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Basin Profile and Synthesis

The Eel River is located in northern California, approximately 200 miles north of San Francisco at latitude 40° 38' 32" N, longitude 124° 18' 43" W (Figure 1). The Eel River catchment lies predominantly in Humboldt and Mendocino Counties and also extends into Trinity, Glenn and Lake counties.

The mainstem Eel River is approximately 197 miles in length and receives flow from 832 tributaries – adding up to 3,526 miles of stream. It is the third largest river in California with a drainage basin of 3,684 square miles (CDFG 1997). Elevations on the mainstem range from sea level at the mouth to over 6,700 feet at the headwaters. Four principle tributaries are the Van Duzen River, South Fork Eel River, North Fork Eel River, and Middle Fork Eel River.

Because the Eel River catchment is large and complex, it has been divided into several basins for assessment (Figure 2). This report assesses the Lower Eel Basin. The Outlet Creek, Van Duzen River, and South Fork Eel River basins have been or are also currently being assessed by the CWPAP team.

The Lower Eel Basin assessment area is composed of less than 5% of the entire Eel River catchment at approximately 172 square miles and is defined as the watershed area from the river'smouth, upstream approximately 21 miles. As the Lower Eel Basin comprises the most downstream and depositional section of the entire Eel River catchment, any discussion of watershed processes within the basin must be considered within this larger context.

While the name of the Eel River reflects the number of so-called lamprey eels (*Lampetra tridentata*) that Euro-American settlers observed being collected by the native peoples in the area, its Native American name summarizes once healthy salmon runs: "…Eel River is called by the Indians, Weott [sic] – plenty- from the immense quantities of salmon obtained by them every fall in that stream…" (Humboldt Times September 23, 1854). These large salmon runs allowed Euro-American settlers to establish a lucrative commercial fishery, which by 1858 was supplying canned and salted salmon markets from California to the east coast, as well as outside the country (McEvoy 1986). Historical records show that the Eel River was one of the largest producers of salmon and steelhead in the state. This young fishery was described as equal to the Sacramento River fishery, though surpassing it in terms of price (Humboldt Times April 10, September 11, 1858).

Even though the Eel River remains the third largest producer of salmon and second largest of steelhead in the state, overall salmon runs in the Eel have dramatically declined (CDFG 1997 [salmon and steelhead action plan]). Defining and quantifying the causes of this decline can be difficult, though most surely they are a result of cumulative effects of human impacts in a dynamic system. Anadromous salmonids currently present with the Lower Eel River Basin are coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus clarki*). The NMFS has listed northern California runs of coho (1997),Chinook (1999), and steelhead (2000) as threatened under the federal Endangered Species Act. The California Fish and Game Commission also listed coho as threatened in 2005.

The Lower Eel River Basin is the depositional zone for the entire Eel River catchment, and as such responds to the watershed delivery processes throughout the system. As part of this highly dynamic environment, the Lower Eel experiences high levels of sedimentation due to natural hillslope processes including very erodible bedrock and high levels of precipitation (Reynolds et al. 1981). Additionally, the area is situated in a tectonically active area. Landslides and erosion introduce large quantities of sediment to streams, and are exacerbated by the region's climate, geology, topography and land use.

The Eel has the highest recorded average suspended sediment yield of any U.S. river its size (Brown and Ritter 1971), and in 2002, the US Environmental Protection Agency (EPA) listed the lower portion of the Eel River as an impaired water body due to excessive sediment and high summer water temperature. The EPA defined the lower portion of the Eel River as the watershed area of the Eel River downstream from the confluence with the South Eel, excluding the Van Duzen River.

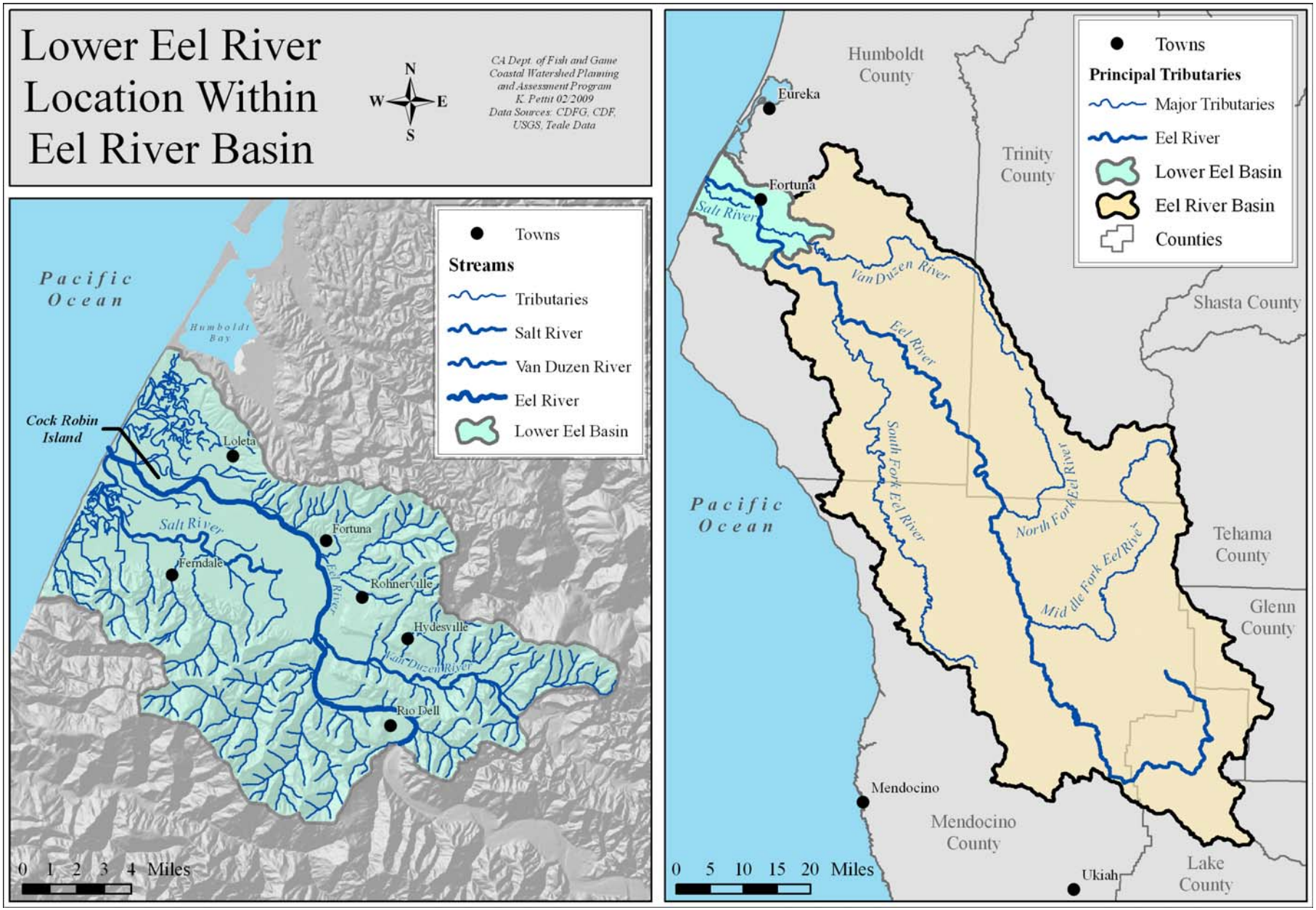

Figure 1. Location of the Lower Eel Basin within the Eel River Basin.

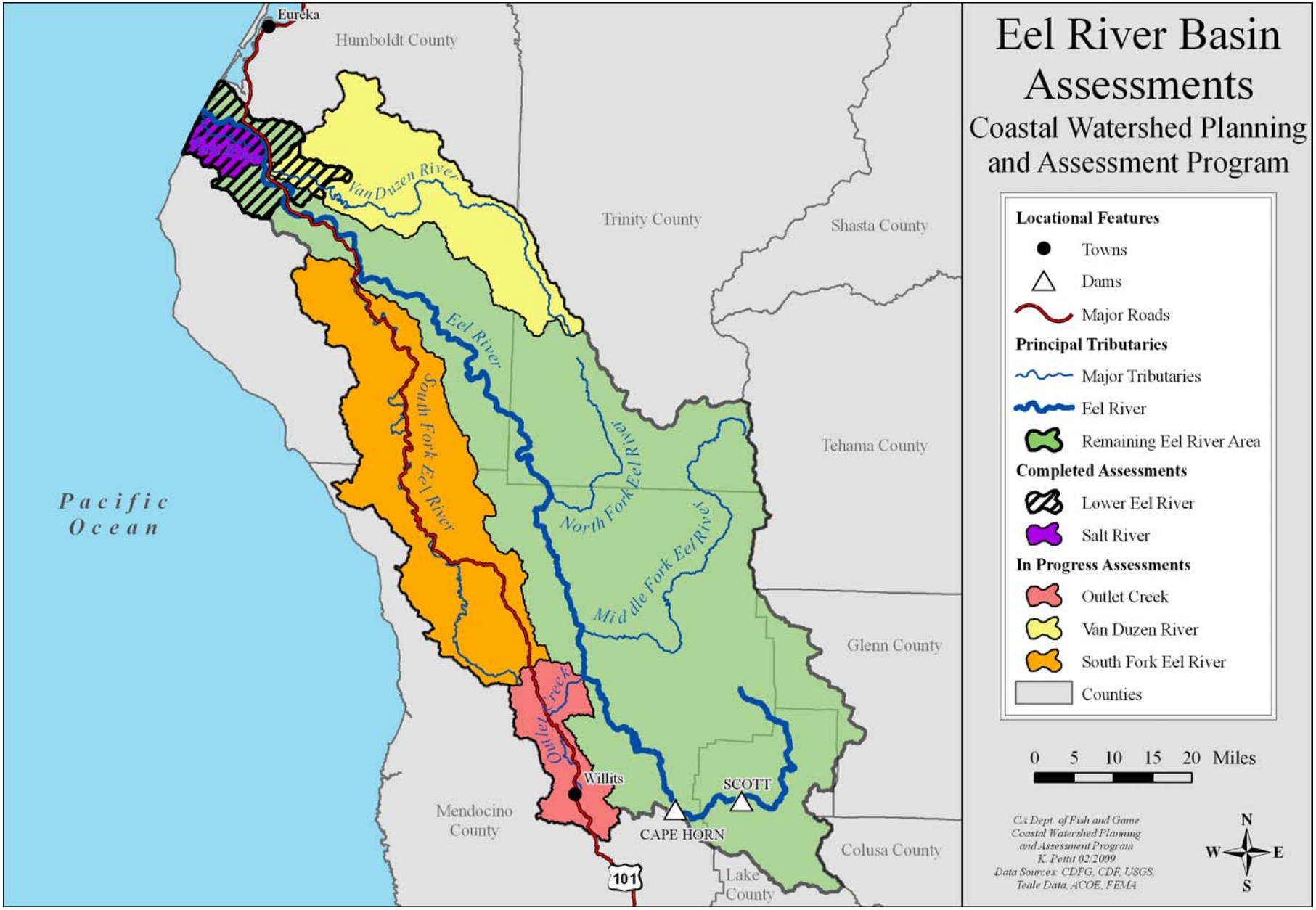

Figure 2. CWPAP assessment areas within the Eel River catchment.

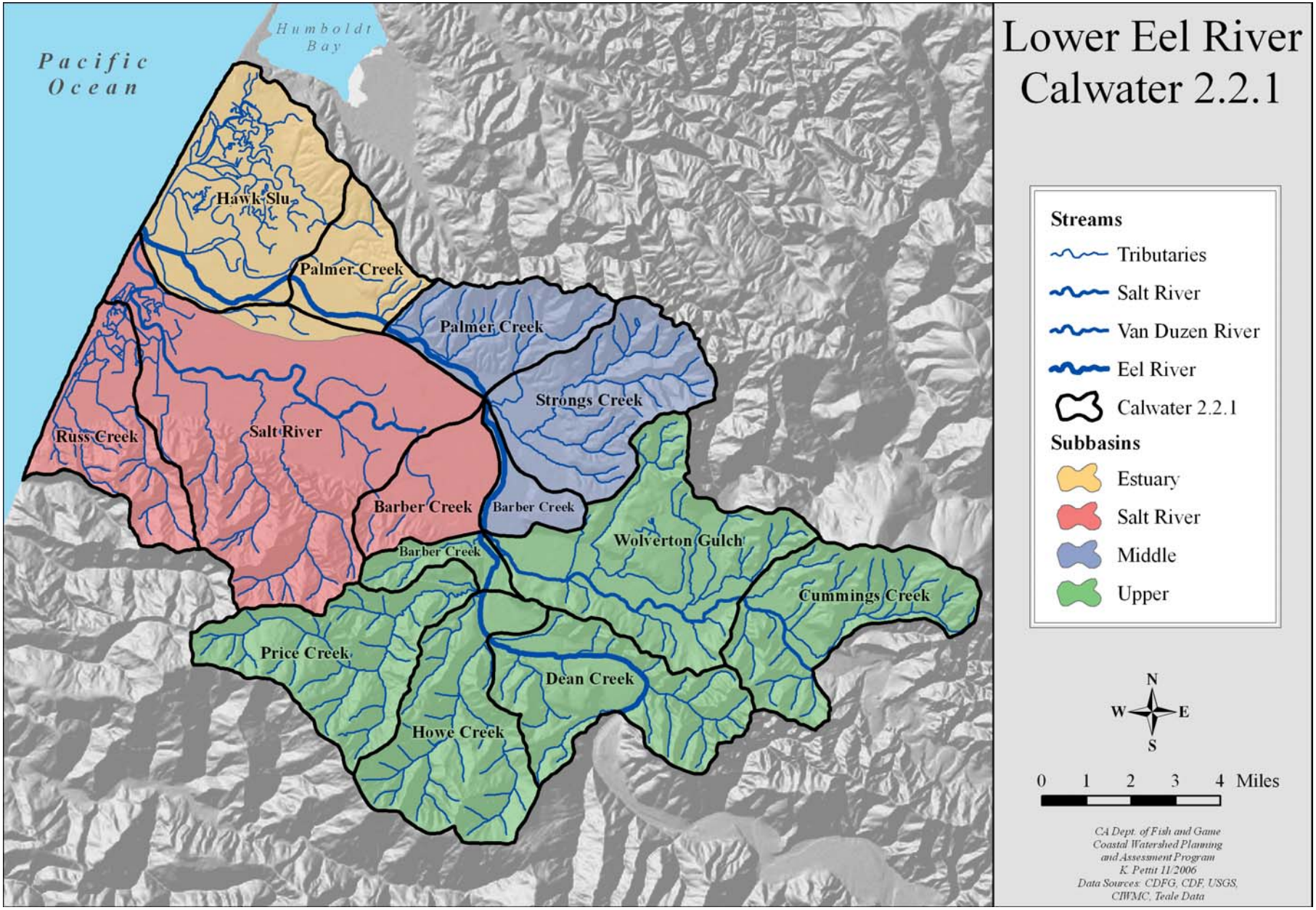

Figure 3. Lower Eel Basin subbasins delineated using CalWater 2.2.1.

Subbasin Scale

For purpose of this assessment and analysis, the Lower Eel Basin was divided into four subbasins (Estuary, Salt River, Middle, and Upper) comprised of a total of 11 CalWater 2.2.1 Planning Watersheds (PWs) (Figure 3 [above], Table 1). Subbasins were designated based on several attributes, including geography, geology, climate patterns, and land use. Original PW boundaries were edited to more accurately reflect the drainage patterns and watershed processes within the Lower Eel Basin when defining subbasins.

The Eel River estuary was divided into two subbasins: the Estuary Subbasin and the Salt River Subbasin. The Salt River drainage was previously assessed separately by Downie and Lucey (2005) in order to assist key entities with impending management decisions. Findings and recommendations from the Salt River Watershed Assessment have been incorporated into the Salt River Subbasin section. For this Lower Eel River watershed assessment, the Estuary and Salt River subbasins are viewed as two integral parts, which describe the Eel River estuary as a whole.

The Estuary Subbasin is the northern most portion of the Eel River estuary. It is 24 square miles in area and includes approximately 7 miles of the mainstem from the mouth to Fernbridge, as well as nearly 40 miles of predominantly brackish water sloughs and 3 miles of intermittent streams. The area receives sediment transported from the entire Eel River Basin, and responds dynamically in size and shape. The estuary is a nursery, feeding and holding area for variety of freshwater, marine, estuarine, and anadromous fish, including juvenile coho salmon, Chinook salmon, steelhead, and coastal cutthroat.

The Salt River Subbasin is the southern portion of the Eel River estuary. In its 49 square miles, it contains 42 miles of sloughs and freshwater tributaries. As is detailed in the Salt River watershed assessment (Downie and Lucey 2005), this subbasin is composed of two significant ecological units: the delta, identified by the alluvial floodplain, and the Wildcat Range, which describes the tributaries that originate in the Wildcat Hills and flow across the delta. As in the Estuary Subbasin, the Salt River Subbasin provides valuable areas for juvenile and adult estuarine fish species. The Wildcat tributaries have historically provided spawning and rearing habitat for freshwater fish, including coho salmon, Chinook salmon, steelhead, and coastal cutthroat.

The Middle Subbasin contains approximately 46 miles of permanent and intermittent stream, including the mainstem, in a 24 square mile area. This subbasin contains the largest human population, with the principle community of Fortuna. Fish surveys of the streams in this subbasin have identified coho salmon, Chinook salmon, steelhead, and coastal cutthroat.

The Upper Subbasin is the largest subbasin in the assessment area at 75 square miles. This subbasin includes approximately 7.5 miles of the Eel River mainstem from Barber Creek to Dean Creek. It also includes the Van Duzen River from its mouth to Cummings Creek, approximately 9 miles above its confluence with the Eel River. There are approximately 133 miles of permanent and intermittent streams in this subbasin. Chinook salmon, coho salmon, and steelhead have been documented in fish surveys.

Table 1. General attributes of the Lower Eel River Basin.

Attribute	Estuary Subbasin	Salt River Subbasin	Middle Subbasin	Upper Subbasin
Area (square miles)	24	49	24	75
Percent of Basin	14	29	14	43
Miles of Stream (permanent + intermittent)	43 miles	42 miles	40 miles	133 miles
Principal Communities	Loleta, Fernbridge	Ferndale	Fortuna, Rohnerville	Hydesville, Carlotta, Rio Dell
Predominant Geology	Alluvium	Alluvium	Unconsolidated river terrace deposits	Wildcat Group
Predominant Vegetation	Grassland	Grassland	Conifer	Conifer
Predominant Land Use	Agriculture	Agriculture	Urban, Agriculture, Mining	Forestry, Agriculture, Mining
Salmonid Species	Coho, Chinook, Steelhead, Coastal Cutthroat	Coho, Chinook, Steelhead, Coastal Cutthroat	Coho, Steelhead, Coastal Cutthroat	Coho, Chinook, Steelhead

Climate

A long rainy season and foggy summer season are characteristic of the climate in the Lower Eel Basin. The rainy season, which generally begins in October, and lasts through April, accounts for 90% of the river's mean annual runoff (Monroe et al. 1974).

California Department of Water Resources (DWR) has precipitation data for Eureka, located approximately 14 miles north of the Eel River mouth, from water years (WY) 1906 to the present. Data is also available from Scotia, located just south and outside of the basin, from WY 1926 to 2005. Eureka receives a mean annual precipitation of 38 inches and Scotia receives 47 inches. An isohyetal contour map of the Lower Eel Basin shows that mean annual precipitation is lowest in the Estuary Subbasin (40 inches per year) and highest in the upper elevations of the Upper Subbasin (80 inches per year) (Figure 4).

Throughout the year, the Eel River Basin receives highly varied precipitation. While average monthly precipitation ranges from less than 1 inch to greater than 9 inches over the period of record, monthly maximum precipitation has reached over 27 inches at Scotia, and over 23 inches at Eureka (both maxima occurred in December 2002) (Figure 5).

The dry season, generally May through September, is usually defined by morning fog and overcast conditions. On average, only about 78 days out of the year are clear, with the remaining 287 days being either cloudy or partly cloudy. The average annual temperature is 53°F, and average temperatures range very little throughout the year, from 48° F in January to 58°F in August (Western Regional Climate Center, www.wrcc.dri.edu).

