Lower Eel River and Eel River Delta Watershed Analysis
Scotia, California

Cumulative Watershed Effects Assessment

HARTCROWSER
Delivering smarter solutions

Prepared for
Pacific Lumber Company (PALCO)
Scotia, California

6911

REGISTERED GEOLOGIST
WAYNE C. ADAMS
No. 2242
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

EXPIRATION: 01/31/06

CONTENTS Page

CONTENTS (Continued)

TABLES

CONTENTS (Continued)

Page

FIGURES

MAPS

CONTENTS (Continued) Page

LOWER EEL RIVER/EEL RIVER DELTA CUMULATIVE WATERSHED EFFECTS

INTRODUCTION

The Pacific Lumber Company (PALCO) initiated watershed analyses on the Lower Eel River and Eel River Delta Watershed Analysis Units (WAUs) in Humboldt County, California, per the requirements in its Habitat Conservation Plan (HCP) (PALCO 1999). We combined the Lower Eel River and the Eel River Delta WAUs into one large study area we refer to collectively as the LEED to expedite the watershed analysis process on contiguous PALCO ownership blocks in adjacent WAUs that are part of the same watershed. In this Cumulative Watershed Effects (CWE) Assessment, we summarize and integrate information that we developed during the resource assessment phase of the watershed analysis process.

The CWE Assessment is the primary report for the Watershed Analysis, and we provide other work as appendices. The purposes of the CWE Assessment are to evaluate the effects of management practices — both individually and cumulatively — on aquatic resources; document pertinent information and justification supporting the delineation of sensitive areas; and identify specific management actions affecting aquatic resources. We followed the methods detailed in the Watershed Assessment Methods for PALCO Lands (PALCO 2000), which the PALCO HCP Signatory Review Team (SRT) developed, and in the Work Plan for Lower Eel River and Eel River Delta Watershed Analysis (Hart Crowser 2000a).

In this CWE Assessment, we synthesize information from separate resource assessments to tell the story of the watershed. To do this, we draw on information detailed in seven resource assessment modules (see Appendices A through G) and include additional analyses to identify linkages between management practices and potential resource effects. In the module reports we assess the current and past condition of stream channels, fish habitat, and amphibian and reptile habitat in the WAUs, and the effects of management practices on the inputs of coarse and fine sediment, stream flows, heat, and large woody debris (LWD) to streams in the LEED. We encourage the reader to review the resource modules for details on information we used in the CWE Assessment process. In the CWE report, we summarize the key aspects of the individual resource assessments and develop the connections among those resources.

We also present our responses to public concerns about potential resource impacts from logging and to key issues that were defined by the HCP Signatory Review Team.

We provide a summary of our findings in the Causal Mechanism Reports (CMRs). The CMRs specify management actions and associated situations that are determined to have significant effects on the aquatic resources. A Prescription Team was convened to develop prescriptions and methods of operation in the LEED that address the identified linkages between management practices and watershed effects. This team consisted of representatives from PALCO and the signatory and other participating agencies. The prescriptions are provided in Attachment 2 and were subject to the constraints specified in the HCP.

WATERSHED OVERVIEW

Watershed Characteristics

Geographic Setting and Study Area Definition

The Eel River flows down the west side of the northern California Coast Range into the Pacific Ocean at Ferndale, south of Humboldt Bay and Eureka. The Eel River drainage has a basin area of approximately 3,600 square miles (Brown and Ritter 1971). The headwaters arise in the mountains near Ukiah, about halfway between San Francisco and Eureka. The three main forks of the Eel River flow north until they converge at South Fork, just upstream of the watershed analysis study area.

The LEED WAUs together have an area of approximately 136,000 acres (approximately 200 square miles, Figure 1). PALCO owns 36,040 of the 44,265 acres (81 percent) in the Lower Eel WAU and 11,461 of the 91,609 acres (12.5 percent) in the Eel Delta WAU. We depict PALCO ownership in most of the Watershed Analysis maps as the white areas within the LEED WAUs. The study area includes tributaries to the Eel River that are located downstream of the confluence of the South Fork Eel River near Founders Grove. The largest of these are Bear, Jordan, Monument, and Stitz Creeks in the Lower Eel WAU and Strongs, Howe, Atwell, and Nanning Creeks in the Eel Delta WAU. The study area excludes Larabee Creek and the Van Duzen River (those basins are evaluated in separate technical studies).

The mainstem of the Eel River was excluded from the LEED watershed analysis. This was done because watershed processes outside of the LEED have a significantly greater influence on the Eel River at this location compared to watershed processes within the LEED (the LEED watershed analysis area comprises less than 6 percent of the total Eel River basin). Brown and Ritter (1971), for example, reported that the majority of total measured suspended sediment yield (approximately 68 percent of the total suspended sediment load measured at Scotia) derives from the mainstem Eel River upstream of the confluence with the South Fork Eel River and downstream of the confluence with the Middle Fork Eel River. They attributed the remaining 32 percent of the total suspended load to the South Fork Eel River, the Middle Fork Eel River, and other portions of the Eel River basin located upstream of the LEED study area. The reported distribution of sediment source areas suggests that the quantity of suspended sediment contributed from the LEED study area is negligible in comparison to that derived from upstream portions of the Eel River basin. Based on this, we designed the Stream Channel Conditions analysis presuming that activities on PALCO lands primarily manifest their effects within the sub-basin tributaries and not within the mainstem Eel River. We divided the analysis area of the Eel Delta WAU into five sub-basins and that of the Lower Eel WAU into twenty-three sub-basins for this analysis (Map C-1).

Topography

Within the LEED WAUs, two ridges that open to the northwest flank the Eel River Valley, spreading out and tapering down in elevation as the river crosses the delta flats and approaches the Pacific Ocean. Elevation ranges from near sea level on the delta to slightly over 3,000 feet on the southern ridgeline. The Eel River has formed a well-defined floodplain in the valley bottom, and the river meanders back and forth across the floodplain, sporadically intersecting the hill slopes on both sides of the valley. Tributaries to the Eel River are deeply incised into the landscape with low-gradient mainstem channels that typically transition sharply to steep headwater tributaries.

Steep slopes are typically present at the higher elevations and in the inner gorges of the LEED. These slopes are commonly present in the Strongs, Stitz, Kiler, Dinner, Jordan, Bear, Nanning, and Greenlaw sub-basins. Slope angle is controlled mainly by the geologic structure, strength of soil and rock materials in the watershed, and their resistance to erosion. Much of the steep topography in the southern part of the study area is mantled by soil derived from terrace deposits and the more resistant members of the Coastal Belt Franciscan Complex and Yager terrane. In the northern portion of the study area, the soil is related to terrace deposits and weathering of the less resistant underlying

Wildcat Formation and Yager terrane. The resulting topography north of the Eel River tends to be less steep in comparison to the areas south of the Eel River. Low-gradient alluvial areas make up a small portion of the watershed, and they are typically located near the mouths of creeks flowing to the Eel River, and on abandoned, uplifted river terraces.

There are approximately 700 miles of delineated stream channels in the LEED study area (Table 1). Most (70 percent) of the stream network occurs in the Lower Eel WAU and 30 percent occurs in the Eel Delta WAU. In the Lower Eel, the stream density measured from the USGS 1:24,000 topographic quadrangles is 1.2 miles/square mile, and the stream density measured from the more detailed PALCO Hydro layer is 6.9 miles/square mile. The relevant land area in both cases is 69 square miles. In the Eel Delta, the stream density measured from the USGS 1:24,000 topographic quads is 1.3 miles/square mile for all land in the WAU (143 square miles), and the stream density measured from the more detailed PALCO Hydro layer is 7.5 miles/square mile for the PALCO analysis area (29 square miles).

Geology and Soils

Regional Geology

The regional geology of the coastal area in Northern California is strongly influenced by a relatively active tectonic regime. Three plates join at the Mendocino Triple Junction offshore to the west of the LEED, and the coastal area is subject to combinations of transverse motion along one plate boundary and subduction/uplift 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 LEED. The combination of the geologic processes, the types of soil/rock materials, and the amount and levels of groundwater seepage influences the frequency and distribution of landslides in both space and time.

Geologic mapping (Map A-1; McLaughlin et al. 2000) indicates that the majority of PALCO ownership in the Lower Eel WAU is underlain by formations of the Coastal Belt of the Franciscan Complex and the majority of the Eel Delta WAU is underlain by the Wildcat Group (Map A-1). The Franciscan deposits in the LEED are generally late Cretaceous to Tertiary in age and are further subdivided by McLaughlin (et al. 2000) into five main units: cob, co1, co2, co3, and co4. The four numbered sub-units were divided partly based on topographic expression where co1 forms the most gentle and co4 the steeper slopes. Deposits of the younger Quaternary/Tertiary Wildcat Group unconformably overlie the Yager terrane and Franciscan deposits. The rock units of the Wildcat are located in the north and east portion of the Lower Eel WAU and within the lower elevations in the Eel Delta WAU. The Russ fault, a high angle southwest dipping reverse fault that roughly defines the south-west boundary of the Lower Eel WAU, has essentially "pinched out" the Yager terrane and placed units of the younger Wildcat group in contact with the Franciscan co1 and co3 units. The youngest sediments in the LEED, Alluvium and Terrace Deposits, are exposed in the floodplains of the Eel River delta and perched along the banks of the lower Eel River. The distributions of the geology, including mapped landslide deposits, in relation to the total PALCO ownership in the LEED WAUs is provided in Table A-1.

The Wildcat Group consists of poorly compacted sandstones, siltstones, and mudstones, which are erodible and potentially less stable by nature. Their silty and sandy composition results in rapid weathering and the development of granular, non-cohesive soil materials. The sediments have a relatively high susceptibility to erosion where exposed mainly because they are primarily silt- and sand-sized and are geologically young sediments (not indurated into hard rock). Streambed gravels that are derived from Wildcat are typically very soft and can be broken between the fingers; they weather and break down into fine materials once in the stream. Hence, stream channels draining Wildcat geology are often dominated by silts and sands and can have high suspended sediment loads during high flows.

The Wildcat Group dominates the geology of Strongs, Dean, north Stitz, North Central, Sammy-Kari, Darnell, Shively, and Bridge Creek sub-basins (generally those on the north side of the Eel River). The Nanning Creek sub-basin is entirely underlain by relatively more resistant units of the Wildcat Group. These units are moderately indurated sandstones that form steeper slopes in comparison to the rest of the Wildcat Group in this area.

The Coastal Belt Franciscan Complex rock units consist of alternating beds of marine sandstone and argillite, which have been locally sheared and folded. The coarse texture and indurated nature of these materials contribute to lower erosion potential than those in the Wildcat. Similar to the Wildcat, however, this group weathers to sand, silt, and clay, although the soils and streambed deposits have a higher fraction of larger rock that weather more slowly. The Franciscan Complex generally dominates sub-basins on the south side of the Eel River. Monument Creek and the areas west of Rio Dell are almost completely underlain by the more fine-grained co1 unit of the Coastal Belt Franciscan

Complex. The Howe, Atwell, Kiler, Dinner, Twin, Jordan, Greenlaw, and Bear Creek sub-basins are underlain by the most resistant co4 unit in their headwaters, down into the less resistant, highly-sheared co3 unit, and then into the somewhat more resistant co2 unit in their lower reaches.

The Yager terrane and Quaternary deposits make up the rest of the LEED. Both are located in the lower elevations along the Eel River. Yager underlies the Scotia, south Stitz, Chadd, High Rock, Weber, Perrot, Allen, and Dean Creek sub-basins. The Yager Complex consists of dark gray indurated mudstones, shales, graywackes, siltstones, and conglomerates, with interbedded limey siltstones. Rocks from the Yager formation are much more resistant to weathering and generate larger classes of gravel and cobble. The Yager weathers bimodally because the sandstones are more resistant and the shale is relatively less resistant. We observed during stream surveys that Yager sandstone and conglomerate clasts were more resistant to erosion and weathering.

Quaternary deposits, typically located along the Eel River and farmlands of Ferndale, are primarily unconsolidated, poorly sorted broken rock, gravels, sands, silts, and clays that have been deposited by colluvial or fluvial processes.

Three mapped structures that also influence the form and character of the LEED are the above-mentioned Russ fault, the Little Salmon fault, and the Eel River syncline. The Russ fault, shown on maps as located between False Cape and Stafford, is a northwest- to westward-trending high angle reverse or thrust fault of the Pleistocene Epoch (McLaughlin et al. 2000, Ogle 1953). The Little Salmon fault is located along the northern border of the Eel Delta WAU. This northwest-trending Quaternary thrust is said to displace as much as 1,800 feet of strata (see Carver and Burke 1992). The Eel River syncline is a west- to northwest-trending Quaternary structure located along the Eel River in the Ferndale area.

Soil Conditions

Bottomland and Farmland Soils. Bottomland and farmland soils are developed on the Quaternary alluvium along the mainstem of the Eel River and in the Eel River delta.

Colluvial and Residual Soil. Colluvial and residual soil covers the majority of the landscape in the watershed, except where bedrock is exposed. These deposits are generally relatively thin on ridge tops and steep upper slopes, and increase in thickness down hillsides toward the bottom of slopes where they can form thick accumulations. Residual soil forms from the mechanical breakdown and chemical weathering of the underlying bedrock or unconsolidated geologic materials. Colluvium is defined as weathered material that has moved downslope by gravity-induced movement and accumulated on the hillside. We have observed that colluvial deposits in the LEED are generally about 8 to10 feet in depth. Soil thickness and location are not provided on the geologic maps.

Fill. Fill is present along the margins of the roadways in the watershed. It is also present at most watercourse crossings and along the outside margins of landings and borrow pits. It is composed of soil/colluvium, bedrock materials, and locally organic debris. The presence of fill is sporadic and exists throughout the LEED, though not shown on geologic maps.

Subsurface Soil Conditions. Mechanical grain size analyses of samples from the five main soil units found on PALCO land in the LEED indicate that the soil associated with the Wildcat and Franciscan Melange (co1) geologic formations had the highest proportion of fines, with median values of greater than 60 percent by weight. The soil associated with the underlying Yager formation generally produces over 50 percent fines, and the Franciscan formations co2, co3, and co4 typically are associated with overlying soil that contain about 25 percent fine material. Fines are defined as silt- and clay-sized material less than 0.075 mm in diameter (number 200 U.S. Sieve). Reported percentages are the median value for all samples (see Figure A-1). We assume that the soil sampled at a site is indirectly related to the geologic units (parent material) from which they are derived; this becomes less likely to be a correct assumption where colluvium has developed from geologic units and deposits at great distances upslope.

Climate and Hydrology

Precipitation Patterns

The LEED is located within the northern California coastal region. Rantz (1968) summarized the northern California coastal basin's climate as characterized by highly seasonal precipitation that varies with distance from the ocean, elevation, and slope steepness and orientation. Generally, higher precipitation is associated with close proximity to the ocean, higher elevation, and steep south- or west-facing slopes. Precipitation tends to increase from south to north. Roughly 75 percent of precipitation falls in the winter months of November through March. Typical storms have moderately intense rainfall lasting for several days.

One long-term meteorological station, Scotia (NCDC Coop ID 048045), is located within the study area. The annual precipitation at the Scotia weather station from 1931 to 1999 ranged between 28.3 and 88.4 inches with a long-term annual average of 48.4 inches (Figure 2). Recent isohyetal maps created using PRISM, a model described in the methods manual (PALCO 2000), indicate variation in the average annual precipitation in the study area from a high of 60 inches along Monument Ridge (the southwestern study area boundary) to a low 48 inches in the valley bottom, to 56 inches along the northeastern ridgeline.

Monthly average precipitation at Scotia ranges from 0.1 inch in July to 9.0 inches in January. Precipitation has exceeded 3 inches on 55 days of the 69-year record, and 5 inches on 3 days. Two of the events with greater than 5 inches of precipitation were associated with floods (1955 and 1964). The 1955-56 water year contained both the highest two-month total (37.3 inches) and the highest three-month total (48.7 inches) for the 72-year period of record (Pacific Watershed Associates [PWA] 1999). Recent water years 1997-98, 1996-97, and 1994-95 contain the second, fourth, and tenth highest two-month precipitation totals for the entire period of record. The 1997-98 water year also displayed the fourth highest three-month precipitation total (45.4 inches).

Monthly data can indicate the occurrence of large frontal storms and high intensity events that trigger watershed response. However, it does not provide perspective on the temporal distribution of rainfall or the influence of temperature and snowpack. The 1964 flood, for example, is commonly regarded as the worst in recent history; however, the 1964/65 two-month and three-month precipitation totals were not among the top ten events over the period of record.

Major Storm Events and Flood History

Harden (1995), Coghlan (1984), and Helley and LaMarche (1973) describe flood histories applicable to the 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 1996/97 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 and are thought to have been comparable to, or larger than those recorded from 1953 to 1975. These include the floods of 1861-62, 1867, 1879, 1881, and 1888. North of the Eel River, the 1890 flood is thought to have exceeded the magnitude of the 1964 event (PWA 1999).

Temperature Patterns

Average annual temperatures at the weather station in Scotia hover around the low 50 degrees Fahrenheit (10 to 12 C) with cooler temperatures occurring from November through February, and the warmest occurring from June through October (Figures 3 and 4). Minimum annual temperatures at Scotia are typically just below freezing and typically occur during December and January. Annual maxima generally range between 80 and 100 degrees Fahrenheit (27 to 38 C) and typically occur in July. Temperatures at higher elevations in the hills would tend to be somewhat cooler than those at Scotia.

Redwood Forest Ecology

The LEED is part of the Redwood Forest ecosystem. The coast redwoods *(Sequoia sempervirens)* are a southern extension of the coastal coniferous forests of Washington and Oregon. The native range is restricted to approximately 724 km of coastal forest in California and the southwest corner of Oregon. Redwood forests exist on the moist, western end of a steep moisture gradient, and the redwood belt is seldom more than 40 km wide (Barbour and Major 1988). The influx of marine air seems to be related to the distribution of the redwood forest. Redwoods do not tolerate salt spray and are not present immediately adjacent to the coastline. Inland of this effect, redwood forests extend until the marine air influence is overcome by inland heating of the land (Barbour and Major 1988).

Although redwood is a dominant tree throughout its range, it is generally mixed with other conifers and broad-leaf trees. Pure stands of redwood are present only on some of the best sites, usually the moist river flats. Douglas-fir *(Pseudotsuga menziesii)* is well distributed throughout most of the redwood type (Olson et al. 1990). Other tree species associated with redwoods in the vicinity of the LEED are grand fir *(Abies grandis)*, western hemlock *(Tsuga heterophylla)*, Sitka spruce *(Picea sitchensis)*, tanoak *(Lithocarpus densiflorus)*, red alder *(Alnus rubra)*, and bigleaf maple *(Acer macrophyllum)*.

In traversing these forests from moist to dry locations (as along the coast from Crescent City to Ukiah), one progresses from Sitka spruce-grand fir-hemlock in moist areas, to redwood mixed with other conifers, to redwood mixed with hardwoods, to Douglas-fir-hardwoods, and finally to grassland-oak woodland mosaics in the driest situations. This zonation of forest types is complex, following both latitudinal and inland gradients (Barbour and Major 1988). Most interior valleys trend from southeast to northwest. This tends to accentuate the inland climatic aspects of some of the interior valleys in their headwaters areas.

On the other hand, where the valleys open toward the ocean so as to reinforce the summer marine air indraft with its prevailing flow from the northwest, as at the mouth of the Eel River, the redwood belt extends further inland (Barbour and Major 1988). The upper extent of the redwood forest along the south fork of the Eel River is near the Leggett valley.

The geology of the north coastal forest area in terms of the major rock types and the soils derived from them plays an important role in determining vegetation types. The rocks of the area are predominantly sedimentary. Redwoods grow well in the deeper, younger soils with greater water-holding capacities that are nearer the coast than the older and harder sedimentary rocks farther inland (Barbour and Major 1988). However, some coastal terraces have very old surfaces with old, infertile soils, and the depauperate vegetation types *(Pinus contorta* ssp. *Bolanderi, Cupressus pygmaea),* occur on them (Gardner and Bradshaw 1954). Redwoods are not present on intrusions of serpentine and peridotite rock (Barbour and Major 1988).

Redwoods are considered a shade-tolerant species being able to grow in extremely low light intensities. Redwood trees grow and survive at 0.62 percent of full sunlight (Bates and Roeser 1927). In addition, redwood plants of any age that have been growing slowly in the shade for many years can grow rapidly when shade and root competition are removed (Olson et al. 1990, Fritz 1933). When growing with other species, redwood is usually a dominant tree. Douglas-fir can keep pace with redwood on many sites and occupy dominant and codominant crown positions (Olson et al. 1990). Redwoods have no taproots, but lateral roots are large and wide-spreading. Small trees have better-than-average windfirmness, and large redwoods are windfirm under most conditions.

In addition to seed regeneration, redwoods have the ability to sprout at any season of the year within two or three weeks after logging. Cut stumps are often encircled by more than 100 sprouts, which can sustain the stump-root system (Cole 1983). Juvenile redwood trees usually grow rapidly in full sunlight in moist soil conditions. Established seedlings commonly grow 50 cm in their first year. In open conditions, saplings from either seed or sprout sources can grow more than 2 meters in a single growing season, whereas suppressed sprouts grow 1 meter annually (Allen and Barrett 1985). Diameter growth of individual young trees can be rapid or very slow. In dense stands where competition for light and soil moisture is severe, annual radial increment is commonly as small as one-thirtieth inch. At the other extreme, under ideal conditions, radial growth can be as great as 1 inch a year. Fritz (1957) reported one redwood growing with little competition reached an 84-inch diameter in 108 years.

The most serious impediment to redwood regeneration following harvest is competition from hardwood species, especially tanoak (Rydelius and Libby 1993, Olson et al. 1990). Redwood sprouts are less susceptible to competition from hardwoods than redwood seedlings as a result of their quick growth in the first year following harvest (Olson et al. 1990, Rydelius and Libby 1993). Since old-growth redwood stands typically exhibit a low density of trees from which to sprout, a strong potential exists for these stands to form hardwood "brushfields" with extremely poor redwood regeneration after harvest (Rydelius and Libby 1993).

Fire-return intervals are thought to vary widely among redwood forests, and fire is thought to have a moderate ecological importance (Olson et al. 1990) in these forests. Stand opening fires may favor Douglas-fir establishment, whereas longer fire-free intervals may favor establishment of the more shade-tolerant redwood and tanoak. Fire-return intervals likely vary along an ocean to inland gradient. Coastal sites have been suggested to experience a fire-return interval of 250 to 500 years, intermediate sites 150 to 200 years, and inland sites 33 to 50 years (Veirs 1996). A pre-settlement fire-return interval of 26 years was estimated by Stuart (1987) at the Humboldt Redwoods State Park.

