from mass wasting, bank erosion, and other upland sediment sources?

- CQ4. What percent over background are management-related sediment inputs in each sub-basin?

- CQ5. Where are existing and known potential future sediment sources in each sub-basin? How could they affect existing and expected future stream and aquatic habitat conditions?

Sediment Input Budget

To answer the critical questions, we compiled a sediment input budget for the Elk River and Little Salmon Creek portions of the ERSC. Sediment inputs were determined based on studies and modeling undertaken as part of the Mass Wasting and Surface Erosion modules of this report as well as information from a sediment source study by Pacific Watershed Associates on the North Fork Elk River portion of the ERSC (PWA 1998).

The sediment budget was computed on average annual inputs for the 1988-2000 time period, with road surface erosion conditions based on either 1997 (pre-HCP) or 2000 (With-HCP) conditions. Sediment input from soil creep, streambank erosion, and harvest-related and road surface erosion were based on modeling of average rates of input based on the condition of the watershed (e.g., acres harvested and miles of roads and streams) during the 1988-2000 time period. These models estimate average annual input of sediment rather than the actual amount of sediment that occurred during any specific year of the analysis period. Sediment input from mass wasting and road gullies/culvert failures were based on actual landslides measured from aerial photographs or ground surveys during the 1988-2000 period as described in Appendix A and PWA (1998). The choice of this time period likely increases the relative inputs from episodic sources such as mass wasting and gullying in comparison to less episodic sources such as surface erosion since there were several very large storms that triggered mass wasting events in this period.

The following sediment inputs were considered in this analysis:

Background Input:

- Soil creep;
- Stream bank erosion;
- Shallow landslides;
- Deep-seated landslides; and
- Stream-side landslides.

Management-Related Erosion:

- Harvest-related (hillslope) landslides;

- Harvest-related surface erosion;
- Hillslope deep-seated landslides;
- Road-related surface erosion;
- Road-related landslides;
- Road-related stream-side landslides;
- Road gullies/culvert failures; and
- Management-related bank erosion.

These categories are slightly different than the sediment sources considered in the previous sediment input investigation of the North Fork Elk River by PWA (1998). PWA considered sediment sources produced over a longer time period (mid- to late 1940s through 1997) and did not differentiate between management- and non-management-related sources. The PWA analysis was limited to the North Fork Elk River Watershed. The following chart provides a comparison between sediment inputs considered in the current report and those considered by PWA.

Current Report	**PWA (1998)**
Background Input	
Soil creep	Not included in analysis
Stream bank erosion	Bank erosion (not separated into background/management)
Shallow landslides	Debris landslides and torrent track scour (not separated into background/management)
Deep-seated landslide	Not included in analysis
Stream-side landslides	Inner gorge and Stream-side landslides
Management-Related Erosion	
Harvest-related (hillslope) landslides (includes those related to skid trails)	Debris landslides and torrent track scour (not separated into background/management)
Harvest-related surface erosion	Not included in analysis
Hillslope deep-seated landslides	Not included in analysis
Road-related surface erosion	Not included in analysis
Road-related landslides	Road-related landslides (fill failures, cutslope failures, road-related hillslope failures)
Road-related stream-side landslides	Road-related streambank and channel erosion
Road gullies/culvert failures	Stream crossing washouts and gullies
Management-related bank erosion	Bank erosion (not separated into background/management)
Not included in analysis (management practice no longer used)	Scour of tractor-filled channels

There are other legacy inputs of sediment that are still supplying sediment to streams in the basin related to management activities that are no longer allowed under current forest practice rules. One example is scour of tractor-filled channels (PWA 1998). This source is related to the filling of small stream channels with sediment and slash during steam donkey, oxen, and tractor yarding activities that allowed yarding down stream channels. These practices were discontinued in the mid-1970s, but some streams are still continuing to scour these filled sediments. An estimated 22,000 cubic yards were eroded from this source in the North Fork Elk River during the 1990s, an average of 2,200 cubic yards (2,640 tons) per year over the decade (PWA 1998). Sediment from this source consists of whatever size classes were present in the surrounding soil. These generally tend to have a high content of fine sand and smaller sized particles in all soil types of this watershed. Legacy sediment volumes are not included in the sediment input budget since they are not related to on-going management practices. However, the stream system is still processing these legacy sediments, and they contribute to cumulative effects of past management practices.

Another potential sediment source that has been of concern is headward channel incision at the upstream extents of the channel network due to timber harvest. Because this is primarily an erosional process in the soil column, sediment contributed by this process is dominated by fine material. Studies conducted by PWA during the Freshwater Creek Watershed Analysis documented apparent extensive headcutting in channels in Wildcat geology associated with first-cycle entry and harvest (PALCO 2001a); similar results were not noted in Franciscan geology. The Freshwater Creek study identified no evidence of additional incision associated with second harvest entries. Because of the similarity between the Freshwater and Elk River Watersheds, the same findings are assumed to apply in the ERSC Watershed Analysis. Therefore, the sediment budget does not incorporate this sediment source as an element.

After discussions with the agencies, PALCO and O'Connor Environmental undertook one study investigating the transport of sediment from headwater channels in different bedrock geology and with different management conditions. PALCO and O'Connor are currently engaged in a second monitoring study of headwater headcutting and incision in Freshwater Creek that was developed with input from state and federal agencies. Results will be used to modify the ERSC sediment budget if necessary when the ERSC Watershed Analysis is revised following the next watershed analysis of these lands (i.e., in 5 years).

Sediment inputs for each sediment source considered were quantified for each sub-basin using the methods described in the Surface Erosion and Mass Wasting modules. To provide a reasonable estimate of the potential variability in the sediment source estimates, we made a high, middle, and low estimate for several of the sources based on a reasonable range of either input variables or erosion rates (Table 10). This information is also displayed graphically on Figure 8. Details of sediment inputs by sub-basin are included in Tables 11, 12, and 13. Based on the measured sediment inputs in the nearby Freshwater Watershed (235 to 375 tons/mi^2 measured over approximately 6 months during the fall/winter/spring rainy season), it is most likely that the low to moderate estimates provide a reasonable range of sediment inputs for the ERSC Watershed. The middle estimate is shown in Table 12 and Figure 9.

Note that estimated sediment input from non-PALCO land is incomplete; the only sources that included non-PALCO inputs were soil creep and bank erosion (estimated for the entire watershed) and road surface erosion (estimated for roads in the GIS database, which was incomplete on non-PALCO lands). Table 12 shows the percent of each sub-basin that is included in PALCO ownership. Due to the difference in completeness and density of information available to calculate sediment inputs on PALCO and non-PALCO lands, sub-basins with a higher percentage of PALCO ownership have a “more complete” sediment budget than those with only a small percentage.

The largest sediment sources in the watershed during the 1988-2000 time period are related to mass wasting events, either background, road, or harvest-related. Soil creep is another potentially large input, but there is a high level of uncertainty in creep rates resulting in a large variability in the relative importance of soil creep as a sediment source. Road surface erosion and road gullies/ washouts are moderate sources of sediment during this time period, and harvest surface erosion is a minor source. The dominance of the sediment sources associated with landslides could in part be due to the occurrence of several large storms that likely influenced the increase in the number of mass wasting events during this time period.

Coarse sediment is generally only contributed by landsliding, road gullies or washouts, and, in some situations, bank erosion. The particle sizes contributed depend on the geology at the source. In Wildcat and Hookton geologies, the parent material source itself consists of sand and smaller particles. Any coarse material from the parent geologic unit quickly breaks down into its constituent fine sand and smaller particles. Landslide sources in the areas mapped as underlain by Yager and Franciscan geologies can contribute larger material, including large boulders. However, these geologic units appear to contribute large quantities of fine material mixed with the coarse. Surface erosional processes are surficial and only erode small particles, independent of the mapped geologic unit. Bank erosion and soil creep can contribute some coarse material when that is present in the soil column. However, because it is a breakdown product of the underlying rock or reworking of colluvium, the soil column tends to be dominated by fine sediment.

Based on the range of high/low estimates for the different sediment inputs, we have high to moderate confidence regarding the relative importance of each source with the exception of soil creep and stream-side landsliding. The range of potential values for these two sources is very large, and could make them the dominant sediment sources in the basin (high estimate) or more moderate sources (middle to low estimates).

Effect on Fish and Aquatic Resources

The majority of sediment inputs, both background (natural) and management-related in the ERSC, are fine-grained (sand, silt, clay) due to the fine-grained texture of the soils and underlying geology. As a result, many of the streambeds in the watershed are dominated by fines. These channels received a "UG" channel designation and do not, and never will, meet NMFS PFCs for substrate. Potential use by salmonids in those channels is limited to juvenile rearing. The "CG" channels in the ERSC do have coarse sediments and do provide appropriate-sized gravel substrate for spawning (Table F-5a). Most of the CG channel segments that were surveyed had low substrate embeddedness. One Class I segment at the upper end of Lake Creek had high embeddedness in the spawning gravels. Lake Creek appears to be recovering from stream channel burial as a tractor road and is generally laden with both legacy sediments from the fill and from active sideslopes that provide a continuous supply of fine sediment.

Most of the Class II channels in the ERSC tend to have high fines content and embeddedness. A reduction in the input of fine sediment in these channels may improve their suitability as amphibian habitat. However, the presence of fines is due to the process of recovery from legacy channel burial and to the nature of the material in which they are formed. Most Class II channels are in UG geologic units. Even soils associated with relatively CG geologic units in this watershed have many fines, and the small size and stream power in these channels limit their ability to transport large sediment quantities.

Disturbance Index

The disturbance index (DI) computed for each sub-basin is defined as the ratio of management-related sediment sources to background sediment sources. A higher DI value corresponds to a higher proportion of management-related sediment inputs. A DI value of 0 indicates no management sediment sources; a DI value of 1 indicates management sediment sources are equal to background inputs, and a DI value greater than 1 indicates management sources are higher than background sources.

Watershed-wide DI values varied from 2.5 to 0.4 for the low to high estimated sediment inputs in the Elk River WAU (Table 10). DI values in each sub-basin varied from 0.1 to 7.9 (Tables 11, 12, and 13). Sub-basins with the highest DI values included the Lower North Fork, North Branch North Fork, and Railroad Gulch areas. Large inputs from shallow hillslope landslides in each of these sub-basins resulted in the higher DI values.

Because most sub-basins have DI values greater than 1.0, and given the abundance of fine sediments in many stream sections, a reasonable connection is that there is a cumulative sediment effect present in most portions of the Elk River Watershed.

Stream Flow

Peak Flows in Low-Order Channels

Evidence of headward channel incision has been identified in Wildcat geology associated with first-cycle harvesting in Freshwater Creek (PALCO 2001a). However, no evidence for this was identified in Franciscan geology or associated with second-cycle harvesting. A study of Class III channels conducted by O'Connor Environmental as part of the ERSC Watershed Analysis (Appendix E, Attachment E-3) identified little evidence of active channel erosion and no evidence of headward channel incision. There were small differences in channel incision and bank erosion between Wildcat and Franciscan geologies and no statistically significant differences between recently harvested and control channels. Thus, channel incision and extension of the channel network upslope likely occurred in at least some areas in ERSC following the first cycle of timber harvesting. Since all of the PALCO land in the ERSC has already been harvested at least once, no further significant erosion from headwater channel incision or headcutting is expected currently or in the future. This assumption may be modified in the future based on results from an ongoing study of this phenomenon on PALCO lands.

Mainstem Peak Flows and Flooding

Increases in peak flows and flooding within the mainstem Elk River and lowest reach of the North Fork Elk River during the 1990s initiated inquiries into factors that could affect the magnitude and extent of flood events. Generally, the dominant factors that affect flooding include climate, landscape conditions that determine runoff volumes, and physical characteristics of the floodway. The flood history for the ERSC Watersheds is discussed in the Watershed Overview section of this report under the heading "Major Storm Events and Flood History." In 1999, PALCO prepared a report on the Analysis of Flooding in Elk River and Freshwater Creek Watersheds (PALCO 1999b). Conroy (1999) addresses peak flow events in the Elk River Watershed. The Freshwater Creek, Van Duzen River, and LEED Watershed Analyses (PALCO 2001a, 2001b, and 2002a, respectively) provide recent nearby parallels for the ERSC Watershed Analysis. The following discussion summarizes the available data and analyses pertaining to these factors from these reports.

Climate has clearly played a key role in peak flows and flooding during the 1990s, which was an historically unprecedented wet period. At the EKA, the years 1995 through 1998 were consistently some of the wettest years in the previous 50-year record and even some of the wettest in the entire 111-year precipitation record for Eureka (PALCO 1999b). This wet period was preceded by a long, dry period when few flooding events were noted (Figure 6).

Harvest effects on runoff are also a likely factor affecting flooding. The Freshwater Creek, Van Duzen River, and LEED Watershed Analyses (PALCO 2001a, 2001b, and 2002a, respectively) included hydrologic analyses to evaluate changes in peak flows associated with timber management. The analyses predicted modest temporal increases in peak flows, typically less than 10 percent above normal peak flows, associated with timber harvest. Predicted effects of harvest on flooding during the 1970s are therefore believed to be small compared to climatic and channel conveyance impacts in this region.