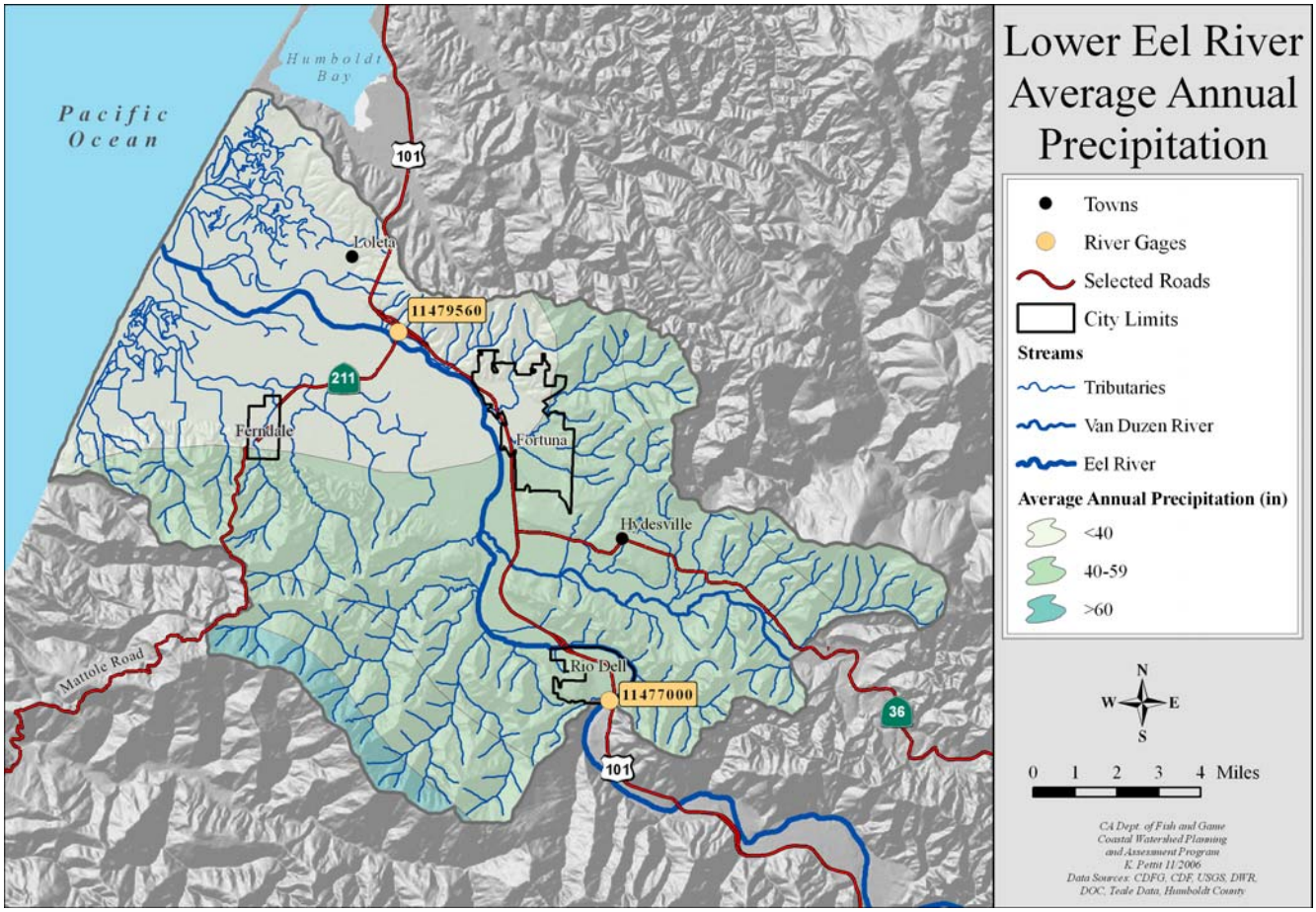

Figure 4. Average annual precipitation and river gage locations within the Lower Eel Basin.

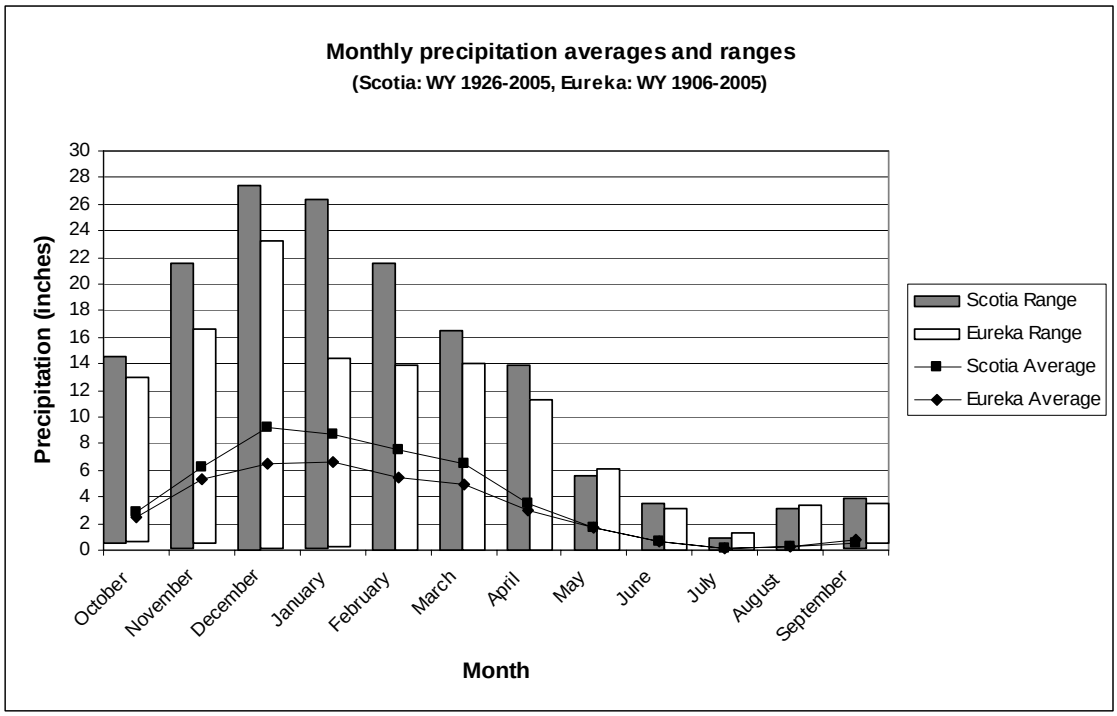

Figure 5. Monthly precipitation statistics over the period of record in the Lower Eel Basin.

Hydrology

The Eel River is the third largest river in California with a catchment area of 3,684 square miles square miles. The Lower Eel Basin has a catchment area of 172 square miles. The Lower Eel River Basin includes tributaries to the Eel River from its mouth upstream approximately 21 miles, as well as Van Duzen River tributaries from its confluence with the Eel upstream to RM 9. There are approximately 300 miles of stream within the Lower Eel Basin. Lengths of individual streams and river mile locations are detailed in the subbasin sections.

In order to help evaluate and categorize streams and rivers, streams are assigned a stream order classification based on the branching pattern of river systems (Strahler 1957). A first order stream is defined as the smallest un-branched tributary to appear on a 7.5-minute USGS quadrangle (1:24,000 scale) (Leopold et al. 1964). This system includes only perennial streams (i.e. those with sufficient flow to develop biota). When two first order streams join, they form a second order stream. When two second order streams join, they result in a third order stream; and as streams of equal order meet they result in a stream of the next higher order (Flosi et al. 1998). Accordingly, the mainstem Eel River is a sixth order stream in the Lower Eel Basin, while the Van Duzer River is classified as a fifth orders stream. Most tributaries in this basin are intermittent or first or second order (Figure 6).

There are two USGS river gages located within the basin: at Scotia (USGS ID 11477000) and Fernbridge (USGS ID 11479560) (Figure 4 [above]). The Scotia gage (WYs 1911 to present, excluding WYs 1915 and 1916) measures gage height and discharge while the Fernbridge gage (WY 1911 to present) only measures gage height for flood-warning purposes.

Annual mean discharge at the Scotia gage over the period of record was 7,335 cfs. Monthly mean discharge ranged from approximately 140 to 20,000 cfs (Table 2). While maximum mean monthly discharge ranged from approximately 420 to 84,400 cfs, maximum mean daily discharges are far greater, ranging from 2,540 to 648,000 cfs. As a point of reference, in 1974 the Eel River channel had a capacity of approximately 150,000 cfs (Monroe et al.).

Because the Eel River Basin receives highly varied precipitation and has extremely altered runoff rates, discharge is typified by low flows in the summer and extreme peaks in the winter. For example, a minimum mean daily flow of 19 cfs was once recorded in the late summer of 1924 at Scotia, while over the period of record, 35 years have recorded at least 1 day with a mean daily discharge greater than 150,000 cfs (Data from USGS 2005) (Table 3). Moreover, there have

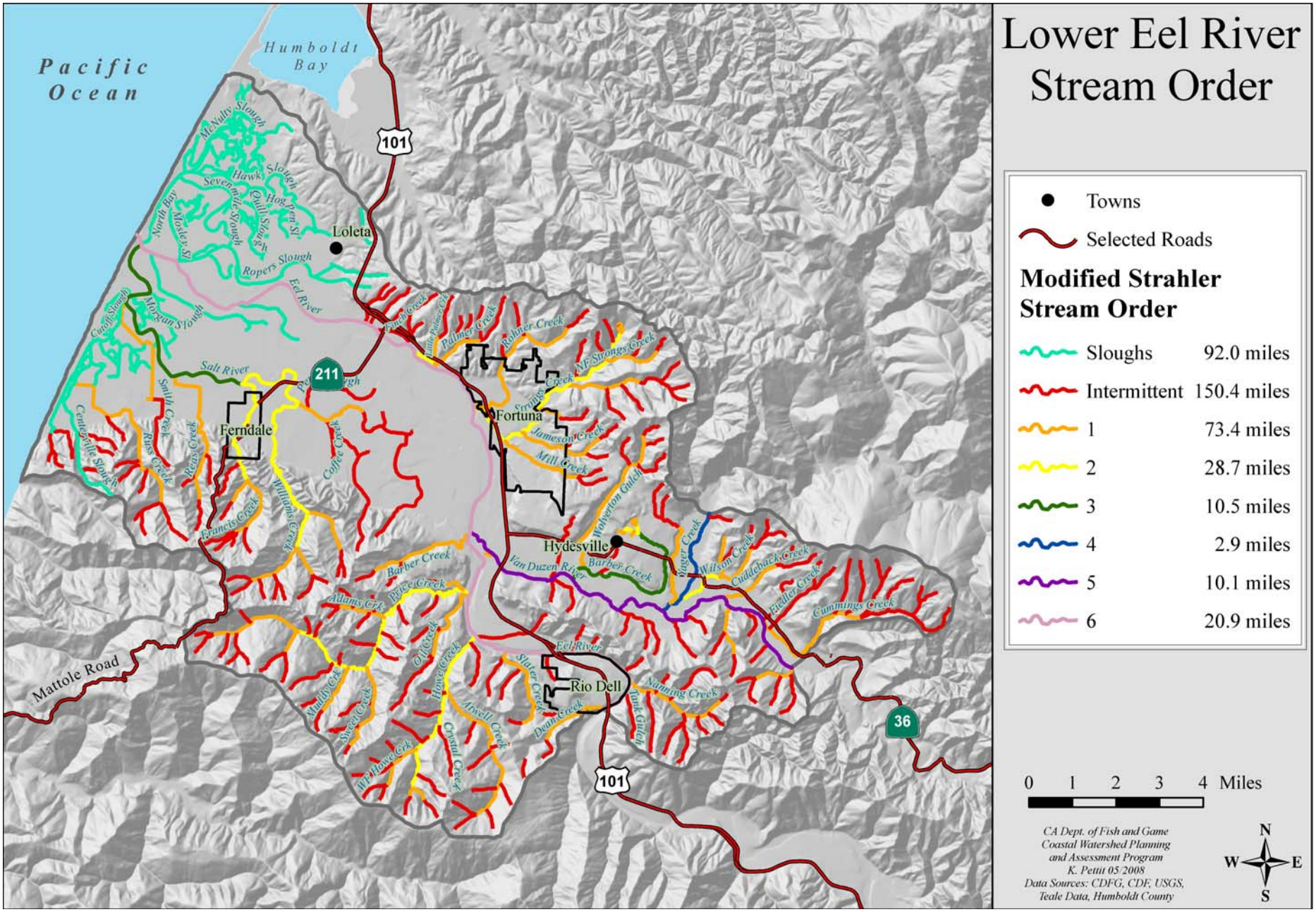

Figure 6. Stream order in the Lower Eel Basin.

Table 2. Statistics of mean monthly discharge for Eel River at Scotia over the period of record, WY 1911 to 2005.

Month	Mean Discharge (cfs)	Maximum Mean Discharge (cfs)	WY	Minimum Mean Discharge (cfs)	WY
October	642	10,910	1963	51	1930
November	4,934	38,690	1974	59	1930
December	14,220	84,420	1965	168	1977
January	20,050	69,950	1970	659	1977
February	19,920	77,680	1958	389	1920
March	14,290	51,150	1983	946	1924
April	8,884	39,190	1982	703	1924
May	3,803	14,000	2005	278	1924
June	1,308	7,511	1993	76	1924
July	347	1,182	2005	25	1924
August	151	422	1983	22	1924
September	141	735	1986	19	1924

Data from USGS (2005).

Table 3. Water years with mean daily discharge at Scotia greater than the channel's 1974 capacity of 150,000 cfs.

WY	Number of days with discharge >150,000 cfs	Maximum mean daily (cfs)	Range (cfs)
1914	4	231,000	66,000
1917	1	218,000	
1927	2	179,000	7,000
1928	1	166,000	
1936	2	182,000	14,000
1938	4	316,000	145,000
1940	2	261,000	91,000
1942	2	184,000	23,000
1943	2	208,000	21,000
1946	3	186,000	34,000
1951	2	199,000	43,000
1952	3	188,000	16,000
1953	1	158,000	
1954	1	213,000	
1956	6	433,000	281,000
1958	1	174,000	
1960	2	261,000	60,000
1963	1	212,000	
1965	5	648,000	472,000
1966	2	261,000	64,000
1969	4	190,000	39,000
1970	3	267,000	100,000
1971	3	195,000	22,000
1974	4	324,000	149,000
1975	3	186,000	31,000
1978	1	157,000	
1980	2	194,000	10,000
1982	3	232,000	57,000
1983	2	229,000	57,000
1986	4	304,000	124,000
1993	1	200,000	
1995	3	284,000	67,000
1997	3	316,000	54,000
2003	3	173,000	22,000
2004	1	173,000	

The period of record is WY 1911 to 2005

also been several substantial floods in the latter half of the 20th century. The most destructive floods in the period of record occurred in WYs 1956 and 1965. During the December 1964 flood, the maximum mean daily flow at Scotia was 648,000 cfs; the maximum peak flow was 752,000 cfs (USGS data). On December 23, 1964, the river gage at Fernbridge was 9.5 feet above flood stage (20 feet), and discharge at

840,000 cfs was nearly six times the normal channel capacity (Monroe et al. 1974).

Changes in the watershed, including increased impervious surfaces, road drainage and vegetation removal, have altered the basin's response to heavy precipitation. Heavy sedimentation has changed Eel River channels from deep, wide, and stable to aggraded, shallow, and shifting (Roberts 1992). These factors combined with the rugged terrain, elevations within the Eel River catchment reach over 6,700 feet, and loss of riparian vegetation in upstream tributaries cause water to be delivered rapidly downstream. During periods of extensive or intensive rain, river levels rise rapidly and flooding often occurs in the lower Eel River and estuary. Periods of intensive or extensive rain often occur during winter months and flooding becomes an issue throughout the basin.

Geology

The Lower Eel River Basin is located on the Coastal Belt of the Franciscan Complex of the Coast Ranges geomorphic province. In this area the Coastal Belt is overlain by Cenozoic sedimentary rock types. Specific rock units within the basin include the following: Pliocene – Pleistocene marine deposits of the Wildcat Group, Quaternary alluvium, river terrace deposits and older river terrace deposits, Coastal terrane, and Eocene marine deposits of the Yager terrane (Table 4).

The geologic setting in which the basin lays greatly contributes to very high sediment yields within the river system. Bedrock that has gone through a complex process of tectonic deformation, as part of the accretionary process resulting from collision and subduction of the Farallon/Gorda Plate, has made it relatively incompetent. High rates of tectonic uplift and compression have further faulted, folded, and weakened this bedrock. Uplift has also effectively raised the potential energy of the streams, allowing them to erode the landscape and incise at higher rates.

Accelerated uplift during the last 500,000 years has allowed the river to carve down into what was once a wide floodplain leaving large predominantly unconsolidated gravel terraces steeply perched above the active stream channel. These perched sediments tend to slump, slide, and ravel into the watercourses contributing to the high rate of sedimentation of this region.

This river system has also cut into "soft" poorly cemented sedimentary rock types of the Wildcat group. The majority of the Wildcat group is made up of weakly cemented, fine grained, shallow marine sediments that filled the plunging Eel River syncline during the Pleistocene and Pliocene (see the Estuary Subbasin geology section for a detailed explanation of synclines). The sequence of sediments within the Wildcat group is well over 10,000 feet thick attesting to the highly erodable nature of the surrounding countryside.

The unstable geology, dynamic tectonism, steep topography, and high precipitation rates of this region combine to make it one of the most erosion prone areas in the United States.

The erosion rates within the basin are most affected by:

- Composition of bedrock–soft sedimentary rock and sheared matrix mélange are easily eroded;
- Incompetence of bedrock–folded, faulted, and sheared rock is easily eroded;
- Abundance of unconsolidated alluvium and river terrace deposits–contribute fine sediments to the streams through slope instability and dry ravel;
- High rate of uplift–increases the erosion potential of the area;
- Seismic activity–triggers landsliding within the basin and liquefaction of unconsolidated sediments in the gently sloped areas;
- Climate–saturation of steep slopes by heavy sustained seasonal rain triggers landsliding within the basin;
- Land use practice–grazing, timber harvest, road building, vegetation change, etc., increases the amount of surface erosion as well as landsliding.

Table 4. Rock types of the Lower Eel Basin.

Rock Type	% of Basin	Description
Alluvium	26.6	Unconsolidated river sediments within the active influence of streams.
Dunes	1.5	Windblown sand deposited along the shoreline as dunes.
Landslides	3.2	Large landslide features mapped as Quaternary Landslides
Terrace deposits	21	Unconsolidated, poorly sorted river sediments that have been uplifted above the active stream influence.
Wildcat Group	37	A series of 5 formations; 4 consisting of poorly cemented, fine-grained, shallow marine sediments and one consisting of courser, poorly consolidated, predominately nonmarine sediment.
Yager Terrane	1.8	Moderately-well consolidated, locally sheared, sandstone, argillite, and conglomerate.
Coastal Belt Sandstone/argillite	.5	Well consolidated, locally sheared, metasandstone, meta-argillite, and conglomerate.
Coastal Belt mélange	8.5	A pervasively sheared argillaceous matrix containing mappable blocks of varying rock types.

A spatial overview of the Lower Eel Basin's surface geology can be found in the USGS Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern part of the Hayfork 30 x 60 Minute Quadrangles and Adjacent Offshore Area, Northern California geologic map of California. Using these data, the entire lower Eel River Basin is composed of 8 differing lithologies (Figure 7, Table 4).

The "Scotia Slide" broke loose in the winter of 2005/2006. This was a very wet winter and there were a few large seismic events which could have helped trigger the slide. It appears from the photos that although re-vegetating somewhat, the slide has continued to move in the relatively dry winter of 2006/2007. A few trees have come down and previously downed trees have become buried. The toe of the slide while eroding back by tens of feet is somewhat thicker. On the same bank of the river a sand bar has built up in response to the position of the toe. The sand that makes up this bar seems to be completely derived from the eroded toe of this slide.

The bedrock underlying the Lower Eel Basin has undergone substantial uplift, compression, and deformation, and is composed of fine grain depositional materials. The uplifting and faulting of the Franciscan Complex produced landscapes with steep slopes and narrow canyons trending in a southeast-northwest direction, which is also reflected in the drainage patterns of the basin (Brown Ritter 1971).