Since coast redwood is somewhat fire-resistant, one might expect to find substantial accumulations of coarse woody debris. However, generally frequent fire-return intervals allow multiple fires to consume large redwood logs incrementally. If the first fires do not result in total log consumption, later fires complete the process; so upland sites should not have unusually high loads of coarse woody debris. Riparian areas, being more protected from fire, are expected to maintain larger inventories of coarse woody debris (Agee 1993).

Aquatic Resources

During an extensive study in the Eel River estuary between 1973 and 1974, 27 species of fish were captured and identified within the estuary (Table F-2) (Puckett 1977). However, only aquatic species of concern designated in the Methods manual (PALCO 2000) were addressed in this report. Designated Aquatic Species of Concern in the LEED are coho salmon *(Oncorhynchus kisutch)*, chinook salmon *(O. tshawytscha)*, steelhead/rainbow trout *(O. mykiss)*, coastal cutthroat trout *(O. clarki clarki*), southern torrent salamander *(Rhyacotriton variegatus);* tailed frog *(Ascaphus truei),* northern red-legged frog *(Rana aurora aurora*), foothill yellow-legged frog *(Rana boylii*), and northwestern pond turtle *(Clemmys marmorata marmorata)*.

Upstream of the Eel River estuary, coho, chinook, steelhead, and cutthroat trout use the mainstem of the Eel River as well as many of its sub-basins for adult and juvenile migration, rearing, and spawning (Map F-2). One run of coho salmon exists in the Eel River. Upstream adult spawning migration generally occurs from October to mid-February, peaking in December (Preston 2001; Fukushima and Lesh 1998).

Two runs of chinook salmon existed at one time in the Eel River. Upstream adult migration for the existing fall chinook run generally occurs from October through mid-January, peaking in November, although migrating chinook have been observed until March (Preston 2001; Fukushima and Lesh 1998). Upstream adult migration for the spring chinook run occurred from March through June (Fukushima and Lesh 1998), but is now extinct (Free 2002).

Two runs of steelhead exist in the Eel River. The winter-run adult steelhead trout (anadromous rainbow trout) upstream migration usually occurs from September through June, peaking in December and January (Preston 2001, Fukushima and Lesh 1998). The summer-run adult steelhead upstream migration usually occurs from March through July (Fukushima and Lesh 1998).

Although little is known about the distribution and areas of dominant use of resident and anadromous coastal cutthroat trout, they are likely to inhabit all Class I streams within the LEED. Resident coastal cutthroat trout likely occur in all Class I streams upstream of anadromous fish barriers.

Torrent salamanders and tailed frogs are found in the steep, rocky stream reaches and in seeps and springs (Map G-1). Red- and yellow-legged frogs are ubiquitous throughout the LEED (Map G-2). Northwestern pond turtles are only believed to use the floodplain areas of the Eel River and around the mouths of some of the tributary streams where they cross the Eel River floodplain (Map G-2).

Dams and Flow Diversions

The Russian River drainage, which supports a substantial winegrape vineyard industry, lies just over the ridge to the southwest from the Eel River headwaters. Since 1908, a portion of the Eel River flow has been diverted from the Eel River Basin into the Russian River Basin to augment irrigation under the auspices of the Potter Valley Project (PVP). Lake Pillsbury, dammed by Scott Dam, collects the headwaters of the mainstem Eel River and has a drainage area of 290 mi^2. It lies on the Mendocino National Forest, approximately 20 miles east of the town of Willits (USGS 2000). Van Arsdale Reservoir is a smaller reservoir that lies 11 river-miles downstream of Scott Dam. Van Arsdale (Cape Horn) Dam retains the Van Arsdale Reservoir. Flow is diverted from Van Arsdale Reservoir to the Potter Valley Powerhouse, which then diverts that flow to two irrigation canals and to a tunnel that empties directly into the Russian River to augment flows.

Snow Mountain Water & Power Co. completed construction of the initial portion of the PVP, including Cape Horn Dam, the Van Arsdale Reservoir, and the tunnel system diverting water to the Potter Valley Powerhouse and the Russian River, in 1908. In 1922, Snow Mountain constructed Scott Dam and the Lake Pillsbury Reservoir. PG&E purchased the PVP in 1930. In 1970, PG&E applied to renew the license for the PVP. Federal Energy Regulatory Commission (FERC) relicensed the PVP for 50 years in 1983 under the condition that they study the effects of the PVP on fish (USGS 2000).

Figure 5 shows the Water Year 2000 discharges associated with the PVP, as well as the discharge at Scotia, 138 miles downstream for reference. From the end of October to the middle of June, the diverted flow is such a small proportion of the flow at Scotia that there is unlikely to be any measurable effect on the channel morphologies of the Eel River and the tributaries in the LEED.

However, from June through October, the diverted flow matches and exceeds the discharge at Scotia, 138 miles downstream. Figure 6 is a larger-scale version of Figure 5 and better shows the relationships among the discharges at low flow levels. The PVP appears to have a maximum diversion discharge of just over 300 cfs. From June through December, the diverted flow is much higher than that flowing out of Van Arsdale Reservoir to the Eel River. The flow into Van Arsdale is regulated by the discharge from Lake Pillsbury, so the total flow is not the natural base flow. No records were found that showed the natural river flow prior to implementation of the PVP, so we were unable to assess precisely how the Eel River flow regime, especially in the LEED, has been altered.

Land Use and Forest Management

Land Use

Land use within the LEED is dominated by forestry (86 percent of the total area) with the remainder of the terrestrial watershed occupied by other land uses, including agricultural/residential (7 percent), urban (2 percent), and roads (2 percent) (see Residual Canopy Cover Map C-4 in Appendix C). The remaining 3 percent of the LEED study area is occupied by river and ocean. Most of the forestry occurs in the uplands and mostly in the eastern portions of the Lower Eel WAU. Agriculture lands are confined to the floodplain areas adjacent to the Eel River and occur mostly in the Eel Delta WAU. Urban lands occur in association with the towns of Scotia, Fortuna, Loleta, Fernbridge, Ferndale, Rohnerville, and Rio Dell.

The Eel Delta WAU contains the towns of Loleta, Fernbridge, Ferndale, Fortuna, Rohnerville, and Rio Dell. Rohnerville Airport lies across the Eel Delta/Van Duzen River watershed boundary. The Eel River Wildlife Area extends along the Pacific Ocean shore on the north side of the mouth of the river. PALCO owns 11,461 of the 91,609 acres (12.5 percent) in the Eel Delta WAU. Approximately 2,113 acres (2 percent) of the Eel Delta are state-owned, and 39 acres (less than 1 percent) are federally owned (Figure 7, California Spatial Information Library 1999).

The Lower Eel WAU includes the town of Scotia and the settlements of Stafford, Pepperwood, Shively, Elinor, Holmes, Redcrest, and Englewood. The Humboldt Ecology Center and Humboldt Redwoods State Park are contained within this WAU. The Redwood Highway (Hwy 101) roughly parallels the Eel River through the length of the WAU. PALCO owns 36,040 of the 44,265 acres (81 percent) in the Lower Eel WAU. Approximately 4,445 acres (10 percent) of the Lower Eel are state-owned, and there is no federal ownership (Figure 7, California Spatial Information Library 1999).

Forest Management History

Harvesting in the Lower Eel first began in the 1890s in Strongs and Shively Creeks (Wood 1956) (see Map E-4 and Figure 8). During that time, the Pacific Lumber Company was still completing a railroad system for transporting logs, Mill A was barely completed, and at Fields Landing a wharf was under construction (Wood 1956). Between 1890 and 1930, most of the logging operations in the Lower Eel took place within tributary basins located on river right of the Eel River (looking downstream). Most of the unnamed tributaries in this area were logged within a 10-year period (1900 to 1910); the larger streams, such as Strongs, Stitz, and Shively Creeks, were logged over a 30-year period and were fully harvested by 1920. Allen Creek was clearcut over a 10-year period from 1910 to 1920, as were Bridge and Byron Creeks from 1920 to 1930. Weber and Perrott Creeks were logged over a much longer time period (from 1920 to 1960 and 1920 to 1970, respectively). Remnants of old-growth stands existed in small, isolated patches that were not harvested until the 1970s and 1980s. The earliest harvesting activities on river left of the Eel River began around 1900, but were limited to the lower reaches of Dinner, Twin, and Kiler

Creeks (as well as the unnamed tributaries in this area). Even though these creeks were largely logged-out by 1920, large-scale operations did not begin in this area of the Lower Eel until the 1950s, except in Monument Creek. The majority of the Monument Creek basin was logged from 1930 to 1940, and was largely logged out by 1950. Bear, Jordan, Greenlaw, and Chadd Creeks as well as the unnamed tributaries in between were logged within a 30-year period from 1940 to 1970; most of the logging occurred in the 1940s. The portions of Atwell and Howe Creeks under PALCO-ownership were logged over a longer period, from 1920 to 1990. Second-cycle logging activities have since ensued throughout the Lower Eel.

The management style for early logging (pre-1966) was typical for most areas of the north coast and can be described as "intense," with substantial ground disturbance, little protection for stream channels and riparian zones, extensive road construction, and little or no recognition of the potential influence of harvesting on inner gorge slope stability (PWA 1999). The removal of stable log jams formed by ancient key pieces may have occurred in the early years of PALCO operations for road and bridge maintenance, or for salvaging.

Prior to 1890, teams of up to 19 horses or oxen were used to bring logs over skid roads. Logs were floated down the lower portion of Shively Creek to Scotia to build the mill. By 1892, bull (steam) donkeys were in full use for hauling downed trees to the railroad (Wood 1956). By the 1930s, tractors, bulldozers, diesel yarders, and swing-boom and heel loaders were used to haul logs to railroad landings where trains transported them to mills. Currently, yarding may be performed using tractors, harvester/yarder machines, ground-based cable yarders, suspension cable yarders, or helicopters, and log hauling is done exclusively with trucks.

ISSUES IDENTIFICATION

Issues of concern raised at the public issues identification meeting, and from participating agencies are presented in the LEED Issues Response Matrix (Attachment 1). Questions and concerns raised during the public meeting held July 17, 2000, along with those received in writing were considered. After review, we categorized and prioritized the comments. The issues are categorized by corresponding module and designated with a Resource Assessment Task code as outlined in the LEED Work Plan of March 13, 2001 (Hart Crowser 2001a). All issues raised were addressed and screened according to the methods detailed in the Watershed Assessment Methods for PALCO Lands (PALCO 2000). The response code for Public Issues indicates categorization as a result of the sorting process (See key in Public Issues section of the LEED Issues ResponseMatrix - Attachment 1).

We present the issues in two sections: Site-Specific Issues and Public Issues. In each section we list the issue, the module(s) and section(s) where the issue is addressed, and a brief response.

MODULE SUMMARIES

Mass Wasting Assessment

The number of shallow landslides contributing sediment to streams declined during the period of the aerial photographic record in nearly all sub-basins in the Lower Eel (considering the continuous photo records starting in 1955) and in the Eel Delta (considering photo record beginning in 1975) WAUs. In the Lower Eel, the estimated shallow landslide volume (based on depletion zone areas) contributing sediment to streams has steadily decreased in all sub-basins since approximately 1955. This is true for the Eel Delta since about 1975.

Sediment delivery to streams from shallow hillslope landslides has significantly decreased during the period between 1988 and 2000 in comparison to other years of the aerial photographic record. The contribution of sediment to streams from all shallow landslides that initiate at roadways is significantly less than the contribution from landslides that initiate on the hillslopes. We did not have significant data to comprehensively determine relations between management and landsliding. However, landslide densities are greater in clearcuts (30 years and younger) with convex and incised steep landforms in comparison to landslide densities in thinned second growth (30 years and older) forests with convex and incised steep landforms.

Large, deep-seated landslides are relatively common in the watershed, but aerial photograph interpretation and field reconnaissance indicate that past clearcutting and road-building practices have not significantly increased the likelihood of deep-seated movement of these features. Very few deep-seated landslides exhibit features indicating they are active.

The potential for shallow landsliding varies depending on a) the location in the LEED, b) the soil conditions, c) associated underlying geology, and d) slope angles. Shallow landslide potential increases with distance from the Eel River as slopes become steeper near ridges. The potential hazard of delivery to streams, see Maps A-6 and A-7, from both hillslopes and roadways is greatest (High to Very High) where:

- Areas are steepest adjacent to the heads of the tributaries and incised drainages within Franciscan geologic units;
- The Franciscan co3 and co4 units coincide with steep slopes and coarse-grained soil conditions that contain fewer fines; and
- Where northeast trending dip direction and angles are nearly equal to the general direction of topographic slopes and slope angles in the south portions of the LEED.

The potential hazard of delivery to streams, see Maps A-6 and A-7, from both hillslopes and roadways is Moderate to High where:

- Geologic units dip in the opposite direction of the general slope angles in the north portions of the LEED; and
- The previous conditions coincide with areas of less resistant mudstones and siltstones that generate soil with higher proportions of fine-grained particles (such as those of the Wildcat).

Surface Erosion Assessment

Soils in the southern part of the Lower Eel WAU have a high to extreme erosion potential, while soils in the northern and eastern parts of this WAU have a moderate to high erosion potential. Inner gorges contained by the Franciscan Coastal terrane mélange have extreme erosion potential, while those contained by the Wildcat Group and Yager terrane have high erosion potential. Erosion potential in the Eel Delta WAU was generally moderate to high.

Background surface erosion resulting from soil creep delivered an estimated 337 tons/mi^2/yr to streams in the Lower Eel and 330 tons/mi^2/yr to streams in the Eel Delta. Sediment input from natural fires, while significant in some parts of California, was deemed low in the LEED based on the infrequent occurrence of natural fire in redwood stands.

Timber harvest-related activities were estimated to deliver 75 tons/mi^2/yr in the Lower Eel and 57 tons/mi^2/yr in the Eel Delta. The highest erosion rates were estimated for units that were cable yarded. This is a result of the steep surface gradients, rather than of the yarding method; cable yarding is the method typically used in steep harvest units.

Road surface erosion delivers an average of approximately 270 tons/mi^2/yr in the Lower Eel and 255 tons/mi^2/yr in the Eel Delta under current road use conditions. In both the Lower Eel and Eel Delta, the majority (60 percent) of the road sediment is produced from native-surfaced roads. These roads make up 55 and 65 percent of the road length in the Lower Eel and Eel Delta, respectively. In the Lower Eel, sediment production is approximately commensurate with road length. In the Eel Delta, however, 35 percent of road sediment is produced from gravel-surfaced roads, which make up only 15 percent of the road length. This is because most of the gravel roads in the Eel Delta are main roads. Because of higher traffic volume on main roads, they deliver much more sediment per road mile than native-surfaced spur roads. The highest sediment-producing sub-basins had road networks with numerous stream crossings. In addition, we estimated that road gully erosion and stream crossing washouts deliver an average of 340 tons/mi^2/yr of sediment to streams in each WAU.

A qualitative evaluation of surface erosion from other land uses in the Lower Eel indicated the volume of sediment from agricultural, residential, mineral extraction, and recreational activities is likely to be negligible. In the Eel Delta, however, grazing may be a significant cause of surface erosion.

Because of the fine-grained nature of soils in the project area, surface erosion from all sources delivers primarily silt- and clay-sized particles to streams in the LEED. We estimate that about 60 percent of the sediment delivered is silt- and clay-sized, 30 percent is sand-sized, and the remaining 10 percent is fine gravel.

Hydrologic Change Assessment

Our review of flood history shows that the LEED experienced at least seven significant flood events affecting northwestern California in the 19th century. Between 1915 and 1950 relatively few large storms occurred, with notable exceptions in 1915 and 1937. After 1950, the frequency of large storm events increased, producing substantial flooding in 1955, 1964, 1974, 1986, 1995, and 1997. Since none of the tributary sub-basins within the LEED has stream gauges, the analysis estimated flows within the study area by extrapolation from stream flow records at Bull Creek, a nearby reference stream located outside the LEED. The 1997 event was the largest on record for Bull Creek, eclipsing the previous high recorded in 1964.

The Bull Creek flow record, when extrapolated to the study area, suggests the LEED sub-basin tributaries experienced floods of between 10- and 15-year recurrence intervals in 1964 and 1995, and greater than 25-year recurrence interval in 1997.

The analysis of increases in peak flows shows that timber harvest has mixed results depending on the size of the flow event. For average antecedent wetness conditions in tributary sub-basins, the model predicts peak flow increases ranging from 5 to 19 percent for the 2-year flow event. The average predicted 2-year event peak flow increase is 11 percent. The predicted increases are comparable to the range of measurement error typical to flow measurement techniques. The effects of logging on peak flows are most pronounced for small storms that occur early in the wet season when antecedent moisture conditions are driest. The effect of timber harvest on peak flows decreases as flow magnitude increases. Timber harvest has little effect on flow events larger than the 15-year flow.

Riparian Function Assessment

Coast redwood trees dominate the majority of the riparian zones within the LEED, with minor amounts of Douglas-fir and grand fir also present. Hardwood stands include tanoak, alder, and bigleaf maple. Approximately 57 percent of the current riparian stands in the Lower Eel WAU have medium (and large) sized conifer and mixed stands that are potentially capable of supporting Properly Functioning Condition (PFC) Matrix guidelines for LWD recruitment. In the Eel Delta WAU, approximately 68 percent of the riparian areas have current stands that have adequate recruitment potential to support PFC guidelines. LWD recruitment from inner gorge landslides and bank erosion are major sources of wood input to stream channels in the watershed.

A high percentage of riparian canopy shade occurs in the LEED. Approximately 72 percent of the total stream channel network meets or exceeds the target canopy shade level of 85 percent. Bear, Jordan, and Howe/Atwell Creeks have below-target shade levels along major portions of the stream length. In these sub-basins and in Panther Creek, stream temperatures exceeded the PFC Matrix guideline of 16.8 C during one or more sample years. These results suggest temperatures closely reflect shade levels upstream.

Stream Channel Assessment

We classified channel segments of the LEED into nine channel geomorphic units (CGUs). The majority of the Lower Eel and Eel Delta (75 and 66 percent, respectively) channel lengths consist of greater than 20 percent gradient source channels. Eleven percent of the Lower Eel channel length is in steep (6.5 to 20 percent) gradient channels in consolidated geology. The rest of the channel length is distributed in small amounts through the rest of the CGUs. Twelve percent of the analyzed Eel Delta channel length is in steep (6.5 to 20 percent) gradient channels in unconsolidated geology, and ten percent is in lower-gradient alluvial deposits. The stream channels in the LEED analysis area are confined or moderately confined. Unconfined channels did not occur within the LEED.

The only historical channel change visible at the scale of the available historical aerial photographs was temporary channel widening. Channel widening was attributed (based on field survey evidence) to two mechanisms including in-stream debris torrents within steeper transport reaches and storm event-related sediment accumulation in lower-gradient response reaches. No other signs of channel migration or planform changes were visible in the photographs available. The potential effects of timber harvest on channel disturbance cycles cannot be discerned from the available data and analysis. Channel disturbance occurred both before and after the initiation of timber harvest, and the extent and locations of channel disturbance associated with each situation are similar.

Fifty-seven stream segments were surveyed within the eight CGUs present on PALCO land in the LEED. Channel, fish, and amphibian habitat data were collected from 300-meter-long stream segments in most streams. In some situations, shorter segments were surveyed due to impassable conditions and in some circumstances, 500-meter segments were surveyed to better understand habitat conditions within a particular sub-basin in a CGU. Our channel/fish/amphibian/reptile assessment team surveyed kilometers (10 miles) of stream channel.

Currently, vegetative disturbance zones exist on most medium and large sized creeks, especially in consolidated geologies. Overall, LWD is abundant throughout the LEED drainage network (see Appendix E). Key piece abundance is highly variable throughout the watershed and ranges from 0 to 1.8 pieces per channel width.

CGUs respond differently to changes in habitat factor input rates (Table E-21). We assume all CGUs respond moderately or strongly to changes in LWD input (usually assessed in terms of a decrease in LWD). The channels that respond most strongly are low to moderate-gradient channels (2 to 4 percent; CG0 and CG3) in consolidated geologies. Channels at this gradient tend to be plane-bed in the absence of forcing materials such as LWD. The presence of LWD, or lack thereof, can determine whether the channel contains any features such as pools, bars, and riffles. This is especially true when there is a source of coarse sediment to create that in-channel structure. Lower-gradient channels respond strongly to the input of coarse sediment while higher-gradient channels respond less. Only the lowest-gradient channels in the LEED respond strongly to fine sediment. Other channels are unresponsive either because the channels are steep enough that fines are easily flushed downstream or because the streambeds are naturally dominated by fine sediment and additional inputs do not substantially change the character of the channel. Conversely, most channel types do respond to peak flows. The exceptions are:

- Steeper Consolidated Geology channels (CG3 and CG6.5), which are relatively unresponsive to peak flows because their substrate materials are already so large and resistant they are impervious to all but the highest flows;

- Estuarine/Intertidal channels, which are unresponsive to peak flows because the extensive floodplains through which they flow effectively dissipate the flow energy; and

- The character of Alluvial Deposit channels is not altered by peak flows, because they already flow through the active floodplain of the larger river and their morphology is driven by the Eel River flows.

Fisheries Assessment

Coho, chinook, steelhead, and cutthroat trout use the mainstem of the Eel River and many of its sub-basins for adult and juvenile migration, rearing, and spawning. Barriers to adult salmonid passage were identified in the form of two perched culverts (both on county roads) and of logjams, which occurred throughout the LEED.

The Eel Delta WAU has approximately 26 miles of Class I stream, of which 19 percent is potential chinook salmon habitat, 13 percent potential coho habitat, and 40 percent potential steelhead trout habitat. The majority of this habitat is located in Strongs and Howe Creeks. CGU ratings for fish habitat were higher for reaches surveyed in Howe Creek than those in Strongs Creek, indicating that Howe Creek would provide better quality habitat than Strongs Creek for each species of concern. The Lower Eel WAU has approximately 36 miles of Class I stream, of which 23 percent is potential chinook salmon habitat, 17 percent potential coho habitat, and 56 percent potential steelhead trout habitat. The majority of this habitat is located in Bear and Chadd Creeks. Both of these creeks had similar CGU ratings for fish habitat.