The peak flow analysis methodology employed within these studies predicts the greatest potential for increased peak flow for scenarios in which widespread clearcutting occurs. Although large portions of PALCO's land in the Elk River Watershed were harvested in the late 1980s and 1990s (Maps 7 and 8), very little of this area was clearcut (PALCO 1999b, Figure 2). Moreover, timber harvest practices within the Elk River Basin evolved significantly over time (see discussion on Forest Management History). and partial cutting and thinning have been the dominant harvest methods in the Elk River Watershed. More than 50 percent of the canopy cover typically remains after harvesting. Small increases in peak flow volumes attributable to changes in canopy conditions resulting from recent timber management activities in the Elk River Watershed are not likely to significantly modify flood hazards in the lower North Fork and mainstem Elk River (PALCO 1999b).

Changes in the floodplain and channel conveyance capacity of streams can affect the magnitude and extent of flooding. If channels fill in with sediment or have higher toughness from vegetation and large wood, a given level of water flow is more likely to result in flooding. Within the lower North Fork and mainstem Elk River, reductions in floodplain and channel conveyance compared to previous periods are evident. Both increases in channel filling from sediment, and increased channel and floodplain roughness from trees and brush are present. These changes may be related to local land use changes, sediment aggradation within the channel, flow constraints imposed by bridges and other structures, increases in the density and extent of vegetation within and adjacent to the channel, and increases in debris accumulations within the channel. The relation between timber management and sediment delivery to the channel network is documented as part of the current ERSC Watershed Analysis. The relation between timber management and sediment accumulation within the lower North Fork and mainstem Elk River is indirect and rendered ambiguous by many confounding factors that affect sediment transport and deposition. It seems likely that management-related sediment inputs from PALCO's lands have contributed to reduced channel conveyance, as have reductions in stream clearing and riparian vegetation removal by downstream land owners. However, the relative magnitude of these effects and of their ultimate impact on flooding remains uncertain. Additional study of this subject is currently being conducted jointly by PALCO and the North Coast Regional Water Quality Control Board.

Effects on Aquatic Resources

The primary concern with peak flows with regard to aquatic resources is the potential increase in streambed scour and associated redd loss. Redd scour is a natural process and is a function of redd location both at the unit scale (for example, redds located in the tails of pools, in riffles, or along the margins of channel) and at the watershed scale (for example the CGU and position in watershed occupied). The potential effects of peak flows also depend on species and timing of events. For instance, spring spawners may be less susceptible to scouring events than fall spawners due to differences in flow event characteristics during egg incubation periods. So effects due to any changes in flow magnitude are difficult to predict, unless we know more specific information about location, timing, and magnitude of events relative to the natural event regime.

An additional habitat concern is the potential for increased loading of fine sediment and the resulting turbidity and substrate infilling in both headwater amphibian habitats and downstream in channels with heavy fish use. Previous timber harvesting may have caused some increase in fine sediment due to initial headward channel incision and to bank erosion caused by combinations of riparian vegetation removal and small increases in peak flows. However, headwater channel incision and headcutting were primarily noted in Wildcat geology channels, where fish use is minimal and where the natural substrate consists almost entirely of fines. The lack of apparent headward channel expansion in second-round harvesting and the implementation of current riparian buffer rules suggest that the extent of these effects that existed in fish-bearing stream drainages have now been minimized. This suggestion is supported by the general lack of fine material and gravel embeddedness in the non-Wildcat stream channels (Table F-5a).

Wood

The current status of wood in streams varies dramatically from very little to very high volumes, depending on the history and size of the particular stream. Many of the smaller channels are still buried under wood and debris that were used to fill in the channels to use them as logging corridors during prior timber harvest periods. Although there are no wood loading criteria for these smaller channels (i.e., less than 4 meters wide), observed and calculated wood loadings are judged to be extremely high (e.g., Browns Gulch tributary at 103 cubic meters per 100 meter length). Bridge and Lake Creeks also have large wood deposits that bury the channel for as much as several hundred nearly contiguous meters as a result of landslides, especially in their lower reaches.

The larger river channels that were used for log driving (North and South Forks, and mainstem) were cleared of wood to facilitate passage of logs. Instream wood is still low in many parts of these channels. The lower mainstem has also been kept clear by farmers and valley residents over the years to facilitate peak flow conveyance (Personal communication with local residents who wish to remain anonymous, 2002). Furthermore, most larger tributaries that were considered important for fisheries were cleared of virtually all LWD during the 1980s to ensure fish passage and as an overreaction to the desire to rid these channels of excess debris. Therefore, most moderately sized channels used by fish tend to have low wood levels. More recently, LWD and logjams have been installed in an effort to correct the low wood conditions. Most of this work has been done on the North Fork mainstem, and current surveys on the North Fork report adequate in-channel wood (Table F-5c).

Bank erosion is the dominant source of wood recruitment for most of the moderate to large sized streams in this watershed. The lower mainstem reaches of the North and South Forks are areas that could especially receive significant bank erosion recruitment. Based on our observations, mass wasting events are significant sources of LWD in Clapp, Railroad, Dunlap, Browns, Bridge, Lower North Fork, Lake Creek, and portions of the Upper North Fork sub-basins. Most wood recruited from landslides to these channels stays where it falls because of the limited capacity for the small ERSC channels to transport large wood.

Effects on Channels and Aquatic Resources

Large wood and wood structures promote channel complexity (e.g., diverse pool and riffle formations) and floodplain connectivity. These features provide rearing habitat such as pools, cover, and areas of refuge during storm events. Debris jams also promote gravel storage and potentially increase the amount and quality of spawning habitat. The latter may be most beneficial for chinook salmon populations because they are more likely than other species to be limited by the quantity of spawning habitat during the freshwater phase in the ERSC. Coho and steelhead populations, for example, tend to be limited by the quality and quantity of juvenile rearing habitat. Along with accumulating stores of gravel, large wood and debris jams promote the development of deep pools, which are important not only for juvenile rearing, but also for migrating adult salmon for resting and holding.

Installed wood structures in the mainstem rivers currently make up the majority of the wood loading in the major fish-bearing channels. These appear to be effective at generating pools, storing sediment, and generally creating diverse habitat features in and around them. The high densities of juvenile salmonids in reaches that have such installed structures and the documented use of these structures by pond turtles suggest that they are successful elements in the effort to increase and improve habitat for these species of concern. However, stream channels in the Hookton and Wildcat that have large wood and debris deposits can be blocked by the dams that may form from these deposits. The nature of the fine clay materials in the deposits cements the material and not only prevents dispersal of the debris, but also dams water from flowing through. Therefore, they can effectively block access for fish.

Stream channels that were buried or filled by early timber harvest practices or landslides have few pools and many steps, limiting use by salmonids. They also tend to have beds dominated by fines, and the coarser substrate that may be present is embedded, reducing desirable habitat for torrent salamanders and tailed frogs.

Stream Temperature

Stream canopy cover is generally "high" (greater than 70 percent) in the ERSC. Ninety-four percent of the Class I and II channel segments were estimated to have at least 70 percent canopy cover. In-channel shade measurements tended to be slightly lower than the aerial photo estimates, but still resulted in most channels having at least 70 percent canopy cover.

Effects on Channels and Aquatic Resources

The limited temperature data indicate that stream temperatures in most of the Elk River Watershed are within a good range for salmonid fish. The lower mainstem North Fork at times exceeds the APFC maximum temperature criterion that the mean weekly average temperature (MWAT) not exceed 16.8 degrees centigrade (C).

Watershed Future Trends under Existing HCP and Forest Practices Rules

The following are summaries of expected overall trends for the watersheds. Following the determination of timber harvest prescriptions for the ERSC, we will be able to further and more specifically address future trends.

Sediment

The estimated sediment inputs in Table 12 and Figure 8 are based on the 1988-2000 time period. Harvest and road maintenance practices during much of this time were based on pre-HCP regulations. The existing practices under the HCP have several provisions that should decrease sediment inputs on PALCO land through time, including more cautious treatment of mass wasting areas of concern, stormproofing and hydrologically disconnecting roads, and leaving wider buffers on harvest units. As a result of these measures, sediment inputs from areas subject to these regulations should continue to decrease and result in improved instream conditions through time. Implementation of real-time sediment monitoring in Elk River and a system of communication with harvest managers are expected to provide timely feedback that will lead to further reductions in fine sediment inputs.

Coarse sediment inputs may be reduced by implementation of stricter mass wasting protections. However, climate patterns and the incidence of earthquakes will continue to play a large role in initiating landslides, which are the dominant source of coarse sediment input to streams.

Effects on Aquatic Resources

Expected reductions in road surface erosion fine sediment will reduce embeddedness in small channels used by torrent salamanders, tailed frogs, and juvenile trout, which tend to be most directly affected by the road network.

Reduction of coarse sediment input from management-related landslides may adversely influence supply to some CG channels. Natural sources of coarse sediment have limited the distribution of spawning habitat in the ERSC.

Stream Flow

As discussed previously, climate, harvest, and changes in channel conveyance affect peak flows and flooding. Nothing can be done locally by PALCO to address climatic impacts. Thus, future periods of drought will have a low incidence of high flows and flooding, while periods of high rainfall will have a much greater incidence of these events. Harvest effects on peak flows are limited to perhaps 10 percent of the flows that cause flooding. Additional studies by John Munn (Munn 2000 and 2001) of the California Department of Forestry and Fire Protection (CDF) have resulted in a new harvest rate limitation of 600 clearcut-equivalent acres per year in Elk River to prevent any increase in peak flows over current conditions. With this harvest rate limitation in the ERSC and restrictions in PALCO's HCP that require retention of trees and ground cover in many harvested areas, effects of futures timber harvesting on peak flows are expected to decrease or remain steady in the future, but should not increase. Finally, to the extent that channel conveyance has been reduced by management-related sediment, the many sediment reduction measures of PALCO's HCP should cause such conveyance to increase over time and, therefore, reduce the incidence of flooding in the future. This benefit will likely develop gradually as existing sediment deposits are removed by natural flows. However, reductions in channel conveyance due to greater roughness (i.e., LWD) in stream channels and floodplains are likely to increase in the future as regulation and changing land use ethics result in greater restoration of riparian and floodplain vegetation and forests. This increase in channel roughness, although associated with ecosystem recovery, will likely have the effect of increasing the frequency of local flooding events over time.

A Total Maximum Daily Load (TMDL) is being developed for the Elk River Basin in conformance with requirements of the Clean Water Act. TMDL-related studies are examining the technical issues associated with flooding in greater detail than in this watershed analysis and, therefore, may lead to additional conclusions and remedial approaches regarding flooding in the ERSC.

Effects on Aquatic Resources

See ***Synthesis of Current Conditions*** section.

Wood

Current wood installations in the middle and lower North Fork have a limited life and are likely to require replacement before enough riparian timber can recruit to the channel, despite the potential for channel migration in these reaches. Even in reaches with adequate timber in the riparian zones, it will take many years for natural recruitment to make up for the past practices of clearing wood out of the major fish-bearing channels. Therefore, continued artificial wood inputs may be appropriate in larger fish-bearing streams, especially CG1.5 and MSG segments that have a high response to LWD.

New riparian buffer rules provide for increased buffer widths along more reaches of stream than previous forest practices have provided. This will result in a general trend toward denser stands of larger trees. Most of the riparian buffers that do not currently consist of suitable trees for adequate LWD recruitment and shade are well on their way to growing suitable conifer or mixed conifer/ hardwood stands. However, the riparian zones along several reaches on the North Fork (N2, N3, and N4) are unlikely to provide significant quantities of suitable riparian timber for recruitment in the near future. The current riparian buffers lack large down wood, which reduces the chance for conifer to establish in the wet low terrace and floodplain zone, and the existing dense hardwood stands tend to shade out any young conifer that might establish. Active management such as LWD placement on the riparian forest floor, as well as in the channels, and vegetation conversion projects can hasten the establishment of conifer stands that will eventually provide a sustainable supply of LWD to the channel.

Bank erosion is expected to continue to be the dominant LWD recruitment mechanism in the major fish-bearing channels. Many of the stands farther up the North Fork Elk River are even-aged regeneration stands that are at an age where there may also be significant inputs due to stem exclusion in the near future. Lower mainstem reaches in agricultural areas are likely to receive inputs of LWD from limited hardwood riparian vegetation in future due to livestock-induced bank erosion and tree mortality.

LWD in tributary channels that are currently overloaded is not likely to move into downstream channels. The channels are too small for fluvial transport and too low-gradient for debris torrent transport. Dam-break floods are possible, but of limited frequency and likelihood. In cases where the wood is well above the active channel, it is likely to stay there for a long time because redwood is so resistant to decay. However, even above the channels it can provide habitat for amphibians.

Effects on Aquatic Resources

All aquatic resources will benefit from the improving LWD recruitment potential. Many channel reaches with high potential fish use are still lacking in large wood and attendant habitat features. The installed wood structures that currently provide most of the LWD in major fish-bearing channel reaches have limited life spans and will need to be maintained over the years until the natural processes, cycles, and reserves of wood recruitment are fully restored.