Scotia Slide 4/2006

Scotia Slide 4/2007

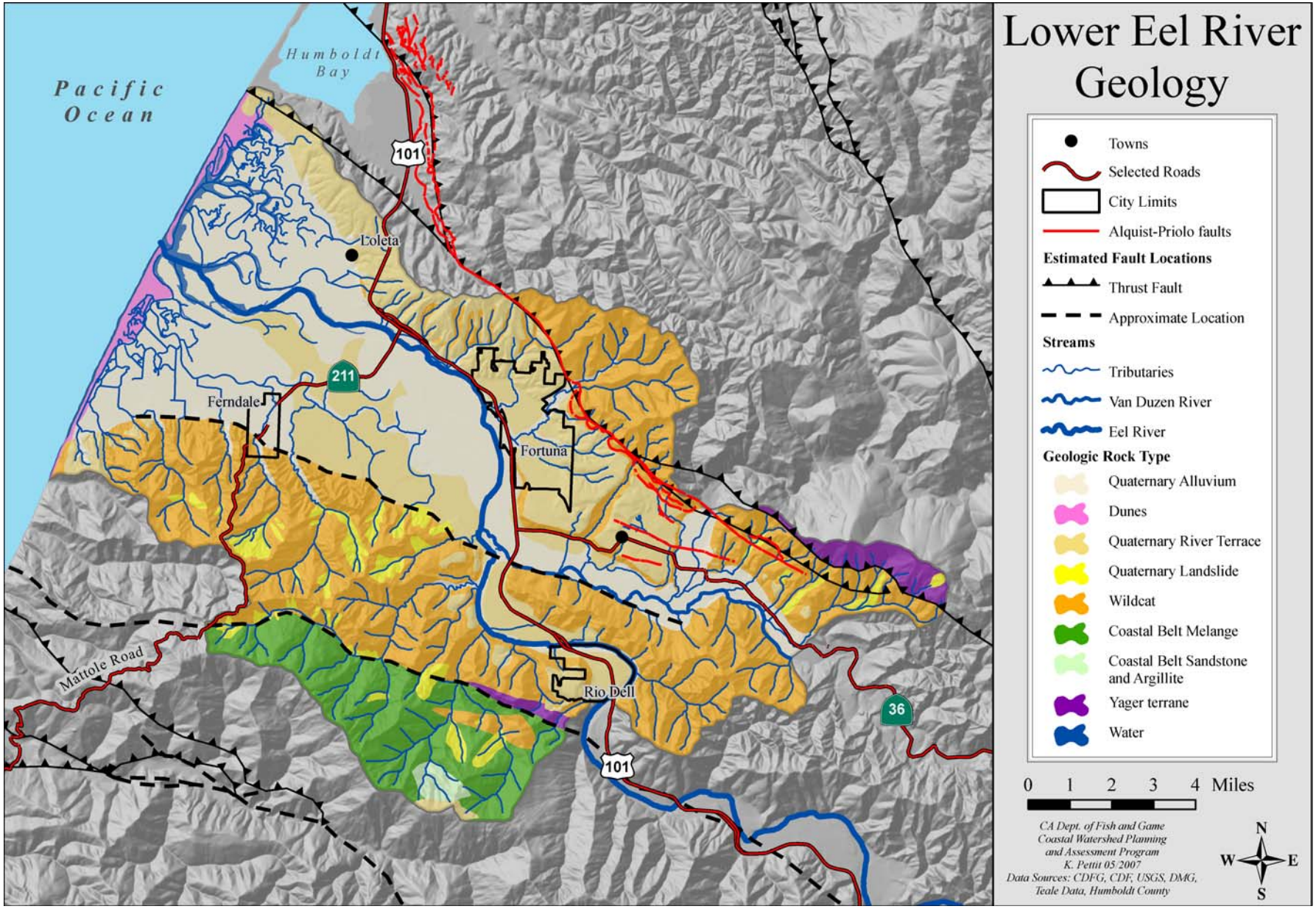

Figure 7. Geology of the Lower Eel Basin

Although the focus of the geological sections within this report relates to the negative impact and causes of sediment related issues, most naturally occurring geologic processes outlined herein have positive aspects as well:

- Naturally occurring landslides within forested lands supply large woody debris, large boulders, and spawnable gravels to the river system balancing out to some extent their contribution of fine sediments;
- Terrace deposits tend to store fine sediments for hundreds to hundreds of thousands of years helping to regulate sediment discharge pulse events;
- The high uplift rate and its corresponding seismicity are what have provided the land on which the rivers run;
- Folding and faulting of the bedrock gives rivers their trend and morphologic characteristics;
- The heavy rainfall in this region is responsible for the many streams that can and have historically supported salmonids;
- The nature of the bedrock and its soils give rise to the lush forested environment that is crucial to the health of the streams.

Tectonics

The Lower Eel Basin is located in an area that is extremely tectonically active. The interaction of three lithospheric plates causes this area to be in a constant state of movement. The forces generated from this triple junction of plates are currently causing the land in the immediate area to rise at an immense rate.

Three basic processes are thought to be causing the majority of uplift:

- Crustal thickening caused by the northward migration of the triple junction;
- Underplating and accretionary tectonics along the Cascadia Subduction Zone;
- Compression generated by convergence of the North American Plate and the Gorda Plate.

Compression is causing this area to buckle either upwards or downwards, much like the hood of wrecked car. If the land bends too far it breaks in a series of faults, which causes the land to thrust under itself – shortening laterally and thickening vertically.

Many of these folds and faults cut through the Lower Eel Basin, weakening the bedrock, making it even more susceptible to erosion and landsliding. Also, as the land rises the rivers gain more potential energy which helps them erode the landscape at an accelerated pace. The faster the rivers cut into the landscape the steeper and higher the banks become, further increasing landslide activity.

Faults can enhance erosion by generating large earthquake events as well as disrupting and weakening bedrock. The Lower Eel Basin contains several faults that disrupt and shear bedrock and are capable of producing earthquakes. Major faults within or in near proximity to the Lower Eel Basin include: Little Salmon fault, Yager fault, Ferndale fault, Russ fault, Cascadia Megathrust, and San Andreas fault.

Earthquakes and Faults

The Eel River Delta is located upon a complex tectonic setting near the junction of three crustal plates known as the Mendocino Triple Junction (MTJ). The MTJ is where the Pacific and the Gorda Oceanic plates meet the North American plate. The Cascadia Subduction Zone (CSZ) is an area just offshore where the Juan de Fuca and the Gorda plates are under thrusting beneath the North American Plate. The CSZ originates at the Mendocino Triple Junction and extends north through Oregon and Washington running parallel to the Pacific Northwest coast line. The complex tectonic structure contributes to a high concentration of earthquakes in the north coast region. The Salt River area has experienced hundreds of earthquakes of significance ($M \geq 4$ on Richter scale) in the past 120 years (USDA 1993).

Movement along the myriad of local faults produces frequent earthquakes. A good number of these earthquakes are quite large. In January of 1700 there was a magnitude 9 earthquake along the coast in this area resulting from subduction of the Gorda Plate. The earthquake in April of 1906 along the San Andreas fault, which is associated mostly with San Francisco, was one of the most devastating earthquakes to hit the Lower Eel Basin in historic times (Dengler 2006). There have been over 16

earthquakes of at least magnitude 6 in the county in the past 30 years, the largest, a 7.2, occurring in 1923.

More recently, a magnitude 6.5 earthquake occurred on January 9th, 2010 approximately 20 miles off the coast west of Ferndale. While there were no major injuries reported, the earthquake caused a significant amount of damage, especially in the Eureka area. The county was declared a "state of emergency" as 251 buildings were damaged and the governor estimated over 43 million dollars in total damage (Greenson 2010). Of greater significance was the 1992 "Cape Mendocino" earthquake. This M7.1 earthquake occurred on April 25th, 1992 and was followed up with two M6.5 aftershocks that rattled the towns located in the Lower Eel River Basin causing injury and extensive damage. This earthquake caused significant ground shaking, landslides, coastal uplift, and liquefaction. The magnitude of this event caused the whole coastline near Cape Mendocino to raise several feet and resulted in a two foot tsunami in Crescent City (Carver, et al. 1994). The center of Ferndale was severely impacted with significant damage to buildings, but Ferndale citizens were fortunate as there were no major injuries reported. Countywide a total of 356 injuries were reported with five people being admitted to the hospital. All told the earthquake resulted in $61 million dollars in losses in Humboldt County as it destroyed 159 homes and caused major damage to 150 businesses and public offices (Cox 1992). Due to the extensive damages and economic costs Humboldt County was declared a Federal Disaster area.

Large earthquake events on the north coast not only cause injury and extensive damage to the local communities, they also tend to trigger landslides especially during periods when the steep basin slopes are saturated by heavy, seasonal rain. Within the last 200 years earthquakes along the Humboldt County coastline have unleashed approximately a quarter of California's historic earthquake energy.

Soils

Bedrock throughout the basin is considered to be soft to very soft, producing soils that are highly erodible and prone to landslides. Nearly all of the soils are loamy, and range from 20 to 60 inches in depth (Table 5). Slopes in the basin are considered to be moderate to highly unstable and prone to mass wasting. The terrain in upstream tributaries is generally dominated by steep slopes that are composed of relatively sensitive soils. Therefore, landslides are common upstream, and are usually activated during the rainy season (Syvitski and Morehead 1999).

Nearly all of the soils in the basin have parent rock sources that share similar characteristics. The U.S. Natural Resources Conservation Service (NRCS) is currently mapping the soils of Humboldt County, with a projected completion date of 2010. Based on NRCS draft data (no date), the Lower Eel River Basin contains very fine soil, both silty and loamy. All soils are very deep, and most are considered to be very poorly drained. The NRCS has classified most of the soils in the Lower Eel Basin as being used either for pasture or hay production, or wetland wildlife habitat.

The underlying bedrock is generally responsible for the soil's texture and erodable characteristics. The stability of the soils and sediment contribution from soils found in the Lower Eel River Basin depends largely on:

- Soil sediment size, consolidation, cohesion and compaction;
- The terrain – soils move more easily on steep slopes;
- Climate – soils are easily saturated by sustained, heavy rain and are more prone to sliding and surface erosion;
- Type and amount of vegetation cover;
- Land use practices – grazing, timber harvest, roads, etc. increase erosion.

Soils with high sand and silt content are typically more susceptible to erosion than soils with high clay content which exhibit a greater degree of cohesion. The soils present within the Lower Eel River Basin generally range from loam to sand, the majority being in the silt loam and the silt clay loam category and range from 20 to 60 inches in depth.

Slopes in the basin are considered to be moderate to highly unstable and prone to mass wasting. The terrain in upstream tributaries is generally dominated by steep slopes that are mantled with sensitive soils.

During periods of extensive rain, as well as episodes of intensive rain stream water becomes heavily saturated with suspended sediment. The amount, duration and intensity of precipitation have a direct effect on sediment stability and erodibility. The Eel River has the highest recorded average annual suspended sediment load per square mile of any river in the United States (Brown and Ritter 1971).

Sedimentation has had a substantial effect on the hydrology and vegetation of the basin and thus has

impacted habitat use by salmonids (Monroe et. al 1974, Williams 1988).

Table 5. Soils of the Lower Eel Basin.

Soil Type	% of Basin	Composition
Tramway-Irmulco-Empire	29	Loam
Udifluvents	15	Silt loam
Riverwash-Loleta-Ferndale-Bayside	13	Loam/silt loam/silty clay loam
Timmons-Rohnerville-Hookton-Carlotta-Arcata	13	loam/silty clay loam/fine sandy loam
Fluvents-Riverwash complex	6	Loam
Weott	6	Silt loam
Arlynda	2	Peat/silty clay loam
Ferndale	2	Silt loam
Occidental	2	Peat/silty clay loam
Russ	2	Loam
Yorktree-Kneeland variant-Kneeland-Kinman	2	Loam/gravelly loam/clay loam
Barbercreek	1	Silty clay loam
Dungan	1	Silt loam
Fluvaquents	1	Sandy loam
Loleta	1	Loam
Somoa-clambeach-dune land complex	1	Sand
Swainslough	1	Peat/silty clay loam
Beaches-sanoma-dune land complex	<1	Sand
Canalschool	<1	Silt loam
Grizzlybluff	<1	Loam
Madriver	<1	Loam
Swainslough-Occidental complex	<1	Peat/silty clay loam
Vandamme-Tramway-Irmulco-Hotel-Dehaven	<1	Loam/clay/gravelly loam
Waldport family-Dune land-Beaches	<1	Fine sand
Wigi	<1	Silt clay loam
Wigi complex	<1	Silt clay loam
Worswick	<1	Loam/sandy loam

Fluvial Geomorphology

Discussion of fluvial processes in the lower Eel River must be considered within the larger context of the whole Eel River drainage area. Hillslopes in the basin range from very low in the low, flat alluvial floodplain to steep slopes in the Wildcat Mountains and the bluffs across the Eel River from Rio Dell (Figure 8). The wide, flat area of the lower mainstem contains a preponderance of very low gradient depositional reaches, which respond to watershed processes that occur upstream throughout the entire drainage system.

The Eel River has the highest recorded average suspended sediment yield of any U.S. river its size (Brown and Ritter 1971). In 2002, the EPA listed the lower portion of the Eel River as an impaired water body due to sediment and temperature.

Stream gradients were classified within the watershed using the 1/3 arc second digital elevation model (DEM) from the USGS National Elevation Dataset. This dataset uses the best available elevation data in any given geographic area. The analysis showed 389 miles of blue-line streams (those shown as blue lines on USGS topographic maps) within the Lower Eel Basin. About 33 percent (127 miles) of the 389 miles of stream consists of source reaches having gradients greater than 20%; 19% (about 76 miles) consists of transport reaches having gradients greater than 4 percent and up to 20%; and 48% (about 186 miles) consists of depositional reaches having gradients of 4% or less. In fact, 33% (about 128 miles) comprise the very lowest gradient depositional reaches – those equal to or less than 1(Table 6, Figure 9).

Table 6. Miles of blue- line stream in different gradient classes in the Lower Eel Basin.

Gradient Class	Total Miles	Estuary	Middle	Salt River	Upper	Percent
≤ 1%	128.06	57.28	7.58	41.57	21.62	33.00
>1% and ≤ 4%	57.84	11.18	8.65	17.43	20.58	15.00
>4% and ≤ 20%	76.26	4.85	16.46	14.71	40.24	19.00
> 20%	126.79	3.37	16.36	21.72	85.34	33.00
Totals	**388.94**	**76.68**	**49.05**	**95.43**	**167.78**	**100.00**

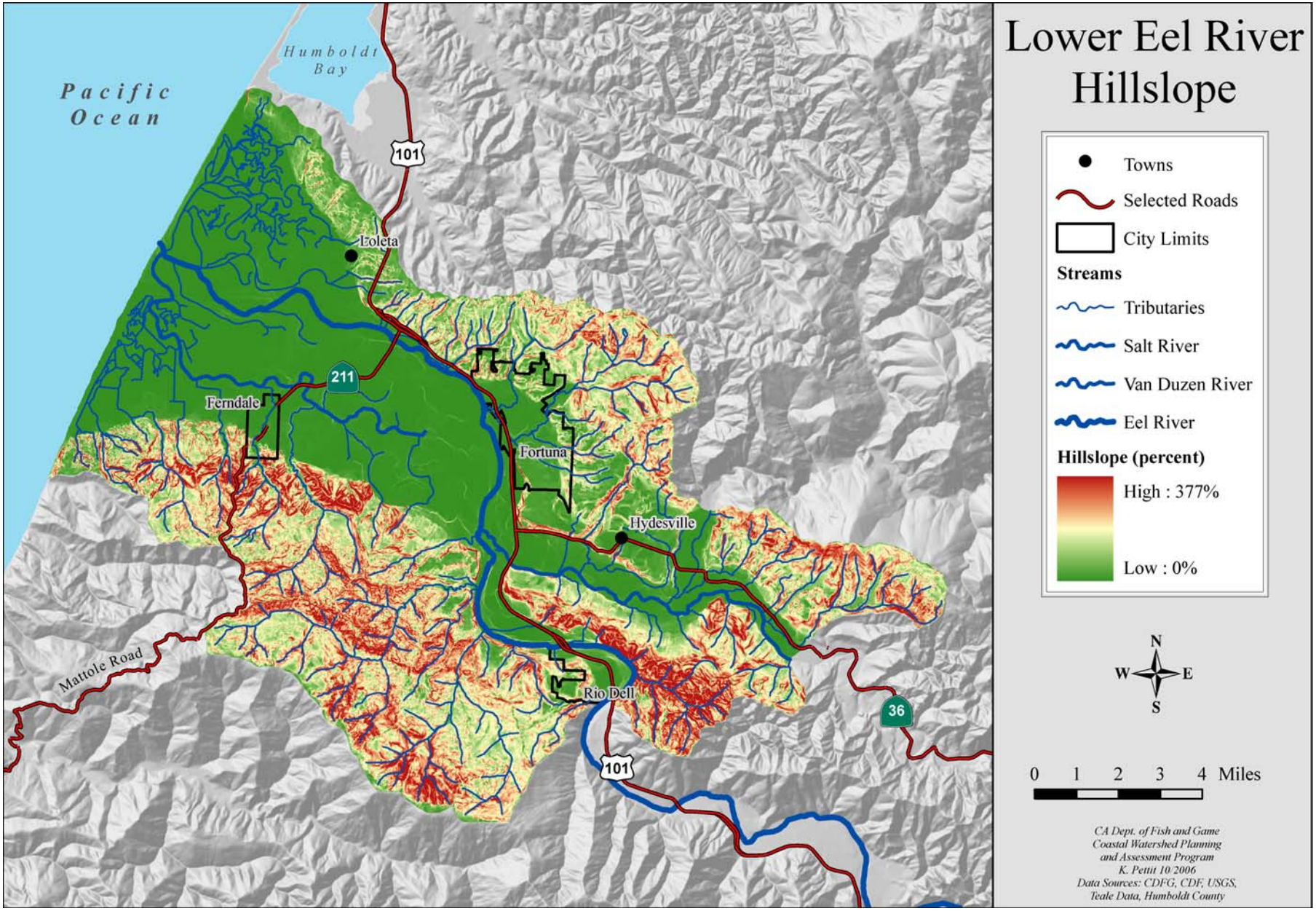

Figure 8. Hillslope of the Lower Eel Basin.

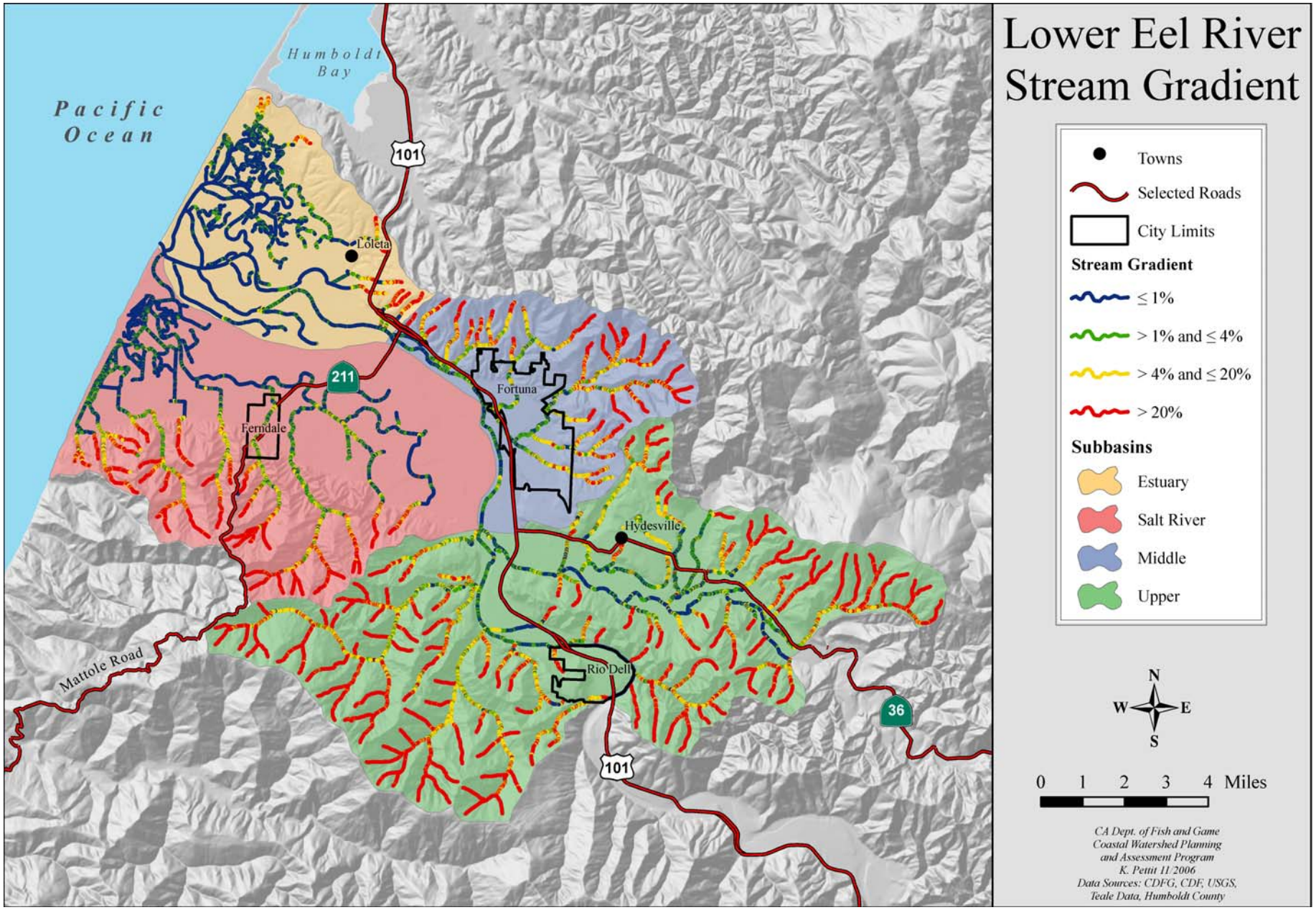

Figure 9. Stream gradients in the Lower Eel Basin.

Vegetation

The USDA Forest Service (USFS) CALVEG vegetation data were used to describe basin-wide vegetation. This classification breaks down vegetation into major "vegetative cover types." These are further broken down into a number of "vegetation types." The predominant vegetative cover type in the Lower Eel Basin is conifer forest at 32% (Figure 10). Of this cover type, 41% is described as redwood alliance, and 32% is redwood – Douglas-fir alliance (Table 7). Redwood occurs primarily upstream of the estuary, in small pockets of the Middle Subbasin, as well as in concentrations in the Upper Subbasin in the Van Duzen River tributaries, and southern-most Eel River tributaries. Coast redwood stands generally grow within a narrow strip along the Northern California coast, and are closely associated with fog and sediments deposited from continual river flooding. Residual redwood stands in the Lower Eel River Basin are limited and are generally concentrated in small protected areas, such as Rohner Park in Fortuna.