Overall, spawning gravel quality ratings (spawning quality, availability, and embeddedness) in surveyed reaches were good for stream segments within consolidated geology and in the lower reaches that flow across the Eel River floodplain. These streams are typically located to the south of the Eel River and include Howe, Monument, Kiler, Dinner, Twin, Jordan, Greenlaw, Bear, and Chadd Creeks. Overall substrate ratings in surveyed reaches were fair for stream segments within unconsolidated geology. These streams are typically located to the north of the Eel River and include Strongs, Nanning, Stitz, Shively, and Bridge Creeks. Overall substrate ratings in surveyed reaches were rated as poor for stream segments within terrace deposit geology or any stream segment with gradient greater than 20 percent. However, stream segments with greater than 20 percent gradient were typically above the anadromous fish zones. Overall LWD (number of LWD key pieces per channel width and volume of LWD key piece) was rated good for surveyed stream segments in the CGUs except for unconsolidated geology at 0 to 3 percent gradient (UG0) and the alluvial geology (AG) streams where they flowed through old alluvial terraces. In these two CGUs, LWD was rated as fair. LWD does not appear to be lacking in the LEED as a whole.

The surveyed reaches in the resident fish zone were rated as having poor pool frequency, regardless of CGU, although the overall rating of pool habitat ranged from fair to good. The surveyed reaches in the anadromous fish zone were rated as having poor to good pool frequency, with the overall rating of pool habitat ranging from poor to good.

Based on the limited temperature data, temperature appears to be a concern in the Eel River and to a lesser extent in Chadd, Twin, Shively, Strongs, Bear, Jordan, and Monument Creeks. The limited turbidity measurements in Jordan and Stitz Creeks indicate that levels associated with behavioral or sublethal effects can occur there.

Amphibian and Reptile Assessment

In addition to the habitat surveys, PALCO conducted area-constrained surveys for southern torrent salamanders and tailed frogs on 3,952 meters (2.5 miles) of Class II streams.

The potential distributions of four amphibian species (southern torrent salamander, tailed frog, northern red-legged frog, and foothill yellow-legged frog) and one reptilian species (northwestern pond turtle) were assessed on PALCO holdings in the LEED.

The northwestern pond turtle was not encountered during the survey, nor was habitat identified within the areas surveyed that would meet the habitat requirements of this species. The survey was restricted to areas of the watershed within PALCO's holdings and did not include the mainstem Eel River or its floodplain, which likely contains habitat that would support this species. The specific habitat of this species includes a variety of permanent and ephemeral aquatic habitats such as ponds, lakes, rivers, marshes, sloughs, and drainage ditches (Zeiner et al. 1990, Bury 1962, Holland 1994, Nussbaum et al. 1983). Aquatic habitat has been described by Bury (1972) and Reese (1996) as water less than 32 C and greater than 0.5-meter deep in nearshore, low or no velocity stream or river reaches. Nesting areas tend to be on south- or west-facing slopes, vegetated by short grasses or forbs (Holland 1994). Because suitable habitat conditions for this species were not identified in the surveyed areas, it is unlikely that this species would occur in those areas. Therefore, the potential distribution of this species on PALCO holdings is not discussed further.

The southern torrent salamander was only observed in Class II streams in consolidated geologies (co2, Melange - shattered sandstone and argillite; co4, intact sandstones and argillite; and y1, Yager terrane) during the area-constrained surveys conducted by PALCO. Thus, this species is most likely to occur in perennial Class II streams with gradients greater than 6.5 percent in consolidated geologies, temperatures between 6.5 and 15 C, with boulder/cobble or cobble gravel substrates, and with a canopy cover of greater than 70 percent.

No tailed frogs were encountered during the LEED Watershed Analysis or by PALCO during their area-constrained surveys. The tailed frog can occur in the same steep consolidated-geology streams as the southern torrent salamander, but their distribution may also extend downstream into fish-bearing streams.

The foothill yellow-legged frog was observed in the Class I and II streams surveyed. It was more frequently observed than the red-legged frog. Generally, Class I and Class II streams in consolidated geologies provide the best habitat for this species, which prefers interstitial spaces between cobbles and boulders in low-gradient, large stream segments as substrate for egg laying and refugia for tadpoles.

Red-legged frogs were recorded in only three stream segments of the surveyed Class I and II streams, which were in consolidated geologies with gradients of 3 to 6.5 percent and canopy cover of 85 percent or more. Based on the specific habitat needs of the northern red-legged frog, this species most likely would occur in low-gradient (0 to 3 percent) Class I and II streams, although it was also observed in streams of moderate gradient (less than 6.5 percent). Northern red-legged frogs may also occur in ponds and ditches; however, these types of environments were not encountered during the survey.

SYNTHESIS

Resource Situation Summaries

Aquatic Resources

Potential Habitat

The potential habitat assessment is designed to identify and delineate stream channel segments that are potentially suitable for fish and amphibians within the LEED. Channel segments with potential fish and amphibian habitat are delineated based on the following assumptions:

- Potential habitat is closely correlated with CGU. That is, habitat characteristics (e.g., pools and riffles) can be predicted from channel geomorphic characteristics. For example, CGUs with 0 to 3 percent gradients tend to be pool/riffle regimes, whereas CGUs with 3 to 6.5 percent gradient tend to have cascade or stepped regimes.

- Current fish and amphibian distribution also closely correlates with CGU because CGU is an indicator of potential habitat type and quality. For example, CGUs with 0 to 3 percent gradient tend to have more suitable spawning gravel than CGUs located in steeper gradients. CGUs located in unconsolidated geologies tend to have substrates dominated by more fine sediment (silt and sand) than do CGUs in consolidated geologies.

- Fish and amphibian distribution is not uniform across the stream network because CGUs are not uniformly distributed across the stream network.

- Amphibians were identified as potentially occurring in all Class I and II streams, and the CGU/habitat association was used to evaluate the likelihood of species occurrence.

The potential habitat (Map 1) for fish species of concern was derived from:

- The fish distribution map (Map F-2), which was submitted to PALCO by the Wildlife Agencies;

- Additional existing information on species occurrence; and

- Information on habitat preferences (Table 2) (Fukushima and Lesh 1998, Slaney and Zaldokas 1997, and Groot and Margolis 1991).

Potential habitat for steelhead and resident trout was assumed to be identical to their distribution as shown on Map F-2. Potential habitat for chinook was assumed to be identical to the distribution shown on Map F-2 for the streams surveyed, except Bear Creek. In Bear Creek, Map F-2 indicates that chinook occur in the upper tributaries in CGUs with gradients greater than 6.5 percent. Because ocean-type chinook are not known to extend into gradients this steep, their distribution within CGUs with gradients greater than 6.5 percent is unlikely.

The coho distribution shown on Map F-2 is most likely incomplete based on information from Brown and Moyle (1991) and SFSC (2001). Brown and Moyle (1991) and SFSC (2001) reported the presence of coho within several tributaries that were not depicted as having coho salmon on Map F-2. However, neither report identified specific areas where the observations occurred in each stream. Therefore, to determine the uppermost extent of potential habitat for each fish species of concern, existing potential habitat for coho salmon was identified as all sub-basins identified in Brown and Moyle (1991) and SFSC (2001) up to the uppermost CGU with a gradient of 3 to 6.5 percent. In those cases where short CGUs with gradients steeper than 6.5 percent occurred between two CGUs with gradients less than 6.5 percent, it was assumed that potential habitat for coho occurred within these CGUs.

The distribution of CGUs by different geology and location suggests there is a clear distinction in habitat potential between those sub-basins located to the north and those located to the south of the Eel River. Sub-basins located to the north of the Eel River are relatively small and are dominated by unconsolidated geology compared to basins south of the river. The streams in these sub-basins tend to have smaller channels, higher amounts of silt- and sand-embedded substrate, and limited spawning gravel. These conditions limit habitat potential and indicate there is a lower probability that salmon (coho and chinook) and headwater amphibian species will occur in these sub-basins. Some headwater amphibians (e.g., southern torrent salamander) could occur in these sub-basins in localized cases where gravel patches or LWD accumulations are sufficient to provide habitat. Additionally, limited habitat for steelhead, yellow-legged frogs, and red-legged frogs may exist in the lower reaches of some streams that flow across the Eel River floodplain. In these streams, alluvial gravel deposits from the Eel River may form suitable habitat (Map 1 – Potential Fish Habitat, Maps G-1 and G-2 – Potential Amphibian Habitat). The Strongs Creek sub-basin is an exception in that potential habitat exists for chinook, coho, trout, and amphibians. This may be partly due to the fact that the Strongs Creek sub-basin is larger than most of the north-side basins and it supports flows large enough to develop suitable habitat. Table 3 lists the potential habitat for each salmonid species of concern.

Sub-basins located to the south of the Eel River are mostly within consolidated geologies. The channels in these basins are typically larger than those on the north side of the Eel River, gravel is abundant, and silt/sand substrate is limited. These channel characteristics have a higher probability of providing habitat for salmon, trout, and amphibians. The larger streams (Howe, Monument, Jordan, Bear, and Chadd Creeks) provide potential habitat for chinook salmon (Table 3). Potential coho habitat exists in the lower reaches of Monument, Kiler, Dinner, Twin, Jordan, and Shively Creeks, as well as throughout most of Bear and Chadd Creeks. Steelhead and resident trout occur in most of these streams.

The southern torrent salamander was only observed in Class II streams in consolidated geologies (co2, Melange-shattered sandstone and argillite; co4, intact sandstones and argillite; and y1, Yager terrane) during the area-constrained surveys conducted by PALCO. The channel and habitat characteristics associated with these observations suggest that this species is most likely to occur in perennial Class II streams with gradients greater than 6.5 percent in consolidated geologies, temperatures between 6.5 and 15 C, with boulder/ cobble or cobble/gravel substrates, and with a canopy cover of greater than 70 percent. Thus, this species has a higher likelihood of occurring within north-facing sub-basins located in consolidated geologies on the south side of the lower Eel River. The unconsolidated geologies associated with the south-facing sub-basins on the north side of the Eel River are less likely to provide the preferred habitat requirements of this species, thus there is a reduced potential for the occurrence of the southern torrent salamander within these sub-basins. However, there may be isolated patches of habitat within the sub-basins to the north of the Eel River that could support small populations of southern torrent salamanders, but in general, it is expected that habitat potential for this species is low in those sub-basins.

Seeps and springs may also provide habitat for southern torrent salamander (Nussbaum et al. 1983); however, no habitat requirements have been documented for upland habitat for this species (PALCO 2000). Potential upland habitats were not surveyed as part of the Watershed Analysis; however, it is recognized that such areas may provide some of the habitat requirements for this species and that there is the potential for occurrence in these areas.

No tailed frogs were encountered during the LEED Watershed Analysis or by PALCO during its area-constrained surveys. The tailed frog is expected to occur in the same steep consolidated-geology streams as the southern torrent salamander, but their distribution may also extend downstream.

Habitat Vulnerability

The species vulnerabilities to changes in watershed inputs were based on the species life history requirements and the species sensitivity to changes in watershed inputs. To simplify the process, species vulnerabilities were grouped for species with similar life histories and habitat requirements. That is, resident trout (referred to as Trout) were evaluated as one group, chinook and coho salmon and steelhead trout (referred to as Salmon) were combined as one group, northern red-legged frog and foothill yellow-legged frog (referred to as Frogs) were combined as another group, and tailed frog and southern torrent salamander (referred to as Headwater species) were combined as a separate group. Species vulnerabilities are shown in Table 4.

Habitat vulnerability is a function of species vulnerability in the stream channel segment of concern, life stage vulnerability, timing of input events, and channel sensitivity. Habitat vulnerabilities are shown in Table 5. In general, the following rationale were used to determine habitat vulnerabilities:

- Habitat vulnerabilities are no higher than the species vulnerability to an input.

- Trout species vulnerabilities to heat are high in all Class I channels; salmon vulnerabilities are high in those CGUs where they are likely to occur.

- Salmonid vulnerabilities to coarse and fine sediment are high in the AD and CG0 channel segments, which are those most likely to be used for spawning and rearing and are most sensitive to sediment inputs; moderate vulnerabilities were assigned to those CGUs that are somewhat less likely to be used and are less sensitive to sediment input.

- In CGUs where species were unlikely to occur, the vulnerability was rated low.

- The habitat vulnerability to peak flow was assumed to be lower for Trout than for Salmon because the scouring of redds is more likely to occur during fall and winter when Salmon redds may be present, but less likely to occur during spring when Trout redds are present.

- Trout species vulnerabilities to heat are high in all Class I channels; salmon vulnerabilities to heat are high in those CGUs where they are likely to occur.

- If there were no watershed input ratings for a given species, the vulnerability is assumed low.

Sediment

Sediment Input Budget

A typical sediment budget assesses the sediment input, the sediment storage within the watershed, and checks the assessment through comparison to sediment output, or yield. We produced a 'partial' sediment budget for the LEED. The project area does not lend itself to traditional sediment budgets because it is actually a collection of tributaries, rather than a distinct watershed. The Eel River extends far upstream from the project area. Additionally, there are no sediment yield data specific to the tributaries of the Eel River in the project area. Therefore, this sediment budget is an estimate of sediment contributions to the stream system and does not take into account sediment storage or depletion.

Methods and Assumptions

Potential Input Sources. We distinguished sediment sources by process and by origin. We provided sediment estimates for shallow and deep-seated landslides in Appendix A. Shallow rapid landslides can be road-related or timber-harvest-related, in addition to having natural causes. We defined the surrogate for "natural background rate" as the rate with which landslides originating in stands greater than 15 years old occur. This is consistent with the Hydrologic Change Assessment assumption that hydrologic maturity is reached by the time regenerating timber is 15 years old in Northern California (Appendix C; PALCO 2000). We mapped seven active deep-seated landslides in the LEED. Based on our observations, we conclude that deep-seated failure mechanisms are generally not directly responsible for delivering significant sediment to streams in the LEED. However, shallow (streamside) landslides near the toe of the deep-seated features can often deliver sediment to the stream channel. Delivery from these shallow landslide mechanisms is captured in Appendix A and in the sediment budget.

Sediment influx is considered for the period between the 1987 and 1997 photo years (i.e., features that first appeared, and landscape condition in 1997). The estimates in this document for the Lower Eel and Eel Delta WAUs, therefore, do not include the 1964 storm event. However, they do reflect conditions resulting from timber management since implementation of forest practices rules, which provides us with meaningful information for the current assessment.

Streamside landslides (SSLS), which also include inner-gorge failures, were treated separately from other landslides due to their position in the landscape. This is because:

- We found it difficult to identify SSLS using only photographic inventory methods,
- Their causes are distinct;
- Sediment delivery is immediate; and
- Their occurrence and sediment contributions are influenced more by stream length and less by typical hillslope processes.

Data on SSLS were extracted from sediment source investigations done by PWA in the Bear and Jordan Creek sub-basins (PWA 1998 and 1999) and augmented by delivery from additional landslides in the Mass Wasting landslide database (mapped by GeoEngineers). We developed an average sediment input rate from SSLS in Bear and Jordan Creek sub-basins using estimates of landslide volumes and delivery efficiency. Lacking other data, we applied the rates developed for Bear and Jordan Creeks as the basis for estimating SSLS sediment input in the other sub-basins. However, because landslide delivery potential is not uniform across the watershed, we adjusted the rate to account for material and landform variability within each sub-basin.

We used the landslide potential ratings developed in the Mass Wasting module (as shown on Map A-7 Empirical Landslide Delivery – Hillslope) to adjust the average sediment input rate to account for landslide potential. We assumed that:

- SSLS sediment input is a function of stream length;
- Large shallow landslides deliver most of the sediment (PWA 1998); and
- Large shallow landslides that deliver sediment to the stream network are most likely in areas classified as having high and very high landslide delivery potential (see Map A-7).

We then estimated, for each sub-basin, the total stream miles within regions of high and very high landslide delivery potential. We calculated an average potential sediment input rate from SSLS per high/very-high landslide delivery stream mile within Bear and Jordan Creek sub-basins. We then calculated potential sediment input from SSLS for each sub-basin by multiplying the average potential input rate by the sub-basin stream miles within regions with high and very high landslide delivery potential.

We took estimates for natural soil creep, road surface erosion, timber-harvest-related surface erosion, and gullying from the Surface Erosion Assessment. Soil creep was estimated based on published values of creep rate, measured soil depths and textures, and GIS-derived stream lengths. Road surface erosion was calculated using the SEDMODL program. Hillslope surface erosion (resulting from timber harvest) was calculated using the WEPP program (see Appendix B). Sediment from gullies (assumed related to timber harvest activities) was estimated based on previously conducted field surveys. These gully surveys were conducted in only three watersheds within the project area, and it was necessary to extrapolate the results to the other sub-basins. Although fire (both natural and anthropogenic) is often considered in a sediment budget, sediment delivery related to fire was assumed low because natural fires are rare in the project area. Prescribed burns used for site preparation were accounted for in the WEPP model.

The LEED watershed analysis addresses all categories of sediment delivery listed in the PALCO watershed analysis methods manual, although it divides mass wasting into shallow-rapid and deep-seated landslides. We did not include background or management-related stream bank erosion separately, because we assumed that it was accounted for in estimates of other processes. We assumed stream bank erosion and soil creep to represent the same process and did not include bank erosion as an additional background sediment source. We also assumed that streamside landslides would represent the combined near bank input from landslides and bank erosion. Our field observations suggested that this was a reasonable assumption because sediment input from bank erosion appeared to follow the same pattern as streamside landslides. In addition, streamside landslide estimates were so large relative to other inputs that the addition of bank erosion estimates would have made little difference. Rock pits and scour of skidder trail fill are not addressed in this analysis.

Sediment Grain Size. We divided sediment input from a given sub-basin into two broad categories: coarse sediment or fine sediment delivery. The distinction was based on local soil gradation and sediment delivery method. We assumed that coarse sediment was delivered from sub-basins with soils classified as coarse material, and fine sediment was delivered from sub-basins with soils classified as fine material or coarse/fine mixture (see Surface Erosion Assessment, Section B.2.3.1 and Tables B-2 and B-3 for soil classification). The general category was adjusted, as needed, based on sediment delivery method. Within sub-basins where mass wasting processes dominate, no adjustment was made; we assumed the gradation of delivered sediment to be the same as the local soil gradation. Sub-basins where surface erosion processes dominated were characterized as fine sediment delivery, assuming that only the fine fraction of local soils would be delivered.

Results and Discussion

Sediment Input. Sub-basins contributing the most sediment annually (13,000 to 39,000 tons per year) to the stream network in the Lower Eel were Bear, Jordan, Bridge, Monument, and Stitz Creeks and Strongs Creek was the dominant sediment source in the Eel Delta (Table 6). Although this information is useful, it does not tell us very much about how the sub-basin characteristics or anthropogenic disturbances influence the sediment flux, because it does not account for sub-basin area. The sediment flux normalized by the sub-basin area provides somewhat more information.

Normalized sediment fluxes were approximately 3,800 and 1,400 tons/mi^2/yr for the entire Lower Eel and Eel Delta WAUs, respectively (Table 6). Among the sub-basins, Jordan and Bridge in the Lower Eel WAU, and Nanning in the Eel Delta WAU have the highest sediment fluxes, normalized by total sub-basin area. Jordan Creek contributes approximately 6,300 tons/mi^2/yr and Bridge Creek contributes 5,900 tons/mi^2/yr in the Lower Eel. Allen, Bear, Dinner, Twin, Weber, Stafford, and Stitz Creeks also had sediment fluxes that exceeded the Lower Eel average (4,000 to 4,700 tons/mi^2/yr). The sediment flux rate to Nanning Creek (approximately 1,800 tons/mi^2/yr) was noticeably higher than those for the other Eel Delta sub-basins, which were all around 1,100 tons/mi^2/yr. Be aware that these flux rates normalized simply by sub-basin area integrate the sediment contribution from all areas of the sub-basin. They are not weighted by the proportion of the sub-basins in various states of harvest and regeneration and, therefore, represent neither background nor harvested conditions specifically.

Overall, the largest sediment sources for the Lower Eel WAU were shallow and streamside landslides, road surface erosion, and road-related gullies/crossing washouts (Table 6). In the Eel Delta WAU, road surface erosion and gullies/crossing washouts were the major sediment sources. In general, streamside landslides were the dominant source of sediment in higher elevation sub-basins underlain by Franciscan geology. Road-related sediment inputs were most significant in sub-basins underlain by Wildcat geology or sub-basins at lower elevations. In both WAUs, hillslope erosion and road-related shallow landslides were the smallest contributors of sediment delivery.

Sensitivity to Management. The main contributors in the sediment budget appeared to be sensitive to management. Based on our observations and data collected in Bear and Jordan Creek (PWA 1998 and 1999), the rate of SSLS appeared to be substantially higher for units that had been recently harvested (mostly from clearcut units). We estimate that SSLS rates increase by about 150 percent on clearcut units over the period from 1988 to 2000. The other two main contributors, road surface erosion, and road gullies/crossing washouts are caused by timber management.

Sediment Grain Sizes. Within the Lower Eel WAU, sub-basins in the north and east parts of the watershed (e.g., Stitz, Scotia, and Bridge sub-basins) and the Monument sub-basin were characterized as delivering predominantly fine sediment (60 percent of material is smaller than 0.075 mm). Approximately 30 percent of the material is sand (0.075 to 4.75 mm). The greatest increase in fines (over background rates) occurred in the Scotia sub-basin, with more than a 300 percent increase. In the southwestern part of the watershed, the sub-basins (such as Bear and Jordan Creek) were characterized as delivering much more coarse material. The gradation of material likely delivered to the stream has 45 percent gravel (greater than 4.75 mm). The approximate percentage of sand is similar to that delivered in other sub-basins (~30 percent of material between 0.075 to 4.75 mm). Therefore, in these sub-basins increased sediment delivery due to anthropogenic sources results in similar quantities of sand, but significantly more gravel reaching the stream system than in other parts of the watershed.

Within the Eel Delta, most sub-basins were characterized as having fine sediment delivery. The greatest increase in fines (over background rates) occurred in the Strongs and Dean sub-basins, with an increase of approximately 300 percent in each. The only exception is the Howe sub-basin, which was characterized by coarse sediment delivery.

Sediment input processes did not affect these general classifications. Surface erosion was a significant source of sediment in basins already characterized as having fine sediment delivery. In sub-basins delivering primarily coarse sediment, the contribution of surface erosion was small enough that it had minimal impact on the final gradation estimate.

In-Channel Sediment Transport Potential

Sediment is transported through the channel network by colluvial, fluvial, and mass wasting processes. In steep Class III channels, colluvial processes can move sediment downstream. Fluvial transport occurs in all channel types, although the size of sediment that can be transported depends on the channel gradient, size, restrictions (such as log jams and other structures), and flow. In general, smaller sediment is transported more readily than larger. The low-gradient channel types (CG0, UG0, AD) are generally considered response reaches that sometimes transport fine sediment, but often tend to allow deposition of fines. CG6.5, UG6.5, >20%, and the steeper ALD channel types were generally classified as transport channels that can effectively transport coarse sediment as well as fine. The moderate-gradient channel types (CG3, UG3, and moderate-gradient ALD) tend to transport fines and smaller coarse sediment, but they tend to respond to deposition of larger coarse sediment.