Increased wood recruitment potential, in addition to the installed structures so important in the interim, will eventually lead to the recovery of wood-related habitat in the larger tributaries and mainstem channels. Increases in the wood input processes and rates will continue to promote channel complexity and floodplain connectivity. This in turn should improve rearing habitat by increasing the amount of pools, increasing cover, and increase areas of refuge during storm events. Debris jams will promote gravel storage and potentially increase the amount and quality of spawning habitat. Wood is particularly important in the moderate gradient 1.5 and 3.0 CGUs because it increases pool frequency and gravel storage in those highly responsive channels. Although gravel storage is not as important in MSG channels, LWD and logjams are important in them as formers of pool, refuge, and off-channel habitats for fish, amphibians, and pond turtles.

Removal of blocking debris jams, such as at the mouth of Lake Creek, could make short reaches of potential salmonid habitat available, although most of the habitat that would be accessed would only ever be of marginal utility due to the geology. Habitat near the mouths of those tributaries is likely very good and would be used as refuge habitat under high stream flows. LWD currently in those jams could be placed in the mainstem Elk River, improving habitat in both streams.

Shade and Temperature

As with wood recruitment, current riparian buffer prescriptions will generally tend toward improving stream canopy shade conditions. The currently high levels of canopy cover overall in the watersheds make this of lower concern than the lack of channel LWD. The lower reaches of the North and South Forks Elk River that have low shade are unlikely to have high shade for many years, if at all, because of their channel width and because of the limited growth potential for the hardwood vegetation that composes the riparian stands.

Water temperature is expected to remain similar to current levels and within standards at most locations except the lower North and South Forks and mainstem Elk River.

Effects on Aquatic Resources

Most aquatic species of interest will benefit from increased shading, although temperature does not currently appear to be a problem for fish and amphibians in most areas of the ERSC.

Northwestern pond turtles may see a decrease in upland breeding habitat along the mainstem North Fork Elk River where currently open grassy areas adjacent to the river will regenerate with conifer.

Sub-Basin Group Summaries

The previous CWE discussion focused on specific input and process categories. The following lumps these categories together for each sub-basin to provide for a more spatially oriented perspective on cumulative effects.

East "Mixed" Geology Sub-Basins

This sub-basin group includes the upper reaches of the North Fork Elk River (North Fork Elk) and the North Branch of the North Fork (North Branch NF) sub-basins. The uppermost reaches of the North Fork sub-basin are in Franciscan (cm2) geology. This is the only sub-basin that has significant area in this geology. The rest of this sub-basin group is underlain by Wildcat on the upper and sideslopes and Yager in the main valleys where the stream channels have cut down into that substrate. The NRCS has mapped Hugo soils generally covering the areas underlain by Franciscan and Yager geologies. These have a moderate erosion hazard associated with the Franciscan/Hugo upper section of the sub-basins and low to moderate hazard associated with the Yager/Hugo valley bottoms. Erosion hazard is high to extreme in areas mapped as Larabee soils overlying Wildcat geology on the upper slopes. The hazard in areas underlain by the Wildcat/Larabee combination drops to moderate along the ridgetops. These sub-basins are in the range of very high annual rainfall (63 to 71 inches on average). However, they are mostly above the summer fog line and experience very warm summer conditions, especially on ridges.

The majority of streams in both sub-basins are in the sediment source and transport categories. The proportion of the stream channel network in each category is approximately the same in each sub-basin, with the North Branch having a higher proportion of source reaches. The total stream density in the sub-basin group is 10.3 mi/mi^2, while in the North Fork it is 11.3 mi/mi^2, and in the North Branch it is 90.3 mi/mi^2.

The main channels are CG types, fed by steep, Class II UG channels. The head of the mainstem Elk River is very low-gradient (CG0, CG1.5), Class II, and goes dry during the summer months. This flows into CG3 and CG6.5 channels (segments N23, N22, N21) through the Franciscan geology, then flattens out to CG1.5 through a long Wildcat stretch (N20 to N16). The gradient then increases somewhat to CG3 through the Yager to the confluence with the North Branch of the North Fork Elk (N12). The North Branch starts out as a CG6.5 channel following the Franciscan/Wildcat contact (NI16). It gradually decreases in gradient along its length to CG0 at the confluence with the main North Fork (segment NI1). Channel surveys include two PALCO monitoring stations, one long-term monitoring reach, several amphibian habitat surveys, and six Hart Crowser and O'Connor Environmental (OEI) surveys.

Coho and chinook salmon use the North Fork up through segment N14, although they potentially use up through segment N20. Steelhead are assumed to use the North Fork up through segment N21. Coho, chinook, and steelhead appear to use the North Branch up through segment NI3, although they could potentially use NI4, NI5, and the lowest reaches of Doe Creek. Moderate densities (0.54 per square meter) of juvenile coho were identified at the PALCO monitoring site on segment NI1 of the North Branch Elk River (Table F-4). There is potential trout habitat, and assumed use, up the North Fork to segment N24; all the way up the North Branch; segments NI3.10, 3.11, and 3.11.1 of Doe Creek; segment NI15.10 and NI15.11 of the Little North Fork; and tributary segments NI6.3 and NI6.20.

The steeper channels in the Franciscan and Yager geologic units have high potential torrent salamander use because of the occurrence of coarse substrate in the stream bed. The lower-gradient streams in this area and the steeper streams in Wildcat have low potential use, except for the reaches down near the Yager interface where substrates become coarse. Tailed frog habitat potential is the same as that for torrent salamanders except that the moderate-gradient mainstream channels of the North Branch and North Fork also have high potential. Incidental observations of the torrent salamander were made in the upper North Fork, and of the tailed frog near the confluence of the North Branch and North Fork. Yellow-legged and red-legged frogs are likely to be present in the low-gradient reaches of the mainstem North Branch and North Fork. There is a slight chance that northwestern pond turtles could be present in the same areas. Potential use of other channels is low for red-legged and yellow-legged frogs and non-existent for the turtles.

The northern ridge of the North Branch sub-basin was harvested in the 1930s, apparently as overflow from the Freshwater Basin. The majority of the North Branch was initially harvested in the 1940s, when tractor/truck harvesting was becoming prevalent. Stream channel infilling and burial would have been typical, and we expect most of the smaller channels in this sub-basin to be re-excavating through those fill deposits. Entries to these same harvest areas in the 1990s relied heavily on non-tractor-yarding methods and presumably had far less impact on the stream channels than the first entry. Riparian buffers were not left on channels during the first round of harvesting, and the riparian stands are consistent with adjacent upland stands.

Harvesting in the North Fork sub-basin began in the 1940s and continued steadily through the 1990s, with large blocks cut in the 1960s, '70s, and '80s. The first round of harvesting in the upper southeast portions of the watershed, in Boulder Creek and War Whoop Canyon, did not occur until the 1980s and '90s. In the late 1980s and 1990s, partial cut reentries were made throughout the rest of this sub-basin, presumably to remove residual old-growth trees left during the first entry. Tractor yarding was the dominant method used in the North Fork sub-basin. Because most of the harvesting in the North Fork sub-basin has occurred since the advent of truck hauling and the Forest Practice rules, channels have been less subject to scouring, dragging, and infilling than areas of the watershed that were harvested during earlier periods, and some form of riparian buffers were left on many larger stream channels. However, tractor skid trails in exposed locations in some higher elevation areas, such as near the Turkey Foot, are not regenerating as quickly as in other more protected areas, due presumably to the dry growing season climate at elevations above the summer fog belt and the nature of the soil overlying the Wildcat. Wind may also be an important factor contributing to surface erosion and slow re-establishment of vegetation.

Current Status

Sediment Inputs. The dominant sediment source in this sub-basin is from road-related shallow landslides, though this varies dramatically between the two sub-basins. The North Branch North Fork had a delivered sediment rate of 893 tons/mi^2/year (between 1988 and 2000), while the North Fork Elk River had a rate of only 24 tons/mi^2/year for the same period. This difference is most likely due to the geologic differences between the two sub-basins. The difference in lithology between Wildcat and Franciscan mélange corresponds to a difference in erosion hazard, which is moderate in the upper North Fork, but high in the rest of the sub-basin group. The road density is similar in both sub-basins.

The secondmost prominent sediment source is from non-management stream-side landslides. A total of 2,600 tons per year is delivered from these features in the entire sub-basin group; the contribution of each sub-basin is about the same.

Overall, the management-related sediment delivery was over twice as high as naturally caused sediment delivery and the North Branch sub-basin has the highest DI of any sub-basin in the ERSC. The total normalized sediment delivery for the sub-basin group (natural and management-related) was 1,068 tons/mi^2/year, or about average for sub-basin groups in this watershed.

Riparian Response. Much of these two sub-basins is still in young reproduction. Areas of mature even-aged timber exist in the lower portions of the North Branch sub-basin. Over half of the riparian zone in the North Fork sub-basin is in the mixed-small-dense condition category. The upper North Fork riparian zones are in the Conifer-Small-Dense category. Most of the North Branch sub-basin, however, is in the Conifer-Large-Sparse condition category.

The riparian zone condition reflects the recruitment potential. Consequently, recruitment potential in the North Fork is almost entirely poor (a few segments of tributaries with old growth in the riparian zones have adequate recruitment potential). In contrast, LWD recruitment potential in the North Branch sub-basin is generally adequate. Exceptions are a few low-order tributaries.

Stream canopy cover in the sub-basin group is generally above 70 percent. This is attributable in part to the combination of mature forest in the North Branch sub-basin and the dense young second growth in the North Fork. Several smaller tributaries to both creeks have less than 70 percent canopy as a result of recent timber harvest.

Channel Condition and Response. The lower mainstem (NI1) of the North Branch is mostly CG0 and is the response-type reach in that sub-basin. LWD in this reach contributes generally to pool formation. Potential response to both coarse and fine sediment is moderate, meaning that these sediments will not get flushed immediately through the reach when deposited. Farther upstream on the North Branch, the gradient increases quickly, leading to a source-dominated regime. In these reaches, LWD is likely to form pools and plays a role in trapping small amounts of coarse and fine sediment. There are several small UG tributaries that would be more susceptible to any coarse sediment inputs.

In the North Fork, the channel segments are also mostly in consolidated geology, with gradients above 3 percent. LWD is important in these reaches, as it will readily become integrated into the lotic system. On the south side of the lower North Fork, most of the small, steep tributary channels are UG channels up to 20 percent in gradient. In these streams, loose fine sediment is readily flushed from the system due to the high stream power. LWD is not an effective pool-forming component in these very steep streams because they are too narrow for LWD to get into the channel.

Temperature Response. During the monitoring of stream temperature conducted in the watershed, there were no measured temperature exceedances in the East Mixed Geology sub-basin group (Table F-6). It is likely that the generally high percentage of stream canopy cover (noted above) keeps temperatures down. Also steep terrain and possible groundwater influence contribute to keeping streams cool. However, this sub-basin is above the zone of summer coast fog influence, and upper slope tributaries, which are only shaded by low vegetation, are not topographically shaded, and receive little groundwater flow, could experience warm summer water temperatures.

Aquatic Resource Vulnerabilities

The CG3 channel types that make up the lower 2 miles of the North Fork are highly responsive to LWD. Wood is often the critical factor creating diverse and desirable fish habitat in what otherwise tends to be featureless, planar bed channels. Because there is a lack of recruitable wood on the North Fork in most of these CG3 lower reaches, habitat that currently exists for all fish species is vulnerable to homogenization and bed coarsening.

The high potential habitat for the northern red-legged frog and the foothill yellow-legged frog may be vulnerable to temporary burial from coarse and fine sediment input by stream-side landsliding in the Yager and Franciscan geologic units. These coarse sediment supplies, however, are also important sources of downstream gravels.

Expected Future Condition

Riparian zone shade and wood recruitment potential will continue to increase throughout the sub-basin under current forest practice and HCP rules. The upper basin that currently has poor recruitment potential and potential shading issues will most quickly see improvement due to the small stream channel sizes and consequently smaller riparian vegetation required to provide shade and effective wood input. In the lower basins, existing LWD will continue to leave the system while input levels are still low. In the absence of artificial wood placement, the stream beds are susceptible to substrate coarsening and bedform homogenization.

Road-related landsliding is expected to decrease in the future from levels observed over the analysis period due to improved road-building and maintenance methods and to more restrictive harvesting and road construction activities in landslide hazard areas. Skid trail-related erosion may continue in the near future but will gradually improve as the land revegetates. Such skid trail creation will not occur in the future, so this will be an improving situation and futher inputs will only be from the legacy trails.

Yager Sub-Basins

This sub-basin group includes the South Branch (South Branch NF) and mid-portion (Upper NF) of the North Fork Elk River and the Lake Creek sub-basins. The three sub-basins are dominated by the poorly consolidated sedimentary rocks of the Wildcat Group. The Lake Creek sub-basin is almost entirely within this unit. In the upper North Fork and South Branch sub-basins, the mainstem streams have incised down to the Yager Terrane. This unit is thus exposed in the valley bottom and toeslopes of the valley side walls. The distribution of soils mapped by NRCS parallels the geology; Hugo soils are present where the Yager Terrane has been exposed, while Larabee soils have developed on the rocks of the Wildcat Group.