Vegetation that commonly occurs in stands of redwood and Douglas-fir often includes redwood sorrel, western sword fern, Sitka spruce, and madrone, among others. All coniferous forest in the Lower Eel River Basin except for the Pacific Douglas-fir alliance is considered by the USFS as productive timberland capable of producing 10% cover of industrial tree species. Conifer forest increases in area with increased distance from the mouth of the Eel River. The Upper Subbasin contains the most area classified as conifer forest; less than 1% of the vegetation in the Estuary Subbasin is coniferous (made up entirely of the Sitka spruce alliance).

Agricultural land makes up 28% of the Lower Eel Basin, and increases in area with increased proximity to the mouth. This vegetation cover type dominates the Eel River delta, within the estuary and also in smaller concentrations in the low-lying areas along the mainstem Van Duzen and Eel Rivers. Agriculture land, as defined by the USFS, is that which is used to produce food and fiber. Within the Lower Eel Basin, pastures used for grazing of livestock may not be included in this vegetation designation since land use is often difficult to remotely ascertain. For this reason, it can be assumed that areas mapped as annual grasslands may also be agricultural in nature. Grasslands that are not mapped as agricultural are given the classification of herbaceous vegetation, which is the third most abundant category in the Lower Eel Basin at 14% of the total area.

Ninety-three percent of the herbaceous vegetation in the Lower Eel Basin is considered annual grass, which as described above, is most likely used for agricultural purposes. This vegetation may be made up of either native or nonnative species. Pickleweed comprises 7% of this category, and is found solely in the estuary. The remaining vegetation in the Lower Eel Basin is composed of: mixed conifer/hardwood forestland, hardwood, barren lands, urban lands, or shrubs. Like the previous vegetation types, these classifications vary in abundance by subbasin.

This USFS classification describes current vegetation as of the mid to late 1990s. However, vegetation in the Lower Eel Basin has changed considerably over time. For example, in the estuary, salt marsh was aggressively drained, and riparian vegetation cleared in order to convert tidelands to pasture. In addition, native bunch grasses have been replaced over time by European annual grasses in pasture lands throughout the Lower Eel Basin. This has in turn reduced the strength of prairie vegetation and increased slumping in the system (Reynolds et al. 1981, Kelsey 1977). Additional changes have come from timber harvesting practices that have depleted forest stands and riparian vegetation. Some of the earliest timber harvesting began as a result of agriculture, when ranchers hired loggers with the singular purpose of clearing lands for grazing (PALCO Van Duzen Watershed Analysis 2002). More details of these activities are in the Land Use and Subbasin sections of this report.

Table 7. USFS classification of vegetation of the Lower Eel Basin.

Vegetative Cover Type	Percent of Basin	Primary Vegetation Type	Percent of Cover Type
Conifer	32	Redwood Alliance	41
		Redwood – Douglas-fir Alliance	32
		Douglas-Fir – Grand fir Alliance	16
		Sitka spruce Alliance	4
		Pacific Douglas-fir Alliance	4
		Sitka spruce – Grand fir Alliance	1
		Sitka spruce – Redwood Alliance	1
		Monterey Cypress Alliance	<1
Agriculture	28	Agriculture	100
Herbaceous	14	Annual Grass/Forb Alliance	93
		Pickleweed – Cordgrass Alliance	7
		Nonnative/Ornamental Grass Alliance	<0.5
		Tule/Cattail Alliance	<0.1
Mixed (conifer stand with hardwood	11	Douglas-fir – Grand fir Alliance	31
		Sitka spruce Alliance	20
		Redwood – Douglas-fir Alliance	19
		Sitka spruce – Grand fir Alliance	14
		Redwood Alliance	10
		Pacific Douglas-fir Alliance	4
		Sitka spruce – Redwood Alliance	2
Hardwood	7	Red Alder Alliance	82
		Black Cottonwood Alliance	7
		Mixed Riparian Hardwoods Alliance	5
		Willow Alliance	4
		Fremont cottonwood Alliance	1
		California Bay Alliance	<0.5
		Tan Oak (Madrone) Alliance	<0.5
		Eucalyptus Alliance	<0.5
Barren	3	Barren	81
		Dunes	19
Urban	3	Urban	100
Shrub	2	Willow (riparian scrub) Alliance	33
		North Coastal Shrub Alliance	27
		Salal-California huckleberry Alliance	20
		Blueblossom Alliance	18
		Coyote brush Alliance	2

These statistics exclude the classification of water

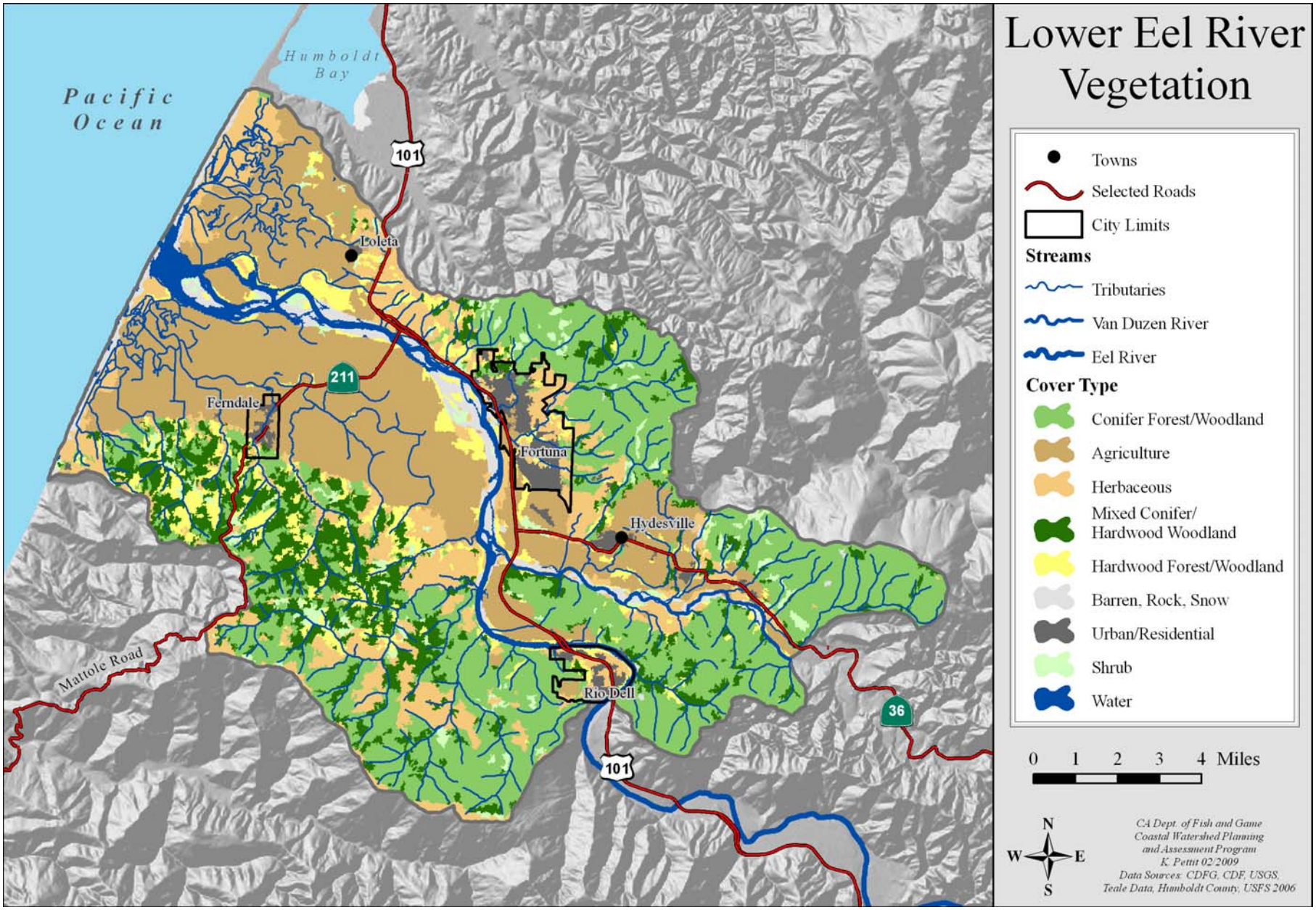

Figure 10. Vegetation of the Lower Eel River Basin.

The CALVEG classification also describes crown diameters of conifers, which are ordered into groups based on average visible diameter (Table 8). In the Lower Eel Basin, crown diameters of all primary coniferous vegetation range from saplings to greater than 40 feet (Table 9). The most common crown diameter for redwoods is in the medium range, or 24 to 40 feet. Canopy density is also expressed by CALVEG, and is given as a percentage of crown closure. Using these data, conifer canopy density described as 90 to 100% crown closure makes up the greatest amount of area in the Lower Eel Basin (Figure 11, Table 10). However, these areas, which are primarily in the headwaters of the Upper Subbasin, only represent 31% of the land covered by conifers. Canopy density directly over streams in the Lower Eel Basin is discussed in the tributary analysis sections of this report.

Table 8. USFS CALVEG classification of conifer crown diameter.

Classification	Tree Size Description	Average Visible Crown Diameter
0	Seedling	Derived from plantation age
1	Sapling	Derived from plantation age
2	Pole	Crown diameter less than 12 feet
3	Small	Crown diameter from 12 feet to 24 feet
4	Medium	Crown diameter from 24 feet to 40 feet
5	Large	Crown diameter greater than 40 feet

Table 9. Crown diameter of vegetation classified as primarily conifer forest in the Lower Eel Basin.

Conifer Alliance	Size Range Classification	Most abundant by area
Redwood	Sapling to Large	Medium
Redwood – Douglas-fir	Sapling to Large	Medium
Douglas-fir – Grand fir	Sapling to Large	Small
Pacific Douglas-fir	Sapling to Medium	Small
Sitka spruce – Redwood	Sapling to Large	Medium
Sitka spruce	Sapling to Large	Small
Sitka spruce – Grand fir	Sapling to Large	Small

Table 10. Canopy density classifications and percentages of the vegetation classified as conifer in the Lower Eel Basin.

Percent Crown Closure	Percentage of Conifer Vegetation
10 to 19	2
20 to 29	5
30 to 39	7
40 to 49	3
50 to 59	9
60 to 69	13
70 to 79	13
80 to 89	17
90 to 100	31

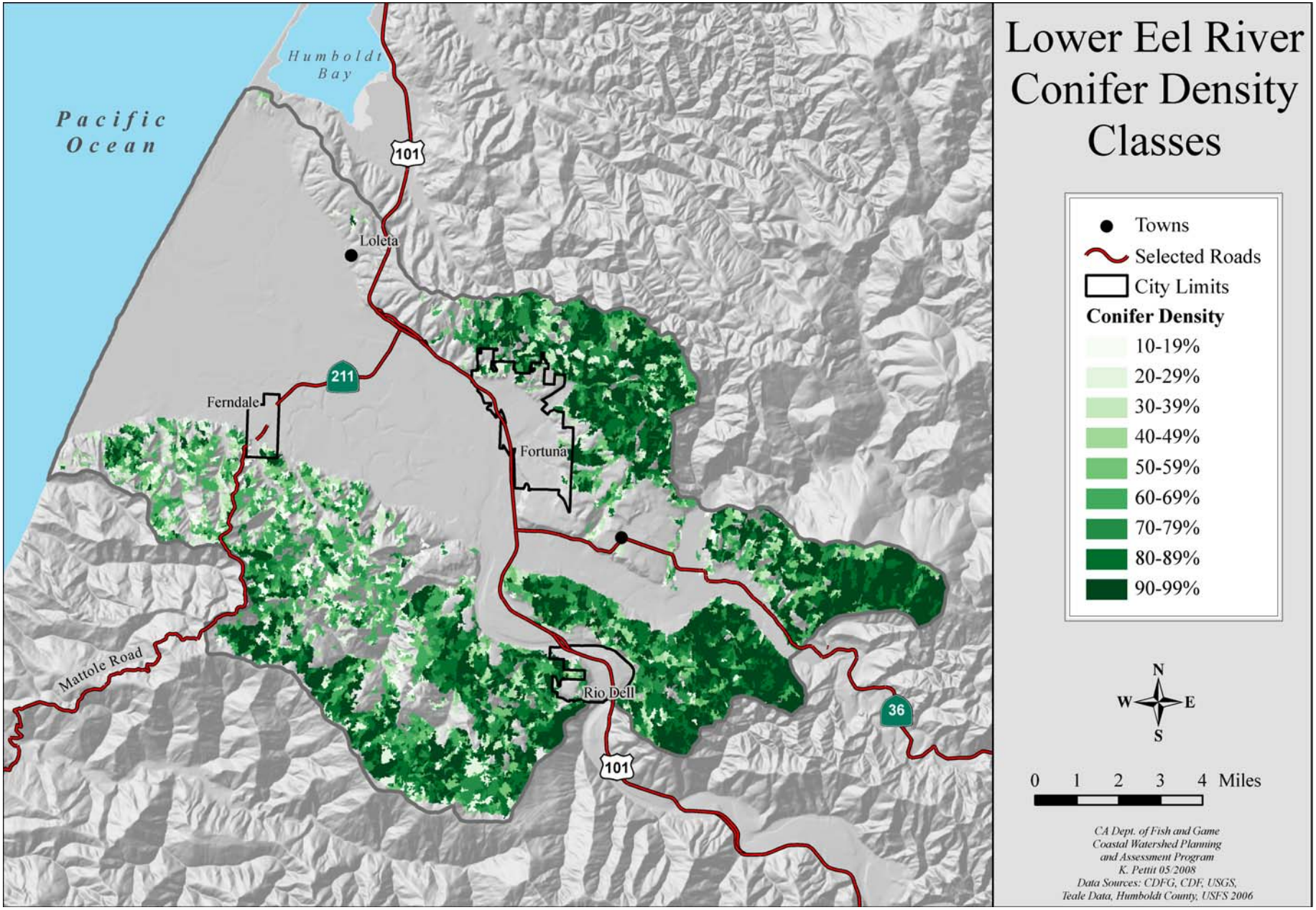

Figure 11. Conifer canopy density of the Lower Eel River Basin (2005).

Land and Resource Use

Long before written descriptions of the Eel River valley were made by Euro-American settlers, the Wiyot people inhabited the lands from Little River in the north to Bear River in the south. They concentrated in centers around Humboldt Bay and nearby rivers. The tribe takes its name from the Wiyot name for the Eel River (which is Wiyot). In the Lower Eel River Basin, the tribe's territory extended inland to Wolverton Gulch on the Van Duzen River, and occupied land that would eventually become the towns of Loleta, Ferndale, Fortuna, and Rohnerville (Kroeber 1976, Wiyot website). While the majority of the Lower Eel River Basin lies within what was Wiyot territory, it also enters portions of lands inhabited by tribes of the Athabascan family, namely the Mattole and Nongatl. The Mattole people's territory extended onto the Eel River and the Van Duzen River "immediately above the Wiyot" (Kroeber 1976). The Nongatl, which was the northernmost Athabascan tribe, were settled along the Eel River near Yager Creek on the Van Duzen River (Kroeber 1976).

Most of the Euro-American settlers who first came to the Eel River valley in the early 1850s were former gold prospectors looking for another way of life. The fertile soils in the Eel River delta were attractive, and soon the surrounding lands were being converted for agricultural purposes. Initially, agricultural production in the area was centered on row crops. As time passed, settlers began to realize that lands that had been cleared for crops were capable of producing lush grass. By the early 1900s, agriculture in the Eel River delta had been almost completely converted for the purposes of grazing livestock (Parry 1963). Individual dairy farmers soon began to consolidate their creameries forming the largest cooperative creameries in the state. Several towns in the area, such as Loleta and Ferndale, soon prospered due to the success of their innovative creameries and the export of dairy products.

In order to create pasture lands, considerable amounts of tidal marshland were reclaimed and riparian vegetation was cleared. Some of the first timber production in the area was a result of this land clearing. However, it was not until transportation improved that these felled trees became an important commodity. In the area near Rohnerville, a mill was constructed to convert timber that had been cleared for agriculture into shingles, shakes, and rough wood (Genzoli 1976). By the late 1800s to the early 1900s, several timber mills were established as timber harvesting was occurring in areas around Fortuna, and Rohnerville, and also along the Van Duzen and Eel River tributaries near Rio Dell.

The Eel River was once deep enough to accommodate shipping vessels. This fact was first realized when a vessel entered the estuary in 1850, mistaking it for Humboldt Bay. Soon after, a port was established within the estuary on Salt River at Port Kenyon and was used to ship goods. Through the improvement of roads and the construction of bridges to Eureka and Humboldt Bay, as well as the completion of the Northwestern Pacific Railroad, the area was able to more efficiently export crops, dairy products, cattle, timber products and salmon. By the early 1900s, towns like Ferndale and Springville (now Fortuna) became quite affluent, touting several stores, luxury hotels, fairgrounds, and racetracks.

Population

Several small towns lie within the basin; the major population center is the city of Fortuna (Table 11). The total Lower Eel Basin resident population estimated from the year 2000 census was 21,516 people (Table 12). Over half of the population lives in the Middle Subbasin, which contains Fortuna. The second most populous subbasin is the Upper, which includes the small towns of Hydesville and Rio Dell. Population density is sparse in the Estuary, Salt River, and Upper subbasins; it is much higher in the Middle Subbasin, reflecting the more urban nature of Fortuna. However, the majority of people in all of the subbasins except for the Estuary Subbasin live in towns.

Table 11. Available 2000 and 2004 data from the U. S. Census Bureau for communities in the Lower Eel Basin.

Principal Communities	2000 Census	2004 Census
Ferndale	1,382	1,406
Fortuna*	10,497	10,995
Rio Dell	3,174	3157
Hydesville	1,209	N/A
Loleta	750	N/A

* Census data for Fortuna include the Rohnerville area.

Table 12. Population and population density of the Lower Eel Basin by subbasin (2000 Census).

Subbasin	Population	Area (Square Miles)	Population Density (Population/Square Mile)	% of Population in Towns
Estuary	1,900	24	79.2	39.5
Salt River	2,507	49	51.2	55.1
Middle	12,906	24	537.8	81.3
Upper	5,667	75	75.6	77.3
Total	22,980	172	133.6	74.0

Ownership

Landownership in the basin is primarily held in private parcels of 40 to 500 acres in size (47%) followed by private parcels of ≤ 40 acres (23%) (Figure 13). Less than 4% of the area is public property. Private timber companies, including the Humboldt Redwood Company (formerly Pacific Lumber Company) and Green Diamond Resource Company, make up the remaining area.

General land use across the basin includes timber harvest, agriculture, grazing, residential, and commercial (Figure 12). The major cities and towns in the basin are Fortuna, Ferndale, Loleta, Hydesville, and Rio Dell.

Forest Management

Historic

The Pacific Lumber Company began logging the Lower Eel Basin in the 1890s in the Strongs Creek watershed, which today includes the Fortuna area. Until 1890, teams of horses or oxen were used to pull logs over skid trails and by 1892 steam donkeys were in full use hauling downed timber (Wood 1956). By 1920, Strongs Creek had been fully logged (HartCrowser 2004). Most timber harvest by Palco remained on the north side of the Lower Eel River until 1930, when their operations expanded to Atwell Creek across the river. By this time, other local timber companies had begun harvest operations, among them: E.J. Dodge Company in Atwell/Howe and Hammond Lumber Company and Holmes-Eureka Company in Cummings Creek. Mills were located on the Salt River, on Cummings Creek, in historic Newberg near Fortuna, and in Metropolitan on the Eel River. The Eel River had a brief run as a lumber shipping port from 1876 until 1909 at Port Kenyon before Humboldt Bay became established as the more reliable port. After that, timber products were either sold locally or were transported south via the Northwest Pacific Railroad.

Around 1944, tractor yarding and truck hauling became the predominant timber harvest and log transport methods replacing steam donkey cable yarding and railroad hauling (HartCrowser 2004). Peak timber harvest year for Humboldt County was 1959 (Downie 1995). Following WWII, timber harvest was characterized by an extensive increase in heavy machinery, namely bulldozers, and little thought was given to ground disturbance, water quality or habitat protection. Those invasive and highly disruptive harvest methods soon resulted in unstable stream banks, loss of aquatic habitat complexity, and log jams acting as fish passage barriers. Since 1973, with the passage of the Z'Berg-Nejedly Forest Practice Act, environmental regulations have increased which has improved timber harvest practices. There has also been a general decline in Humboldt County timber production. Land conversion to grazing or residential development has also contributed to the decrease in timber production (Downie 1995; Hackett 2002).