Dam-break floods, evidence of which is present in the LEED, are capable of moving large amounts of debris and sediment in infrequent, episodic waves. These events tend to transport sediment of all sizes with less gradation and sorting than are seen during normal fluvial transport.

Even more so, debris flows also transport enormous volumes of material, with little or no size sorting. Debris flow deposits tend to be a mixed jumble of sediment and debris that comes to rest either where the channel gradient is low enough that the flow runs out of energy or behind some kind of restriction in the valley (rock outcrop, large timber, etc.). The only sorting that tends to occur is that large debris and sediment pieces may rise to the top of the moving mass, much as chunks of butter will rise to the top of a shaken pan of flour. The large number of sub-basins having long channel lengths with vegetative disturbance zones in the consolidated geology channels (Map E-3) attests to the prevalence of debris flow and dam-break flood phenomena in the LEED. Because of the small channel sizes in the LEED sub-basins, those two processes are probably the dominant sediment and LWD transport processes in those channels.

Wood

LWD Input Budget from Channel

We present analyses of in-channel LWD and recruitment processes in Section E.5.3 of the Stream Channel Assessment (Appendix E). We are providing general results of those analyses and some additional discussion regarding wood transport here. The LWD recruitment budget (Table 7) is also included with this report section for ease of reference.

Generally, LWD loading and recruitment both increase progressively upstream within the tributary sub-basins. Bank erosion and landslides provide the majority of the recruits. We found that mortality, windthrow, and other recruitment processes were relatively insignificant in the LEED (Figure E-8). The landslide recruitment process typically increases in importance, relative to other processes, in moderate and higher gradient CGU channels. Bank erosion dominates recruitment in the consolidated geology channels, while landsliding dominates recruitment in unconsolidated geology channels. Low-gradient channels in alluvial deposits, consolidated geology, and ancient landslide deposits derive most of their LWD from upstream transport; recruitment in these channels is primarily from bank erosion.

Minimum recruitment rates were determined by assigning average ages to recruited LWD according to their decay classes; total LWD recruitment rates range from 2.6 to 4.6 m^3/km/year in both the Lower Eel and Eel Delta WAUs. Average total annual wood recruitment to the LEED sub-basins is estimated at 3,580 m^3/year.

The incidence of shallow landsliding is generally in progressive decline over the last 50-year period. In the last 13 years (1987 through 2000), shallow hillslope landslides delivered more debris to the slopes than to the streams. This trend is the reverse of the trend in all previous periods of the photo record (i.e., there was significantly more hillslope landslide delivery to streams than to the slopes prior to 1988). The period between 1987 and 1997 did experience a significant increase in landslide rates, but the dominant proportion of landslides delivered to slopes rather than to streams. The decrease in the proportion of landslides that deliver sediment to streams is probably an effect of modern streamside buffering rules. The increase in landslide rates during the 1987-1997 period is likely related to the large storm events in 1996 and 1997.

A survey of logjams and landslides in inner gorges revealed that LWD recruited by landsliding comes from an average distance of 44 meters (range 9 to 183 meters) from the stream channel edge in channels having such inner gorges. Ninety-nine percent of the LWD recruited through bank erosion comes from within 10 meters of the channel edge (Figure E-11). Approximately 98 percent of LWD recruitment from both mortality and windthrow comes from within 15 meters of the stream channel edge.

Although the majority (about 62 percent) of the 101 logjams identified in the inner gorge survey could not be clearly linked with a landslide, the majority (about 75 percent) of the 51 identified landslides were clearly linked with a logjam. Fluvial processes such as bank erosion and LWD transport capacity dominate in determining the location and formation of logjams throughout the surveyed streams, but landslides can be an important factor in logjam formation locally.

Transport

The size of the recruited channel wood relative to the channel size and confinement determines the likelihood of downstream fluvial transport. Larger channels are able to transport more and larger pieces of LWD to downstream reaches. When large wood is recruited to small headwater channels, it tends to remain in place. This is reflected in the generally increasing loading of recruited wood pieces in steeper channels illustrated on Figure E-5.

The tributaries of the LEED tend to be rather small relative to the riparian timber, so fluvial transport is unlikely to be an important process in distributing LWD any place in the stream network except the lowest reaches of Bear, Jordan, Shively, and Stitz Creeks and in AD-type channels in the Eel River floodplain. Debris flows and dam break floods may actually be the more important LWD transport mechanism in the steeper LEED tributaries. Wood and sediment can be transported long distances during these high-energy events despite small stream channel widths. The high loading of mobile and, especially, embedded wood pieces in the moderate-gradient and steep channels (Figure E-5) is probably related to the increased frequency of debris flows and streamside landsliding, in those channel types.

The Role of LWD in Class III Channels

Class III streams in the LEED are typically narrow, steep, and incised as a result of dynamic interaction between overlapping hillslope and fluvial processes. Within this context, LWD accumulates in the channels to the point of completely covering the channel and can serve in the formation of sediment storage reservoirs. Sediment can be retained behind wood structures and be metered out more slowly over time than it would be if wood structures were not present. However, the size of LWD pieces is likely important. Very large pieces frequently span Class III channels, limiting their effectiveness. In contrast, small pieces of wood, roots, boulders, and large cobbles located within the active channel of Class III streams can be effective in regulating sediment movement because of the low transport energies of these streams.

Both sediment and LWD may move downstream episodically during sporadic debris torrents that force LWD downstream and create large logjams. These jams form new steps in the stream profile that trap and retain sediment.

Heat

The heat input assessment is designed to assess the current water temperature conditions within the LEED, and identify and delineate areas sensitive to increases in heat input that could cause increases in water temperature. This information combined with the areas identified as potential fish habitat, will help to establish prescriptions.

To delineate the areas likely sensitive to increases in heat input, existing temperature data were correlated with topographic shade conditions and existing stream and riparian shade conditions. The following assumptions were used to delineate stream channel segments sensitive to increases in heat input:

- Topographic characteristics can help to shade some stream channel segments; north-facing streams are shaded more than south-facing streams, and narrow valleys provide more shade than broad valleys. Streams with a floodplain have less topographic shading despite their orientation.

- Tree size and density needed to provide shade is a function of channel width. That is, smaller channels can be adequately shaded with smaller trees or understory vegetation (e.g., shrubs), whereas, broader channels require taller, more dense trees to provide adequate shading.

- Stream segments with recorded temperatures exceeding 16.8 C were assumed to be sensitive to increases in heat input.

- Water temperatures that are below the preferred tolerances of the species of concern do not exist within the LEED.

Several areas have recorded temperatures exceeding 16.8 C (Table F-7 and Figure F-2). These areas occurred in stream channel segments with less than 50 percent stream shade and were located in a broad valley. Despite not having temperature data throughout the LEED, it is likely that other stream channel segments located in broad valleys would also have similar temperature regimes if there were a significant reduction (e.g., 50 percent) in stream shade. Therefore, stream channel segments providing habitat to salmonids and amphibians located in broad valleys are assumed to be sensitive to increases in heat input through activities that may reduce current shade cover (Map 2).

Resource Status Relative to Agency Properly Functioning Condition Levels

To determine whether conditions within the LEED were functioning properly, summary data collected in the field were compared to the National Marine Fisheries Service (NMFS 1997) Aquatic Properly Functioning Conditions matrix (APFC). Because of sampling techniques used, not all parameters discussed in the matrix nor all the data collected could be evaluated. Substrate was visually evaluated in the field to identify dominant and subdominant substrate. Since recommended methods in the APFC matrix used various grain size analysis techniques, a direct comparison of data collected to the APFC matrix could not be made. However, visual estimations of substrate size were compared to two APFC parameters to determine a gross estimation of current stream conditions. Substrate embeddedness was compared to the "% Particles <6.35mm" parameter (target: <20-25%) because our visual estimation of embeddedness would identify, at a minimum, the same areas as the recommended methods for this parameter would. Dominant and subdominant substrates were compared to the Geometric Mean Diameter parameter (target: >20mm) because substrate class sizes used for the visual classification in the field would likely identify the same areas as the APFC recommended methods. Summarized habitat data and whether or not they meet APFC targets are shown in Table 8. Table 8a shows the relationship between the NMFS APFC parameters and targets, and those measured for watershed analysis.

Spawning substrate quality tended to meet the APFC target conditions in consolidated geology reaches, and often did in survey reaches in unconsolidated geology reaches. Bridge, Byron, and Stitz Creeks had notably poor spawning substrate. The creeks with reaches that did not meet APFC target conditions in most cases did not because of an excess of fine sediments. These results are consistent with the observations that the Wildcat unconsolidated geology produces fine-grained sediment under natural and management-related conditions. Embeddedness of spawning gravels with fine sediment did not meet APFC target conditions in most of the surveyed reaches. The only reaches that had low embeddedness were in Kiler and Dinner Creeks.

Pool area had mixed results relative to the APFC target conditions. There was no particular pattern to the percent pool area results. Reaches surveyed in Atwell/Howe and Strongs Creeks were particularly poor in the Eel Delta WAU. Chadd, Dinner, Greenlaw, Jordan and Weber Creeks had particularly low pool area in the Lower Eel WAU. The reaches that did not meet percent pool area targets met the percent LWD-formed pools targets in nearly every case, however, and the reaches that did meet the percent pool area usually did not meet the percent LWD-formed pool target. LWD loading generally met the APFC "Good" target throughout the LEED, so it is unlikely that a lack of wood volume was responsible for either the low pool area or the cases where wood formed a low percentage of the pools present. Channel surveyors often observed that there was a large amount of wood in the channel, but that it tended to occur in jams, which had associated pools, and that the interjam reaches had both few pools and little LWD. The pool spacing conditions had mixed results according to the APFC targets and no clear patterns.

Modified Disturbance Index

The Disturbance Index (DI) is defined as the ratio of the rate of sediment input to the stream channel network due to management practices to the natural background rate of sediment input. The background input rate is subtracted from the input rate associated with managed areas to obtain the input rate due to forest management practices. The DI was calculated for each sub-basin and is presented in Table 6.

Overall in the LEED, anthropogenic sediment sources are estimated to have contributed two to three times as much sediment as was contributed from natural sources during the 13-year sediment analysis period. Within the sub-basins, the DI ranged from 0.2 (Stafford sub-basin) to 3.0 (Scotia sub-basin). In the Lower Eel WAU, for most of the sub-basins with higher DIs (greater than 2.5), the major contributors are road-related sediment sources. The exception is Scotia, in which the major contributor was shallow hillslope landsliding. SSLS were major contributors in sub-basins with lower DIs. In the Eel Delta WAU, the sub-basins with the higher DIs (greater than 2) were those in which road surface erosion was the major contributor.

The modified DI is the DI that is expected under various proposed management scenarios with proposed management prescriptions. The modified DIs may be calculated and presented with proposed prescriptions.

Linkages Among Effects

Linkages among watershed inputs (wood, water, sediment, heat) and their cumulative effects on habitat are most detectable and have the greatest influence on aquatic resources in the moderate- and low-gradient CGUs of the LEED. Habitat conditions in these channel response segments reflect the interaction of multiple inputs from different sources (e.g., sediment transported from headwaters and adjacent hillslopes) and from different input processes (e.g., sediment from mass wasting and road surface erosion). In the LEED the best example of cumulative effects is demonstrated in stream segments that have a Visual Disturbance Zone (VDZ; see Stream Channel Assessment). The VDZ is formed by debris flows, dam break floods, or both that transport sediment and woody debris into and through the moderate- and low-gradient CGU segments of a mainstem stream. Sediment and wood deposits from these events cause significant changes in channel morphology, substrate size composition, wood loading, and channel complexity. Bank erosion and changes in bed elevation due to sediment deposition causes channel shifting that has a significant influence on wood recruitment and the vegetative compositions of the riparian zone. This influences the timing of woody debris recruitment (most linked to disturbance events), the size/species composition of potential recruits (the VDZ is dominated by deciduous or mixed deciduous/conifer stands), and shade potential. Trees on the outer edge of the VDZ contribute less LWD to the stream because their increased distance from the channel reduces the probability of hitting the channel and recruitment is limited to input processes that have lower recruit rates (i.e., stand mortality or windthrow). In smaller streams, the dense canopy formed by a deciduous or mixed stand VDZ will result in higher levels of shade than is the case for streams with a mature conifer stand. In contrast, a VDZ along a larger stream (e.g., Bear Creek) will reduce shading compared to that from a mature conifer stand because the VDZ stand is shorter and has a reduced shadow potential.

Linking management activities to watershed processes that directly influence the formation of habitat in the response segments is an essential product of watershed analysis. Because the interaction between inputs and processes is complex, the evaluation of management influences on inputs is problematic. In this watershed analysis we can identify input sources, input processes, and channel response segments with a high degree of certainty. Therefore, rather than identify all potential linkages between management activities and habitat responses, we focus the evaluation on identifying the situations where management activities could have the greatest impact on aquatic resources. This evaluation is documented by sub-basin and management activity through the causal mechanism reports.

CAUSAL MECHANISM REPORTS

INTRODUCTION

The purpose of the Causal Mechanism Reports (CMRs) is to link hillslope hazards, which can be influenced by management activities, to potential effects on aquatic biological resources. Because there are four watershed input types (coarse and fine sediment, LWD, heat, and peak flows) with varying input processes, land management influences, and hazard potential, and the aquatic resource potential in the LEED varies by location, there is a suite of potential management resource situations. We organized the CMRs by the major processes that trigger inputs to the stream network to identify land management activities that pose the most risk to aquatic resources. Then for each input process, we evaluated three components that could affect the management resource situation—input potential, transport potential, and resource habitat vulnerability. Different combinations of these variables affect the overall resource risk. Therefore, by evaluating different variable combinations, we identified a suite of management situations with different resource risks for each input process. The land management activities that trigger the input processes and specific conditions and locations that result for each situation are described in the CMRs.

We recognize that an assessment of resource risk requires that we make a number of assumptions and that each assumption embodies different levels of scientific uncertainty. This assessment is subjective and, consequently, we recognize that the risk ratings are debatable. However, the ratings reflect our current understanding of watershed processes and resource responses. Our results demonstrate that watershed processes and magnitude vary by location and that biological resources are not uniformly distributed. Therefore, resource risks relative to management activities should also vary in association with the distribution of potential hazards and the distribution of aquatic resources.

Process

The hazard input potential is derived from the likelihood of occurrence of an event or detrimental condition and the probability of the effects of that event or condition (coarse sediment, fine sediment, LWD, or heat input) entering the stream network. The interaction of these factors yields an "input potential rating." This rating relies on our assessment of such things as the density of landslides per acre that deliver to the streams, the dominant LWD recruitment mechanisms, and the LWD recruitment potential.

The transport potential is based on the likelihood of the input being transported to any segment of concern. Transport potential varies depending on the proximity of the considered segment to the delivery point, the input type, the transport mechanism, and the characteristics of the channel segments between the delivery point and the considered resource reach. We determined transport potentials for coarse and fine sediment and LWD using Tables 9 and 10.

Three transport proximity categories were considered: direct, near, and far. Direct transport is when the hazard is delivered from the bank or hillslope into the resource channel segment being considered. Near transport is when the input enters the stream network in the segment immediately upstream (within one channel segment) of the resource segment being considered. Far transport is when the input enters any place farther upstream than one channel segment of the considered resource segment. We assumed that material entering the stream channel upstream from a considered location is of lower risk to a species at the considered location than material entering the stream at the considered location because a) the likelihood of it reaching the considered location is lower than if it were deposited there directly, and b) the time over which it is transported to the considered location is greater. In the case of sediment for example, an input pulse that is delivered to the stream network half a mile upstream of the considered resource reach will be reduced in magnitude and stretched out in duration relative to the same input occurring directly into the resource reach. A sediment input pulse that would be detrimental to the aquatic resources if delivered directly as an overwhelming, abrupt pulse can be beneficial if delivered somewhere upstream where it may be transported to the fish-bearing reach at lower magnitude over a long period and thereby provide a long-term source of needed spawning substrate.

As described elsewhere in the CWE report, downstream transport of sediment and wood occurs primarily through three processes: fluvial, dam-break flooding (actually a type of fluvial transport, but through a particular mechanism), and debris torrenting. Fluvial transport potential varies by channel type and size. We estimated the likelihood of fluvial transport occurring for coarse sediment, fine sediment, and LWD by CGU in Table 10. Channel size is considered when specific locations are determined. Debris torrents and dam-break floods are effective transporters of sediment and LWD, regardless of size and channel type. Stream channels in the LEED where these events tend to occur (VDZ channels) typically have a zone of disturbance vegetation that is visible in the aerial photos (Map E-3). We assumed that VDZ channels have a relatively high likelihood of experiencing debris torrents and dam-break flooding. Streams with significant VDZs are Howe Creek in the Eel Delta and Monument, Kiler, Dinner, Twin, Jordan, Greenlaw, Bear Creeks and the lowest reaches of Stitz Creek in the Lower Eel.

The delivered hazard rating (Table 11) is the likelihood of an event occurring on the hillslope and the outfall from that event reaching the resource reach being evaluated. It is generated by combining the input potential and the transport potential.

The resource risk (Table 12) combines the delivered hazard rating with the resource habitat vulnerability in the CGU of the resource reach being evaluated. The habitat vulnerability rating is the likelihood that the input from an event will affect the habitat for the species of concern. The vulnerability rating is derived from the consideration of the sensitivity of each species group (Salmon, Trout, Headwater, and Frog) to the input hazards, the probable timing of the input, the likelihood of those species types to use various channel types (CGUs), and the sensitivity of the various CGUs to the input. The combination of these factors into the habitat vulnerabilities is described in the Aquatic Resources section of the Synthesis, and the resultant habitat vulnerability table is presented in Table 5.

The procedure for assessing the risk posed by any specific hazard unit was to identify the species occurring downhill and downstream of the hazard unit and to determine the highest resource risk situation for each of those species, see attached Situation Location Map for Mass Wasting (Map CMR-1). The timber harvest prescription applied to that hazard unit will depend on the maximum resource risk evaluated for each species and the prescription applicable to that situation/species combination.

MASS WASTING – COARSE AND FINE SEDIMENT

Resource Sensitivity

Coarse Sediment

Coarse sediment can fill in pool habitat, bury log jams, and cause channel aggradation in the low to moderate gradient channels. In the LEED, channel aggradation is evident in the AD segments of channels with a VDZ (e.g., lower Bear, lower Greenlow, and lower Jordan Creeks). In these stream reaches the current pool habitat is rated fair, poor, and fair, respectively (Table F-5, Appendix F). Gravel supply, however, is necessary for the formation of spawning habitat, which is currently rated as good in these channel segments (Table F-5, Appendix F). Coarse sediment is more prevalent on the south side of the Eel River associated with the soil found in conjunction with the Franciscan geology (co2, co3, and co4) units (with the exception of the Franciscan Mélange (co1 geology unit).

Fine Sediment

Fine sediment may accumulate in low gradient channel segments, clogging gravels in spawning habitat (e.g., AD and CG0 CGUs) and filling interstitial spaces and reducing available habitat (e.g., CG6.5 or UG6.5 CGUs) for amphibians. In the LEED, poor spawning gravel quality (high substrate embeddedness) was observed in CG0 or CG3 CGUs in Bear, Chadd, Greenlaw, Jordan, and Monument Creeks (see Table F-5, Appendix F). The poor spawning habitat conditions in these streams also received fine sediment inputs from surface erosion. The fine sediment from roads is a component of the sediment budget. The fine sediment is more prevalent on the north side of the Eel River. Fine sediment is associated with the soil found in conjunction with the Wildcat, Yager, and Franciscan Mélange geology (QTw, y1, and co1) units.

Turbidity caused by fine sediment input may reduce feeding efficiency during freshets. Chronic turbidity may result in sub-lethal effects in fish, amphibians, and other aquatic organisms. In the LEED, the data record for turbidity is inadequate to determine whether problems may exist. Spot checks of turbidity in Jordan and Stitz Creeks indicate that Salmonids in these streams could experience levels high enough to cause behavioral or sub-lethal effects.

Assumptions

- In the LEED, sediment from shallow landslides is the dominant source of sediment delivery to streams. Sediment input from roads is relatively insignificant. Therefore, the CMRs are organized by mass wasting input potential.

- Because habitat potential is not uniformly distributed, the CMRs are also organized by habitat potential category. This enables prescriptions to be conditioned according to levels of resource risk.

- Streamside landslides will require special consideration since: 1) they contribute significantly to the sediment budget, and 2) the scale of our mapping and field verification likely did not sufficiently capture these features.

- Our observations of the number of landslides in each aerial photographic period divided by the area of the associated landform provides a reasonable measure of the density of landslides by area.

- Landslide density is an index of sediment input potential or also can be considered in terms of categories of mass wasting hazard.

- Although the lower channel reaches of Howe Creek are in unconsolidated geology and are classified as UG0 and UG3, they were evaluated as CG0 and CG3, because they are bedded with coarse sediment from the consolidated geologic units upstream and have high use by anadromous salmonids (Map 1).

Situations

Mass Wasting situations are summarized in Table 13.

Mass Wasting 1a

Situation

Shallow and deep-seated landslide Mass Wasting Units with High or Very High delivery hazard rankings that deliver directly to a Class I AD, ALD, CG0, CG3, or CG6.5 channel or that deliver to a VDZ immediately upstream of a Class I AD, ALD, CG0, CG3, or CG6.5 channel segment.

Situation 1a-i: resource reach has potential salmon or steelhead use

Situation 1a-ii: resource reach has only resident trout potential use

Situation Locations

Locations where landslide density is greater than 0.05 landslide per acre upslope of Class I resource CGUs denoted as AD, ALD, CG0, CG3, or CG6.5 (see Table 13 and Map CMR-1). These are typically related to incised steep, complex very steep, and convex very steep landforms.

Management-Related Contributing Factors

- Road cuts or other activities that cut the toe of the slope, thereby removing the natural support for the material and reinitiating the slide.

- Increased surcharge to the slope with large quantities of material such as debris from gravel mining activities. However, relatively small amounts of side cast typically do not result in landslide re-initiation.

- Increase in saturation of the slide material, particularly through interception and diversion of concentrated surface water from roads or skid trails near the head of the slide.

- Loss of root strength following harvesting along the lateral margins of deep-seated landslides may reduce soil shear strength in Douglas-fir dominated stands and, to a lesser degree, in redwood-dominated stands.

Specific to shallow road and hillslope-related landslides:

- Seasonal changes in soil moisture contents following harvesting or due to loss of canopy may contribute to increases in pore water pressure and promote landsliding.

- Oversteepened fill slopes (>55 degrees).

- Overloading of native slopes and soils by road fill materials.

- Roadways (fill slopes) constructed on slope grades steeper than 55 percent within high hazard areas are not likely to be stable in the long-term.