The lower reaches of Lake Creek sub-basin receive 57 inches of precipitation per year on average, while its upper reaches receive 63 inches. The South Branch sub-basin receives between 63 and 65 inches of precipitation annually, while the Upper North Fork is similar to the Lake Creek sub-basin. The ridges in the sub-basin group are generally above the fog line, resulting in high summer temperatures. The lower portions of the valley bottoms, however, are within the fog zone and experience at least some moderating effect on summer high temperatures.

The three sub-basins are characterized by mainstems fed by steep low order tributaries. The most common channel type is UG20, followed by UG6.5. The South Branch North Fork has 27 percent CG3 channels. Although much of the North Fork flows through Wildcat geology, the channel substrate is still dominated by gravel contributed from the Yager and Franciscan geologies upstream. The Upper North Fork is not a true sub-basin and receives water and material from the upper East Mixed sub-basins as well as the South Branch and Lake Creek sub-basins. Channel surveys in this group include three long-term monitoring reaches, a few amphibian habitat surveys, two PALCO monitoring stations, and several Hart Crowser and OEI surveys.

The Upper North Fork is used by coho, chinook, steelhead, and trout along the full length of the mainstem. Salmonids were observed in this sub-basin during the present study. Virtually all of the tributaries are too steep for any fish usage. There is limited use of the Lake Creek sub-basin by trout only, due to the presence of a log/debris barrier at its mouth. The South Branch North Fork has limited (about 0.5 mile) usage by coho, chinook, and steelhead. Although there is no documented occurrence of resident trout in this sub-basin, their presence is presumed. Similar to the Upper North Fork, the tributaries are too steep for fish use. Potential fish use in the Upper North Fork is identical to the current fish use, indicating that the full potential is utilized. In the Lake Creek sub-basin, there is potential for trout use from the mouth to the farthest upstream reach of the mainstem.

Throughout the sub-basin group, there is generally low potential habitat for the southern torrent salamander due to the dominance of clayey/silty substrate associated with Wildcat geology in the steep tributary streams they prefer. Along the mainstems of the Upper North Fork and Lake Creek, there is virtually no habitat for this species. Similarly, there is only low potential habitat for the tailed frog, except in the uppermost reach of Lake Creek, which has a high potential. The South Branch North Fork has a high potential habitat for the tailed frog along most of the mainstem. There is also high potential habitat for the southern torrent salamander in a few short reaches on the mainstem and in a couple of the tributaries.

There is high potential habitat for the northern red-legged frog along the upper North Fork mainstem and most of the Lake Creek mainstem, but only low potential habitat along the South Branch North Fork. There is low potential habitat for this species on virtually every low-order tributary in the sub-basin group. The foothill yellow-legged frog has high potential habitat in the Upper North Fork mainstem and about 1 mile on the mainstem of the South Branch North Fork. There is low potential habitat along Lake Creek and many of the low-order tributaries in the sub-basin group. There is no high potential habitat in the sub-basin group for the northwestern pond turtle. There is low potential along the mainstems of the three sub-basins and no habitat in the low-order tributaries.

The earliest entry in the sub-basin group appears to be in widely scattered portions of the Lake Creek sub-basin, where clearcutting started in the 1930s. Most of the lower quarter of this sub-basin was clearcut in the 1940s. The rest of the lower quarter was cut in the early 1950s. The first entry in the Upper North Fork appears to have been in the early 1950s, where the upper half of the sub-basin was clearcut. There was a period of extensive logging between 1988 and 1997, where the lower third of the Upper North Fork and the entire South Branch North Fork was harvested by partial cut, tractor yarding. During this time, much of the remaining portions of the Lake Creek sub-basin were cut using about half partial cut, tractor yarding and half partial cut, non-tractor (mostly cable) yarding. The remaining old growth in the upper North Fork (about one quarter of the sub-basin) was cut between 1998 and 2000 using partial cut, non-tractor yarding.

Current Status

Sediment Inputs. On average, this sub-basin group has less delivered sediment per square mile than the East Mixed Geology group. The annual total sediment delivery rate is 818 tons per square mile. Sediment attributed to management activities is roughly equal to the background level. Similar to nearby sub-basins, stream-side landslides are the greatest natural contributor of sediment. The Upper North Fork has an especially high amount of sediment delivered in this way, at about 700 tons per year. This may be due to high rates of long-term incision that may have been exacerbated by early logging and log driving. These stream-side landslides in the more competent Yager geologic unit tend to contribute relatively more coarse sediment and less fine material than those in the Wildcat geologic units. Preliminary results from a monitoring station near the old Mill C site on the North Fork show that total suspended sediment transport (fines) is much lower at this site than at stations downstream in the MSF reaches (Kate Sullivan, PALCO, personal communication, January 2004).

Management-related stream-side landslides are the second highest single source of sediment in this sub-basin group, with about 1,000 tons per year. Shallow landslides related to management account for about 840 tons of sediment delivered per year. Most of these occur in the Wildcat-dominated Lake Creek sub-basin. The Lake Creek sub-basin is susceptible to shallow landslides. It has a higher rate of sediment delivery for both natural and management-related shallow landslides than the other sub-basins in this group. It is similar to the North Wildcat sub-basins in that it is subject to landslides from the steep Wildcat sideslopes that deliver piles of wood and fine sediment to the stream channel via many small lateral gullies. These piles block the channel and the fine sediments cement to form stable, long-lived jam structures.

Upper Lake Creek was filled in during the early tractor logging and is still re-excavating itself. This will continue to serve as a source of sediment for some years, although most of the re-incision has been completed.

Riparian Condition. Portions of the Upper North Fork and Lake Creek (about 1 mile each) have Conifer-Large-Dense riparian conditions. These areas exist where there was early harvest in the area and mature forests now stand. Most of the remainder of the two mainstem streams have Conifer-Medium-Dense conditions. The South Branch North Fork is mostly in Mixed-Small-Dense, due to recent harvesting.

Recruitment potential is generally adequate on the Upper North Fork and Lake Creek, while on the South Branch North Fork, again reflecting recent harvest, there is poor LWD recruitment on the mainstem (except the lowermost ¼ mile) and all tributaries. An exception on the Upper North Fork is its lower ½ mile, where LWD recruitment potential is poor.

Canopy cover is greater than 70 percent along most of the Class I stream segments in this sub-basin group. Much of the Lake Creek mainstem has over 85 percent canopy cover. This is due to mature riparian forest in some areas and dense second growth in other areas. Virtually all of the South Branch North Fork has greater than 70 percent canopy cover, including tributaries. One-half of the mainstem has over 85 percent canopy cover.

Channel Condition and Response. The CG1.5 channel at the top of this sub-basin is capable of routing much of the material from the sub-basins upstream, as well as the relatively steep South Branch, down to the lower-gradient MSG response reaches below. Most coarse sediment and wood transported into this reach are likely to be detained in this sub-basin, and the MSG mainstem will be highly responsive to those things. Limited relevant field data indicate that fine sediment deposits do not appear to be a problem in this reach of the North Fork; spawning gravels are dominant and not embedded with fines. Most fine sediment will be routed through to the lower river, although as LWD and resulting pools develop, more fines will be temporarily stored in this reach.

There is a lower-gradient reach of the North Fork between Mill C and McWhinney Creek that was identified as having a high likelihood of being in a floodplain migration zone. Bank erosion, therefore, may be significant there and is the highest LWD recruitment mechanism.

The East Mixed, South Branch, and Upper North Fork sub-basins are the only real sources of competent spawning gravel in the North Fork Elk River, and stream-side landslides in the Franciscan and Yager geologies are an important source of that sediment.

There are many installed LWD structures in this reach of the North Fork that appear to be quite effective and stable. The main channel is responsive to LWD and forms pools and sediment storage bars in response to increased input of LWD. Lake Creek is too low-gradient in its lower reaches to transport large wood out of the sub-basin into the mainstem North Fork, and a series of log and debris jams have formed just upstream from the mouth. This collection could be a good ongoing source of LWD for the lacking main North Fork Elk River if it could be mobilized in a controlled manner.

Temperature Response. Stream water temperatures monitored in tributaries in this sub-basin group do not exceed standards or indicate that there are temperature concerns (Table F-6) for species of concern. Maximum weekly average temperatures (MWATs) are between 13 and 14 degrees C and peak temperatures are about 15 C. One monitor near Mill C in the mainstem recorded a peak temperature of over 17 C, although the MWAT remained below 15 C. Riparian shading is generally high and should continue to increase with continued growth of coniferous riparian buffers.

Aquatic Resource Vulnerabilities

This is a superb sub-basin for salmonids and yellow-legged frogs that appears to be well utilized. The main North Fork channel is low-gradient, cool, and gravel- and wood-rich. It has a good source of gravels from the somewhat steep South Branch and upstream East Mixed sub-basins, and adequate LWD recruitment potential along most of its length. Bank erosion is the dominant recruitment mechanism, although mortality may be significant in those 60-year-old stands that have medium-large conifer and are likely to experience noticeable stem exclusion for the next few decades (N7, N10, and N11). One vulnerability is to large inputs of fine sediment that can embed the rich spawning gravels. Potential sources of fines are the stream-adjacent roads, stream-side landslides in the Wildcat material, and contributions from the tributaries in Wildcat geology.

Expected Future Condition

There are extensive tracts of mature, even-aged timber in this sub-basin that may be targeted for harvest in the next several years. Riparian buffers left in those harvested units may have a few years where there is intrusion of sunlight and wind below the canopy until the edges fill in with undergrowth.

North Wildcat Sub-Basins

This sub-basin group includes McWhinney and Bridge Creeks, which flow into the Upper NF sub-basin; Browns and Dunlap Creeks that flow into the Lower NF sub-basin; and a small portion of the Ryan Creek headwaters that flow northwest from the main Elk River drainage into Eureka. These sub-basins are entirely underlain by the Wildcat Group and overlain by Larabee soils. The sub-basins tend to be highly dissected with extreme erosion hazard in the small lateral drainages. Otherwise, erosion hazard tends to be high. Average annual rainfall ranges from 48 inches in Dunlap Creek to 58 inches in McWhinney Creek. The main channels of these sub-basins are within the summer fog belt, but the ridges and higher tributaries may at times be above the fog. Because of this location and that they are generally south-facing, the summer temperatures are likely to be quite high in these streams.

Main channels are all UG types, typically greater than 1.5 percent gradient, and have many steep lateral drainages. Most of the tributary drainages are Class III gullies, and the Class II side drainages are generally very steep. Channel surveys in this sub-basin group are OEI-28 and NU-44 on McWhinney Creek; NU-22, NU-23, NU-24, NU-28, OEI-18, OEI-20, OEI-38, OEI-39, HC-05, HC-09, and PALCO monitoring station 168 on Bridge Creek; OEI-15, OEI-40, NU-12, NU-14, and NU-15 in Browns Gulch; and OEI-13 and OEI-19 in Dunlap Gulch.

Steelhead and resident trout may use Bridge, Browns, and McWhinney Creeks up to their headwaters. The lack of gravels in the Wildcat substrate limits the desirability and likelihood of use. Most likely use will be for juvenile rearing and stormflow refuge from the North Fork.

Most of the initial harvesting of these sub-basins occurred during the 1930s. Some portions of the Bridge Creek and McWhinney Creek headwaters were harvested using ridgetop railroad systems coming over from Freshwater Creek. The lowest portions of Dunlap Creek and Browns Creek near the North Fork mainstem were harvested in the late 1800s. Many of these tributary channels were probably covered by corduroy logs and used as haul roads during this period.

Most of Dunlap, Browns, and Bridge Creeks were partially harvested in the 1990s using both tractor and cable yarding. Most of McWhinney Creek was partially harvested in the 1998-2000 period using cable yarding methods. Substantial riparian buffer areas were left around the McWhinney mainstem. The central portions of Bridge and Dunlap Creeks were harvested in the 1970s and ‘80s using unspecified harvest and yarding methods. There was also a similar large clearcut adjacent to these units completed in 1990. These harvests extended from the ridgetops down the steep sideslopes to the creek and are related to some of the highest densities of non-road-related landsliding in this sub-basin group.

Current Status

Sediment Inputs. This sub-basin group contributes a high percentage of the sediment in the Elk River channel system. Bridge Creek has been one of the highest contribution per unit area sub-basins in the ERSC. The largest sediment source in the North Wildcat sub-basin group is stream-side landslides attributed to natural causes. The next largest source is management-related shallow landslides. Road-related stream-side landslides is the other large management-related sediment source.

Road densities are relatively high in these sub-basins. Although the newer roads are built along ridges, there are many that run very close to channel heads and down to the mid-slopes that can be problematic in this steep terrain. Many of the road-related failures are related to the old stream-adjacent railroads and crossings.

Riparian Condition. The riparian zones of nearly all of the North Wildcat sub-basin channels consist of Conifer-Medium-Dense trees that are on the verge of crossing over to the Conifer-Large-Dense category. LWD recruitment potential is adequate and shade is high. The exceptions are a few short Conifer-Small-Dense reaches that consequently have poor LWD recruitment potential. Because those channels are small, it will not be long before even those riparian trees are large enough to provide adequately sized LWD to meet PFCs.