Current

Records of logging activity from 1991 to present are available in digital format for all subbasins in the Lower Eel River. Earlier logging information is available in paper records from CDF but, at this time, remains largely unanalyzed. Since 1991, logging operations have occurred in each of the Lower Eel subbasins except for the Estuary Subbasin, which has very little timber land. Based on these same data, basin-wide logging operations have ranged in size from a low of 654 acres in 1991 to as much as 3557 acres in 1994, averaging 1,825 acres per year. That amounts to an annual average of 1.7% of the basin's area in harvest for the 16-year period. The total acreage that is currently zoned for timber production (TPZ) in the basin is 41,456 ac or 38.6% of the basin. By percentage, this is the dominant zoned land use for the study area. Most harvested areas were cut once or twice between 1991 and 2006, but there are some areas that have been harvested as many as six times within that period (Figure 14).

There are many different types of silviculture and yarding methods utilized by timber operators. They

all have different levels of disturbance on the landscape. In general, clear-cutting has the highest level of disturbance of any of the silviculture methods. This disturbance can be thought of as soil exposure and instability due to the removal of trees and aquatic disturbance due to the removal of shade and large woody debris contribution. Commercial thinning is the least disturbing silviculture method. Felling and bucking (cutting timber into segments) is done either manually or, where the terrain is not too steep, by machine. Felling and yarding methods that make the most contact with the forest floor carry the highest level of disturbance. Tractor and skidder yarding is limited to gentle slopes to reduce the potential damage the machine's tracks have on the soil. A tractor or skidder's weight plus the weight of logs will cause soil compaction which increases runoff and the treads will cause soil disturbance, introducing sediment into the runoff. Cable yarding, where logs are pulled uphill by cable to a road or landing, is commonly used in areas with slopes too steep for tractors or skidders. Skyline cable, balloon, or helicopter yarding have the lowest impact on forest soils.

Based on CDF data, the most common types of silviculture methods in the basin since 1991 are group and single tree selection (38% of the harvested area or 701 ac/yr) followed by clear cut (27% of the harvested area or 497 ac/yr) and commercial thinning (18% of the harvested area or 329 ac/yr) (Figure 15). The most frequent yarding method is tractor or skidder yarding (53% of the harvested area or 961 ac/yr) followed by cable system (22% of the harvested area or 396 ac/yr) and the tractor or cable option (14% of the harvested area or 247 ac/yr) (Figure 16). Balloon or helicopter yarding only occurs on 6% of the harvested area (103 ac/yr) in the basin.

All timber operations must conform to California Forest Practice Rules. Some companies operating in the basin have created more complex and sophisticated management plans to guide their timber harvest operations. For example, both Humboldt Redwood Company and Green Diamond Resource Company have developed Habitat Conservation Plans (HCP) which focuses on keeping the forest ecosystem functional concurrent with timber harvest.

In July, 2008 the Pacific Lumber Company was officially transferred over to Mendocino Redwood Company and Marathon Structured Finance Fund LP, a Palco creditor (The Forestry Source 2008). Society of American Foresters Mendocino Redwood Company shortly thereafter renamed Palco as Humboldt Redwood Company. This transfer of ownership will have a significant affect on the management of the 220,000 acres of land in Humboldt County now managed by Humboldt Redwood Co. Under Palco management, an average of 150 to 160 million board feet was cut from 2000 to 2005 on their 220,000 acres of land in Humboldt County. That figure dropped to 99 million bd. ft. in 2006, and fell to 77 million bd. ft. last year. Under the new management of the Humboldt Redwood Co, annual harvesting will be limited to 55 million bd. ft. per year for the next decade and a no-cut policy for old growth will be observed (http://www.building-products.com/readNews.aspx?ID=4893).

The State of the Eel (Downie 1995) did not indicate timber harvest as a threat to the Lower Eel River ecosystem but did mention two related issues–erosion and livestock. Roads and road building are one source of erosion and livestock exacerbate the problem as they trample roads and road grade approaches (Koch 2007). The geological setting in which logging occurs in this basin–steep slopes, rapid uplift, and unstable soils–creates more erosion from acceptable logging practices and from relic logging road and railroad beds. Compared to other land use practices, forest roads are more problematic than grazing, fire, and poor logging practices (Barnhart No Date). In a study carried out by the USFS in California watersheds, converting only 0.6% of a watershed into low standard roads increased sediment by 24% (Anderson 1971). Unless old roads are storm proofed or decommissioned, they will continue to release sediment into water courses.

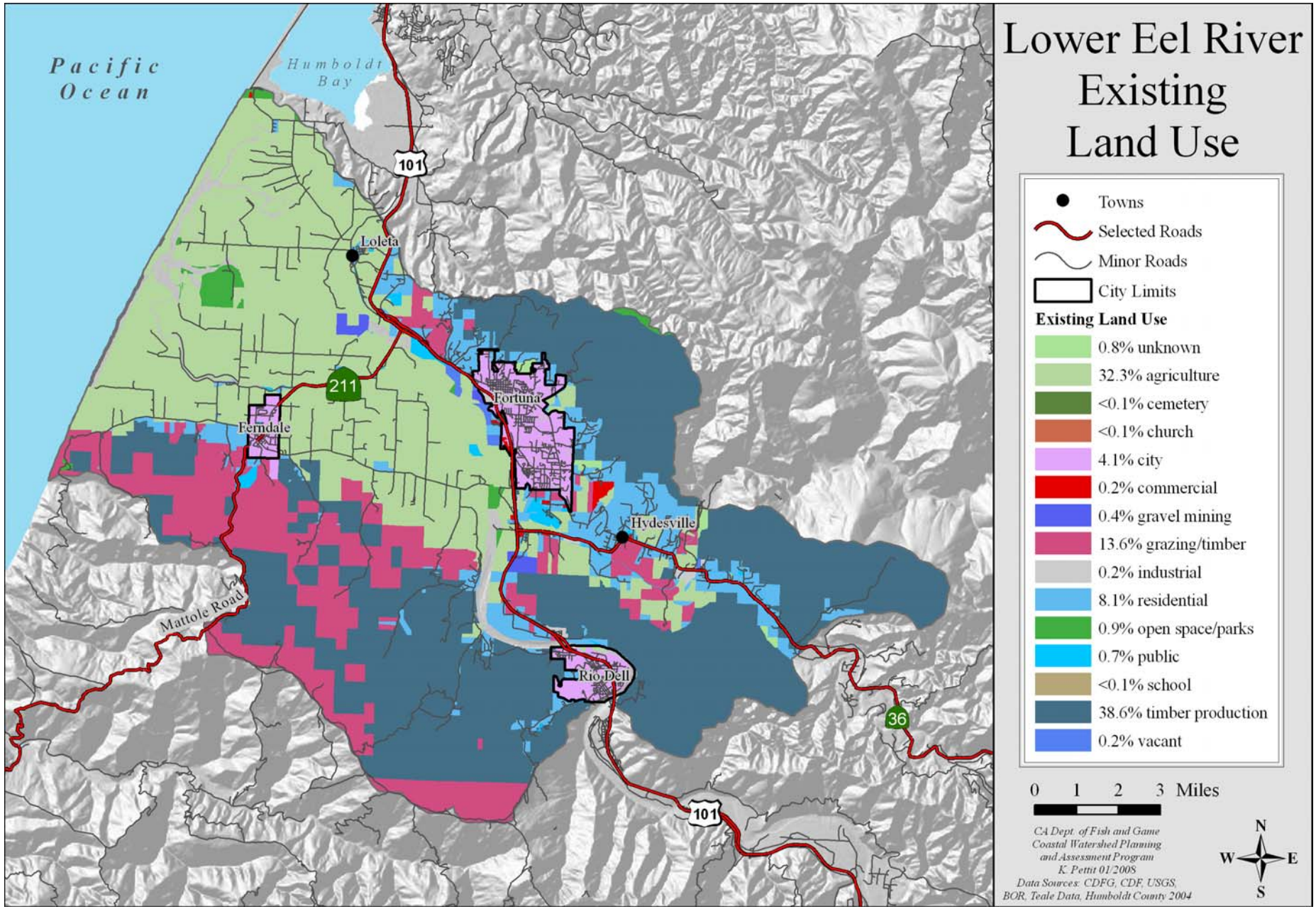

Figure 12. Landuse in the Lower Eel River Basin

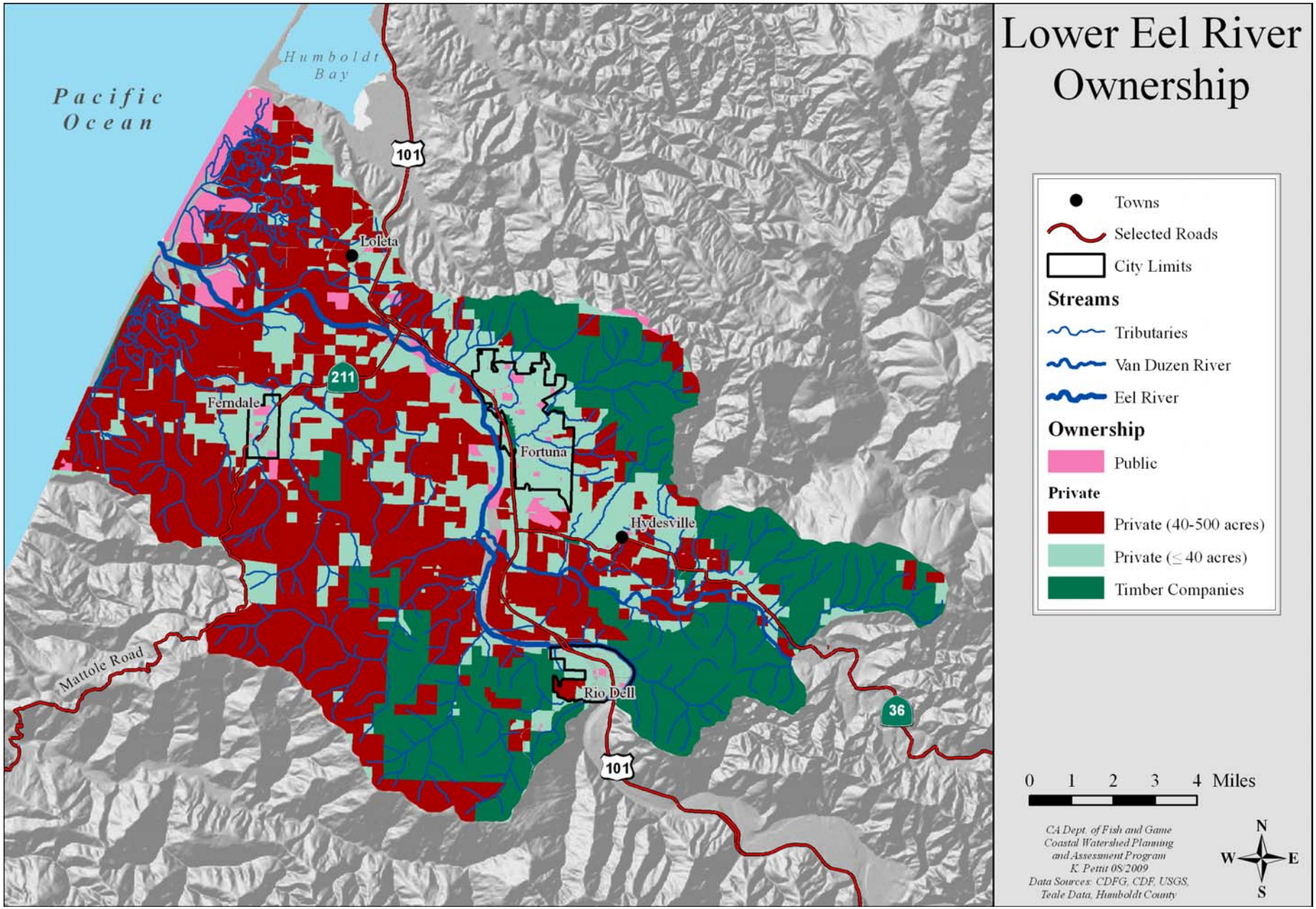

Figure 13. Landownership in the Lower Eel Basin.

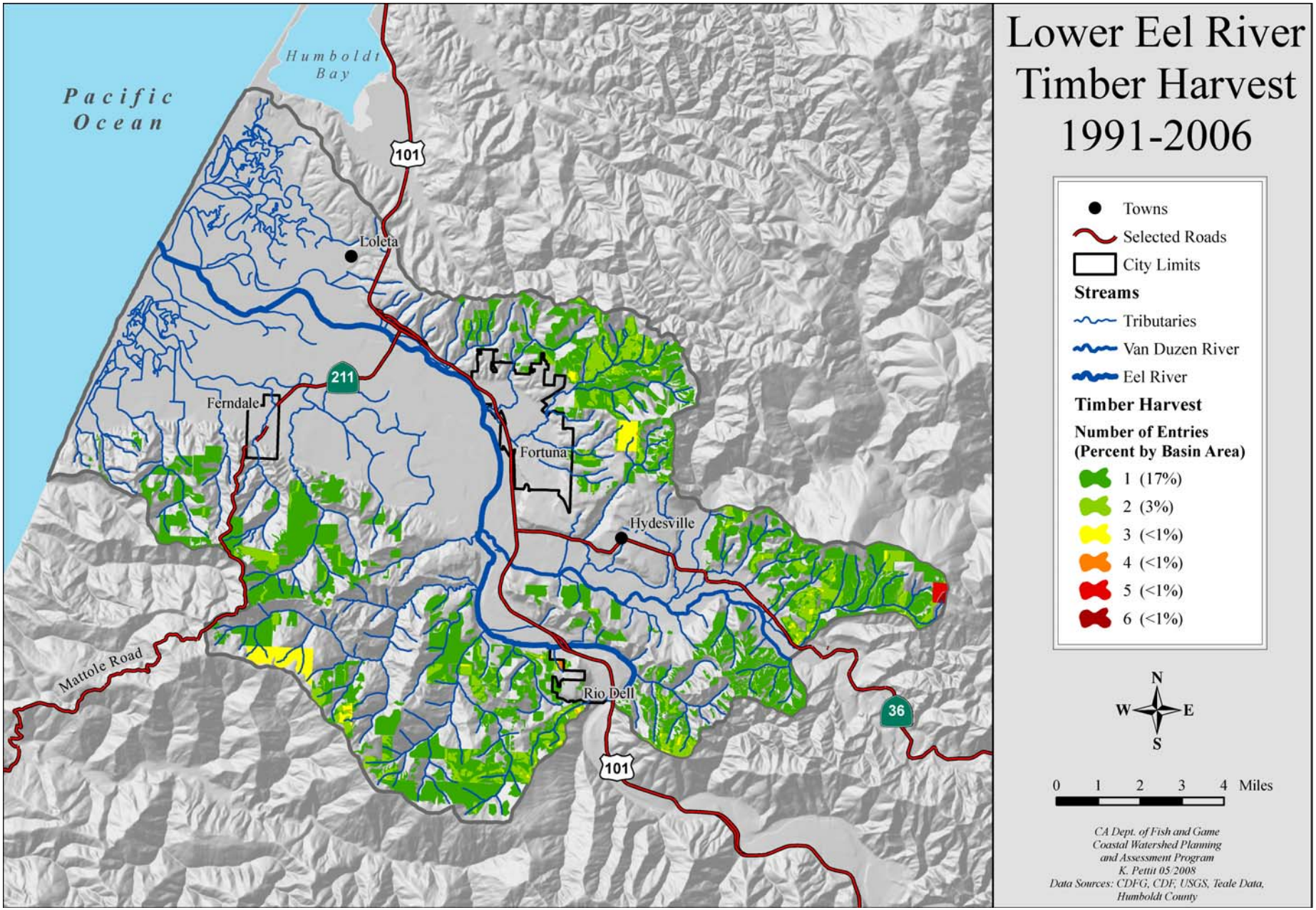

Figure 14. Timber harvest activity by frequency for the Lower Eel River Basin.

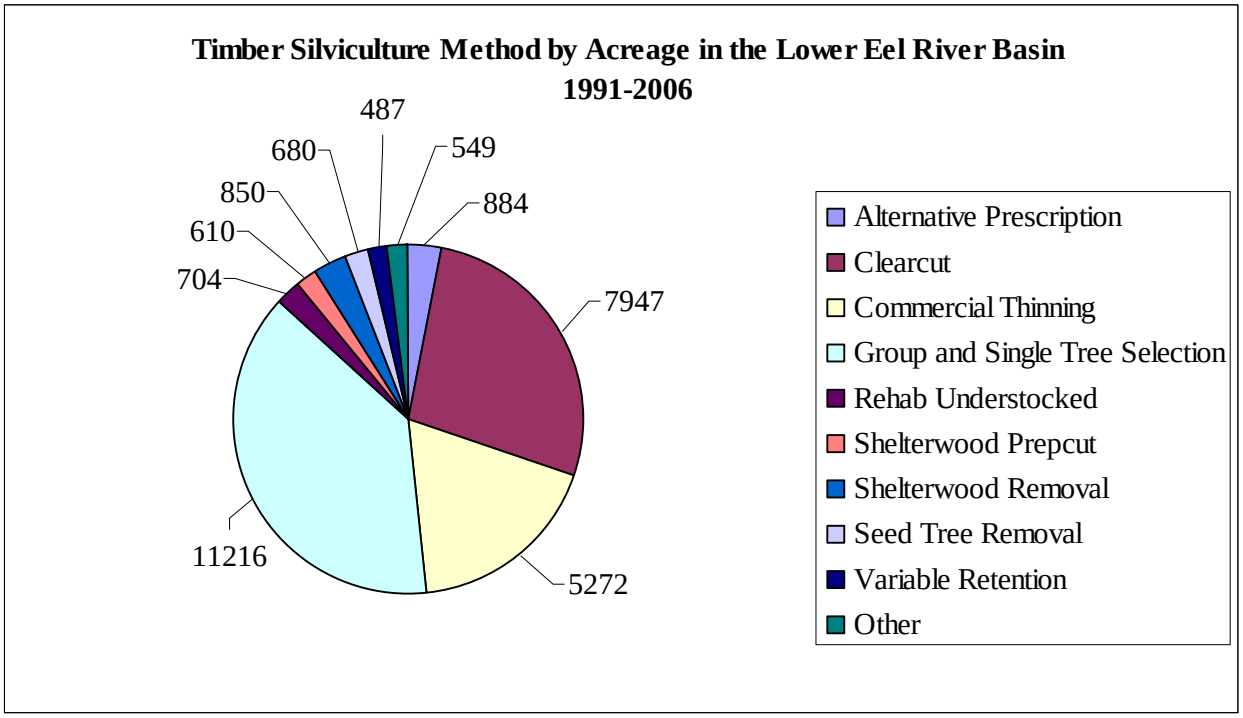

Figure 15. Number of acres in various silviculture methods across the basin from 1991-2006 (CDF data).

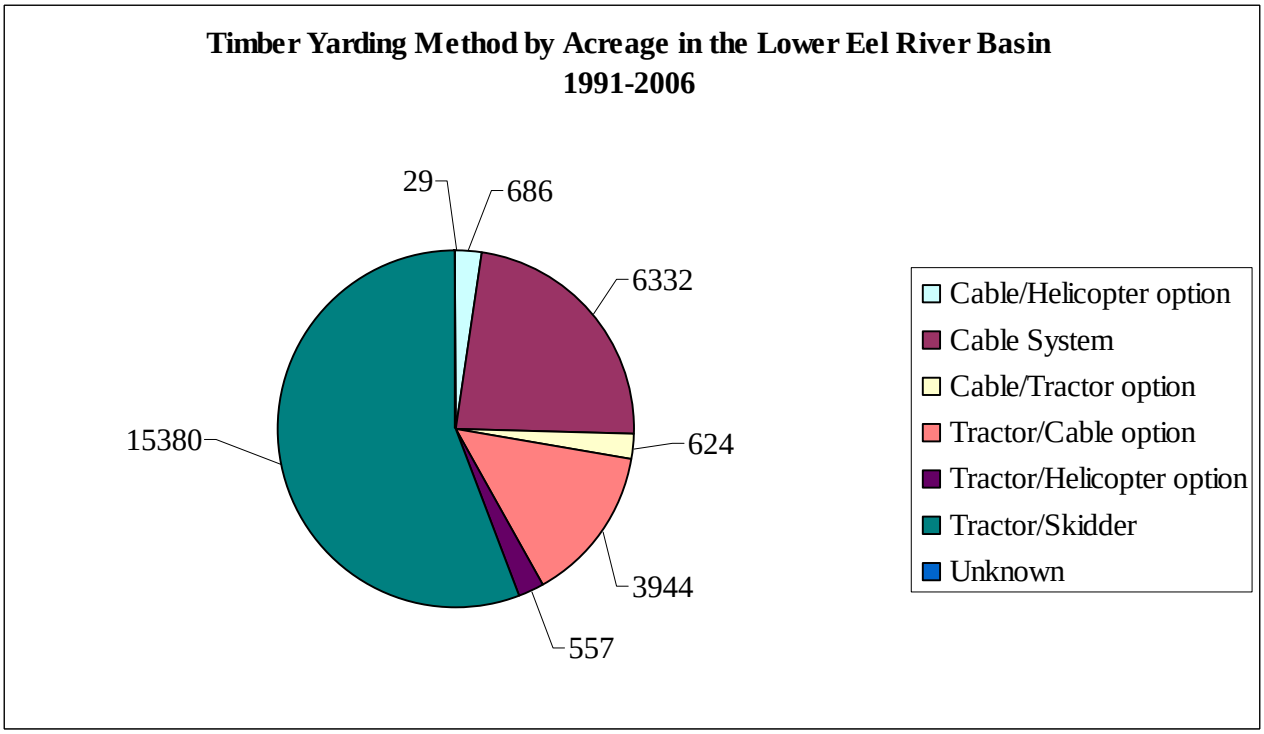

Figure 16. Number of acres in various yarding methods from 1991-2006 (CDF data).