- New road locations and older roads within areas mapped as having a very high road landslide hazard.
- Road cutslopes that intersect weaker geologic strata, discontinuities, and other weaker zones that are situated in adverse directions (increase the potential for slope movement) relative to the cut.
- Road cutslopes that intersect local areas of relatively high seepage and perched groundwater conditions.

Risk Assessment Summary

Input Potential. High, Very High

Transport Potential. High

Habitat Vulnerability. High for salmon, steelhead trout, and resident trout

Resource Risk. High to salmon, steelhead trout, and resident trout

Mass Wasting 1b

Situation

Similar to Mass Wasting 1a except with a moderate transport potential from the sediment input point to the resource reach. Moderate transport potential is assigned when the input segment is immediately upstream of the resource reach of concern (ALD, CG3, CG6.5, UG3, UG6.5, or >20% segment) and is not in a VDZ, or when the input reach is in a VDZ but is greater than one segment above the resource reach.

Situation 1b-i: resource reach has potential salmon or steelhead use

Situation 1b-ii: resource reach has only resident trout potential use

Situation Locations

Locations where landslide density is greater than 0.05 landslide per acre upslope of Class I resource CGUs denoted as AD, ALD, CG0, CG3, or CG6.5 (see Table 13 and Map CMR-1). These are typically related to incised steep, complex very steep, and convex very steep landforms.

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. High, Very High

Transport Potential. Moderate

Habitat Vulnerability. High for salmon, steelhead trout, and resident trout

Resource Risk. Moderate to salmon, steelhead trout, and resident trout

Mass Wasting 2a

Situation

Shallow and deep-seated landslide Mass Wasting Units with moderate delivery hazard rankings that deliver directly to Class I AD or CG0 channel segments or that deliver to a VDZ immediately upstream of a Class I AD or CG0 channel segment.

Situation 2a-i: resource reach has potential salmon or steelhead use

Situation 2a-ii: resource reach has only resident trout potential use

Situation Locations

Locations where landslide density is greater than 0.01 landslide per acre and less than 0.05 landslide per acre upslope of Class I resource CGUs denoted as AD, and CG0 (see Table 13 and Map CMR-1).

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. Moderate

Transport Potential. High

Habitat Vulnerability. High for salmon, steelhead trout, and resident trout

Resource Risk. High to salmon, steelhead trout, and resident trout

Mass Wasting 2b

Situation

Similar to Mass Wasting 2a except with a moderate transport potential from the sediment input point to the Class I AD or CG0 resource reach. Moderate transport potential is assigned when the input segment is immediately upstream of the resource reach and is an ALD, CG3, CG6.5, UG3, UG6.5, or >20% segment or when the input segment is in a VDZ anywhere upstream of the resource reach.

Situation 2b-i: resource reach has potential salmon or steelhead use

Situation 2b-ii: resource reach has only resident trout potential use

Situation Locations

Locations where landslide density is greater than 0.01 landslide per acre and less than 0.05 landslide per acre upslope of Class I resource CGUs denoted as AD or CG0 (see Table 13 and Map CMR-1).

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. Moderate

Transport Potential. Moderate

Habitat Vulnerability. High for salmon, steelhead trout, and resident trout

Resource Risk. Moderate to salmon, steelhead trout, and resident trout

Mass Wasting 3

Situation

Shallow and deep-seated landslide Mass Wasting Units with Moderate delivery hazard rankings that deliver directly to Class I ALD, CG3, or CG6.5 channel segments or that deliver to a VDZ immediately upstream of a Class I ALD, CG3, or CG6.5 channel segment.

Situation 3-i: resource reach has potential salmon or steelhead use

Situation 3-ii: resource reach has only resident trout potential use

Situation Locations

Vulnerable to fine sediment where landslide density is greater than 0.01 landslide per acre and less than 0.05 landslide per acre in resource CGUs denoted as ALD, CG3, or CG6.5 (see Table 13 and Map CMR-1).

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. Moderate

Transport Potential. High

Habitat Vulnerability. Moderate for salmon, steelhead trout, and resident trout

Resource Risk. Moderate to salmon, steelhead trout, and resident trout

Mass Wasting 4

Situation

Shallow and deep-seated landslide Mass Wasting Units with Very High delivery hazard rankings that deliver directly to Class I UG0, UG3, or UG6.5 channel segments with no potential salmon or steelhead use or that deliver to a VDZ immediately upstream of a Class I UG0, UG3, or UG6.5 channel segment with no potential salmon or steelhead use.

Situation Locations

Locations where landslide density is greater than or equal to 0.10 landslide per acre upslope of Class I resource CGUs denoted as UG0, UG3, or UG6.5 (see Table 13 and Map CMR-1). These are typically related to incised steep, complex very steep, and convex very steep landforms.

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. Very High

Transport Potential. High

Habitat Vulnerability. Low for resident trout

Resource Risk. Moderate to resident trout

Mass Wasting 5

Situation

Shallow and deep-seated landslide Mass Wasting Units with High or Very High delivery hazard rankings that deliver directly to or immediately upstream of Class II ALD, CG6.5, or CG>20% channel segments.

Situation Locations

Locations where landslide density is greater than 0.05 landslide per acre upslope of resource CGUs denoted as Class II ALD or CG6.5, or as >20% in consolidated geology (see Table 13 and Map CMR-1). These are typically related to incised steep, complex very steep, and convex very steep landforms.

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. High, Very High

Transport Potential. High

Habitat Vulnerability. Moderate-High for Headwater species

Resource Risk. High to Headwater species

Additional Comments

Mass Wasting Units with High and Very High delivery potential upstream of these high-use Class II resource reaches are of high risk to Headwater amphibians because of the fine sediment, which is easily transportable in small channels and to which those amphibians are highly vulnerable.

Mass Wasting 6

Situation

Shallow landslide Mass Wasting Units with Moderate delivery hazard rankings that deliver directly to or immediately upstream of Class II ALD, CG6.5, or CG>20% channel segments.

Situation Locations

Locations where landslide density is greater than 0.01 landslide per acre and less than 0.05 landslide per acre in resource CGUs denoted as Class II ALD or CG6.5, or as >20% in consolidated geology (see Table 13 and Map CMR-1).

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. Moderate

Transport Potential. High

Habitat Vulnerability. High for Headwater species

Resource Risk. High to Headwater species

Additional Comments

Mass Wasting Units with Moderate delivery potential upstream of these high-use Class II resource reaches are of high risk to Headwater amphibians because of the fine sediment, which is easily transportable in small channels and to which those amphibians are highly vulnerable.

Mass Wasting 7

Situation

Shallow, road-related, and deep-seated landslide Mass Wasting Units with Very High delivery hazard rankings that deliver directly to Class II AD, CG0, CG3, UG0, UG3, UG6.5, or UG>20% channel segments.

Situation Locations

Locations where landslide density is greater than or equal to 0.10 landslide per acre upslope of Class II resource CGUs denoted as Class II AD, CG0, CG3, UG0, UG3, or UG6.5, or as >20% in unconsolidated geology (see Table 13 and Map CMR-1). These are typically related to incised steep, complex very steep, and convex very steep landforms.

Management-Related Contributing Factors

Same as previously described in Mass Wasting 1a.

Risk Assessment Summary

Input Potential. Very High

Transport Potential. High

Habitat Vulnerability. Low for Headwater species

Resource Risk. Moderate to Headwater species

RIPARIAN – LWD RECRUITMENT

Resource Sensitivity

LWD can have a significant influence on the formation of pools and complex habitat in AD, CG0, CG3, and ALD channel segments (see Channel Response Rating Table E-21, Appendix E). In the LEED, current LWD levels are rated either good or fair in all of the streams with these channel types (see Table F-5, Appendix F). This suggests that LWD recruitment from past input sources (e.g., stream-adjacent landside zones and bank erosion zones) has been adequate in many areas of the LEED. Because habitat complexity in these CGUs is influenced by LWD, a continued supply of LWD over the long-term is necessary to maintain habitat quality.

LWD can influence sediment storage and the local channel gradient in the CGUs with higher stream gradient (i.e., CG6.5, UG6.5, >20%). In the LEED, current LWD levels are rated either good or fair in all of the streams with these channel types (see Table F-5, Appendix F).

Assumptions

- In the LEED, streamside landslides and bank erosion provide the majority of the LWD recruits. Stand mortality, windthrow, and other recruitment processes are relatively insignificant (see Figure E-8). Therefore, the CMRs are organized by input process groups.

- Because habitat potential is not uniformly distributed, the CMRs are also organized by habitat potential category. This enables prescriptions to be conditioned according to levels of resource risk.

- The resource risk for LWD is based on linking the dominant LWD input process for riparian buffer segments with the likelihood of LWD transport to a resource reach of concern, and the habitat vulnerabilities of the species. Current riparian stand recruitment potential and in-stream LWD loading does not influence resource risk ratings. These factors influence the timeliness of riparian management activities, not the need for protection.

- The fluvial transport of LWD is assumed to be only significant in the lowest (widest) reaches of Bear, Shively, Jordan and Stitz Creeks and in the AD channels that flow across the Eel River floodplain. All other stream segments are too small to influence the fluvial transport of LWD to downstream segments.

- LWD transport in debris flows and dam-break-floods may be significant in some streams. Streams with a VDZ indicate channel segments that are likely to transport LWD during disturbance events.

- Riparian segments that are not in moderate or high resource risk situations are a minor concern for riparian protection (with regard to LWD recruitment) because LWD that may be recruited from these areas has a low potential to influence salmon, trout, and amphibian habitat.

Situations

LWD Recruitment 1a – Recruitment Dominated by Mass Wasting for Highly Vulnerable Salmon and Trout Habitat

Situation

Reductions in the LWD recruitment potential from streamside landslides that are adjacent to or immediately upstream of highly vulnerable Salmon and Trout habitat are a high risk to maintaining aquatic resources.

Situation Locations

Riparian segments in stream-adjacent mass wasting delivery-prone areas along Class I CG0, CG3, UG0, or UG3 resource channel segments or along a VDZ immediately upstream of Class I CG0, CG3, UG0, or UG3 resource channel segments. Stream-adjacent landslide-prone areas are defined as the linear high and very high mass wasting delivery hazard units found along many of the major streams in the LEED.

Management-Related Contributing Factors

Past timber harvest from streams adjacent to slide-prone areas and the slow regeneration of trees on steep slopes that have failed could reduce the long-term supply of LWD to streams. Because the landslide recruitment process typically increases in importance, relative to other processes, in moderate and higher gradient CGU channels, the slide-prone areas along these streams are a major source of LWD and a prime concern for riparian timber management.

Riparian stands that currently have poor recruitment potential are a higher risk to Salmon and Trout habitat than riparian stands with a good recruitment potential (see Map D-3, Appendix D). Active forest management is an option for accelerating the process of achieving good recruitment potential conditions.

Risk Assessment Summary

Input Potential. Moderate to High

Transport Potential. High

Habitat Vulnerability. High for Salmon and Trout

Resource Risk. High to Salmon and Trout

Additional Comments

The two dominant LWD recruitment mechanisms along these streams are stream-adjacent landsliding and streambank erosion. It is difficult to separate the importance of these processes in landslide-prone areas; therefore, future recruits need to be maintained along all stream banks and in the adjacent slide-prone areas. LWD recruited by landsliding comes from an average distance of 44 meters (range 9 to 183 meters) from the stream channel edge. In certain cases, most of the LWD in these channels is transported from steeper channels upstream. Channels that receive LWD from an upstream reach are often associated with a VDZ.

LWD Recruitment 1b – Recruitment Dominated by Mass Wasting for Moderately Vulnerable Salmon and Trout Habitat Situation

Reductions in the LWD recruitment potential from streamside landslides that are adjacent to or immediately upstream of moderately vulnerable Salmon and Trout habitat are a moderate risk to maintaining aquatic resources.

Situation Locations

Riparian segments in stream-adjacent mass wasting delivery-prone areas along Class I AD, ALD, CG6.5, or UG6.5 resource channel segments or along a VDZ immediately upstream of Class I AD, ALD, CG6.5, or UG6.5 resource channel segments are a moderate risk to Salmon and Trout in the resource segments.

Management-Related Contributing Factors

Past timber harvest from stream-adjacent slide-prone areas and the slow regeneration of trees on steep slopes that have failed could reduce the long-term supply of LWD to streams. Because the landslide recruitment process typically increases in importance, relative to other processes, in moderate and higher gradient CGU channels, the slide-prone areas along these streams are a major source of LWD and a prime concern for riparian timber management.

Riparian stands that currently have poor recruitment potential are a higher risk to Salmon and Trout habitat than riparian stands with a good recruitment potential (see Map D-3, Appendix D). Active forest management is an option for accelerating the process of achieving good recruitment potential conditions.

Risk Assessment Summary

Input Potential. High

Transport Potential. High

Habitat Vulnerability. Low to Moderate for Salmon and Trout

Resource Risk. Moderate to Salmon and Trout

Additional Comments

This situation is similar to Situation 1a, except that Salmon and Trout habitat in these CGUs is less responsive to LWD inputs. In the AD channels, large stable jams are uncommon with LWD predominantly in smaller transient logjams. LWD can form pools and influence channel morphology. In the CG6.5 and UG6.5 CGUs, LWD functions primarily to limit the progress of debris torrents and to store sediment behind large logjams.

LWD Recruitment 2a – Recruitment Dominated by Bank Erosion and Other Stand Mortality Processes for Highly Vulnerable Salmon and Trout Habitat

Situation

Reductions in the near-stream LWD recruitment potential from riparian segments outside of stream-adjacent landslide-prone areas along or immediately upstream of highly vulnerable Salmon and Trout habitat are a high risk to maintaining aquatic resources.

Situation Locations

Riparian segments outside of stream-adjacent landslide-prone areas along Class I CG0, CG3, UG0, or UG3 resource channel segments or along a VDZ immediately upstream of Class I CG0, CG3, UG0, or UG3 resource channel segments.

Management-Related Contributing Factors

Past timber harvest of riparian stands along some streams has reduced stocking or the size of trees sufficient for future LWD. Riparian segments that currently have poor recruitment potential are a higher risk to Salmon and Trout habitat than segments with a good recruitment potential (see Map D-3, Appendix D).

Risk Assessment Summary

Input Potential. Moderate to High

Transport Potential. High

Habitat Vulnerability. High for Salmon and Trout

Resource Risk. High to Salmon and Trout

Additional Comments

The source distance for LWD recruited by bank erosion, windthrow, and stand mortality is shown on Figure E-11. In general, 90 percent of LWD recruitment by these processes is derived from within 7 m of the channel edge and 100 percent is derived from less than 30 m.

In channel segments with a VDZ, the potential supply of LWD from the riparian zone is limited because trees on the channel edge are currently small. Because most of the LWD recruits are derived from near the channel edge (see Figure E-11), the larger trees located behind the VDZ contribute little to LWD supply. Therefore, an active management focus on trees near the channel is probably more beneficial to LWD recruitment and aquatic habitat than passive maintenance of wide buffer zones.

LWD Recruitment 2b – Recruitment Dominated by Bank Erosion and Other Stand Mortality Processes for Moderately Vulnerable Salmon and Trout Habitat

Reductions in the LWD recruitment potential from riparian segments outside of stream-adjacent landslide-prone areas or immediately upstream of moderately vulnerable Salmon and Trout habitat are a moderate risk to maintaining aquatic resources.

Situation Locations

Riparian segments outside of stream-adjacent landslide-prone areas along Class I AD, ALD, CG6.5, or UG6.5 resource channel segments or outside of stream adjacent landslide hazard areas but along a VDZ immediately upstream of Class I AD, ALD, CG6.5, or UG6.5 resource channel segments.

Management-Related Contributing Factors

Past timber harvest of riparian stands along some streams has reduced stocking or the size of trees sufficient for future LWD. Riparian segments that currently have poor recruitment potential are a higher risk to Salmon and Trout habitat than segments with a good recruitment potential (see Map D-3, Appendix D).

Risk Assessment Summary

Input Potential. High

Transport Potential. High

Habitat Vulnerability. Low to Moderate for Salmon and Trout

Resource Risk. Moderate to Salmon and Trout

Additional Comments

This situation is similar to LWD Recruitment 2a, except that Salmon and Trout habitat in these CGUs is less responsive to LWD inputs.

LWD Recruitment 3 – Recruitment by any Process for Moderate and Highly Vulnerable Class II Headwater Species Habitat

Situation

Reductions in the LWD recruitment potential from riparian segments along moderate to highly vulnerable amphibian habitat may be a moderate to high risk to Headwater species.

Situation Location

Riparian segments along Class II ALD, CG6.5, or CG>20% resource channel segments.

Management-Related Contributing Factors

Past timber harvest of riparian stands along some streams has reduced stocking or the size of trees sufficient for future LWD. Riparian segments that currently have poor recruitment potential are a higher risk to Headwater species habitat than segments with a good recruitment potential (see Map D-3, Appendix D).

Risk Assessment Summary

Input Potential. High

Transport Potential. High

Habitat Vulnerability. Moderate to High for Headwater species

Resource Risk. Moderate to High for Headwater species

Additional Comments

This CMR identifies Class II channel segments with a moderate to high habitat potential for Headwater species that are not included in Situations 1 and 2. The importance of LWD to form Headwater species habitat in these CGUs is not well documented. There is documentation that suggests downed wood may be important for tailed frogs, but no data exist for the southern torrent salamander. Survey data from the LEED indicate that the quantity of LWD currently meets properly functioning conditions (see Tables G-12, G-13, G-15, and G-16).

LWD Recruitment 4 – Recruitment by any Process for Channels with Low Headwater Species Habitat Vulnerability or no Aquatic Habitat

Situation

Reductions in LWD recruitment to channels with low habitat potential for Headwater species or with no aquatic habitat potential are low risk to all species.

Situation Location

Riparian segments in any Class II CGU with low habitat potential for Headwater species or segments along Class III channels.

Risk Assessment Summary

Input Potential. Low

Transport Potential. Low

Habitat Vulnerability. N/A for all species

Resource Risk. None to Low to all species

Additional Comments

Small and large woody debris, small trees and shrubs, rocks, and streambank roots provide functions of wood in these small channels. LWD is typically not a dominant factor influencing channel form and function in these colluvial channels.

RIPARIAN – HEAT

Resource Sensitivity

A high percentage of riparian canopy shade occurs in the LEED. Approximately 72 percent of the total stream channel network meets or exceeds the target canopy shade level of 85 percent. Bear, Jordan, and Howe/Atwell Creeks have below-target shade levels along major portions of the stream length. In these sub-basins and in Panther Creek, stream temperatures exceeded the PFC Matrix guideline of 16.8 C during one or more sample years. These results suggest temperatures closely reflect shade levels upstream. Water temperatures above the PFC guideline may influence the growth and survival of Salmon, Trout, and Headwater species in the LEED.

Assumptions

- Target riparian zone canopy cover of 85 percent is adequate to maintain cool stream temperatures in Eel River tributaries in the LEED.
- Stream temperature sensitivity to canopy cover loss is influenced by valley morphology and topography.
- Resource risk is based on channel sensitivity (Map 2) and habitat vulnerability (Table 5).
- Water temperatures in the Eel River are not significantly influenced by the influx of LEED tributaries.
- Because stream temperature sensitivity and habitat vulnerability are not uniform, the CMRs are organized by sensitivity/species vulnerability category. This enables prescriptions to be conditioned according to levels of resource risk.

Situations

Heat 1a - Canopy Cover for Streams with Salmon and Trout Habitat that are Highly Sensitive to Heat Input

Situation

Reductions in canopy cover for Class I streams that have documented water temperature concerns or that occur in certain channel morphology or topography where temperature is sensitive to shade loss is a high risk to Salmon and Trout.

Situation Locations

Current and potentially sensitive reaches in Class I streams (Map 2).

Management-Related Contributing Factors

Riparian and stream canopy cover has been reduced as a result of past timber harvest in riparian zones (see Map D-4) and by channel disturbance events that are sometimes related to forest management activities and roads. Table D-7 shows the percentage of stream channel length having riparian zones that do not meet the target canopy cover conditions in each sub-basin.

Risk Assessment Summary

Channel Sensitivity. High

Habitat Vulnerability. High

Resource Risk. High for Salmon and Trout

Additional Comments

Reductions in canopy cover are not only due to riparian timber harvest, but may be a result of channel over-widening conditions caused by debris flows and dam-break floods. In the LEED, the VDZ is an indicator of these events (Map E-3). Because disturbances may be more frequent than the age of stand maturity, the riparian zones rarely grow large conifer trees and are dominated by small conifer and deciduous vegetation. In these streams, shade potential is limited by the small trees that are directly adjacent to the channel. Potential shade from trees behind the VDZ is dependent on channel width, VDZ width, and potential tree height. A reduction in the frequency of channel disturbance from debris flows and dam-break floods will enable shade recovery.

Sub-Basins that have Vegetative Disturbance Zones. Howe, Monument, Kiler, Dinner, Twin, Jordan, Greenlaw, Bear, and Stitz (Segments E1 and E2) VDZs occur in CGU types AD, ALD, CG0, CG3, CG6.5, and >20%.

Heat 1b - Canopy Cover for Streams with Salmon and Trout Habitat that are Moderately Sensitive to Heat Input

Situation

Reductions in canopy cover for Class I streams that are not highly sensitive to shade loss is a moderate risk to Salmon and Trout.

Situation Locations

Class I streams that are not highly sensitive to shade loss (Map 2).

Management Related Contributing Factors

Riparian and stream canopy cover has been reduced as a result of past timber harvest in riparian zones (see Map D-4) and by channel disturbance events that are sometimes related to forest management activities and roads. Table D-7 shows the percentage of stream channel length having riparian zones that do not meet the target canopy cover conditions in each sub-basin.

Risk Assessment Summary

Channel Sensitivity. Moderate

Habitat Vulnerability. High

Resource Risk. Moderate for Salmon and Trout

Additional Comments

This situation is similar to Heat 1a except these segments are less sensitive to shade loss as a result of topographic shading and valley morphology.

Heat 2 - Canopy Cover for Streams with Good Potential Headwater Species Habitat

Situation

Reductions in canopy cover for Class II streams that have good potential habitat for torrent salamanders and tailed frogs are a moderate risk to these species.

Situation Locations

Good potential headwater amphibian habitat in Class II streams (see Map G-1).

Management-Related Contributing Factors

Riparian and stream canopy cover has been reduced as a result of past timber harvest in riparian zones (see Map D-4) and by channel disturbance events that are sometimes related to forest management activities and roads. Table D-7 shows the percentage of stream channel length having riparian zones that do not meet the target canopy cover conditions in each sub-basin.

Risk Assessment Summary

Channel Sensitivity. Moderate

Habitat Vulnerability. High

Resource Risk. Moderate for Headwater species

Additional Comments

Nearly all of the good potential Headwater species habitat is located in streams with topographic shading as a result of being in small narrow valleys, located on the south side of the Eel River.