Mass wasting is an important LWD recruitment mechanism in these sub-basins. However, because of the minimal fish and amphibian use and lack of transport capacity in the channels, the LWD in these channels provides little habitat function. The most important function provided is the sediment trapping and metering they provide.

Channel Condition and Response. The Wildcat geology results in stream channel beds that are made up almost entirely of fine material. This material often forms a smooth bed of cemented material with very little surface substrate. These sub-basins tend to have large instream deposits of wood and debris deposited by landslides on the valley sideslopes. These channels do not have the capacity to move large material and trees, and these deposits remain where they land. Because of the fine material in the deposits and in the channel bed, these deposits cement and appear to form dams that may persist for long periods.

Channel segment NB1 at the bottom of Browns Gulch was one of a few channels in the watershed identified as probable to have a channel migration zone present (Appendix E, Attachment E-1).

Temperature Response. The MWAT at the mouth of Bridge Creek never exceeded temperature standards in a 3-year monitoring period (2000 to 2002). Stream temperatures in McWhinney Creek were quite warm in 2002. The MWAT was over 16 C and the peak maximum was over 18 C. These temperatures are still not extremely warm and are below the lethal thresholds for salmonids and amphibians that use them. Clearly, though, warm water temperatures have the potential to be a minor problem in these south-facing sub-basins despite high riparian shade.

Aquatic Resource Vulnerabilities

The main use of these channels is for rearing and refuge by trout species, and the most likely vulnerability is the blockage of access by large cemented debris dams. The contribution of warm water to the main North Fork could be contributing to the peak temperatures in that river.

Expected Future Condition

Further thinning or more complete harvesting of these sub-basins in the near future is likely due to the size of the even-aged stands apparent in aerial photos.

Riparian buffers, which in the future will be left on Class II as well as the Class I streams, will continue to grow and are likely already to have achieved Large size class.

Continued mass wasting related to the old road system may persist for some time. However, it is likely that the worst sites were triggered during the period studied because of the potential influence from a high concentration of storm events that tend to influence factors that may contribute to increases in landslide rates.

Hillslope landslides not related to roads are likely to be significantly reduced as a result of the new prescriptions and mass wasting rules. The storms of the 1990s probably aggravated the condition of the susceptible landslide areas left from the 1970s, '80s, and 1990 clearcuts, and the 1990 unit has already regenerated into Conifer-Small-Dense according to the riparian vegetation status of the Class II streams that would have had no buffer left in 1990 (Map D-1).

Sediment and debris dams in the large lower-gradient channels will vegetate on their edges and incise where the stream flows. Material that is not well outside the main flow will gradually winnow out and move downstream. It is possible that these dams will cause the channel to plug up and that dam-break floods will occur in the moderate-gradient (4 to 8 percent) channels. However, even in that case, much of the wood debris is too large to be transported very far and rapid deposition would occur. Because of the low aquatic species use, consequences for them are limited.

Lower North Fork Sub-Basin

The Lower North Fork (Lower NF) sub-basin includes the North Fork Elk River from the Lake Creek confluence downstream to the junction of the North and South Forks of Elk River. Most of this sub-basin is underlain by the Wildcat. There are small areas of the Hookton Formation mapped on the ridgetops, and the river flows into quaternary alluvium just above the confluence with the South Fork. Soils mapped by the NRCS are mostly Larabee with narrow strips of bottomland and terrace soils adjacent to the river. Farmland and those associated soils overlie the alluvium at the lower end of the sub-basin. Erosion hazard is extreme and high along most of the valley slopes confining the river to the south. Hazard is moderate on the valley bottom and terraces, and then tends to be moderate or high up on the hillslopes. Average annual rainfall is about the same as for the contributing North Wildcat sub-basins, ranging from 46 to 54 inches. This sub-basin experiences summer fog, which helps somewhat to moderate summer temperatures.

The main North Fork channel is predominantly low-gradient and gravel bedded (MSG), although it transitions to a fine-dominated bed (MSF) about a mile from the confluence. The MSF channel segments (N1x, N1y) are incised into a fine-sediment floodplain. The lower MSF section appears to begin at the upstream extent of the Quaternary alluvium mapped by McLaughlin et al. (2000). The extent of the fine sediment material making up the entire floodplain at this location indicates that this channel has had this character since long prior to the start of logging. Channel surveys in this sub-basin are PL monitoring station 14 (Bible Camp) and reach PL5; OEI-12, OEI-25, OEI-27, OEI-02, OEI-03, and OEI-26; various unspecified NRM surveys; and several field observations by Hart Crowser.

The four salmonid species of concern use the mainstem North Fork for migration, spawning, and rearing. The highest densities of juvenile coho documented on the North Coast are present in this sub-basin at a monitoring site near the Church Camp (Table F-4).

The lower North Fork Elk River was first harvested in the late 1800s and early 1900s using steam donkeys, oxen hauling, and river driving. Roads and railroads were built along the main channel during this period. Recent (1990s) harvests were alternating partial cuts and clearcuts using tractors on the north side of the sub-basin and cable-yarded clearcuts on the steeper units on the south side of the sub-basin.

Current Status

Sediment Inputs. Sediment introduced to the stream channel network in this sub-basin per unit area are, at 1,900 tons per square mile annually, one of the highest in the watershed and nearly the same as from the Lower South Fork. The highest source is from road-related shallow landslides, which contributed on average nearly 2,200 tons per year. There is a high concentration of these coming off the system of mid-slope and stream-adjacent roads that were last used for timber harvesting in the mid-1990s on the south valley sideslopes (Map A-2).

The next largest sources are natural and road-related stream-side landslides, both at about 670 tons per year. Most stream-side landsliding appears to be concentrated along steep inner gorge Class II tributaries.

Riparian Condition. Currently the riparian vegetation consists of large sparse conifers with an underlayer of small dense hardwoods along most of the mainstem. The lowest mile of river is bordered by small sparse hardwoods on residential and agricultural properties outside of PALCO's ownership. There is poor LWD recruitment potential throughout this sub-basin with the exception of some small Class II tributaries, and stream canopy cover is generally quite low (40 to 70 percent).

Bank erosion is the highest source of natural LWD recruitment to the North Fork in this reach. However, since the riparian has limited source material, the highest actual source of LWD recruitment is artificially constructed log jams.

Channel Condition and Response. Channel migration is probable throughout this sub-basin, although this should be evaluated for particular sites because incision into stream-adjacent terraces may preclude migration in many places.

Temperature Response. Stream temperatures in the mainstem through this reach get quite warm and regularly exceed peak temperature standards during the summer months. Data from four monitoring years show mean weekly average temperatures are typically between 17 and 18 degrees C and peak maxima exceed 20 C (Table F-6). The low elevation and generally moderate coastal climate contribute to these temperatures. However, the lack of large coniferous riparian vegetation and shade along several miles of this channel upstream from the monitoring point is probably the dominant factor.

Aquatic Resource Vulnerabilities

Warm stream temperatures may be detrimental to the growth and success of juvenile salmonids that use this channel heavily for rearing. The presence of deep, protected pools and access to cooler tributaries become more important when juveniles need to find refuge from warm summer water temperatures. Pond turtles and foothill yellow-legged frogs should thrive in this environment.

Expected Future Condition

Sediment introductions in this sub-basin should decline over the next few years as the clearcuts on the south side continue to revegetate and recover, and with the implementation of new mass wasting harvest rules, including inner gorge protections. Road stormproofing improvements should also reduce fine sediment inputs and reduce landslide hazard.

This sub-basin will continue to route fine and coarse sediment from upstream reaches and tributaries for many years to come; according to O'Connor's sediment routing study (Appendix E, Attachment E-2), sediment routing times can be on the order of centuries in this basin. However, the reduction in local contributions should reduce fine sediment volumes and turbidity in the near future and may even result in a downstream shift of the MSG/MSF transition.

Temperatures will continue to be warm in this sub-basin.

South Fork Sub-Basin

This sub-basin consists of the mainstem of the South Fork Elk River from Bear Wallow and Elkhead Springs down to the confluence with the Little South Fork. The sub-basin is dominated by the Yager geologic unit with Wildcat mapped on the upper sideslopes and ridges. The NRCS has mapped Hugo soils on areas generally underlain by soil associated with the Yager, and mapped as Larabee soils on the upper hillslopes and ridges that are underlain by the Wildcat. Soils erosion hazard is rated moderate on most of the sideslopes adjacent to the river, although there are a few areas of extreme hazard inner gorges (esp. segments S4b and S5). Higher on the sideslopes and in small drainages near the ridges erosion hazard tends to be high and extreme.

The South Fork sub-basin experiences a wide range in annual rainfall, ranging from 56 inches at the bottom to over 71 inches at its head. Much of this sub-basin extends up above the summer fog line and is subject to very warm temperatures. Few of the drainages are south-facing, however, which reduces exposure to direct sunlight.

The main channel is moderate gradient (1.5 to 6.5 percent) and in consolidated geology (CG). The substrate tends to be large cobble/boulder throughout much of this sub-basin. There are many north-facing Class II tributaries on the south (left) side of the river. Tributaries on the north side are mostly steep Class III drainages. Corrigan Creek is the largest tributary, and although it is on the north side of the sub-basin, it flows in its own west-draining valley. Channel surveys in this sub-basin group are HC-11, HC-12, and HC-13; PALCO monitoring station 188; and twenty amphibian habitat surveys.

The four salmonid species of concern could potentially use the mainstem South Fork up to the Headwaters Reserve just below Elkhead Springs and up the lower reaches of Corrigan Creek to the geologic passage barrier at segment SC1y. Steelhead and resident trout continue up the South Fork segment S9 into the Headwaters Reserve.

The upper portions of the South Fork sub-basin were apparently not entered until the 1970s, '80s, and '90s. There are still large blocks of unharvested old-growth forest that are now protected as part of the Headwaters Reserve. Most of the rest of the sub-basin was probably first harvested in the late 1800s and early 1900s to serve the mill at Falk (see Milliman 1995). Stand age maps indicate that this area was again harvested in the 1940s, '50s, and '60s with several re-entries in the 1990s to 2001. Tractor yarding has been typical in the upper portions of this sub-basin, while cable yarding is more common in the lower, steeper sideslope portions. There is a high density of abandoned mid-slope roads with many stream crossings that is typical of mid-twentieth century harvesting.

Current Status

Sediment Inputs. The South Fork sub-basin sediment contributions normalized by unit area are about average for the watershed as a whole at 610 tons per square mile annually. The largest source is natural-related stream-side landslides at 2,200 tons annually. Most of these occurred along the main South Fork on the steep sideslopes adjacent to the river. Road-related stream-side landslides are the next largest source at 700 tons annually. These occurred in high concentrations in relation to a system of mid-slope secondary and abandoned roads in the central portion of the sub-basin (Map A-2). Slides tended to occur where these roads cross steep inner gorges of tributaries. Road- and management-related hillslope landslides are also significant contributors. Soil creep is a large contributor in this sub-basin at 542 tons annually.

Riparian Condition. The uppermost reaches of channel, in the Headwaters, primarily has riparian zones consisting of large dense conifer. Downstream reaches of the mainstem have riparian zones dominated by either small or medium-sized dense mixed conifer and hardwood. There is 1-mile-long reach that has dense medium-sized conifer. Recruitment potential is poor in the reaches and small tributaries immediately downstream of the Headwaters boundary and at the downstreammost segment; and adequate on the rest of the mainstem and minor tributaries. Corrigan Creek has adequate recruitment potential along its lower fish-bearing reaches, and poor potential upstream. Stream canopy cover is high throughout the sub-basin.

Channel Condition and Response. Channel surveys show moderate-gradient channels dominated by gravel or cobble and having little embeddedness. Steep channels frequently appear to have many fines, even in CG channel types. Amphibian habitat surveys confirm that fines make up less than 40 percent of the bed substrate in most CG channels in this sub-basin, but greater than 50 percent in all UG channels.

Although there are frequent pools in mainstem channel segments (meet PFC targets for number of pools), there is a notable lack of deep and wood-formed pools. This corresponds to the overall lack of LWD in the South Fork. Whereas the North Fork has benefited from numerous logjam installations, the South Fork does not appear to have had such intensive restoration efforts to date. This will presumably change as the new landowners develop management and restoration plans.

Temperature Response. The one monitoring station in the South Fork sub-basin just below the confluence of Corrigan Creek shows cool summer water temperatures in the mainstem. The MWAT was only 13 C and the peak temperature never exceeded 15 C.

Aquatic Resource Vulnerabilities

The general lack of wood in fish-bearing stream channels results in a lack of habitat structures and other wood benefits for fish and amphibians. Because of this, the channel confinement and moderate gradients, and a lack of off-channel refugia, scour of redds and flushing of juveniles may be a problem in the flashy storm flows this system experiences. The lack of deep pools provides little refuge for rearing juveniles and migrating adults.

High contents of fine material in steep CG channels can embed rocky substrate and compromise both torrent salamander and tailed frog rearing and refuge.

Expected Future Condition

We expect that river restoration efforts will begin to be implemented over the next few years. PALCO has improved several roads on the south side of the mainstem and resumed timber harvesting in that area.