In Pacific Lumber Company's Cumulative Effects Report (HartCrowser 2004), background surface erosion from soil creep to streams in the Lower Eel Basin was estimated to be 330 tons/mi^2/yr. An additional 312 tons/mi^2/yr of surface erosion is contributed through current timber harvest-related activities (57 tons) and current road use conditions (255 tons).

Roads and Railroads

As the Lower Eel was settled in the late 1800s, transportation routes grew and expanded. Trails became roads and roads were upgraded into railroads and highways.

Many of the roads and railroads built in the basin either cross streams or run alongside them. Both of these types of roads can affect streams. Stream crossings can create fish passage barriers or sediment sources. Roads that run along streams can also act as sediment sources as well as possibly stopping the ability of a stream channel to migrate across its floodplain. Additionally, many roads added sediment to streams as they were built.

Roads and railroads serve to transport people and goods throughout the basin (Figure 17). In forested upland areas many logging roads and seasonal railroads were built to facilitate access to and transport of timber. Most of these logging roads are not paved and many are not mapped.

Highway 101 runs through the basin from north to south. It was built from 1909 to 1923 and crosses the mainstem Eel River and several tributaries in the Lower Eel Basin. In addition, Highway 36 starts near the mouth of the Van Duzen River and runs east along the river. This highway was completed in 1912 and crosses the Van Duzen River and several of its tributaries.

The defunct Northwest Pacific Railroad runs along the Eel River, north to Eureka. A major defunct railroad runs along the Eel River and then towards Eureka. There is also a railroad line along the Van Duzen River and several smaller railroad lines built specifically for timber removal in isolated areas, such as along Yager, Lawrence and Cummings creeks.

The main north to south railroad along the Eel River was part of the Northwestern Pacific Railroad line. The Eel River and Eureka Railroad was built in 1884 to provide shipping from the lower Eel River to Humboldt Bay. In 1885, the railroad laid track through the town of Fortuna to Eureka and a railroad depot was built in 1891 in Fortuna. The Pacific Lumber Company built a railroad from Scotia to the Eel River and Eureka line in 1885 and logging branches of this railroad extended eight miles up the Eel River by 1902. An additional line extending up the Van Duzen River to Carlotta was built by a subsidiary to the Eel River and Eureka Railroad called California Midland Railroad in 1902.

Various local railroad companies merged into the Northwestern Pacific Railroad in 1907. The entire line that connected Eureka to Willits and all points south of there was completed in 1914.

Frequent winter flooding caused major maintenance issues for the railroad through the Eel River canyon. For example, the line was shut down from December 1964 to June 1965 due to the 1964 flood when one third of the railroad had to be rebuilt (www.Northcoastrailroad.org).

The North Coast Rail Authority (NCRA) bought line in 1992. The NCRA was founded in 1989 to ensure continuation of service in Northwestern California. However, the line was shut down in 1997 due to major floods and landslides through the Eel River Canyon and has not reopened. There is an ongoing discussion of reopening; however, reopening the line would require a major overhaul as most of the line is derelict. Within the Lower Eel Basin, the section of railroad across the river from Rio Dell no longer has the railroad ties on the grade (Figure 18). In addition, geologic conditions that have led to the poor condition of the railroad have not changed, thus any railroad would require costly maintenance and repair as well as cause further sediment erosion into the Eel River.

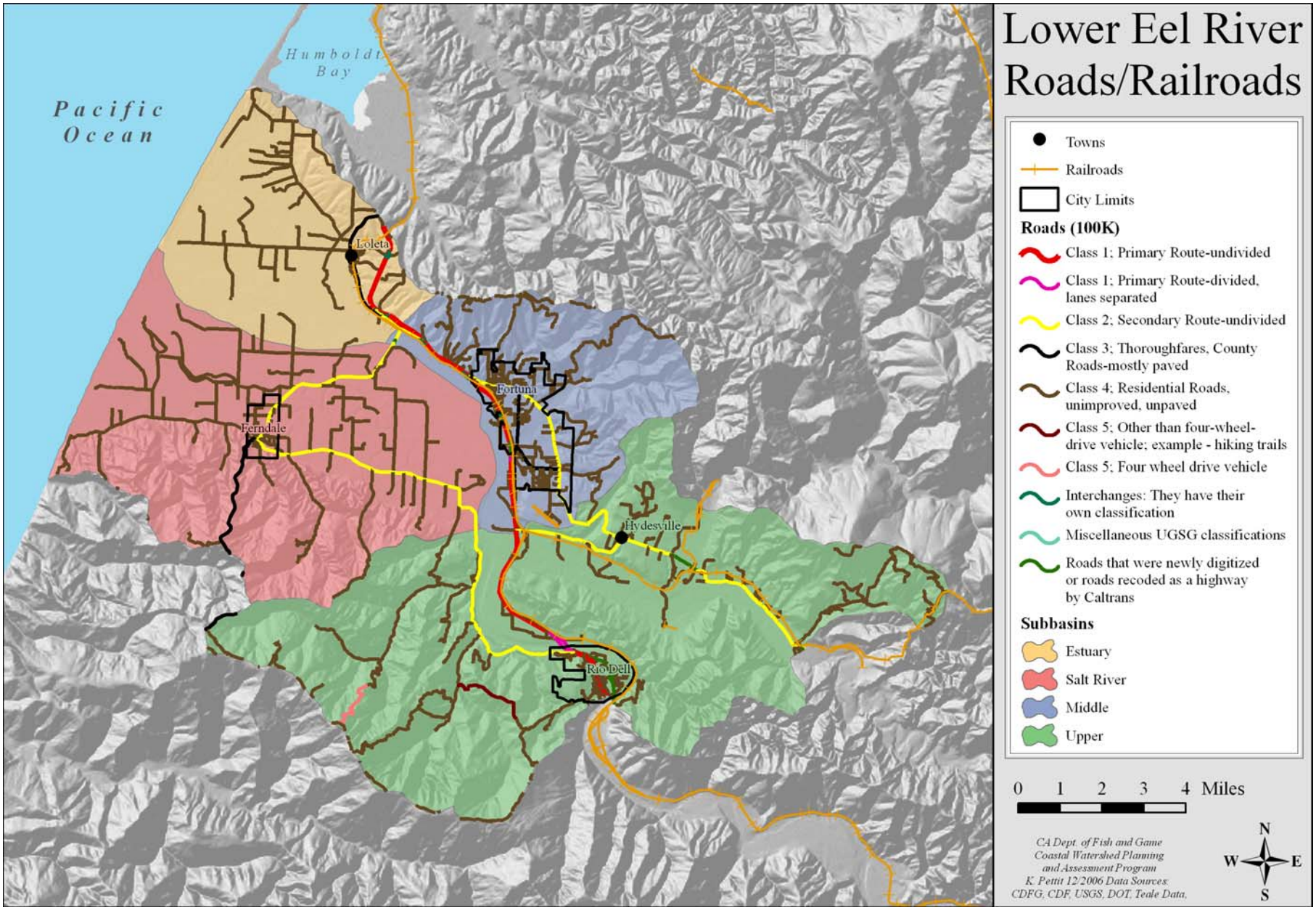

Figure 17. Roads and Railroads in the Lower Eel Basin.

Figure 18. Railroad along Scotia Bluffs July 2008.

Mining

The Lower Eel River holds one of the two highest concentrations of commercial instream aggregate mines and one of the two highest cumulative volumes of instream aggregate extracted on the west coast of the United States (the other is on the Mad River, CA) (Laird et al. 2000) (Figure 19). In light of the high quality of this instream aggregate, there is potential for this resource area to experience elevated demand pressure, especially if transport becomes more cost effective.

In general, gravel mining can have serious impacts on stream channels. Possible effects include the following:

- Altered channel morphology;
- Increased sediment input;
- Changed channel hydraulics;
- Reduced groundwater elevations (NOAA 2004); and
- Loss of riparian vegetation.

In turn, these effects on stream channels can impact aquatic life. Gravel mining has been shown in studies and in practice to negatively affect salmonid habitat for both spawning adults and rearing juveniles (Brown et al. 1998, Laird 2000, USACOE 2003). Direct effects on salmonids can include harming juveniles during mining operations, destruction of spawning and rearing habitat, loss of deep holding pools for adult and juvenile steelhead migration, and creating potential for fish entrapment (NOAA Fisheries 2004).

Additional impacts to salmonids can occur due to destruction of riparian zones, decreased food (macroinvertebrates) in impacted stream channels, and toxic chemical spills that could occur during mining activities (NOAA 2004).

Earliest accounts of gravel extraction from the lower Eel River date to 1911 and are linked with road surfacing needs of the time. Instream mining continued throughout the early part of the century and increased in the 1950s and 1960s. Between 1956 and 1987, from 500,000 to 700,000 cubic yards (cy) were extracted annually from the Eel River between its confluence with the Van Duzen River down stream one mile below Fernbridge (Humboldt County Public Works Department 1992). Gravel harvests increased further to average around 700,000 cy from 1987 to 1996. Problems of over extraction and threats to the fisheries led to a system of monitoring and adaptive management.

In 1992, the County of Humboldt formed a scientific review team–CHERT–to address the complexities in properly managing instream gravel mining in the Mad River. In 1996, CHERT expanded to review most riverine gravel mining operations in Humboldt County that remove 5,000 cy or more annually.

Monitoring of the Lower Eel Basin began in 1996 and divides the Lower Eel Basin into two reaches. One is the Lower Eel River reach which extends from Fernbridge to the confluence of the Van Duzen River (six miles in total); the other is the Lower Van Duzen reach which extends from the confluence with Eel River to five miles upstream (five miles in total).

There are also five instream gravel mines just upstream of the Lower Eel Basin owned and operated by Humboldt Redwood Company. Each of these sites is permitted to remove an average of 15,000 cy over 10 years and no more than 30,000cy during any given year. Any effects these mines have on water quality and fluvial geomorphology directly affect the Lower Eel Basin. Figure 19 shows the locations of gravel mines within the basin and the five above mentioned extra-basin mines.

For each reach, CHERT estimates the mean annual recruitment (MAR) of bedload in relation to the surrounding instream mining operations. From the MAR, they set recommended limits on the amount of aggregate that should be harvested each year. It has been suggested by other local gravel mining consultants that "average annual extraction should not exceed 75% of MAR in salmonid-bearing rivers and streams," and only if thorough analysis has been done to determine the MAR for that particular reach, otherwise 25% of the estimated MAR should be the guideline (Laird et al. 2000). From 1997 through 2007, the average volume extracted in both the Lower Eel River reach and the Lower Van Duzen reach has remained less than 75% of the volume recommended by CHERT (Table 13). Currently, annual extraction volumes average around 200,000 cy in the Eel River and a little over 100,000 in the lower Van Duzen River (CHERT 2007). Note that the table below presents the recommended volume and not necessarily the MAR. Yearly extraction data are presented at the subbasin assessment sections of this report.

CHERT monitors twelve sites on both the Lower Eel River reach and on the Lower Van Duzen reach. However, Trinity Associates (Laird et al. 2000) identified 34 sites that extract over 1,000 cy annually on the lower Eel River (geographic description of the "lower Eel River" was not given), and 43 sites on the Van Duzen River with an additional 40 sites that extracted less than 1,000 cy annually. (Table 13) (CHERT 2007).

The Eel River naturally has one of the highest sediment yields in the world for any river of its size. Clearly, channel aggradation from past floods and poor land practices would seem to be more of a problem than downcutting due to over extraction of gravel. At least three separate studies have used historical cross-section data and aerial photographs to determine if elevational changes have occurred on either the bed of the Lower Eel River or the Van Duzen River.

These reports monitoring streambed height levels in the basin and just upstream of the basin, Van Duzen River, have varied in their conclusions. One study shows aggradation above the area of this watershed assessment on the Van Duzen River between 1941 and 1977 (Kesley 1977). A separate study done by the Humboldt County Planning Department states that no significant change in stream bed elevation has occurred at Fernbridge, while a small to moderate amount (10 feet) of downcut has occurred at the Highway 101 Bridge on the Van Duzen River (Humboldt County Public Works Department 1992). Most recently, a 1999 study by the Army Corps of Engineers concludes that although moderate degradation has occurred on the Lower Eel River and mild aggradation has occurred on the Van Duzen River since 1968, this is not sufficient evidence that gravel mining has had a detrimental impact (USACOE 1999).

While gravel mining in the Lower Eel Basin may have only minimally impacted stream bed elevation changes, it has likely contributed to braiding and flattening of the Eel River between the confluence with the Van Duzen River to one mile downstream of Fernbridge (Humboldt County Public Works Department 1992). This type of shallow and wide channel morphology provides less cover from predation, less food, and higher water temperatures for juvenile fish as the channel is decoupled from riparian vegetation. Historically, the mining activities on the Lower Van Duzen River and mainstem Eel River below S.F. Eel River confluence created migration barriers for adult fish, sometimes leading to stranding on shallows and mortality. Since, mining operators cooperating with the regulatory agencies of the NMFS, USFWS, CDFG, and USACOE have prevented these types of incidents from reoccurring. It is important that gravel mining be managed in a way that does not further decrease salmonid habitat and, ideally, works with riverine dynamics to maintain or improve the quality habitat that still exists.

Table 13. Lower Eel and Lower Van Duzen River Extraction (1997-2007) (CHERT).

Reach	Annual Average	Recommended Volume (cy)	Extracted Volume (cy)	Percent Extracted
Lower Eel River	(1997-2007)	334,217	206,723	62%
Lower Van Duzen	(1997-2007)	159,902	111,347	70%

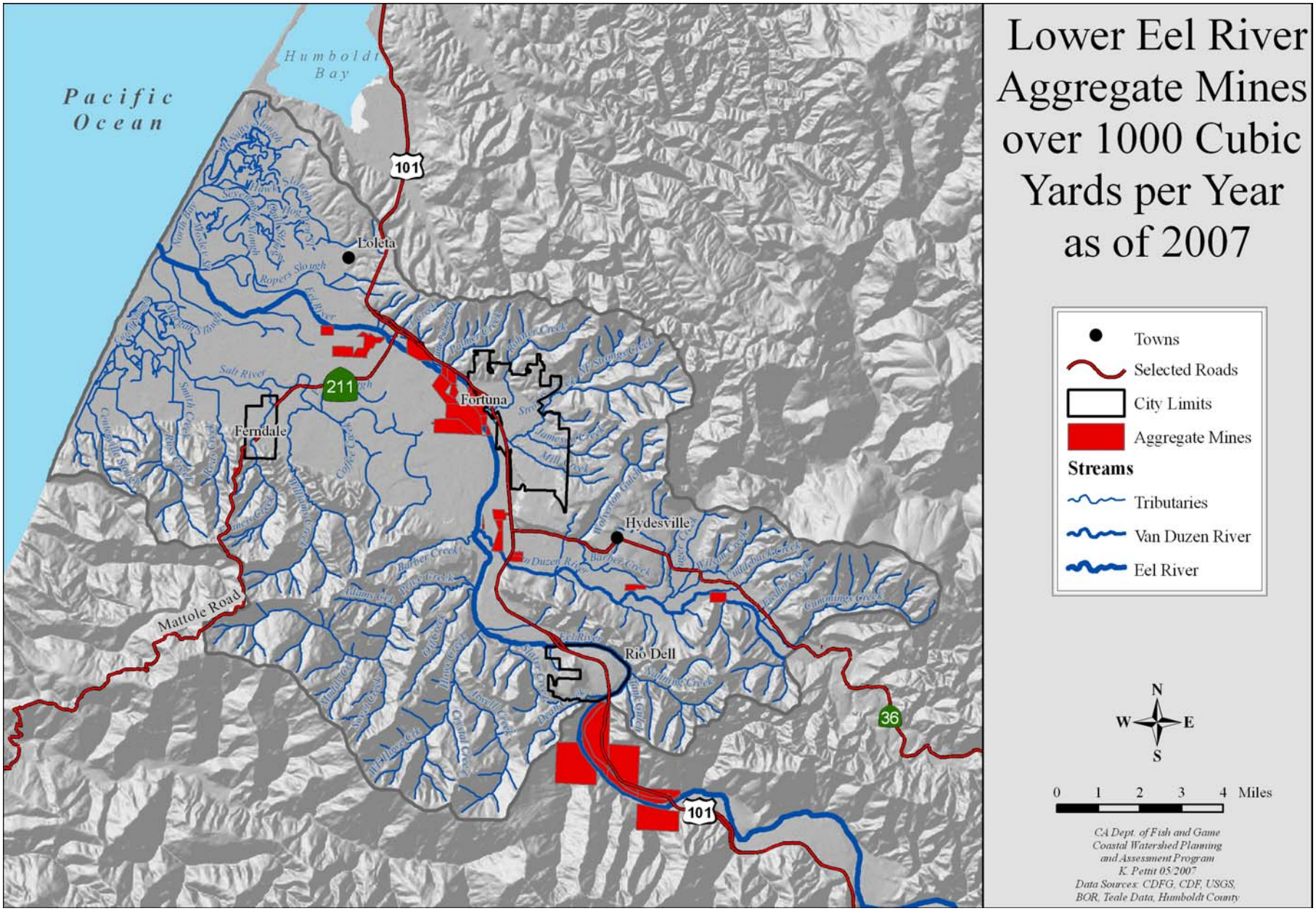

Figure 19. Lower Eel Basin aggregate mine locations.

Water Use: Diversions, Dams, and Power Generation

There are 25 licensed, permitted, or pending water rights within the Lower Eel River Basin (Table 14) (WRIMS 2007). This number does not include riparian users and other diversions that are not registered with the State Division of Water Rights. Water rights permits exist on streams as well as for groundwater in the basin. It is important to remember that groundwater and surface water are connected and will rise and fall together (TU 2007).

Most rights are for direct diversions, although there is one right for diversion storage in the Estuary Subbasin. Diverted water is primarily used for irrigation, stock watering, domestic use, and municipal use by the cities of Fortuna and Rio Dell.

Table 14. Water rights in the Lower Eel Basin (WRIMS 2007).

Creek	Application Number	Direct Diversion	Maximum Application Direct Diversion	Diversion Storage	Purpose
Estuary Subbasin (1)					
McNulty Slough Tributary	A029374			300 afy	Fish and wildlife protection and/or enhancement
Salt River Subbasin (11)					
Near Russ Creek	A013822	0.57 cfs	139.06 afy		Irrigation
Russ Creek	A011118	10000 gallon/day	10000 gallon/day		Stock watering
	A010177	0.21 cfs	57.9 afy		Irrigation
Reas Creek	A020346	0.2 cfs	60.7 afy		Irrigation
Francis Creek	A010052	0.25 cfs	76.37 afy		Irrigation
	S000389		0 afy		Irrigation
	S000145		7200 gallon/day		Irrigation
Francis Creek Tributary	D030417R	1200 gallon/day	0.5 afy		Domestic
Near Francis Creek	S014391	2880 gallon/day			
	A022563	10700 gallon/day	10700 gallon/day		Irrigation
	D030414R	4500 gallon/day	2 afy		Domestic
Middle Subbasin (2)					
Eel River Underflow	A019124	3 cfs	1642 afy		Municipal
Upper Subbasin (13)					
Tributary to Wolverton Gulch	S008687		0 afy		Irrigation
Yager Creek Tributary	C000110		1 afy		Stock-watering
Cooper Mill Creek	A025146	0.93 cfs	360 afy		Fish culture
Fielder Creek	A005194	0.1 cfs	72.39 afy		Irrigation, Domestic
Price Creek	A015581		700 gallon/day		Stock watering
	A019631		300 gallon/day		Stock watering
	A015444	0.39 cfs	82.77 afy		Irrigation
Kemp Creek	A012956		500 gallon/day		Domestic
Eel River	A012319	0.44 cfs	121.31 afy		Irrigation
Eel River Underflow	A023196	0.62 cfs	304 afy		Domestic, Municipal
Eel River Tributary	A008824	0.067 cfs	20.47 afy		Irrigation
Dean Creek Tributary	A023197	0.09 cfs	65.16 afy		Municipal

No major dams or power generating facilities are located within the Lower Eel Basin. However, the Potter Valley Project near the headwaters of the Eel River (Figure 2) consists of two dams, which function to transfer water from the Eel River to the Russian River. Scott Dam at RM 147 forms Lake Pillsbury and blocks anadromous fish passage. The lake has a maximum water elevation of 1,925 feet and a storage capacity of 73,000 acre feet and supports both warm and coldwater fisheries (CDFG 1997).