Small riparian vegetation can be effective at shading these small channels.

PUBLIC COMMENTS

PALCO placed notices that the LEED Public Review Draft Report was available at the Fortuna Public Library and at the PALCO offices in Scotia for a 60-day review and comment period in November of 2002. No public comments were received either by the end of the comment period (February 13, 2003) or since.

PRESCRIPTIONS

Following the Public Review Draft comment period, the SRT proceeded with development of prescriptions for the LEED. PALCO presented the LEED Watershed Analysis and prescriptions at a public meeting on July 29, 2004. The prescriptions are included as Attachment 2 and their justifications as Attachment 3.

REFERENCES

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

Allen, G.M. and M.M. Barrett 1985. A Model of Third Growth Coastal Redwood Sprout Establishment and Growth under Various Levels of Overstory Removal. McIntire-Stennis #74 Project. Final Report. Humboldt State University. Arcata, CA.

Barbour, M.G. and J. Major 1988. Terrestrial Vegetation of California. California Native Plant Society special Publication No. 9. University of Cal., Davis, CA.

Bates, C.G. and J. Roeser, Jr. 1927. Light Intensities Required for Growth of Coniferous Seedlings. American Journal of Botany. 15(3): 185-194.

Brown, L.R. and P.B. Moyle 1991. Status of Coho Salmon in California. Department of Wildlife and Fisheries Biology, University of California, Davis CA.

Brown, W.M. and J.R. Ritter 1971. Sediment Transport and Turbidity in the Eel River Basin, California. U.S. Geological Survey Water Supply Paper 1986, 67 p.

Bury, R. B. 1962. Occurrence of *Clemmys m. marmorata* in north coastal California. Herpetologica, 18:283.

Bury, R. B. 1972. Habits and Home Range of the Pacific Pond Turtle, *Clemmys marmorata*, in a Stream Community. Ph.D. Thesis, University of California, Berkeley.

California Spatial Information Library 1999. Downloaded at http://www.gis.ca.gov/index.epl; government ownership layer, source scale 1:100,000; last updated 9/1999.

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.

Cole, D.W. 1983. Redwood Sprout Growth Three Decades After Thinning. Journal of Forestry. 81:148-150.

Free, Dan 2002. Personal communication from NMFS.

Fritz, E. 1933. The Story Told by a Fallen Redwood. Save-the-Redwoods League, San Francisco.

Fritz, E. 1957. California Coast Redwood, an Annotated Bibliography of 2003 References. Found. Amer. Resources Manage, Recorder Sunset Press, San Francisco.

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.

Gardner, R.A. and K.E. Bradshaw 1954. Characteristics and Vegetation Relationships of Some Podzolic Soils near the Coast of Northern California. Soil Sci. Soc. Amer. Proc. 18:320-325.

Groot C., and L. Margolis, editors 1991. Pacific Salmon Life Histories. Government of Canada, Department of Fisheries and Oceans, Biological Sciences Branch, Pacific Biological Station, Nanaimo, British Columbia, Canada. UBC Press, Vancouver, British Columbia.

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 2000a. Work Plan for Lower Eel and Eel River Delta (LEED) Watershed Analysis, Humboldt County, California. Prepared for the Pacific Lumber Company.

Hart Crowser 2000b. Geology and Stream Channel Morphology Bear Creek Sub-Basin Draft Report, Lower-Eel Watershed, Humboldt County, California. Prepared for the Pacific Lumber Company.

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.

Holland, D.C. 1994. The Western Pond Turtle: Habitat and History. U.S. Department of Energy, Bonneville Power Administration, Environment, Fish and Wildlife. PO Box 3621. Portland, OR. 97208-3621.

Martin, D.J. and L.E. Benda 2001. Patterns of in-stream wood recruitment and transport at the watershed scale. Transaction of American Fisheries Society 130: 940-958.

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.

National Marine Fisheries Service (NMFS) 1997. Aquatic properly functioning condition matrix (a.k.a. species habitat needs matrix). Work-in-progress for the Pacific Lumber Company Habitat Conservation Plan. March 20. Downloaded from http://ceres.ca.gov/headwaters/hcp/v4/v4pds6.pdf.

Nussbaum, R.A., E.D. Brodie Jr. and R.M. Storm 1983. *Amphibians and Reptiles of the Pacific Northwest*. University of Idaho Press. Moscow, Idaho.

Ogle, B.A. 1953. Geology of the Eel River Valley area, Humboldt County, California: California Division of mines and Geology Bulletin 164, 128 p.

Olson, D.F., Jr., D.F. Roy, and G.A. Walters 1990. *Sequoia sempervirens* (D. Don) Endl. *in* R.M. Burns and B.H. Honkala, coordinators. Silvics of North America, Volume 1, Conifers. U.S. Department of Agriculture Handbook 654.

Pacific Watershed Associates (PWA) 1998. Sediment Source Investigation and Sediment Reduction Plan for the Bear Creek Watershed, Humboldt County, California. Prepared for the Pacific Lumber Company, Scotia, CA.

PWA 1999. Sediment Source Investigation and Sediment Reduction Plan for Jordan Creek Watershed, Humboldt County California. Prepared for the Pacific Lumber Company, Scotia, CA.

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

PALCO 2000. Watershed Assessment Methods for PALCO Lands: Stream Channel Assessment. April 2000.

PALCO 2000. Methods to complete watershed analysis on Pacific Lumber Company lands in northern California.

Preston, Larry 2001. California Department of Fish and Game. Personal communication. February 22 and 27, 2001.

Puckett, L.K. 1977. The Eel River Estuary-Observations on Morphometry, Fishes, Water Quality and Invertebrates; Memorandum Report. State of California, Resources Agency, Department of Fish and Game.

Rantz, S.E. 1968. Average Annual Precipitation and Runoff in Northern Coastal California: U.S. Geol. Survey Hydrologic Atlas HA-298.

Reese, D.A. 1996. Comparative demography and habitat use of western pond turtles in northern California: the effects of damming and related alterations. Ph.D. Thesis, University of California, Berkeley.

Rydelius, J.A., and W.J. Libby 1993. Arguments for Redwood Clonal Forestry. Pages 159-168 *in* M.R. Ahuja and W.J. Libby, eds. Clonal Forestry II, Conservation and Application. Springer-Verlag, Heidelberg.

Southwest Fisheries Science Center (SFSC) 2001. Status Review Update for Coho Salmon (Oncorhynchus kisutch) From the Central California Coast and the

California Portion of the Southern Oregon/Northern California Coasts Evolutionally Significant Units. Santa Cruz Laboratory, Santa Cruz, CA.

Slaney, P.A. and D. Zaldokas 1997. Fish Habitat Restoration Procedures. Watershed Restoration Technical Circular No. 9. watershed Restoration Program, Ministry of Environment, Lands, and Parks, Vancouver, British Columbia.

Stuart, John D. 1987. Fire History of an Old-Growth Forest of Sequoia Sempervirens *(Taxodiaceae)* Forest in Humboldt Redwoods State Park, CA. Madrono 34(2):128-141.

USGS 2000. Water Resources Data, California, Water Year 2000, Volume 2. Pacific Slope Basins from Arroyo Grande to Oregon State Line except Central Valley. By M.D. Webster, S.W. Anderson, M.F. Friebel, L.A. Freeman, and J.R. Smithson. Water-Data Report CA-00-2. Downloaded at http://ca.water.usgs.gov/data/ on 4/3/2002.

Viers, S.D. 1996. Ecology of the Coast Redwood. Pages 9-12 *in* LeBlanc, J. 1996. Proceedings of the Conference on Coast Redwood Forest Ecology and Management. Humboldt State University, Arcata, CA.

Wood, C. 1956. The history of the Pacific Lumber Company 1862-1955. Humboldt County Historical Society. Humboldt State College student competition.

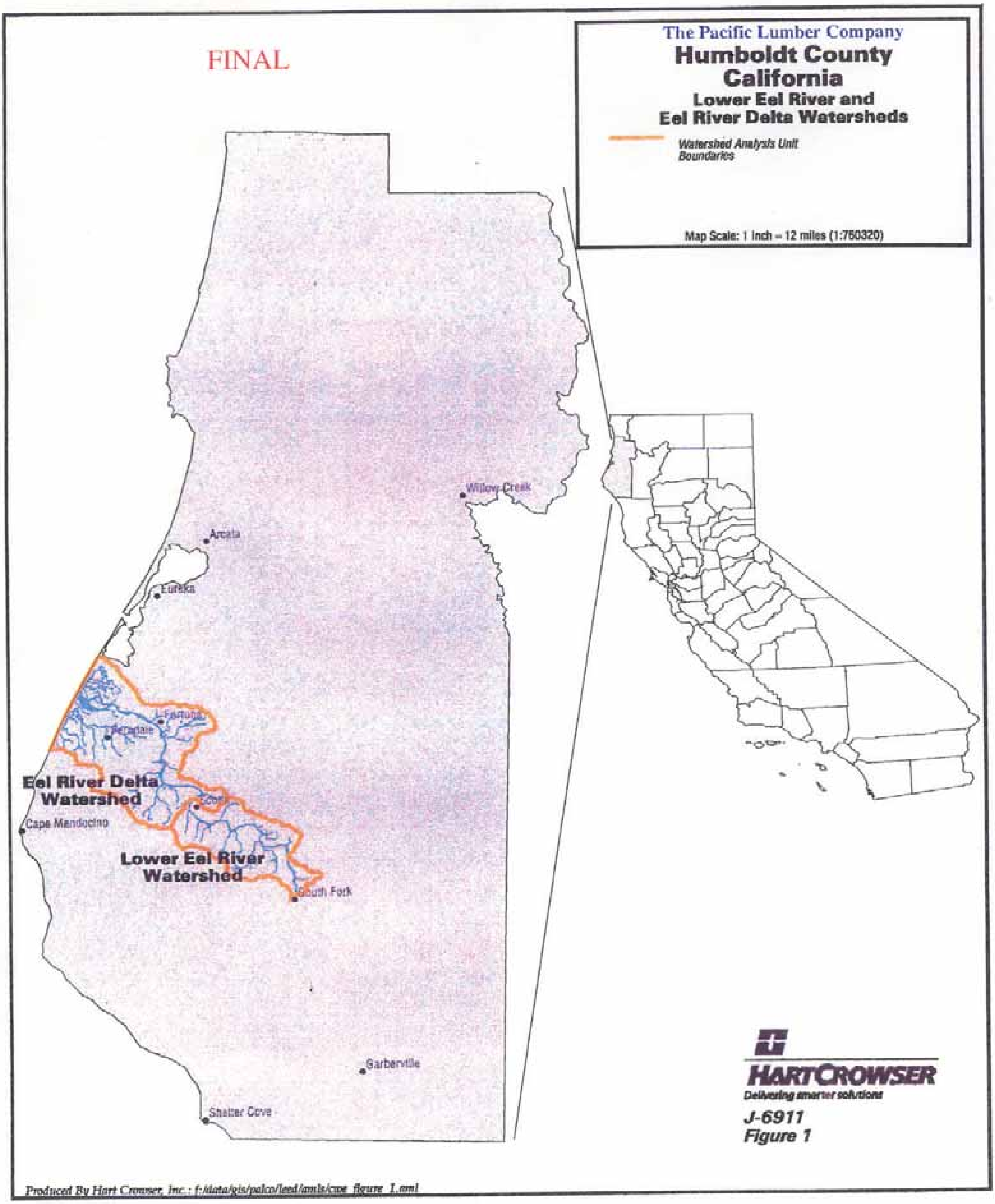
Zeiner, D. C., W. F. Laudenslayer, Jr., K. E. Mayer, and M. White 1990. California's Wildlife, Volume I: Amphibians and Reptiles. Calif. Dept. Fish and Game, Sacramento. 272 pp.

F:\Docs\Jobs\691121\Final\CWE-CMR-Rx Report.doc

ATTACHMENT 1
LEED ISSUES RESPONSE MATRIX

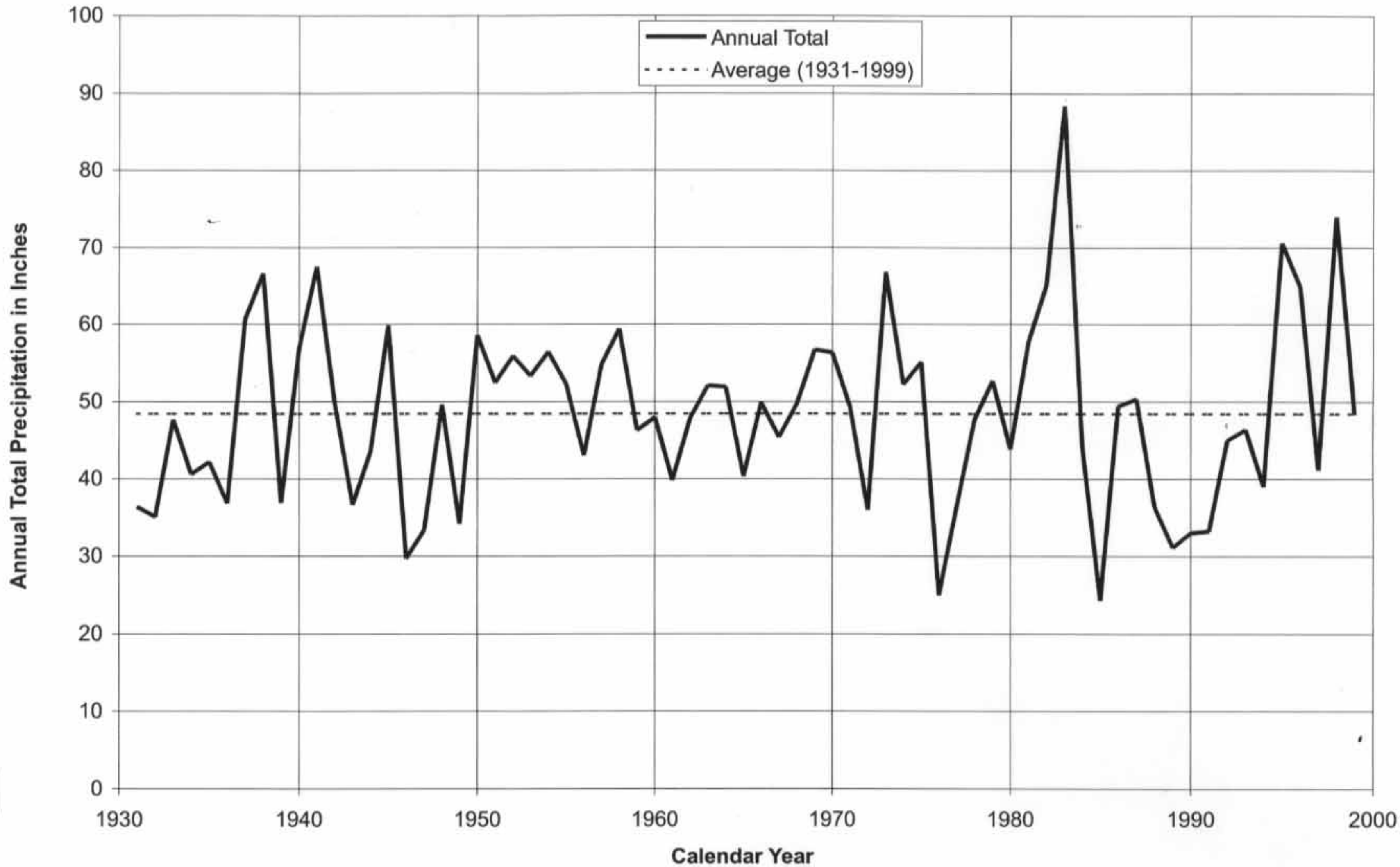
ATTACHMENT 2
PRESCRIPTIONS (Provided by PALCO)

ATTACHMENT 3
JUSTIFICATION FOR PRESCRIPTIONS (Provided by PALCO)



FINAL
The Pacific Lumber Company
Humboldt County
California
Lower Eel River and
Eel River Delta Watersheds
Watershed Analysis Unit
Boundaries
Map Scale: 1 Inch = 12 miles (1:760320)
Willow Creek
Arcata
Eureka
Fortuna
Eel River Delta
Watershed
Cape Mendocino
Lower Eel River
Watershed
South Fork
Garberville
Shelter Cove
HARTCROWSER
Delivering smarter solutions
J-6911
Figure 1
Produced By Hart Crowser, Inc.: f:/data/gis/palco/leed/amls/cme_figure_1.aml

Annual Precipitation at Scotia

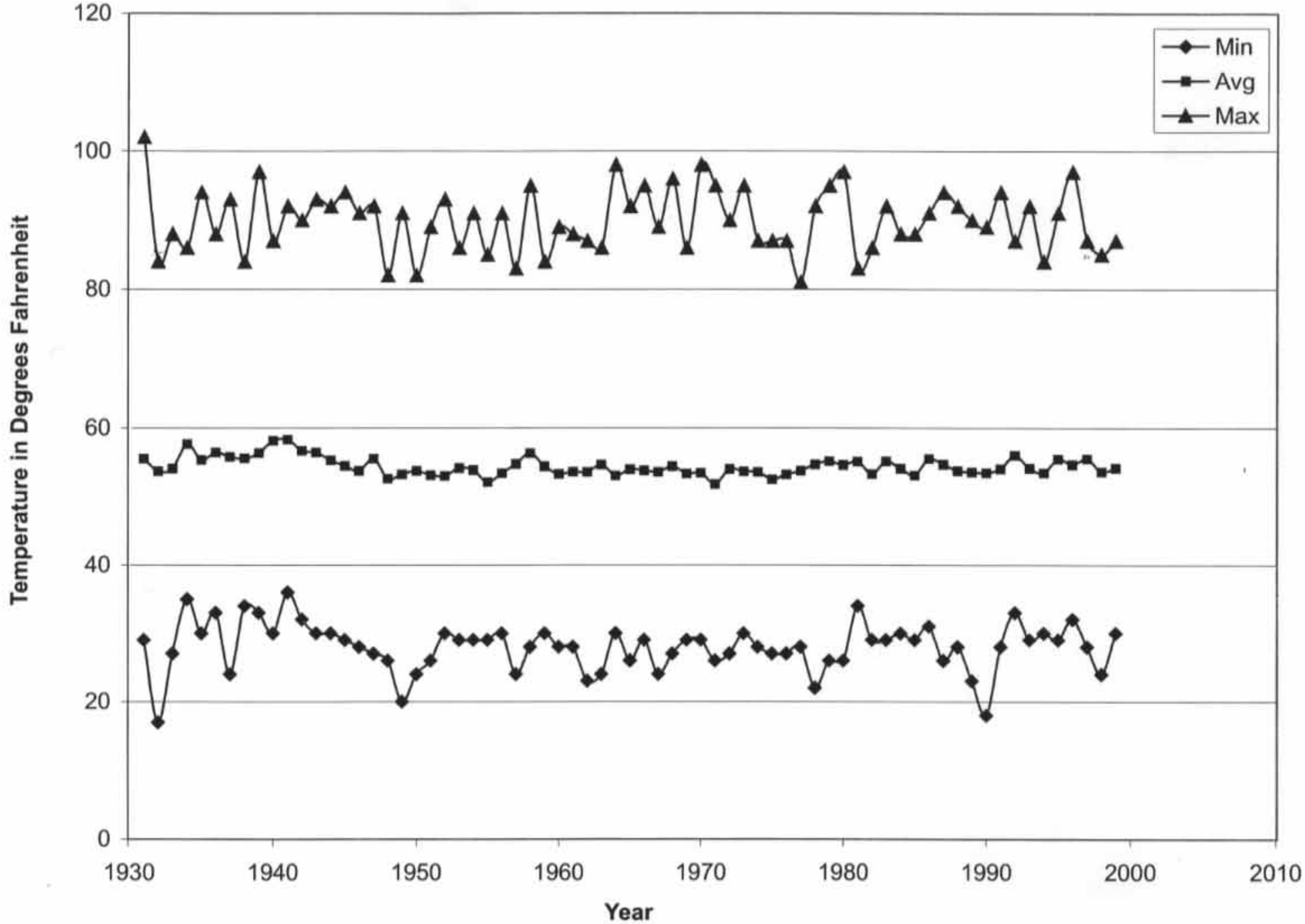


FINAL

HARTCROWSER
6911
Figure 2

691108AC.cdr HEL

Annual Temperatures at Scotia (1931-1999)

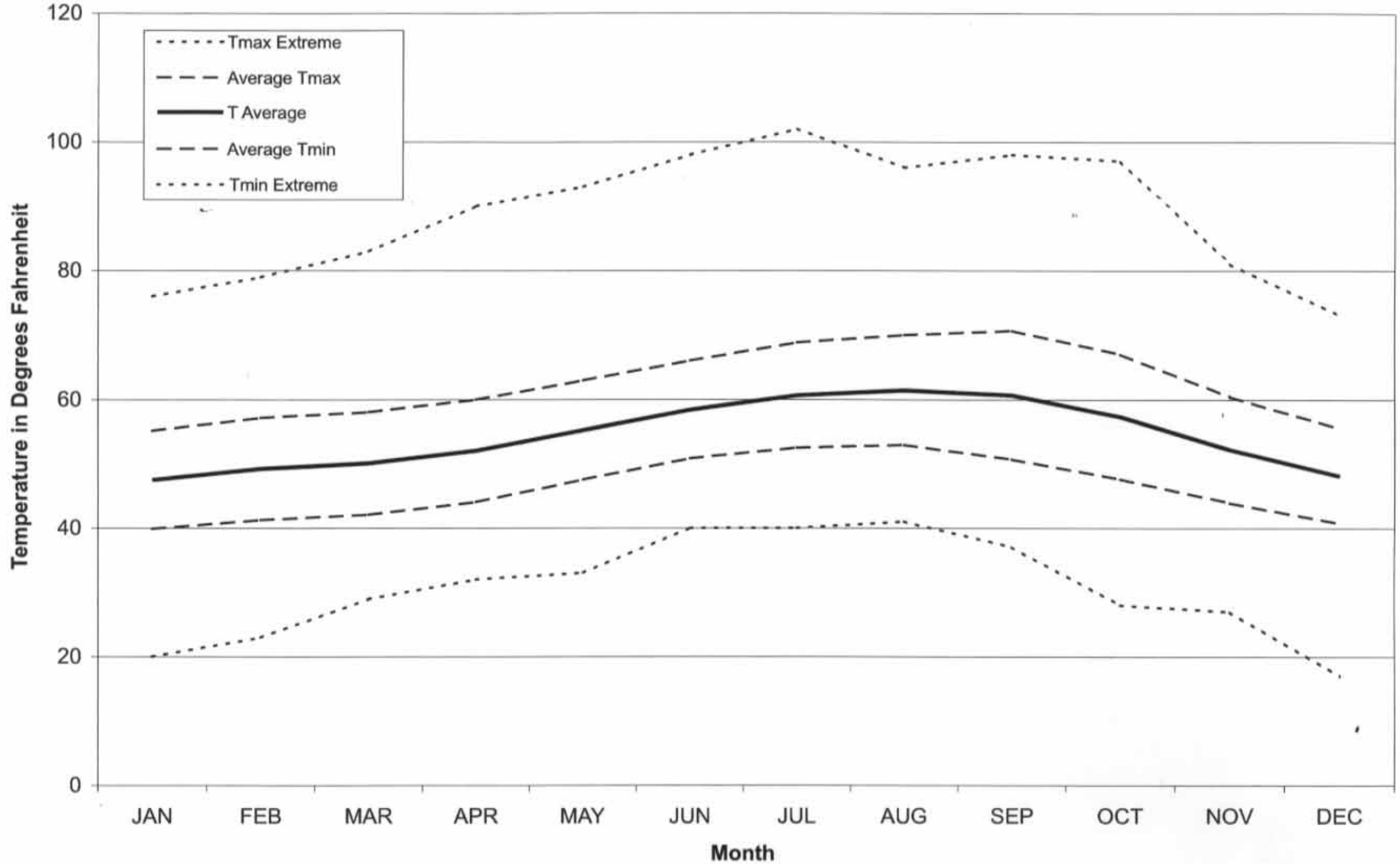


691108AD.cdr HEL

FINAL

HARTCROWSER
6911
Figure 3

Average and Extreme Monthly Temperatures at Scotia (Average over 1931-1999)