The new road management methods combined with more stringent mass wasting rules and buffers on Class II stream channels are expected to result in minimal sediment inputs in the basin from timber harvesting activities. This combined with the lack of activity over the past few years should result in the continued winnowing and flushing of fine sediment from the substrate in the main channels and in the steep CG channels in the Yager geologic units. Steep channels in the UG Wildcat units will always have fine-dominated beds.

Bank erosion and some stream-side landsliding will always be present on the steep sideslopes, and so be a constant source of coarse and fine sediment to the channel. The closure of the north bank stream-adjacent road and implementation of road abandonment prescriptions that reduce landslide hazards should reduce the dominant source of sediment from road-related stream-side landslides.

The main channel is in the 1.5 to 4 percent forced pool-riffle range, which is responsive to wood input. Input of wood structures and recruitment of large wood from the riparian buffers will result in immediate local increases in the channel structure and habitat diversity by storing sediment in local bars and causing scour of pools in the existing bed.

Summer stream temperatures will remain cool.

Lower South Fork Sub-Basins

This sub-basin group includes McCloud Creek and the mainstem South Fork Elk River from the mouth of the Little South Fork to the confluence with the North Fork. PALCO ownership in the McCloud Creek sub-basin is limited to the lowest reaches of the creek. PALCO no longer owns the land adjacent to the South Fork itself in this sub-basin, although they do own the majority of the land contributing to this reach on both sides of the riparian buffer.

The lower South Fork flows through the Wildcat geologic unit into Quaternary alluvium at segment S1. Soil types are mainly Larabee with farmland in the lower river valley bottom. Soil erosion hazard is moderate to high on upper slopes, high on the valley sideslopes, and extreme in places adjacent to the river and in some of the lateral tributary channels. Average annual rainfall is moderate for the watershed, and summer fog is prevalent.

This section of the South Fork Elk River was subject to extensive log driving, damming, and the scour and deposition associated with those activities. Evidence of terraces from the old log pond and incision from log driving is still present. In the past, bed substrate would have been scoured down to bedrock and very coarse sediment in the reaches where driving dominated. The old log pond at Falk would have filled the bed there with gravels and fine sediment. Many of the impounded gravels and fines would have washed downstream whenever the mill pond dam was released (used as a splash-dam, as it appears it may have been on a photo at the trailhead) and certainly when it was blown up in 1952. A gradual “re-fining” of the downstream streambed may have been occurring since that time.

Channel surveys in this sub-basin group are OEI-SFE1 and OEI-SFE2; PALCO long-term monitoring reach PL6 and monitoring station 175; amphibian habitat surveys SU-15 and SU-20; and several field observations by Hart Crowser personnel.

Trout and steelhead could use McCloud Creek mainstem segments SB1 and SB2, although usage is likely to be low due to the dominance of fine sediment in the Wildcat/Hookton unconsolidated geology streambeds. The four salmonid species of concern use the lower South Fork Elk River extensively, and this is one of the prime areas of spawning and rearing habitat in the watershed.

The old mill town of Falk built early in the 1900s sits in the middle of the Lower South Fork sub-basin. This sub-basin group was first harvested around the turn of the twentieth century (Milliman 1995). Indications of overstory stand age indicate that this area was reharvested in the '40s and '50s. Many abandoned stream-adjacent roads appear on maps of this sub-basin and fewer mid-slope roads than farther up the basin. PALCO has no records of recent harvests on PALCO-owned land since that time. However, harvest records from prior to 1988 are not available, and it is possible that more recent thinning harvests have occurred.

Current Status

Sediment Inputs. Normalized sediment input for this sub-basin group is highest of all groups, and the Lower South Fork sub-basin is the highest at nearly 2,000 tons per square mile annual input. The largest source is management-related hillslope landslides. Natural hillslope landslides are the next largest source and account for about half the annual input of management-related. Stream-side landslides, both natural and road-related, are also large contributors. High landslide concentrations exist in McCloud Creek and near the mouth of the Little South Fork.

Surface erosion from roads is a significant contributor in this sub-basin, due in large part to the dense system of secondary native-surfaced roads in McCloud Creek. A few sections of old mainline roads adjacent to the South Fork mainstem are also notable sources.

Riparian Condition. The upstream reach of the South Fork in this sub-basin group is bordered by large sparse conifer. The middle and lower reaches are bordered primarily by small, dense hardwoods. Tributaries have riparian zones of large sparse conifer over a dense layer of small mixed hardwood and conifer or small dense conifer. LWD recruitment potential is poor throughout this sub-basin group. Stream canopy cover is high along reaches of the mainstem and tributaries except for the upstreammost (S3a) segment of the mainstem.

Channel Condition and Response. Observations of the South Fork mainstem indicate a degraded, incised pool-riffle and forced pool-riffle channel that is lacking in LWD. The substrate is dominated by gravels, and bedrock outcrops are common, especially near the old town of Falk. There are substantial amounts of fine sediment in the lower reaches, and the channel transitions to MSF not far downstream of the Headwaters trailhead. Terraces exist along much of the observed river length. These are low and may be the old floodplain prior to the installation of the dam(s) at Falk and possibly upstream. The presence of the dam and use of the river for log drives would have severely degraded the channel bed and made terraces of the old floodplain. The current lack of LWD in the channel slows or prevents the regeneration and aggradation of the channel bed.

The entire South Fork in this sub-basin has the potential to have a significant channel migration zone. Areas of particular likelihood are near the downstream end where the river has retained its connection with the floodplain. Individual sites should be evaluated because there are many hillslope-confined reaches, and terraces may be high and resistant enough to preclude migration on others.

Temperature Response. Data from one temperature monitoring station near the mouth of the South Fork indicate that temperatures in the South Fork get warm, but not extremely high. The MWAT ranges from 15 to 16 C and they peak between 16 and 17 C. These are significantly lower than those at a similar location in the North Fork. Unlike the lower North Fork, the lower South Fork has high canopy cover along the lower few miles of its length, which undoubtedly helps maintain cooler temperatures.

Aquatic Resource Vulnerabilities

The general lack of wood in fish-bearing stream channels results in a lack of habitat structures and other wood benefits for fish and amphibians. Because of this, the relatively high channel gradients, and a lack of off-channel refugia, scour of redds and flushing of juveniles may be a problem in the flashy storm flows this system experiences. The lack of deep pools provides little refuge for rearing juveniles and migrating adults.

Expected Future Condition

Likely future activities include upgrading roads in these sub-basins, harvesting of mature timber on the south sideslopes, and possibly wood placement and other fish habitat restoration activities in the main South Fork by the agencies that now manage the Headwaters Reserve riparian zone. A management plan for the old South Fork mainline that is now used as a hiking trail is an objective for the Headwaters' current land managers, so there will presumably be decreases in the sediment contributed by that source. Upgrades to the south side main road will decrease future inputs from that source, although increased road usage in the next few years will trend sediment inputs the other direction.

LWD structures placed in the channel will help to retain fine gravels and sands in dispersed locations throughout this reach of the South Fork. Other future conditions will be similar to those for the South Fork sub-basin group.

Tom Gulch Sub-Basin

Tom Gulch flows into the Lower South Fork (Lower SF) sub-basin. It is entirely formed in Wildcat geologic map unit and has moderate to high soil erosion hazard throughout most of the drainage. Areas of extreme hazard exist in headwall areas of the uppermost basin and along channel segments SA1 and uppermost SA4. Annual rainfall is moderate, and summer fog is prevalent in the lower basin.

The mainstem channel is fairly low-gradient UG channel type. The UG0 segment at the mouth probably has a significant channel migration zone associated with it. Tributaries are small steep Class III lateral gullies on the mainstem sideslopes. Channel surveys in this sub-basin are the amphibian habitat surveys SU-12 and SU-13.

Trout and steelhead could use the majority of Tom Gulch mainstream and the largest tributary, although usage is likely to be low due to the dominance of fine sediment in the areas mapped as Wildcat/Hookton unconsolidated geology streambeds. Coho and chinook salmon are likely to use the lowest segment of Tom Gulch (SA1) where the gradient is low and any gravels accumulate.

The initial logging history of Tom Gulch is unknown because it was only recently acquired by PALCO. Presumably it was first harvested in the late 1800s and early 1900s when the rest of the lower Elk River Basin was cleared. However, it may not have been entered until the 1940s and '50s due to transportation limitations. The entire sub-basin was cut in the 1940s and '50s, as indicated by the age of the current overstory timber. There is a very dense network of abandoned stream-adjacent and mid-slope roads that is typical of tractor/truck harvesting/hauling from that time.

Current Status

Sediment Inputs. Overall normalized sediment input for this sub-basin is the low end at 444 tons per square mile annually. Natural stream-side landslides are the largest source, but only contributed 300 tons annually over the calculation period. Road-related stream-side landslides are next highest at 250 tons annually. Contributions from road-related stream-side landslides are expected to continue due to the high road density and the length of road adjacent to stream channels.

Riparian Condition. The upper portions of the channel network are bordered by dense, medium-sized conifer. The main reach, however, consist of small, dense hardwoods. Recruitment potential is poor along that reach, but good on the upstream channels. Stream canopy cover is high throughout the sub-basin.

Mass wasting is likely to be the dominant recruitment mechanism in the main part of the sub-basin, and bank erosion will dominate the lowest reaches.

Channel Condition and Response. The limited survey data from Tom Gulch indicate low in-channel wood and high fines content in the substrate. Because this basin was harvested in the 1940s and '50s, it was probably subject to channel filling and may have effective relic wood in the main reaches. On the smaller upper channels, most wood is probably above the active channel.

Temperature Response. There are no temperature monitoring stations in this sub-basin. However, the high canopy cover and the fact that it is north-facing suggest that temperatures in the mainstem probably remain moderate throughout the summer. Temperatures measured during channel surveys were 10 and 11 C.

Aquatic Resource Vulnerabilities

Salmonids using this channel are vulnerable to the lack of LWD in the channel. The most likely salmonid use of the mainstem of Tom Gulch is for rearing, and LWD creates both refuge and pool structure and provides substrate for the growth of organisms on which salmonids feed.

Red-legged frogs should find the mainstem habitat desirable, especially in locations where landsliding has deposited wood and possibly formed small ponds in and near the channel. They may be vulnerable to the lack of wood that provides structure and habitat diversity in the channel.

Expected Future Condition

The riparian zone will continue to grow and eventually will have timber large enough to supply this stream with a steady supply of LWD. However, timber growth in this basin appears to be relatively slow, so this process may take longer than in other sub-basins.

Implementation of the new road maintenance plans should substantially reduce sediment input from the largest management-related source. However, channels in this sub-basin will always be dominated by fine material substrate because of the geology.

Hookton Sub-Basins

This sub-basin group includes Railroad Gulch, Clapp Gulch, and the mainstem Elk River from the North and South Fork confluence down to the mouth. The small portions of PALCO land in the Fields Landing and main Salmon Creek sub-basins are also included in this group. The geology of these sub-basins is dominated by the Hookton formation. The Gulch drainages have cut down through the Hookton sub-unit to the underlying Wildcat in those sub-basins. The mainstem Elk River floodplain is underlain by Quaternary alluvium. Hillslope soils are overlain by Larabee, and the floodplain soils are Farmland type. Erosion hazard tends to be high on the hillslopes and moderate in the floodplain areas owned by PALCO. Small areas of extreme erosion hazard exist, especially along the left bank of both Railroad Gulch branches. Total rainfall in this part of the watershed is relatively low at less than 50 inches. There is extensive summer fog in the lowlands.

The Clapp Gulch and Railroad Gulch main channels are low-gradient alluvial channels for the lowest few hundred meters where they cross the Elk River floodplain. Clapp Gulch then becomes a series of UG3 channel segments to its headwaters; tributaries are also UG3 channels. Railroad Gulch remains low-gradient for the first half mile or so before increasing to UG3 above the road crossing. The main Elk River is low-gradient MSF channel to the estuary and meanders across a broad agricultural floodplain consisting of fine sediments. Smaller tributaries are also UG3 channel types.

Channel surveys in this sub-basin group are OEI-29; amphibian habitat surveys SU-3, SU-4, SU-5, SU-6, SU-10, and SU-11; and PALCO monitoring station 166. Numerous field observations were also made by Hart Crowser personnel in Railroad Gulch, Clapp Gulch, and on the mainstem.

A few juvenile trout/steelhead have been observed in the mainstem of Railroad Gulch. They presumably use Clapp Gulch as well. Numbers are low, and they are assumed to be using these channels for rearing, since there is a lack of spawning areas in these streams. The four salmonid types of concern use the mainstem Elk River up to the North and South Fork confluence, primarily as a migration corridor to the more appropriate habitats up the North and South Forks. PALCO land in the Salmon Creek and Fields Landing sub-basins has only Class III streams with no fish use.

As with Tom Gulch, the initial logging history of Railroad and Clapp Gulches is unknown because it was only recently acquired by PALCO. Presumably it was first harvested in the late 1800s and early 1900s when the rest of the lower Elk

River Basin was cleared. There is anecdotal evidence that there was once a railroad that went up Railroad Gulch (hence the name) and over to the adjacent Salmon Creek or Fields Landing Watershed, although the source of that information and details about the railroad route have not been located. Both sub-basins were cut in the 1930s, ‘40s, and ‘50s, as indicated by the age of the current overstory timber. There is a network of abandoned stream-adjacent and mid-slope roads that is typical of tractor/truck harvesting/hauling from that time. More recent units were apparently reharvested in the 1980s and ‘90s.