Twelve miles downstream from Scott Dam is Cape Horn Dam. Cape Horn Dam forms Van Arsdale

Reservoir, which has a storage capacity of 700 ac-ft (FERC 1983). There is a fish ladder on Cape Horn Dam, facilitating anadromous salmonid passage. Upstream of Van Arsdale is an inter-basin hydroelectric operation owned and operated by the Pacific Gas and Electric Company. There is a 9,258 foot tunnel which diverts water from the Eel River to the Russian River. The project generates some electricity but mainly provides water for municipal and agricultural interests in Mendocino and Sonoma counties (CDFG 1997).

The average annual diversion of the Potter Valley Project is 160,000 acre-feet of water. However, the amount of water diverted varies from month to month. Diversion records have been published for the 91 years from 1910 to 2000. During the high flow months of January, February, and March approximately only 6%, 20%, and 15% of unimpaired flows have been diverted, respectively. During the lower flow months of June, July, August, and September, 81%, 88%, 69%, and 64% of the unimpaired flows are diverted, respectively (CEED 2002). The combination of diversions from Potter Valley Project and all the other diversions along the river impacts the amount of flows in the Lower Eel Basin, especially during low flow periods. These lower flows may cause the loss of connectivity between the estuary and the rest of the basin and delay/prevent adult fish from reaching portions of the Eel River Basin during their fall spawning migrations. Moreover, less water would be available for agricultural production in the Lower Eel Basin.

Flow requirements from the Potter Valley Project were issued by the Federal Energy Regulatory Commission (FERC) in 1983 and updated in 2004 during the re-licensing process. The updated requirement included a 30% reduction in the diversion of water to the Russian River and variable flow in the summer based on whether it is a wet or dry year. Therefore, flows in Eel River increased 15% on an annual basis relative to pre-2004 and 30% since 2004. Additionally, summer flows will now vary from 3 to 35cfs rather than remaining steady at 5cfs (USEPA 2007). In addition to these regulations, the CDFG has water in reserve that can be used for fall attraction flows for adult migration and spring flushing flows.

Fishing

Historic

A commercial salmon fishery was established in the Eel River estuary in the early 1850s and continued until 1922. The early fishery was started by a few men that claimed fishing sites in the lower Eel River estuary. They organized companies or teams of fishermen to perform commercial fishing activities. The fishery quickly grew and by the late 1850's the salmon catch from the Eel River was greater than that of the Sacramento River (Reynolds et al. 1981). The growing commercial fishery brought a significant numbers of jobs and revenues to Humboldt County. In 1859 there were seven or eight fishing and packing companies working along the lower six miles of the river.

Salmon catches varied from year to year. The reported yearly harvest of Chinook salmon ranged from approximately 20,000 in 1857 to 150,000 in 1903. Coho salmon harvests were rarely reported, but in 1895, a meager year for Chinook harvests, 160,000 pounds or approximately 13,600 coho salmon was reported caught and as many as 62,500 steelhead (500,000 lbs) were caught. Factors influencing the size of the harvests were river conditions, the size and timing of salmon runs, the fishing effort, market demand, and fishing regulations. Fishing regulations were introduced in the 1890s as there was concern about depletion of the fishery. Attempts to regulate the commercial fishery with various rules and laws were implemented by the State Fish and Game, which eventually became the CDFG. The laws included net restrictions (most salmon fishing involved employing large seine nets in the river), shortened seasons and closed areas. The last records documenting commercial harvests from the estuary are from 1918 (Report of Commissioner of Fish and Fisheries) and the commercial fishery on the Eel River was closed by legislation in 1922.

The history of the commercial salmon fishery reveals important information about the run size, run timing, and species composition of the Eel River's salmonid stocks. Newspaper articles tell of at least two fall runs of Chinook in the Eel River: 1) an early fall run that were often caught in the estuary from as early as August, but mostly October through mid-November and 2) a second peak in catches that occurred in late fall, from mid-November through December and sometimes in January. Newspaper articles were substantiated by reviews of various reports by the U.S Fish Commission, the State Fish Commission, and the CDFG. Articles also tell of adult steelhead being caught in the estuary year round. The steelhead fishery had peaks in April, May, and June

representing a summer run, and a winter run in December through March. The steelhead half pounder run was strongest in August and September. Further details of the commercial fishery are described in *Land Use* within the Estuary Subbasin section of this report.

In addition to commercial fishing, recreational fishing has also played an important role on the Eel River and estuary. Historically, there was fishing for juvenile trout in the summer and adult trout and salmon in the fall and winter. Historical accounts of the recreational fishery in the Eel River estuary describe excellent conditions for salmon and steelhead fishing over the entire delta, with anglers gaining access to the catch "from boat to shore" (Haley 1970). Fishing also occurred along the mainstem Eel River throughout the basin. The recreational fishery has now been significantly reduced and is catch and release.

Outmigrant and over-summering juvenile steelhead trout fishing was popular throughout the Eel River Basin, especially in the lower river. Juvenile trout were caught from June to August (Murphy and DeWitt 1953, Anders 1953, Pister 1956).

Historically, there was fishing for coho salmon in the fall as well. However, the bulk of the coho salmon runs usually occurred as the turbidity of the water increased in November and December and made fishing more difficult (Murphy and DeWitt 1953).

Current

The Eel River has diminished from once being considered a world class fishery to one that can no longer support a commercial fishery and whose sport fishery's economic contribution to the region is almost non-existent. Presently, salmon and trout fishing in the Eel River targets Chinook salmon and steelhead trout as fishing for coho is prohibited. Chinook salmon fishing usually begins in August and intensifies in October when the first rains increase the number of migrating fish (Murphy and DeWitt 1953, Day 1966). While there are often half-pounder steelhead trout in the river before August, the prime fishing period for them is from August to November. In October, larger winter-run steelhead trout enter the catch, and are often caught by Chinook fishermen. Steelhead fishing increases in the winter months and continues until the end of March. The steelhead fishery is catch and release only, unless the fish have an adipose clip indicating they were of hatchery origin. Both Chinook and steelhead are taken either from the shore or using drift boats, trolling in larger flatwater and pools.

An additional small fishing resource in the basin is the American shad (*Alosa sapidissima*) fishery. Sport fishing for shad occurs from April to June, mostly on riffles immediately downstream from the mouth of the Van Duzen River (Puckett 1975).

In addition to salmonid fishing, there is a marine fishery in the lower estuary. Prior fishing within the lower estuary varied from occasional harvests of Pacific herring (*Clupea harengus pallasii*)and Pacific sardines (*Sardinops sagax*) and surfsmelt species by beach seines in the late 1800s and early 1900s; to dependable catches of pile surfperch (*Damalichthys vacca*) in the early 1950s (Murphy and DeWitt 1953); to mainly redtail surfperch (*Amphistichus rhodoterus*) in the mid 1970s (Puckett 1975). Fish caught today include a variety of surfperch, starry flounder, and netting for surfsmelt species. Native tribal members actively fish along the banks in the estuary for Pacific lamprey (*Lampetra tridentata*). Dungeness crab (*Metacarcinus magister*) is also an additional sport fishery in the estuary with crabs being caught in the fall prior to the rainy season.

Fish Habitat Relationship

Fishery Resources

The Eel River is the third largest producer of salmon and second largest producer of steelhead in the state. The salmonid fishery resources of the Lower Eel Basin include coho salmon, fall-run Chinook salmon, steelhead, and coastal cutthroat trout. The basin provides important habitat for all the life history stages of each species, including the vital migration route to and from the ocean for all of the anadromous fish of the entire Eel River Basin.

In addition to salmonids, there are many additional fish species that inhabit the Lower Eel Basin (Table 15). Most of the marine or estuarine dependent species utilize the estuary as a nursery area and are generally limited to the juvenile stages of their life cycles. Several non-native freshwater species of fish, such as the Sacramento pikeminnow (*Ptychochelis grandis)* and Sacramento sucker (*Catostomus occidentalis*) have been introduced to the basin and have spread throughout the Eel River and some of its tributaries.

Table 15. Fishery resources of the Lower Eel River Basin.

Common Name	Scientific Name
Anadromous	
Coho Salmon	Oncorhynchus kisutch
Chinook Salmon	Oncorhynchus tshawytscha
Steelhead Trout	Oncorhynchus mykiss
Coastal Cutthroat Trout	Oncorhynchus clarkii
Chum Salmon	Oncorhynchus keta
Eulachon	Thaleichthys pacificus
Pacific Lamprey	Lampetra tridentata
Green Sturgeon	Acipenser medirostris
White Sturgeon	Acipenser transmontanus
American Shad,	Alosa sapidissima
Longfin Smelt	Spirinchus thaleichthys
Threespine Stickleback	Gasterosteus aculeatus
Coastrange Sculpin	Cottus aleuticus
Prickly Sculpin	Cottus asper
Freshwater	
California Roach*	Hesperoleucas symmetricus
Sacramento Sucker*	Catostomus occidentalis
Brown Bullhead*	Ameiurus nebulosus
Sacramento Pikeminnow*	Ptychochelis grandis
Green Sunfish*	Lepomis cyanellus
Marine or Estuarine Dependent	
Pacific Herring	Clupea harengus pallasii
Pacific Tomcod	Microgadus proximus
Topsmelt	Atherinops affinis
Bay Pipefish	Sygnathus leptorhynchus
Red-tail Surfperch	Amphistichus rhodoterus
Pile Surfperch	Damalichthys vacca
Walleye Surfperch	Hyperprosopon argentum
Shiner Surfperch	Cymatogaster aggregata
Pacific Sardine	Sardinops sagax
Northern Anchovy	Engraulis mordax
Surf smelt	Hypomesus pretiosis
Kelp greenling	Hexagrammos decarammus
Cabezon	Scorpaenichthys marmoratus
Pacific staghorn sculpin	Leptocottus armatus
Ringtail snailfish	Liparis rutteri
Jack mackeral	Trachurus symmetricus
Saddleback gunnel	Pholis ornata
Pacific sandlance	Ammodytes hexapterus
Tidewater goby	Eucyclogobius newberryi
Bay goby	Lepidogobius lepidus
Sand sole	Psettichthys melanostictus
English sole	Parophrys vetulus
Speckled sanddab	Citharichthys stigmaeus
Starry Flounder	Platicthys stellatus
Amphibians	
Pacific Giant Salamander	Dicamptodon tenebrosus
Northwestern Salamander	Amybstoma gracile
Rough-skinned newt	Taricha granulosa
Tailed Frog	Ascaphus truei
Pacific treefrog	Hyla regilla
Red-legged Frog	Rana aurora
Foothill Yellow-Legged Frog	Rana boylei
Bullfrog	Rana catesbeiana
Western Toad	Bufo boreas

* Indicates non-native species introduced to the basin.
From: Murphy and De Witt 1951, Puckett 1977, Boles 1977, Cannata and Hassler 1995, Franklin and Mitchell 1984, Goldsmith 2004, Monroe et al. 1974, Gilroy 2002.

There are no long-term fish population data sets specifically collected within the Lower Eel Basin. However, Eel River basin-wide data provide trend information about salmonids. Additionally, historic accounts, past stream surveys, and estuary studies provide records of fish species and populations within the basin.

There are two long-term fish count data sets for the Eel River Basin: CDFG fish ladder counts at Benbow Dam and Cape Horn Dam. These counts reflect an over 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the span of the last century (Figure 20, Figure 21). Therefore, it is likely that salmonid populations within the Lower Eel Basin declined similarly over this time period. The NMFS has listed northern California runs of Chinook (1999), coho (1997), and steelhead (2000) as threatened under the federal Endangered Species Act.

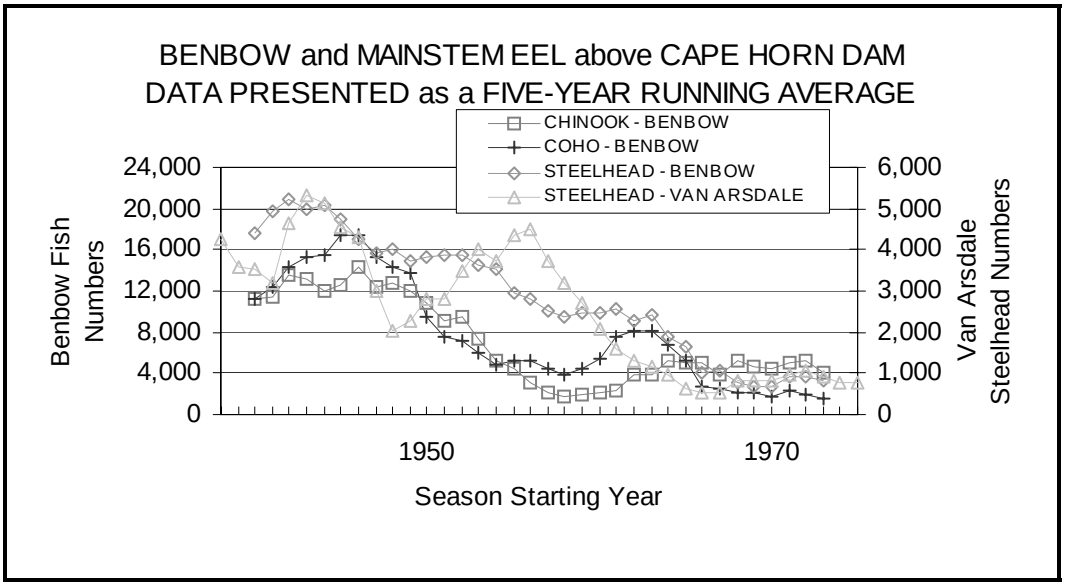

Figure 20. Five-year running average of salmonids at Benbow Dam, South Fork Eel River, and mainstem Eel River above Cape Horn Dam.

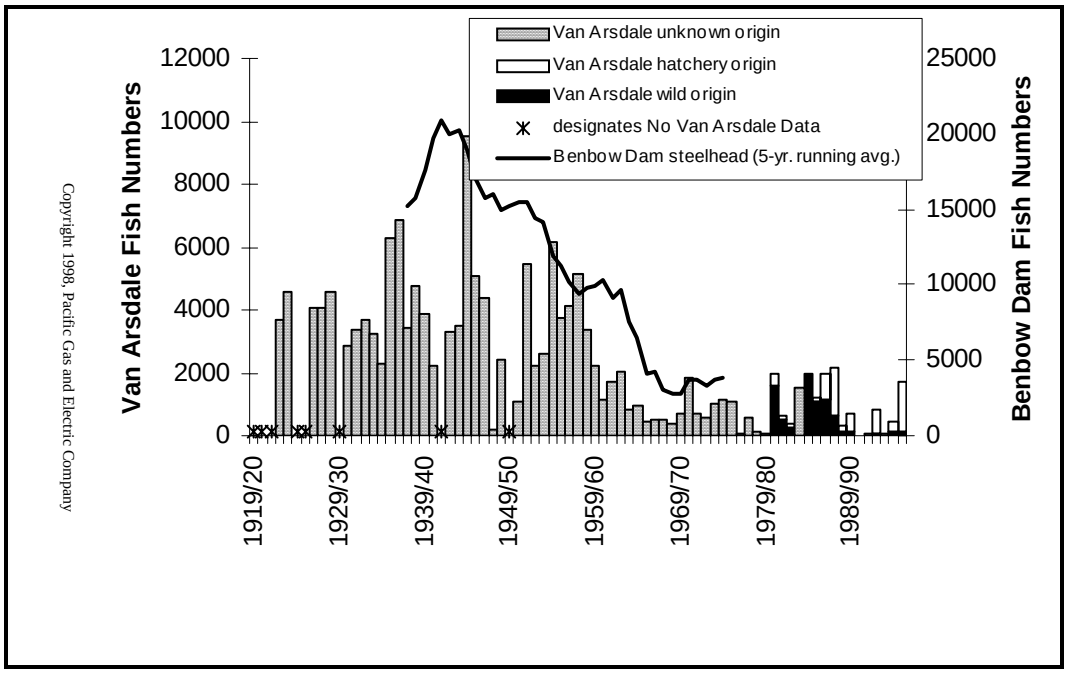

Figure 21. Historical steelhead trout ladder counts at Van Arsdale Fisheries Station, mainstem Eel River, and Benbow Dam, South Fork Eel River.

Coho salmon have been documented in 13 tributaries across the basin and Chinook salmon in six tributaries (Table 16). Steelhead trout have been documented in 21 tributaries and cutthroat trout in eight tributaries. These cutthroat represent the southern extent of coastal cutthroats on the West Coast. In addition, all four species of salmonids use the mainstem Eel River and estuary as critical migration routes and many use the estuary as rearing habitat. Due to the non-comprehensive nature of historic accounts, it is likely that not all streams that once provided habitat for salmonids have documentation of that fact. Therefore, estimates of historic salmonid distributions have been made. Figure 22 through Figure 25 depict the estimated historic and documented current distributions of coho salmon, steelhead trout, Chinook salmon and cutthroat trout, respectively. Current ranges are based on documented presence reports by CDFG since the 1990s (approximately). Salmonids may be present in sites where they have not been documented due to a lack of data or imperfect sampling techniques.

Salmon distribution in the basin was initially estimated using a stream gradient model. The limits of the estimated historic range of steelhead trout, the most athletic of the Lower Eel River salmonids, was initially defined to be a stream reach of 1000 feet or more with a gradient in excess of 10%. The limits of the coho and Chinook salmon range estimates were defined as reaches of 1000 feet or more with a gradient in excess of 5%. These estimates were based on 30 meter digital elevation model (DEM) analyses. The preliminary range estimates were then reviewed by a team of CDFG fishery biologists. The limits of the estimated historic range of coastal cutthroat trout were based on historic accounts of presence and expert opinion.

The preliminary estimates (Figure 22 through Figure 25) are not a definite indication that salmon were historically present in the indicated reaches, rather they indicate the possibility that salmonids were present. Additionally, the estimates do not conclusively prove that salmonids were not historically present in areas above the estimated gradient barriers. Other factors that affect salmonid distributions, such as flow limitations, channel shape and size, and barriers (e.g. waterfalls) could not be incorporated into this gradient-based analysis. Additionally, the 30 meter DEM may not provide enough accuracy for definitive analysis.

Chinook Salmon, *Oncorhynchus tshawytscha*

Today, the Eel River supports a fall run of Chinook salmon. Three to four year-old Chinook salmon generally enter the Eel River estuary between September and February. Creel surveys in the estuary have historically documented angling for adult Chinook salmon in the fall. Two year-old precocious males (jacks) also enter. Spawning occurs in tributary streams on gravel with diameters of 0.5 to 5 inches, with less than 5% fines. Prime spawning water velocities range between 1 to 3.5 feet/second. Optimal spawning water temperatures range between 42ºF to 56ºF. Considerable egg mortality can occur at temperatures greater than 57.5ºF. Eggs that are deposited in redds commonly hatch in 40 to 60 days.

Juvenile Chinook salmon often outmigrate at 3 to 6 months old and have been observed in the estuary in most studies. Puckett (1977) noted that juvenile Chinook salmon were present throughout the Estuary Subbasin in all but the winter months. In documenting that juveniles increased in size with season and proximity to the mouth, he stated that the estuary provides an important transition area for juvenile salmon preparing for out-migration. Similarly, Cannata and Hassler (1995) noted that the higher abundance of juvenile Chinook salmon in the estuary in July corresponded to ocean entry, and described the estuary as a nursery area for juvenile salmon. Increased temperatures in tributaries may cause early outmigration of Chinook salmon, possibly leading to increased reliance on the estuary (Higgins in Roberts 1992).

Coho salmon, *Oncorhynchus kisutch*

The Eel River has one run of coho salmon (three year-old adults) that generally occurs between September and February; arrival in the upper reaches of the river peaks in November-December (Baker and Reynolds 1986). Within the Eel River system, coho salmon are most abundant in the South Fork. However, they are found in streams of the Lower Eel as well and use the estuary and mainstem Eel as critical migration routes.

Optimal spawning conditions are similar to Chinook salmon, but coho salmon usually spawn in smaller streams than those used by Chinooks. Young generally emerge from redds between 10 and 15 weeks (8 to 12 weeks for egg incubation, 4 to 10 weeks for emergence) depending on water temperatures (Moyle et al. 1995).

Table 16. Documented salmonid presence across the Lower Eel Basin.