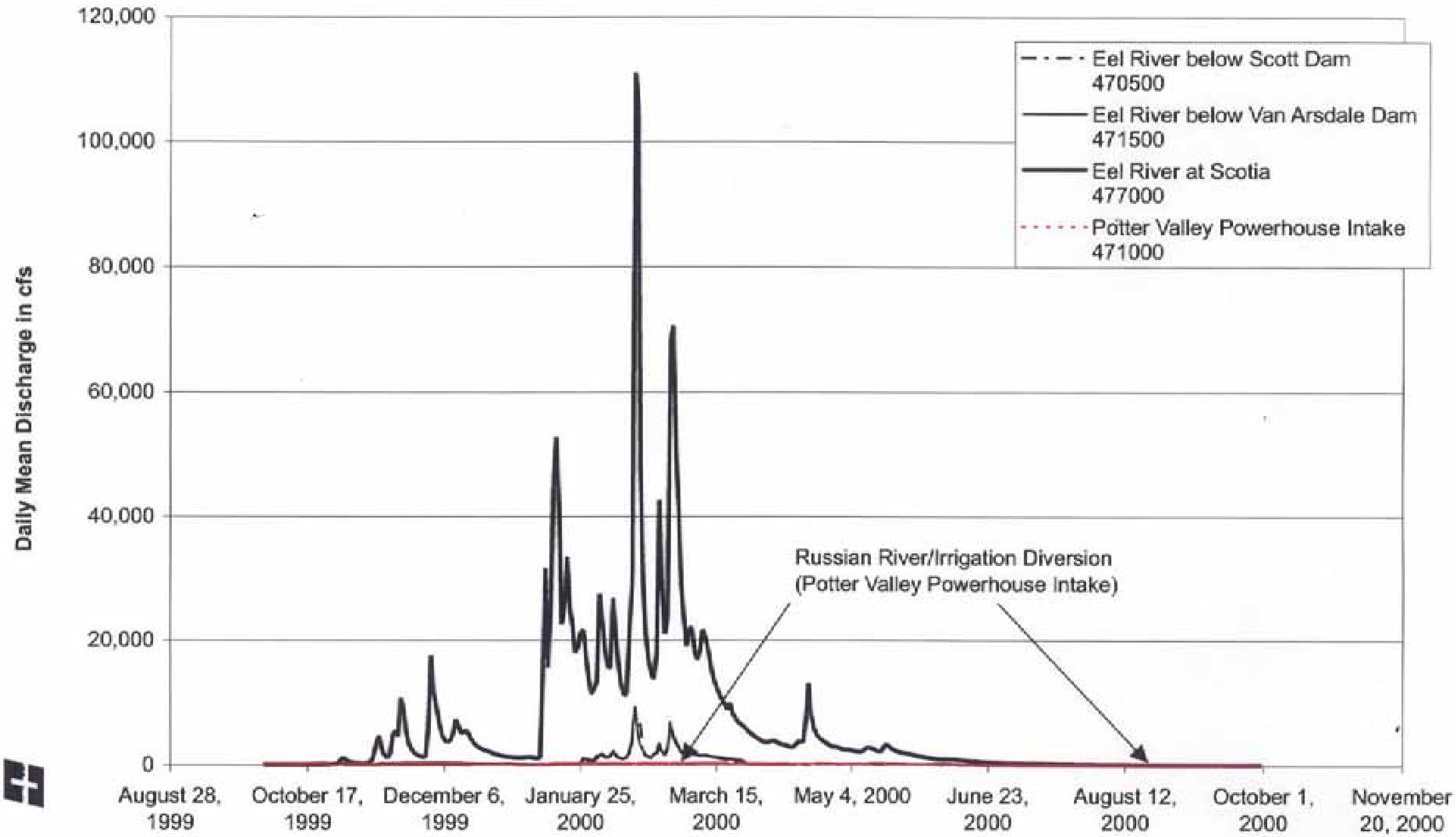


691108AE.cdr HEL

FINAL

HARTCROWSER
6911
Figure 4

Eel River Flows for WY2000



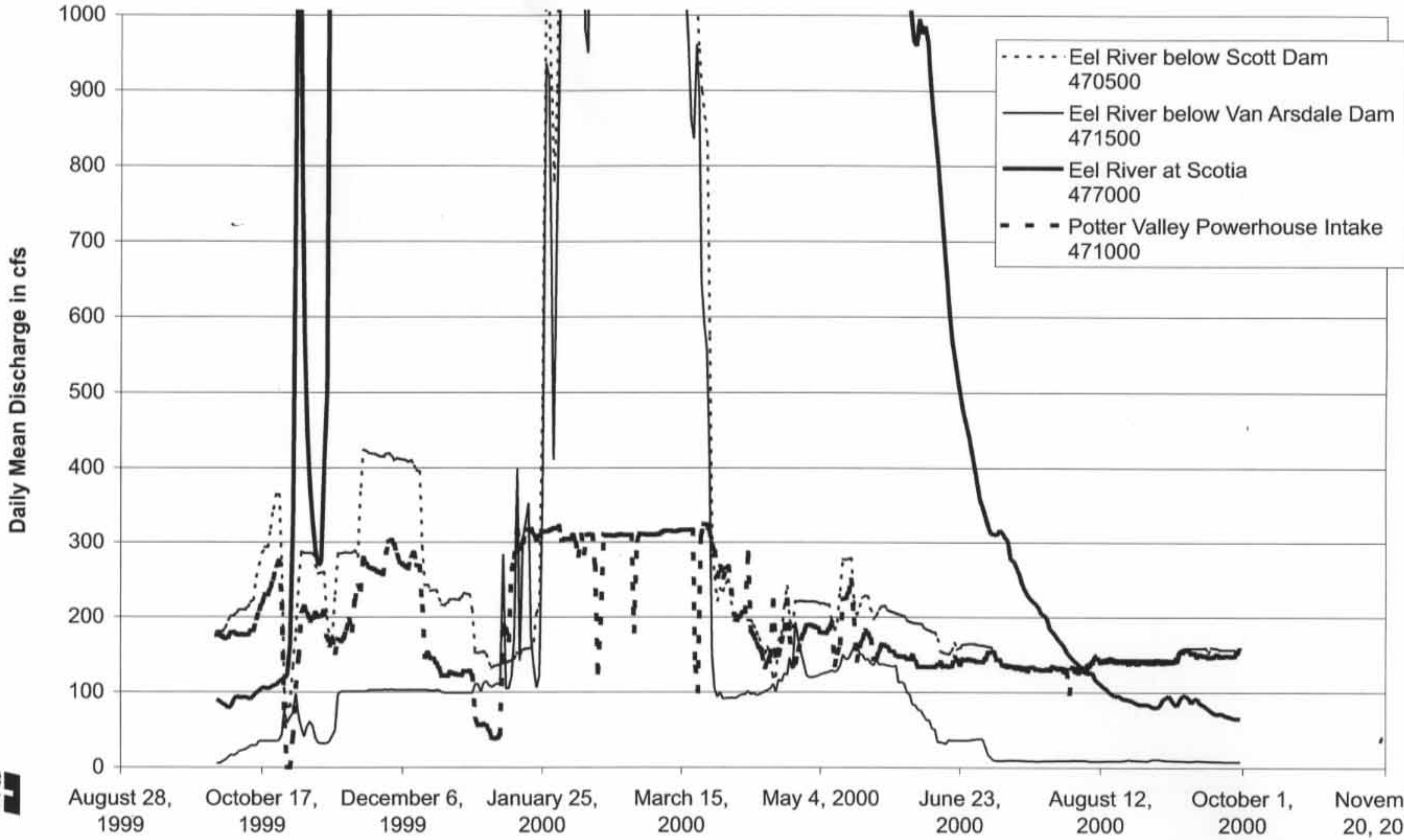
Source: USGS Water Resources Data California, Water Year 2000, Vol. 2
Water-Data Report CA-00-2 http://ca.water.usgs.gov/data/

691108AA.cdr HEL

FINAL

HARTCROWSER
6911
Figure 5

Eel River Flows for WY2000

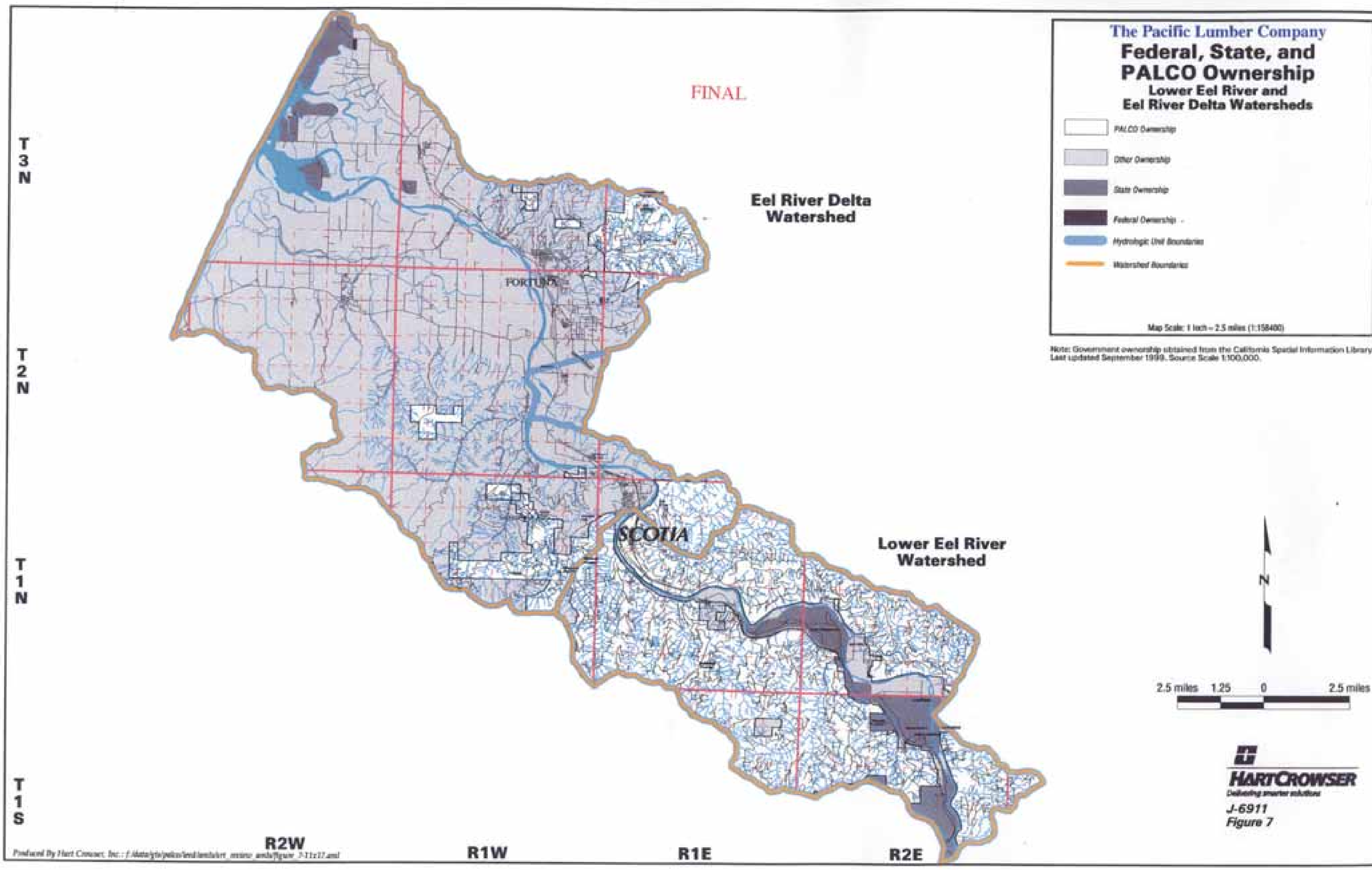


Source: USGS Water Resources Data California, Water Year 2000, Vol. 2
Water-Data Report CA-00-2 http://ca.water.usgs.gov/data/

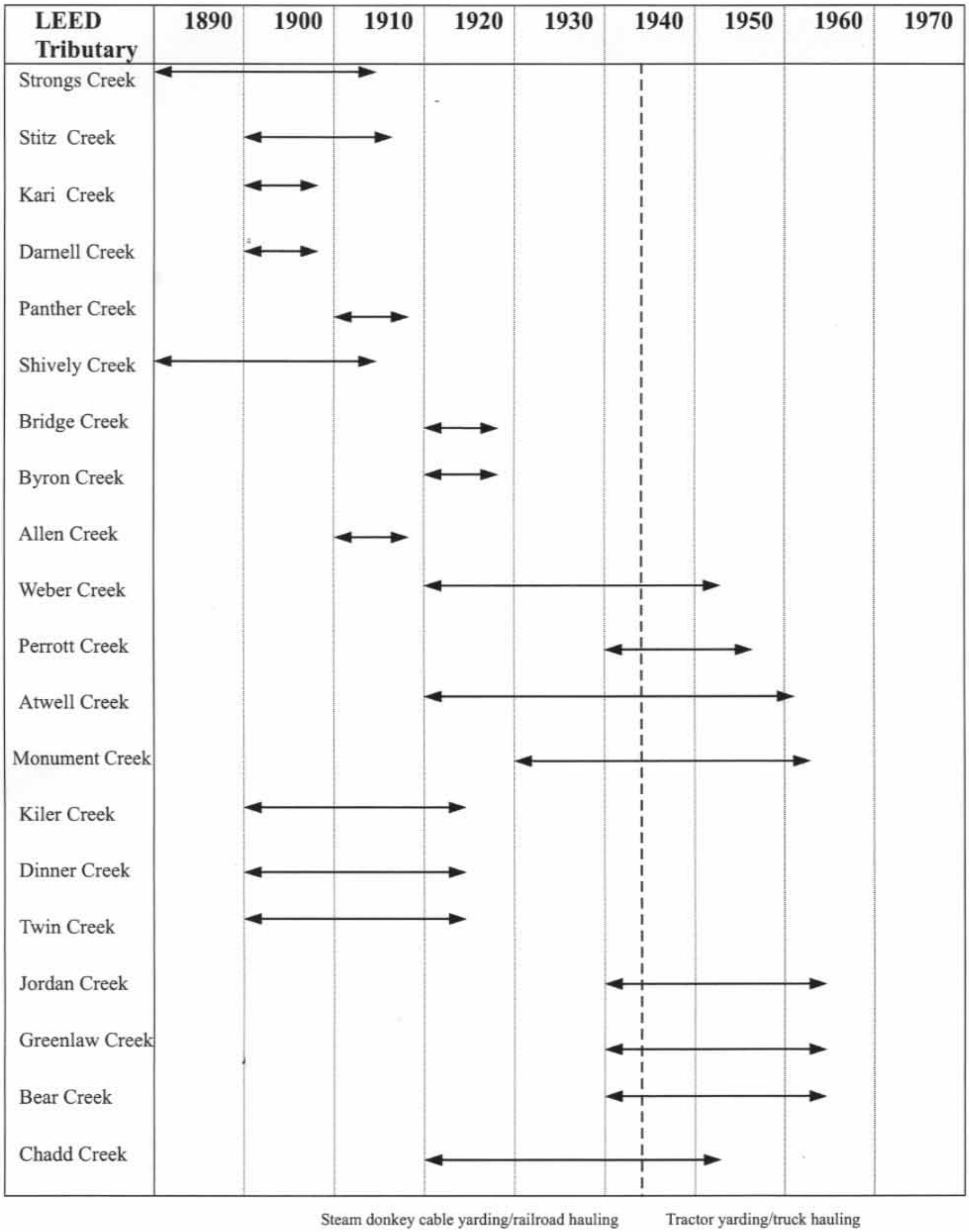
691108AA.cdr HEL

HARTCROWSER
6911-08
Figure 6

FINAL


The Pacific Lumber Company
Federal, State, and
PALCO Ownership
Lower Eel River and
Eel River Delta Watersheds
PALCO Ownership
Other Ownership
State Ownership
Federal Ownership
Hydrologic Unit Boundaries
Watershed Boundaries
Map Scale: 1 inch = 2.5 miles (1:158400)
Note: Government ownership obtained from the California Spatial Information Library.
Last updated September 1999. Source Scale 1:100,000.
FINAL
Eel River Delta
Watershed
Lower Eel River
Watershed
FORTUNA
SCOTIA
N
2.5 miles 1.25 0 2.5 miles
T
3
N
T
2
N
T
1
N
T
1
S
R2W
R1W
R1E
R2E
HARTCROWSER
Delivering smarter solutions
J-6911
Figure 7

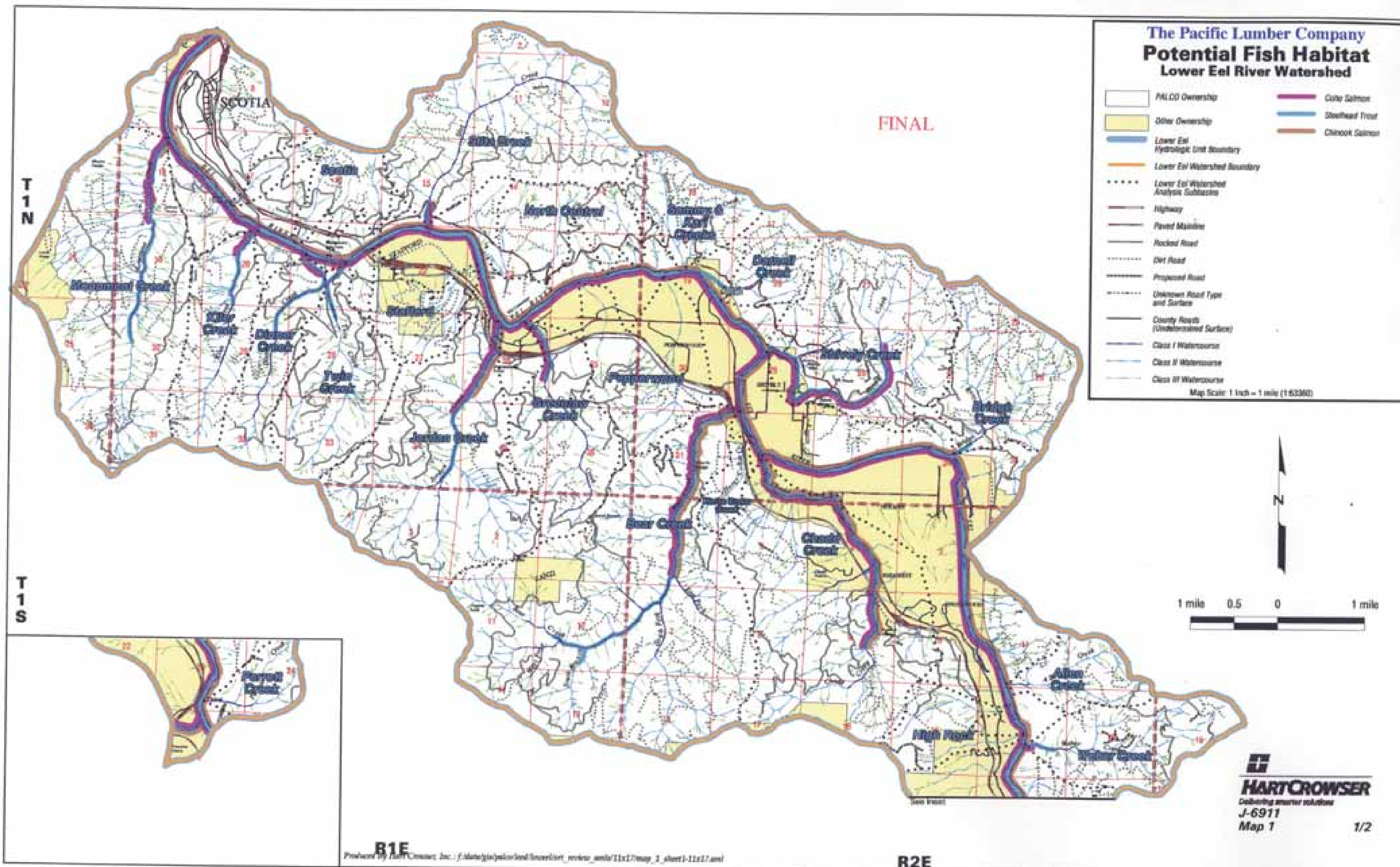
First-Cycle Logging Operations on PALCO Ownership in the LEED