The lower mainstem Elk River Basin was cleared in the 1800s for timber and agricultural purposes and has remained primarily in agriculture ever since. Local farmers have noted that they used to clear the river channel of vegetation and accumulated wood and sediment on a regular basis, but have had to stop since the late 1970s due to restrictions from the US Army Corps of Engineers and Fish and Wildlife. Over the last few decades there have been an increasing number of non-farm residences built in the valley that are subject to flooding and that draw on the river and the limited groundwater for their water supply. Dikes have been built along some portions of the mainstem.

The spit that borders the Elk River entry into Humboldt Bay has grown and extended since 1954. It is unclear whether this is due to an increasing sediment load or to the cessation of dredging of the estuary. The length of the remains of one old pier out into the bay indicates that sediment accumulations from the river have been a problem since at least the time that the pier was built.

Current Status

Sediment Inputs. Clapp and Railroad Gulches and the mainstem are the sub-basins of most concern in terms of sediment inputs that PALCO has influence over. In the mainstem, the largest source accounted for road-related stream-side landslides, which have contributed over 1,000 tons annually for the analysis period. These appear to have occurred in an inner gorge of the small tributary west of Clapp Gulch. Natural stream-side landslides and bank erosion are the other sources of substance.

Natural stream-side landslides are also substantial sources for sediment in Railroad Gulch and Clapp Gulch, contributing about 250 tons annually in each sub-basin. Railroad Gulch experienced high contributions from management-related hillslope landslides, averaging about 450 tons annually. Gullies were a significant source in Clapp Gulch. Total contributions from these sub-basins, normalized by area, are somewhat higher than the watershed average at approximately 1,000 tons per square mile annual delivery.

Preliminary sediment monitoring results from just downstream of Clapp Gulch (upper end of Segment M1y) indicate a decrease in sediment transport between the lower ends of the North and South Forks and the upper end of the main Elk River (Kate Sullivan, PALCO, personal communication, January 28, 2004). This is despite inputs from Railroad Gulch and Clapp Gulch in the intervening reaches.

Riparian Condition. Most of Clapp Gulch, Railroad Gulch, and the tributary in the drainage next to Clapp Gulch have riparian zones consisting of sparse large conifers with an understory of small dense mixed conifer and hardwoods. The mainstem on PALCO property has riparian zones consisting of mixed small dense trees. There is poor LWD recruitment potential throughout these sub-basins. Stream canopy cover, however, is quite high. It is better than 70 percent over the smaller tributaries, and higher than 85 percent over the mainstem and the larger tributary streams.

Mass wasting is the dominant LWD recruitment mechanism in most of Clapp and Railroad Gulches. Bank erosion and mortality are the dominant LWD recruitment mechanisms on the mainstem Elk River.

Channel Condition and Response. Stream beds in this sub-basin group are completely dominated by fine material, with very few patches of small gravels. Wood loading tends to be quite low, although there may be local concentrations in the gulches and the downstream tributary where landsliding deposited wood that is unlikely to move. Large wood is virtually non-existent in the main Elk River due to clearing for flood conveyance reasons.

The entire lower Elk River floodplain is a channel migration zone, although the channel has been controlled and channelized for decades. Although flooding of the entire valley has occurred on multiple occasions, the main river channel has remained in its current locations throughout the photo record.

Aggradation of the mainstem channel has been reported and is discussed in other sections of this report.

Temperature Response. The one temperature monitor on the lower mainstem for which we have data is just below the confluence of Clapp Gulch. Data at this site suggest that stream temperatures are moderated between the lower North Fork and this location. Peak temperature in 2002 was below 18 C, and the MWAT was below 16 C. This moderating is probably due to high riparian canopy cover along the mainstem combined with the cooling influence of the South Fork and tributaries. Cool groundwater inflow from the hillslopes into the floodplain in this upper portion where the floodplain is still relatively narrow may also be a factor.

Resource Vulnerabilities

The addition of large wood to the gulch mainstems could provide more channel structure, refugia, and feeding substrate for rearing trout and amphibian species.

Fish and other biota using the mainstem may be vulnerable to the nutrient loads input from the agricultural lands and the direct access to and use of the river channel by livestock. Any rearing fish are vulnerable to high temperatures in this reach during the summer.

Pond turtles are vulnerable to the lack of off-channel habitat and ponds that once existed along the lower Elk River and to the lack of large wood in the channel that provides basking sites and the formation of deep refuge pools.

Expected Future Condition

Natural and road-related stream-side landslides in inner gorges are expected to continue due to the nature of the geology and soils in these sub-basins and to the legacy stream-adjacent roads. However, future timber harvesting is likely to lead to improvement and stabilization of those legacy roads and/or construction of stable modern roads that have low likelihood of failure and causing sediment introductions to the stream channels. Management-related hillslope landsliding is expected to decrease in the future from levels observed over the analysis period due to the more restrictive current harvesting and road construction activities in landslide hazard areas. However, channels in these sub-basins will continue to be dominated by fine substrate materials because that is what is present in the geologic lithology and soils.

Riparian wood recruitment potential will increase over time throughout the sub-basin under current forest practice and HCP rules, although it will remain poor for quite some time. Large trees are needed to provide adequate key pieces in the large mainstem Elk River channel, and these will take a long time to grow from the current small conifers present. Constructed wood features could be placed to form channel habitat features if it were determined that salmon and pond turtle habitat were higher priorities than the current flood conveyance priority.

Shade is expected to remain high on all channels from hardwood and shrub cover as the riparian conifers regenerate.

Little Salmon Sub-Basin

The Little Salmon sub-basin includes the main upper portion of Little Salmon Creek down to where the creek crosses the Hookton Road, and includes all of the PALCO ownership in this part of the Salmon Creek WAU. Little Salmon Creek flows along a mapped thrust fault (McLaughlin et al. 2000) at the edge of the Hookton and Wildcat group geologic units until it reaches the flatter Quaternary alluvium about a mile downstream of PALCO's ownership boundary (Map 2). Soils are dominated by fine-grained, erodible Larabee soils on the sideslopes and bottomland soils in the flat valley bottom. Annual rainfall is moderate for the north coast (47 to 53 inches), and this drainage is generally within the summer fog zone.

The main channel is a small, low-gradient Class II and Class I UG1.5 that appears to be incising through old valley infill material, probably from previous logging. Tributary channels are small and minor UG Class II channels. The only channel survey in this sub-basin is HC-01, although the main channel was inspected by Hart Crowser personnel from its head down to the Class II/Class I transition in a wetland. None of the channel reaches inspected appears to have very high transport capacity.

The only fish presence survey recorded for Little Salmon Creek did not identify salmonids. As has been observed in other watersheds, the nature of channels in unconsolidated Wildcat and Hookton geology makes them undesirable salmonid habitat, and although they could be used, the potential is low. The main channel is classified as high potential red-legged frog habitat, and the presence of red-legged frogs was noted during the field survey. Potential for other amphibian species is low throughout PALCO's ownership. There is potential northwestern pond turtle habitat in the marsh at the top of the Class I reach, if the channel pools could get deep enough for their use.

The entire sub-basin is forestland. It was first harvested in the late 1800s, although some areas were not harvested until as late as the 1960s. Stream-side and valley bottom areas were harvested during the 1950s and '60s during the tractor era. The stream and valley bottom was probably filled in and used as a yarding road at that time. That is consistent with the current appearance of the stream downcutting through a flat terrace filling the valley, and stocked with trees that appear to be about 40 or 50 years old. Recent harvesting since the late 1980s has consisted of patch clearcutting using both tractor- and non-tractor-yarding methods.

Current Status

Sediment Inputs. The Little Salmon Creek sediment contribution to the channel network, normalized by area, is in the moderate range at 861 tons per square mile annually. Road-related inputs are the dominant source overall. Stream-side landslides attributed to natural causes are the next largest source. Consistent with the level of sediment input and the nature of the sediment associated with unconsolidated geologies, channel survey results show that the substrate consists only of small gravels and fine material.

Riparian Condition. The riparian vegetation is dense on all stream reaches. There are reaches that have small trees, but they are small streams that can be well-shaded by small trees. Although the prevalence of small riparian timber and the general lack of large timber in the riparian buffers is not adversely impacting stream shading, it does present a lack of potential LWD recruitment in the near future.

One potential area of concern is reach LS3, which consists almost exclusively of medium dense hardwoods. The current deciduous riparian vegetation along segment LS3 appeared to be conifer in the earliest photos, indicating that the stream may have been in a more distinct channel and that segment LS3 was once less marshy. This reach may not revert to coniferous forest in the foreseeable future without active management.

Channel Condition and Response. Channels in this sub-basin are going to have fine substrates even in the absence of large sediment inputs, due to the underlying geology. Coarse sediment inputs, such as those from road failures, can easily bury these channels because they have very low stream power and cannot move large material. Other sediment sources are likely to contribute only fines or larger clasts that break down quickly to fines. Although large volumes may temporarily bury the channels, their presence in the substrate is natural and will not otherwise change the channel character significantly.

Channel infilling and landslide debris deposits from first-round logging may have contributed to the formation of the low-gradient marsh surrounding reach LS3. Whatever the origin of the marsh area, that reach is very flat and will continue to serve as a retention area for sediments coming from upstream.

Temperature Response. There are no temperature monitors in or near this sub-basin. However, because the sub-basin is in the cooler fog zone and the main channel is moderately to well shaded, high water temperature is not expected to be a problem. Temperatures measured at mid-day in early September were 11 to 12 C in the shaded, incised Class II stream reach surveyed. The reach through the marsh is less shaded, shallow, and in a broader valley, and so may be subject to stream warming. However, the most likely inhabitants of concern in that reach are pond turtles that prefer warm water temperatures and sunny basking sites.

Resource Vulnerabilities

Salmonids are not vulnerable to conditions in this sub-basin because they do not, and are unlikely to, use it. Amphibians that are likely to be present in these channels are red-legged frogs and northwestern pond turtles, both of which are adapted to and prefer the fine substrate and warm temperatures that may be present here.

Expected Future Condition

The upper channel should continue to cut down and widen through the infill, carrying fine sediment downstream to the flat marsh area downstream at segment LS. Landsliding is likely to continue along the stream-adjacent road and from the recently cut hillslope above it until the forest regenerates. Under current HCP rules, in-unit landsliding is expected to decrease, thereby decreasing the sediment load to the valley bottom and stream channel. Roadside landsliding and sediment production are likely to continue due simply to the geology, topography, and road location. However, sediment produced may not even reach the stream channel due to the presence of a stream-adjacent terrace, and even in-channel will not propagate downstream to fish-bearing waters. Red-legged frogs appear to be thriving in this system despite intermittent bank sloughing, erosion, and landslides.

Aquatic Resource Habitat Condition Summary

Past

Watershed and channel disturbances during early timber harvest practices would have caused large inputs of fine and coarse sediment to streams and increased the flushing capacity of mainstem channels. The clearing of channel obstructions to facilitate log and steam donkey transport in the larger streams probably resulted in channel incision, disconnection of floodplains, removal of habitat features, substrate coarsening, and the loss of salmon redds and fish. Small channels were buried by logs or filled with wood debris and sediment to use them as haul roads. Access to salmonid habitat was restricted due to dams and landslides on the unbuffered streams.

Sediment input was high due to the prevalence of stream-adjacent roads and later extensive mid-slope road network with associated slope failures common to that type of road system; extensive clearcutting; lack of stream-side buffers; landsliding due to unrestricted harvesting of unstable slopes and inner gorges; and filling of channels by later tractor-yarding practices. Larger streams were depleted of sediment by removal of channel obstructions; increased flows due to extensive canopy removal and splash-dam releases; steam donkey and equipment hauling within channels; and driving of logs down stream channels.

Pools were eliminated or reduced in frequency due to the removal of channel structure, especially large wood. Large wood recruitment availability was reduced or eliminated by removal of large riparian trees, although this would have been mitigated somewhat by the practice of leaving non-premium timber and large wood on the ground in conjunction with landsliding that delivered some of this LWD to the channels. Off-channel habitat was reduced when channels incised and became disconnected from floodplains.

Food production (macroinvertebrates) for aquatic resources would have been reduced in channels that were covered or buried and in those where the benthic substrate was removed by flushing or gouging. Water temperatures would have increased due to the removal of the forest canopy shade, although buried channels would have remained a source of cool water input.

Current

Both geologic barriers to fish passage and potentially blocking logjams remain on a few streams in the ERSC. There are no known road-related barriers remaining. There is a good supply of gravel and cobble spawning substrate with low embeddedness in the anadromous fish reaches of mainstem and in the consolidated geology (CG) channels downstream as far as the Bible Camp and below Falk. Downstream of the Bible Camp and Falk, the gravel-dominated substrate transitions to fine-dominated substrate as valley gradient declines and transport capacity is reduced. The channels in unconsolidated geology are dominated by fine substrates, as is typical in those geologies. Class II channels tend to have embedded substrate, even in CG channels.

Pool area and cover tend to exceed APFC targets, but pool frequency is low. This is most likely because instream LWD is generally lacking in the ERSC. Although many of the smaller tributaries have abundant LWD, LWD transport down into the mainstem is limited by the low transport capacity and infrequent debris flows or dam-break floods in those channels. Mainstem channel habitat and aquatic biota rely on and are responding well to numerous constructed wood structures in the larger channels of Elk River. LWD recruitment potential in the riparian timber stands is adequate or on the verge of reaching adequate throughout most of the ERSC. The natural supply of key piece sized LWD is just beginning to enter the stream network.

ERSC streams are generally cool and adequately shaded. The main exception is the lower reach of the North Fork Elk River, where the buffer zones is dominated by a mixed stand of deciduous and conifer trees. Turbidity is highly variable in space and time in the ERSC. Reported peaks, especially in and around tributaries, can reach levels that may cause sublethal effects in salmonids. Duration-exposure data were not available at the time of this watershed analysis. However, PALCO has implemented an extensive on-going turbidity monitoring program and will be able to study and evaluate this parameter in the future.

Future

Fine sediment input to the channel network has and will continue to decrease significantly with the implementation of new road construction and maintenance procedures. Likewise, the implementation of current mass wasting hazard restrictions will reduce sediment inputs of all sizes. Results of these changes will be most strongly seen on Class II channels in consolidated geologies where stream-side buffers and other such protections have not previously extended. Fine sediment will continue to dominate, however, in channels in unconsolidated geologies, despite new forest practices.

Instream LWD will continue to increase as the riparian buffer trees reach key piece size and enter the stem-exclusion stage on upper reaches and bank erosion continues on lower reaches. In addition, some stream-side landsliding will continue to contribute LWD. Continuation of the LWD enhancement program will remain important for the formation of aquatic habitat until stand regeneration and natural recruitment processes can be restored As the LWD loading in channels increases, habitat complexity will increase in association with increased pool frequencies, formation of sediment retention structures, and eventually the connectivity with floodplains and off-channel habitat. Floodplain connectivity will probably result in more frequent flooding in the lowlands and more diversity in riparian timberstands

Stream temperatures will remain cool and may become even cooler as the stream-side canopy matures. The warmest reach of the lower North Fork, however, is not likely to become more shaded until the riparian buffer converts to large conifer trees. Frequent natural disturbances of the floodplain, however, may inhibit full shading of the channel. Turbidity will likely decrease overall, although high peaks will always be present due to contributions from the extensive stream channel network in unconsolidated geologies.

Large-scale monitoring efforts, especially of turbidity and sediment, in Freshwater Creek and Elk River, as well as other property-wide studies, will continue to provide improved information regarding aquatic habitat condition and water quality to facilitate true adaptive management.

PUBLIC COMMENTS

PALCO placed notices that the ERSC Public Review Draft Report was available at the Humboldt County Public Library, Eureka Main Library, 1313 3rd Street, Eureka, CA and at the PALCO offices in Scotia for a 60-day review and comment period in May 2004. No public comments were received either by the end of the comment period (July 8, 2004) or since.

PRESCRIPTIONS

Following the Public Review Draft comment period, the SRT proceeded with development of prescriptions for the ERSC. The agreed-upon prescriptions are included as Attachment 2 and their justifications as Attachment 3.

MONITORING

Past monitoring in this watershed has included juvenile salmonid densities, fish habitat features, channel reach geomorphology, and limited continuous temperature and turbidity monitoring. PALCO has recently implemented an extensive turbidity and sediment transport monitoring program. Data from the first winter of monitoring (2002-2003) are in the preliminary stages of analysis (Kate Sullivan, PALCO, personal communication, January 28, 2004). Preliminary investigation of turbidity versus discharge at several monitoring locations on the Elk River mainstems confirm the hypothesis and observations cited in this report, that fine sediment production generally increases along the gradient of consolidation from Yager to Wildcat to Hookton geologic units. Although the total sediment load values are not yet completely processed, they appear to be consistent with the medium sediment budget estimates of average annual input. The fact that these loads were measured during a year with multiple large storms and must be on the high side of the spectrum lends a relatively high degree of confidence that the sediment budget numbers are overestimates and not underestimates. The measured suspended sediment loads appear to be well below the high sediment budget estimate.

Recommendations

Monitoring recommendations in Watershed Analysis are generally made for two purposes: (1) validation monitoring to increase confidence in critical conclusions (recommended to provide additional information regarding a watershed process that was investigated and identified as an important process, but had a high degree of uncertainty associated with the conclusions); or (2) effectiveness monitoring to determine whether prescriptions are effective at minimizing the effects of land use practices on critical watershed resources. The following are two recommendations that would help to clarify the validity of assumptions and reduce uncertainties in the conclusions of this Watershed Analysis. Additional recommendations from the SRT Prescription team are included in Attachments 2 and 3 (Prescriptions and Justification).

Mass Wasting

Groundwater level fluctuations at the weathered rock/soil contact near the middle and lower slopes as they relate to storm events and management activities are extremely important for slope stability investigations. Monitoring should include stand pipe piezometer measurements of groundwater level changes over time in: a) clear cuts, b) adjacent thinned areas, and c) un-managed areas. The goal of these measurements would be to capture the rise of pore pressure (implied by static water levels or directly measured) at the soil/weathered rock interface in relation to areas of differing management activity as a function of precipitation, soil index characteristics (or measured strength parameters), and slope angles. This monitoring should be completed at a fine enough scale to observe the rapid changes in measurements. These kinds of studies are typically done with the aid of calibrated data loggers that read changes in water levels (or piezometeric pressure using pressure transducers) at carefully selected locations in the stratagraphic profile. It is important that a highly skilled, experienced professional trained in soil mechanics be involved in this monitoring to help ensure: a) proper plan development; b) sound methods for selecting sites, strata, equipment, and soil sample/testing routines; c) adequate installation methods; and d) sound data collection/analyses that are current with standard engineering practice.

Surface Erosion

We have a moderate confidence in the numerical estimates of erosion from harvest units and roads. Some assumptions regarding ground cover or traffic levels could result in different estimates of surface erosion. While monitoring or study of surface erosion rates may be useful to calibrate erosion models, it is not recommended for this watershed because surface erosion represents a small contribution compared to other sources of sediment such as landsliding.

REFERENCES

Abramson, L.W., T.S. Lee, S. Sharma and G.M. Boyce 1996. Slope Stability and Stabilization Methods, John Wiley & Sons, Inc.

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Washington, DC: Island Press.

Blake, T.F., R.A. Hollingsworth and J.P. Stewart, eds. 2002. Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Landslide Hazards in California, by the Southern California Earthquake Center and the American Society of Civil Engineers. See web site: www.scec.org/resources/catalog/LandslideProceduresJune02.pdf.

Carver, G.A. and R.M. Burke 1992. Late Cenozoic deformation on the Cascadia subduction zone in the region of the Mendocino Triple Junction, *In* Burke, R.M., and Carver, G.A., eds., A look at the southern end of the Cascadia Subduction

Zone and the Mendocino Triple Junction: Pacific Cell, Friends of the Pleistocene Guidebook for the field trip to northern coastal California, p. 31-63.

Coghlan, T.M. 1984. A climatologically-based analysis of the storm and flood history of Redwood Creek. Redwood National Park Technical Report 10, Arcata, CA, 47 p.

Conroy, W.J. 1999. A Comparison of Rainfall-Runoff Relations in Elk River, a Small Coastal Northern California Watershed. M.S. Thesis, Humboldt State University, Arcata, CA. 142 pp.

Dengler, L., G. Carver, and R. McPherson 1992. Sources of North Coast Seismicity. California Geology, v. 45, no. 2, pp. 40-53.

Dengler, L. 1997. Recent Earthquakes on California's North Coast. Humboldt Earthquake Education Center, Humboldt State University, Arcata. On the web at: http://www.humboldt.edu/~geodept/earthquakes/recent_eqks.html on October 19, 2003.

Dunklin, T. 1992. "Local Effects of 1991-1992 Earthquake Sequence," in Pacific Cell, Friends of the Pleistocene Guidebook for the Field Trip to Northern Coastal California, June 5-7, 1992.

Falls, J.N. 1999. Geologic and Geomorphic Features Related to Landsliding, Freshwater Creek, Humboldt County, California (OFR 99-10); California Department of Conservation, Division of Mines and Geology (DMG).

Fukushima, L. and E.W. Lesh 1998. Adult and Juvenile Anadromous Salmonid Migration Timing in California Streams. California Fish and Game 84(3):133-145.

Harden, D.R. 1995. A comparison of flood-producing storms and their impacts in northwestern California. In: Geomorphic processes and aquatic habitat in the Redwood Creek basin, northwestern California. U.S. Geological Survey Professional Paper 1454, p. D1-D9.

Hart Crowser 2002. Elk River and Salmon Creek (ERSC) Watershed Analysis Work Plan Outline, Humboldt County, California. Prepared for the Pacific Lumber Company, August 22, 2002.

HEEC 1999. Humboldt Earthquake Education Center. Living on Shaky Ground.

Helley, E.J. and V.C. LeMarche 1973. Historic flood information for northern California streams from geological and botanical evidence. U.S. Geologic Survey Professional Paper 485-E, p. E1-E16.

Huber, O.L. 1992. Sedimentation in a Highly Erosive Watershed: Salmon Creek, Humboldt County. California Geology, Nov/Dec 1992, pp.187-191.

Hull A., and F.S. Shuri 2002. Seismic-disturbance hazards-getting to the source, in Geotechnical Fabrics Report, May 2002, pp. 26-30.

Kelsey, H.K. and G.A. Carver 1988. Late Neogene Quaternary Tectonics Associated With Northward Growth of the San Andreas Transform Fault, Northern California, J. Geophys. Res., 93, 4797-4819.

Kilbourne, R.T., and G.J. Saucedo 1981. Gorda Basin Earthquake North-Western California, in California Geology, March 1981, p. 53-57

McPherson, R.C., and L.A. Dengler 1992. The Honeydew Earthquake, August 17, 1991, in California Geology, v.45, no. 2, pp.31-39.

McLaughlin, R.J., S.D. Ellen, M.C. Blake, Jr., and A.S. Jayko 2000. Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern part of the Hayfork 30 x 60 minute quadrangles and Adjacent Offshore Area, Northern California. USGS, Denver, CO. Available on web at http://geopubs.wr.usgs.gov.

Milliman, J. 1995. Falk: From a timber town to a ghost town. Unpublished essay submitted to the Charles R. Barnum History Award Essays Contest, second place paper. Available in the Humboldt State University Library (Humboldt County Archive Collection). Arcata, CA 22pp.

Munn, J. 2000. California Department of Forestry and Fire Protection Report.

Munn, J. 2001. California Department of Forestry and Fire Protection Report.

OES 1975. Humboldt County Office of Emergency Services, County Emergency Plan.

PALCO 1999a. The Habitat Conservation Plan for the Properties of The Pacific Lumber Company, Scotia Pacific Company LLC, and Salmon Creek Corporation.

PALCO 1999b. An Analysis of Flooding in Elk River and Freshwater Creek Watersheds, Humboldt County, California. The Pacific Lumber Company, Scotia, California.

PALCO 2000. Methods to Complete Watershed Analysis on Pacific Lumber Company Lands in Northern California.

PALCO 2001a. Freshwater Creek Watershed Analysis, draft report prepared for the Pacific Lumber Company by Watershed Professionals Network, Boise, ID. Pacific Lumber Company, Scotia, CA.

PALCO 2001b. Van Duzen River Watershed Analysis, draft report prepared for the Pacific Lumber Company by Tetra Tech. Pacific Lumber Company, Scotia, CA.

PALCO 2002a. Lower Eel River and Eel Delta Watershed Analysis, SRT Review Draft report prepared for Pacific Lumber Company by Hart Crowser, Inc., Fortuna, CA. Pacific Lumber Company, Scotia, CA.

PALCO 2002b. PALCO Watershed Analysis Areas Map. Pacific Lumber Company, Scotia, CA.

PWA 1998. North Fork Elk River Sediment Source Investigation. Report prepared for the Pacific Lumber Co., Scotia, CA.

PWA 1999. Pacific Watershed Associates. Sediment Source Investigation and Sediment Reduction Plan for the Freshwater Creek Watershed, Humboldt County, California, 94 p.

Reid, L.M. 2000. Review of: An Analysis of Flooding in Elk River and Freshwater Creek Watersheds, Humboldt County, California. USDA Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, CA. Prepared for the North Coast Regional Water Quality Control Board.

Rust, D.J. 1984. Coastal Faulting and Erosion Hazards in Humboldt, County, Northern California, Ocean Studies Symposium, California Coastal Commission and California Department of Fish and Game, pp. 821–842.

Tuttle, D.C. 1975. Earthquake Damage in Humboldt County: Memorandum, Humboldt County Department of Public works, June 13, 1975, 8 p.

Wills, C. 1990. Little Salmon and Related Faults, Humboldt, County, California Division of Mines and Geology Fault Evaluation Report FER-215.

Youd, T.L. and S.N. Hoose 1978. Historic Ground Failures in Northern California Triggered by Earthquakes, in U.S. Geological Survey Professional Paper 993.

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