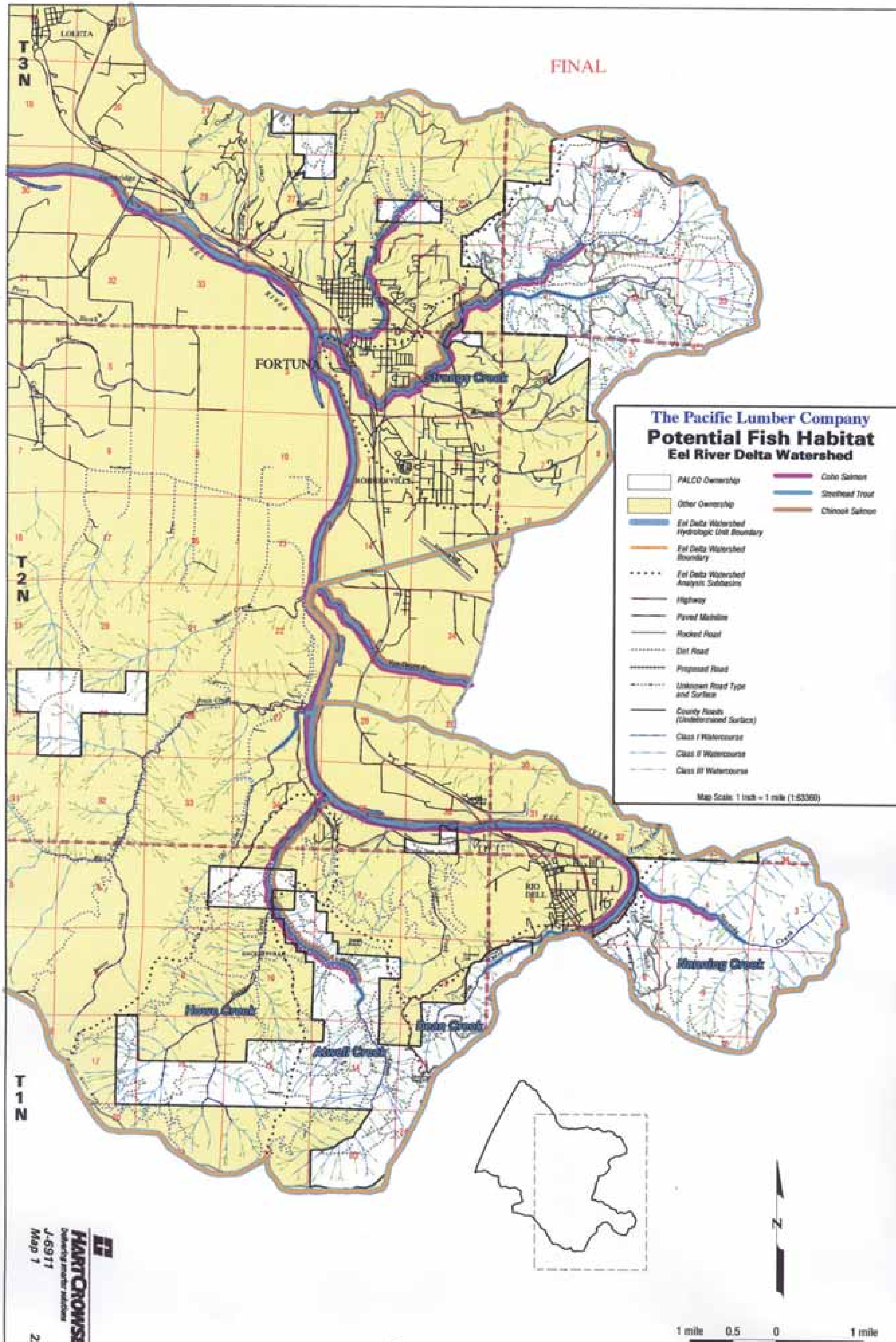
691108AB.cdr HEL

FINAL

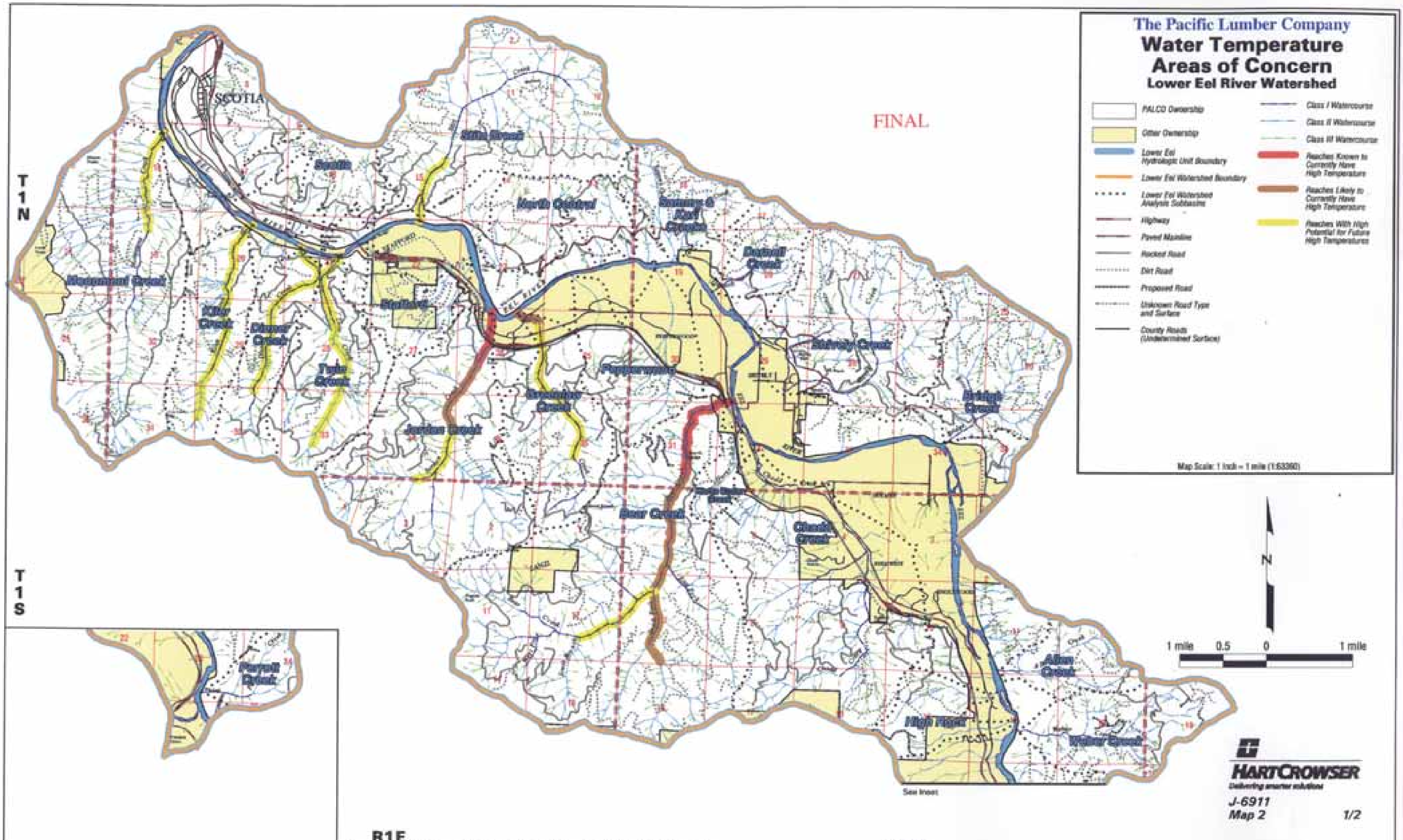
HARTCROWSER
6911
Figure 8



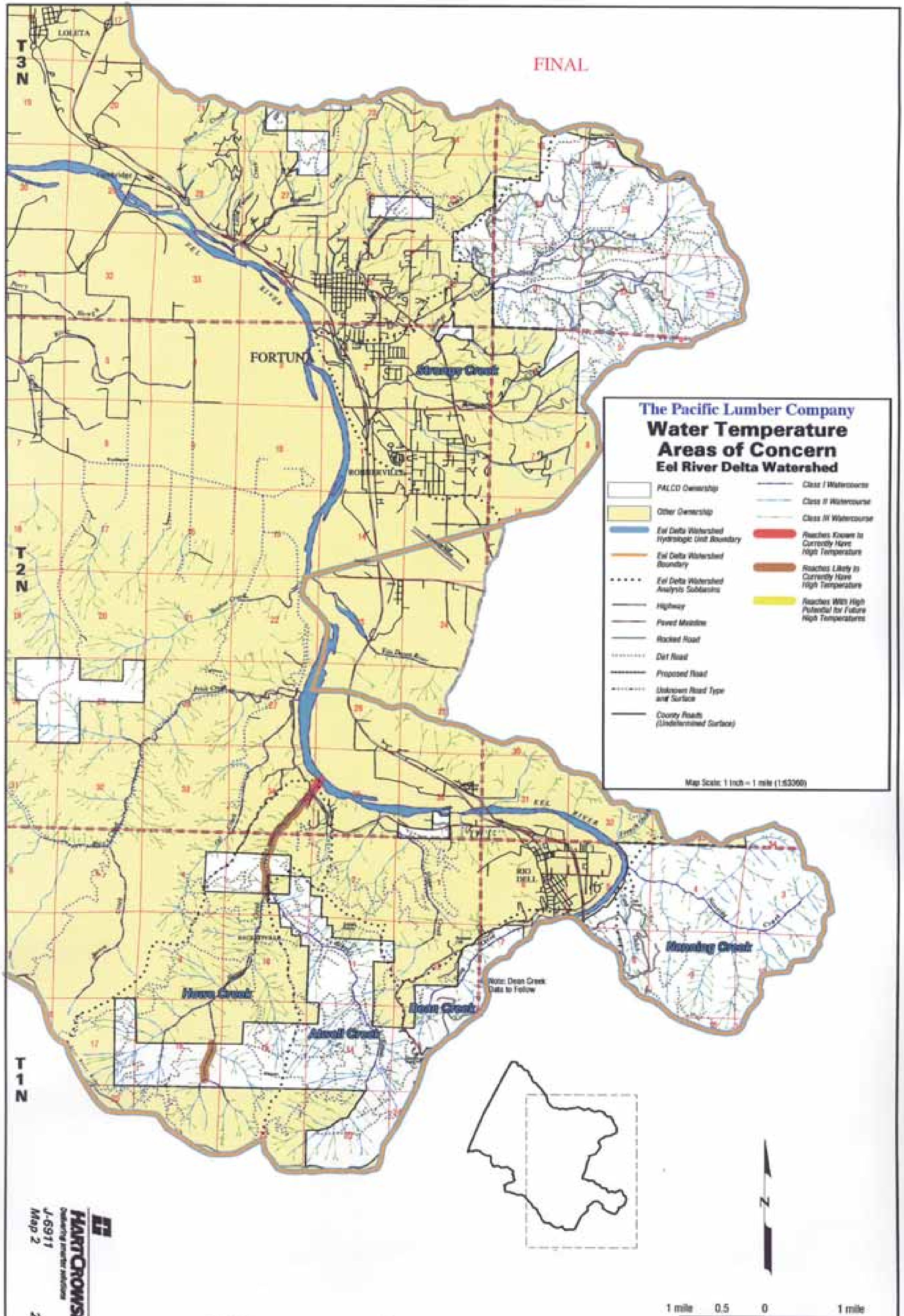
The Pacific Lumber Company
Potential Fish Habitat
Lower Eel River Watershed
PALCO Ownership
Other Ownership
Lower Eel Hydrologic Unit Boundary
Lower Eel Watershed Boundary
Lower Eel Watershed Analysis Subbasins
Highway
Paved Mainline
Rocked Road
Dirt Road
Proposed Road
Unknown Road Type and Surface
County Roads (Undetermined Surface)
Class I Watercourse
Class II Watercourse
Class III Watercourse
Coho Salmon
Steelhead Trout
Chinook Salmon
Map Scale: 1 Inch = 1 mile (1:63360)
FINAL
SCOTIA
Stitz Creek
Scotia
North Central
Monument Creek
Kiler Creek
Dinner Creek
Stafford
Twin Creek
Jordan Creek
Greenlaw Creek
Pepperwood
Darnell Creek
Shively Creek
Bridge Creek
Bear Creek
Chadd Creek
Allen Creek
High Rock
Weber Creek
Parrott Creek
See Insert
N
1 mile 0.5 0 1 mile
T 1 N
T 1 S
R1E
R2E
HARTCROWSER
Delivering smarter solutions
J-6911
Map 1
1/2



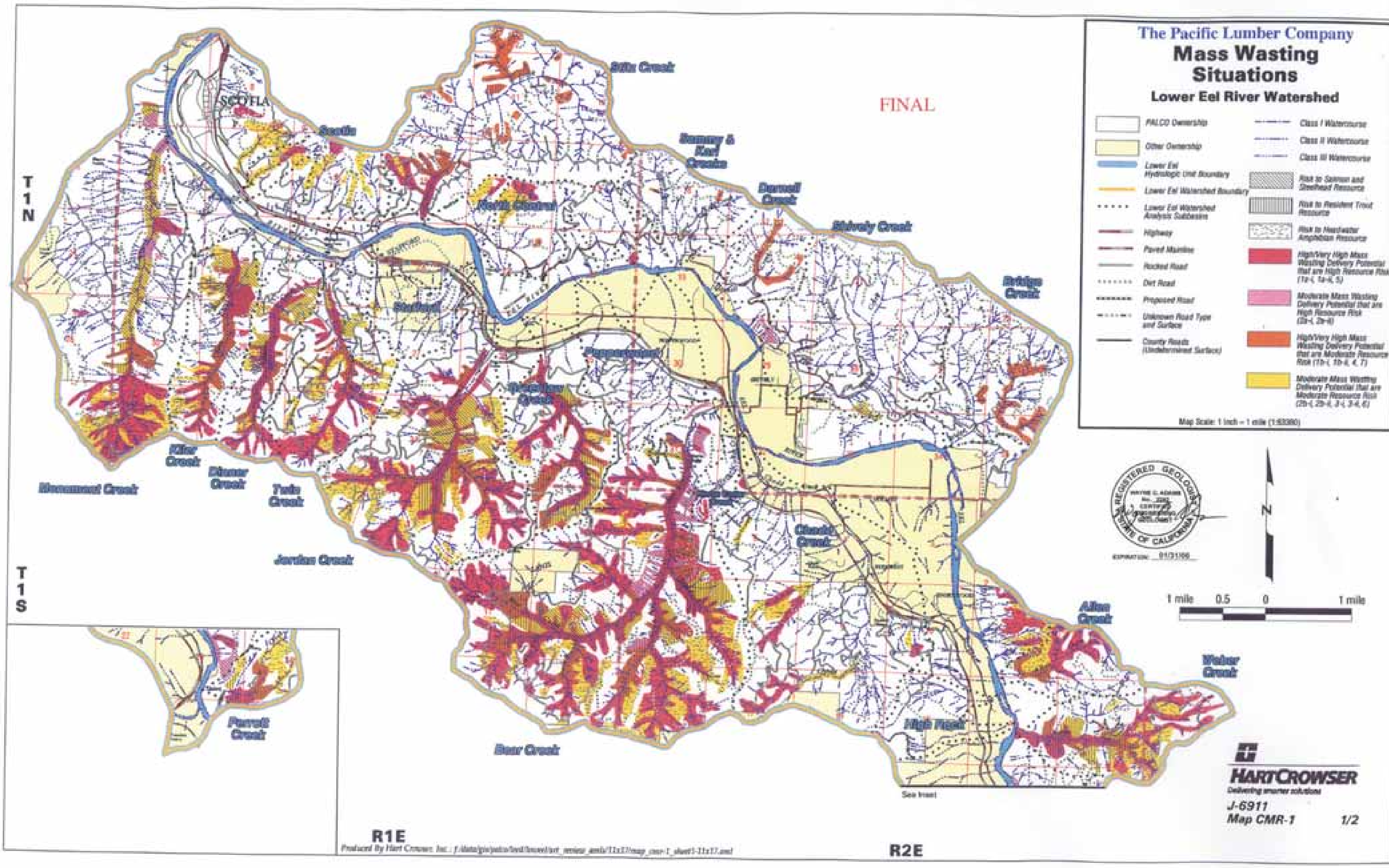
Produced By Hart Crowser, Inc.



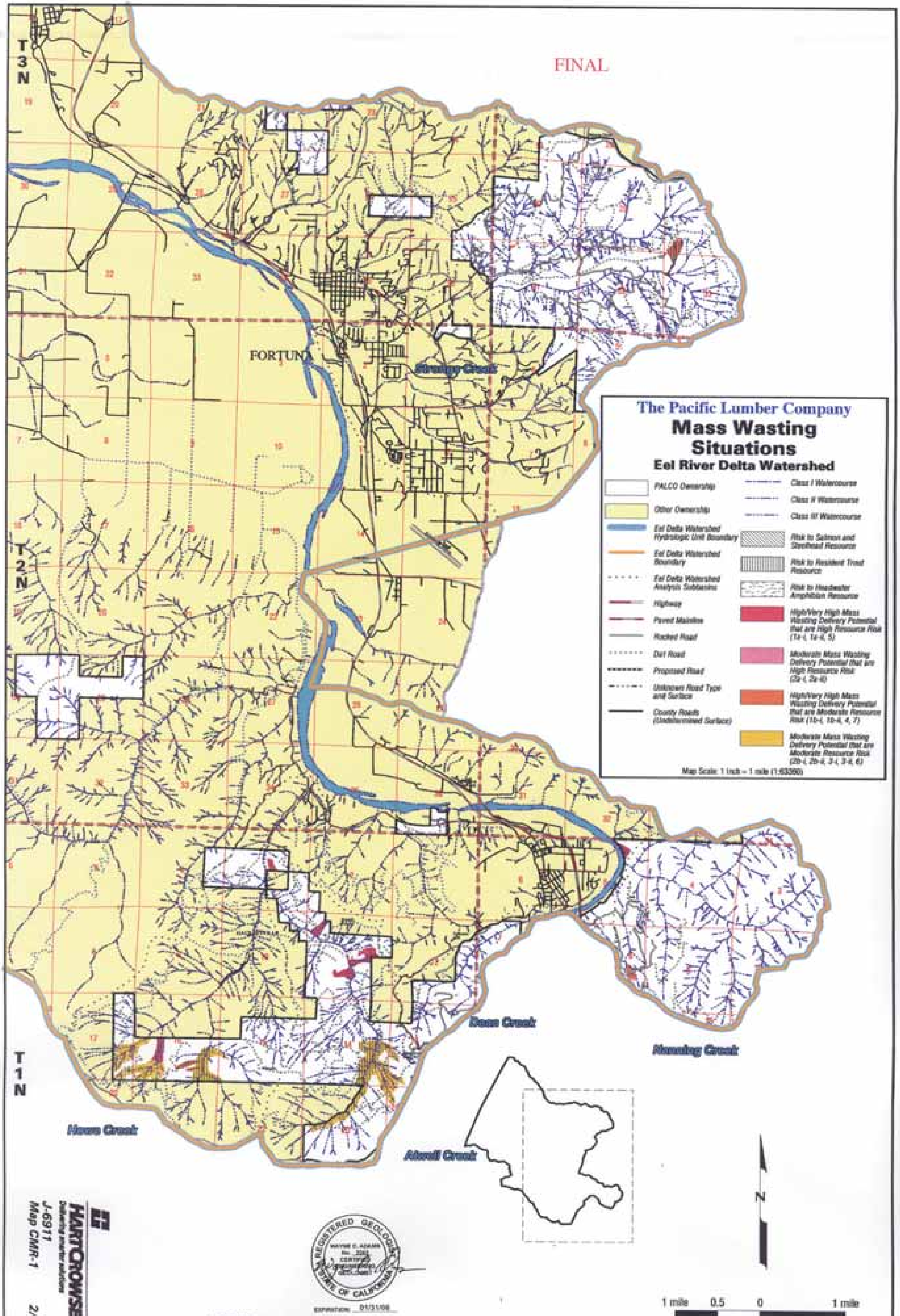
Produced By Hart Crowser, Inc.: f:/data/gis/palco/leel/lowel/wt_review_areas/11x17/map_2_sheet1-11x17.aml



Produced By Hart Crowser, Inc.: f:/data/gis/palco/eel/eeldelta/wr_review_amls/11x17/map_2_sheet2-11x17.aml



The Pacific Lumber Company
Mass Wasting Situations
Lower Eel River Watershed
PALCO Ownership
Other Ownership
Lower Eel Hydrologic Unit Boundary
Lower Eel Watershed Boundary
Lower Eel Watershed Analysis Subbasins
Highway
Paved Mainline
Rocked Road
Dirt Road
Proposed Road
Unknown Road Type and Surface
County Roads (Undetermined Surface)
Class I Watercourse
Class II Watercourse
Class III Watercourse
Risk to Salmon and Steelhead Resource
Risk to Resident Trout Resource
Risk to Headwater Amphibian Resource
High/Very High Mass Wasting Delivery Potential that are High Resource Risk (1a-i, 1a-ii, 5)
Moderate Mass Wasting Delivery Potential that are High Resource Risk (2a-i, 2a-ii)
High/Very High Mass Wasting Delivery Potential that are Moderate Resource Risk (1b-i, 1b-ii, 4, 7)
Moderate Mass Wasting Delivery Potential that are Moderate Resource Risk (2b-i, 2b-ii, 3-i, 3-ii, 6)
Map Scale: 1 inch = 1 mile (1:63360)
FINAL
SCOTIA
Stitz Creek
Scotia
Bear Creek
Jordan Creek
Monument Creek
Kiler Creek
Dinner Creek
Twin Creek
Darnell Creek
Shively Creek
Bridge Creek
Chadd Creek
Allen Creek
Weber Creek
High Rock
Parrott Creek
Stafford
Pepperwood
T 1 N
T 1 S
R1E
R2E
See Inset
EXPIRATION 01/31/06
1 mile 0.5 0 1 mile
N
HARTCROWSER
Delivering smarter solutions
J-6911
Map CMR-1 1/2
Produced By Hart Crowser, Inc.


FINAL
T 3 N
T 2 N
T 1 N
FORTUNA
The Pacific Lumber Company
Mass Wasting Situations
Eel River Delta Watershed
PALCO Ownership
Other Ownership
Eel Delta Watershed Hydrologic Unit Boundary
Eel Delta Watershed Boundary
Eel Delta Watershed Analysis Subbasins
Highway
Paved Mainline
Rocked Road
Dirt Road
Proposed Road
Unknown Road Type and Surface
County Roads (Undetermined Surface)
Class I Watercourse
Class II Watercourse
Class III Watercourse
Risk to Salmon and Steelhead Resource
Risk to Resident Trout Resource
Risk to Headwater Amphibian Resource
High/Very High Mass Wasting Delivery Potential that are High Resource Risk (1a-i, 1a-ii, 5)
Moderate Mass Wasting Delivery Potential that are High Resource Risk (2a-i, 2a-ii)
High/Very High Mass Wasting Delivery Potential that are Moderate Resource Risk (1b-i, 1b-ii, 4, 7)
Moderate Mass Wasting Delivery Potential that are Moderate Resource Risk (2b-i, 2b-ii, 3-i, 3-ii, 6)
Map Scale: 1 inch = 1 mile (1:63360)
Dean Creek
Howe Creek
Atwell Creek
N
1 mile 0.5 0 1 mile
R1W
R1E
HARTCROWSER
J-6911
Map CMR-1
2/2
REGISTERED GEOLOGIST
STATE OF CALIFORNIA
EXPIRATION 01/31/08