Streams	Chinook Salmon	Coho Salmon	Steelhead Trout	Cutthroat Trout	Unidentified salmonids	Source(s)
Estuary Subbasin						
Estuary	X	X	X	X		Murphy 1951, Pucket 1977, Cannata1995
Salt River Subbasin						
Reas Creek		X	X	X		CDFG 1972, 1984, 2001-2004, Downie 2007
Francis Creek		X	X	X	X	CDFG 2000, 2001, 2003-2005
Coffee Creek						CDFG 2005
Centerville Slough		X		X	X	CDFG 1984
Unnamed Tributary to Centerville Slough				X		CDFG 1968
Russ Creek				X		CDFG 1938, 1968, 2001-2005
Williams Creek				X		CDFG 1999, 2003
Middle Subbasin						
Palmer Creek		X	X		X	Hallock et al 1952, Geppert 2004, CDFG 1982, 2000, 2005 HCRCD 1997
Rohner Creek		X	X		X	CDFG 1952, 1972, 1982, 2005, Lewis 1964, Day 1964
Strongs Creek		X	X	X	X	CDFG 1951, 1968, 1969, 1982, 1993, 1995, 2005
North Fork Strongs Creek			X	X		Franklin and Mitchell 1984, CDFG 1993
Mill Creek					X	CDFG 2004
Unnamed Tributary (to Strongs Creek)						CDFG 1980, 2005
Upper Subbasin						
Barber Creek (Eel)			X			CDFG 1973
Barber Creek (Van Duzen)			X		X	CDFG 1965, 1988, Franklin and Mitchell 1984
Wolverton Gulch		X	X	X	X	CDFG 1963, 1965, 1978, 1993, 1994, 1997, 2005, Franklin and Mitchell 1984, Rose 1993, Harris 1997
Wilson Greek	X		X		X	CDFG 1991, 2005, Froland 2001
Cuddeback Creek	X	X	X		X	Shapovalov 1940, CDFG 1963, 1987, 1988, 2005, Froland 2001, 2002
Fiedler Creek	X	X	X		X	Hallock et al. 1952, CDFG 1964, 1965, 1967, 1987, 2005, Froland 2001
Cummings Creek	X	X	X		X	CDFG 1938, 1952, 1961, 1962, 1964, 1966, 1985, 1987- 1992, 1994- 1997, 2000, 2005, Murphy 1950, Hallock 1952, Kimsey 1953, Brown and Moyle 1987, Preston 1993, 1994, PALCO 1998-2000, 2003, Froland 2001, Donker 1987, and Donker 1987
Price Creek	X		X		X	Rinehart 1964, CDFG 1966, 1998, 1999, 2005, Brown 1980, Ganz-Haggard 1981, Froland 1986, Donker 1987, USFS 1995, Harvey et al. 2002
Sweet Creek			X			CDFG 1938, 1981
Oil Creek		X	X		X	CDFG 1977, 1990, 1999, 2002
Howe Creek	X	X	X		X	Kimsey 1952, Brown 1980, CDFG 1980, 1998, 2001, 2005, Moody 1987, Yoshioka 1999, Downie 2007
West Fork Howe Creek			X			CDFG 1998
Atwell Creek	X	X	X		X	Brown 1980, CDFG 1980, 1993, 1999, 2005
Slater Creek						
Nanning Creek			X			CDFG 1973, 1992, Brown 1980, PALCO 2001
Dean Creek			X			CDFG 1992

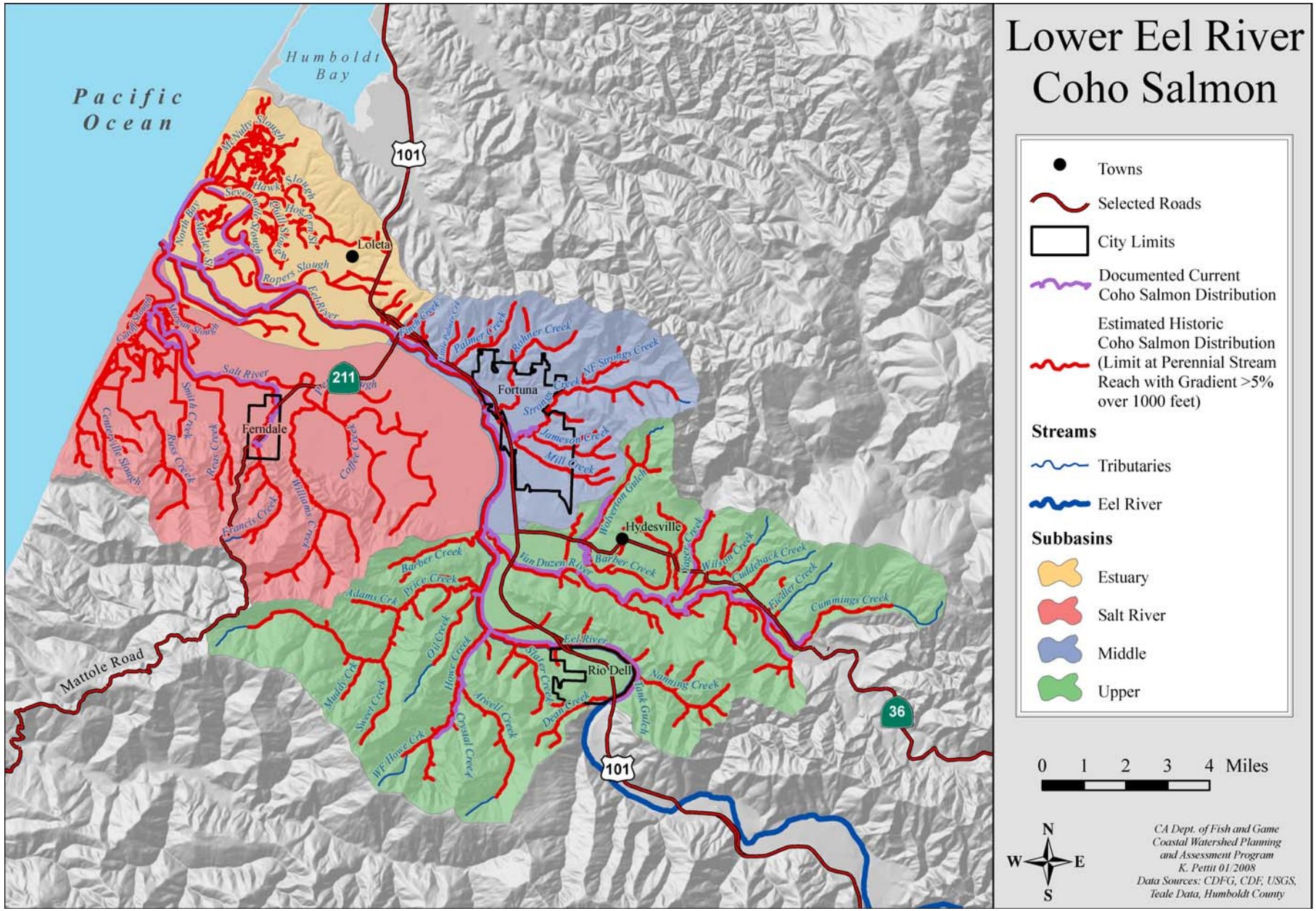

Figure 22. Lower Eel Basin coho salmon estimated range.

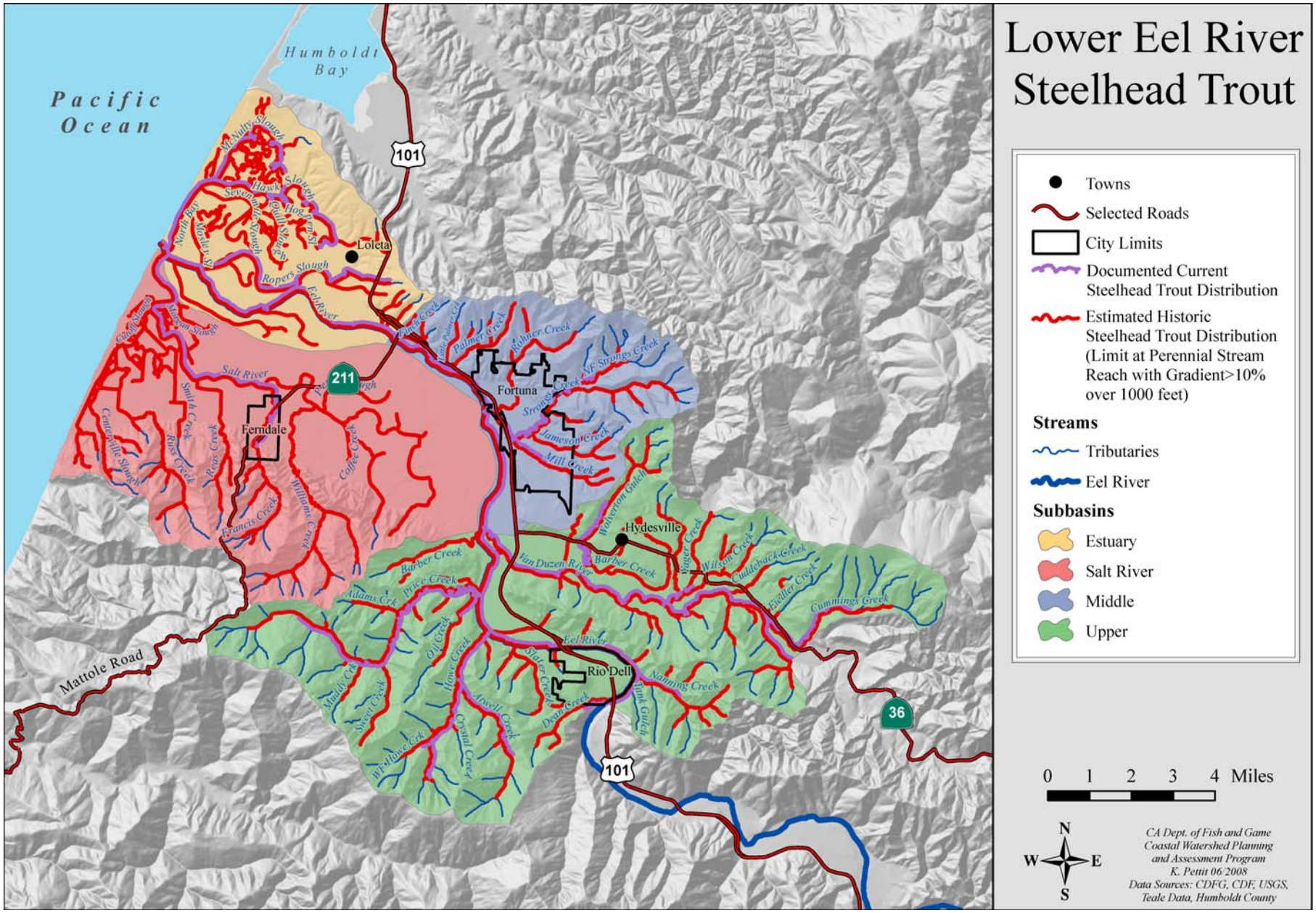

Figure 23. Lower Eel Basin steelhead trout estimated range.

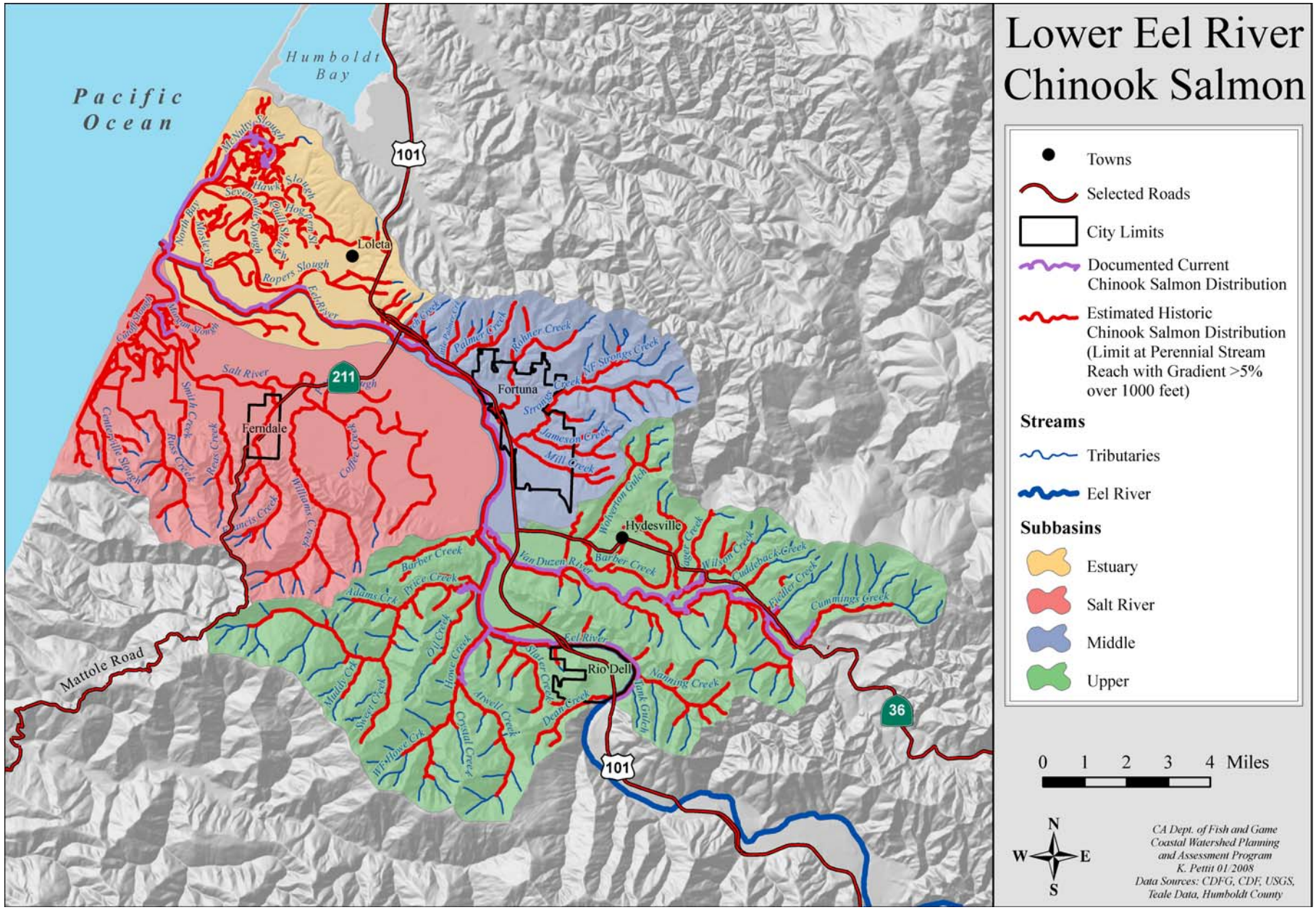

Figure 24. Lower Eel Basin Chinook salmon estimated range.

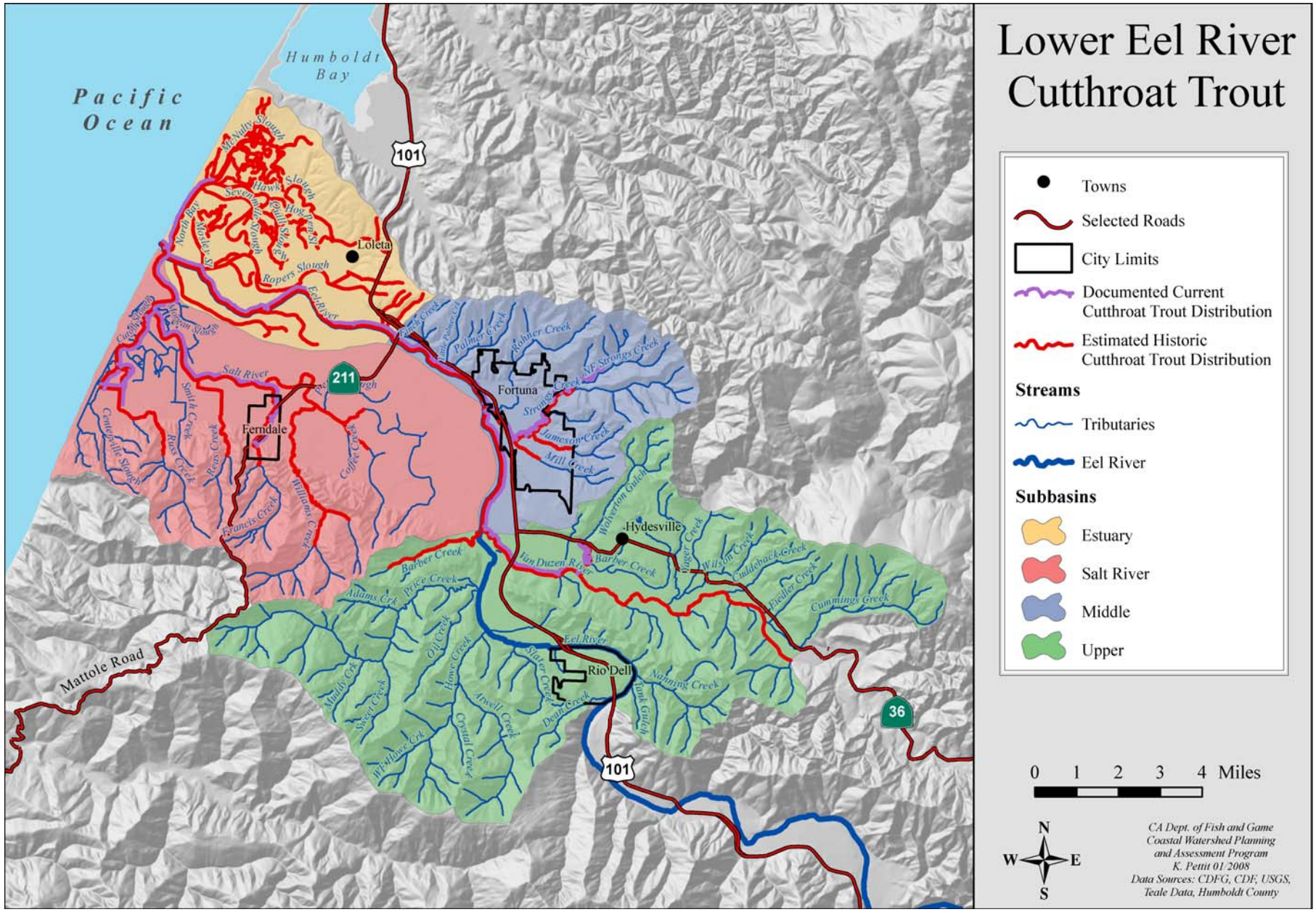

Figure 25. Lower Eel Basin cutthroat trout estimated range.

Juvenile coho salmon then remain in freshwater for one year before downstream migration to the estuary and thence to the ocean.

Once juveniles descend from their freshwater natal streams, it is likely that they use the estuary in the winter and spring as a transition before ocean entry (Cannata and Hassler 1995). Coho salmon presence in the Estuary Subbasin has been documented (Murphy and DeWitt 1951, Puckett 1977, Cannata and Hassler 1995). After entering the ocean, coho salmon typically spend two years feeding, growing, and sexually maturing before returning to their natal streams to spawn.

Steelhead, *Oncorhynchus mykiss*

There are three runs of steelhead in the Eel River: winter-run, fall-run (also referred to as half-pounders), and spring or summer-run. Unlike Pacific salmon, steelhead do not necessarily die after spawning, and can make multiple spawning runs. Winter-run steelhead adults (4 to 5 years old or 2 to 12 lbs) enter the Eel River beginning in September to spawn. The run continues through May, with a peak in February (Eel River Action Plan Doc 082). Steelhead referred to as fall-run are sexually immature individuals that return to natal streams after 3 to 5 months in the ocean. For the most part, these individuals do not spawn, but return to the ocean until they reach maturity, at which time they will again return to freshwater to spawn. Spring/Summer-run steelhead are a smaller presence in Northern California streams. The Middle Fork Eel River supports the largest run of spring/summer run steelhead in California (Moyle et al. 1995). In general, they enter the Middle Fork between March and June migrating to its upper reaches above Black Butte River where they hold in deep pools during the summer months (Puckett 1975, Jones 1980). Spawning doesn't occur then till late December through April (Moyle et al. 1995).

Ideal steelhead spawning conditions include water temperatures between 49ºF and 55ºF, water velocities of 1.5 feet/second, and gravel diameters between 0.25 and 3 inches, with few sediment fines. Under these types of conditions, steelhead eggs will generally hatch in approximately 30 days. The young sac fry tend to stay within the gravel for 2 to 4 weeks, using their yolk before emerging. In general, steelhead remain in freshwater for two years, before migrating to the ocean and returning to spawn at 3 to 4 years of age.

Juvenile steelhead have been noted in nearly all fish surveys of the Lower Eel Basin. This species, like other anadromous salmonids, uses the upstream system in their juvenile and adult migrations. Puckett (1977) observed juvenile steelhead year round throughout the estuary, noting that they were most abundant in the summer and fall.

The estuary serves as a holding area for adult steelhead during upstream spawning migrations (Murphy and DeWitt 1951). During these migrations, the estuary and rivers support a catch and release (0-bag limit) sport fishery for adult steelhead.

Coastal cutthroat trout, *Oncorhynchus clarki*

The Eel River serves as the southern extent of the coastal cutthroat trout range. In California most populations of coastal cutthroat are weakly anadromous and migrate mainly between large and small streams or between rivers and estuaries (Gerstung 1997). Their presence has been noted in the Eel River Estuary by Murphy and DeWitt (1951). These fish were collected by recreational fishermen in 1950. It is interesting to note that the cutthroat collected in this study were described as having "only faint evidence of the cutthroat mark" (Murphy and DeWitt 1951).

More recently, Franklin and Mitchell (1984), and electrofishing in 2004 (CDFG 2005) have documented cutthroat trout in tributaries to the Salt River. Cutthroat have also been observed in Strongs Creek in the Middle Subbasin (CDFG 1993) and were found in Barber Creek (mainstem) in the Upper Subbasin in 1950 (DeWitt 1952). Cutthroat trout remaining in the basin are largely limited to upland portions of delta tributaries and appear to be resident. The population in Strongs Creek is believed to be the southernmost limit of the species; however, if cutthroat remain in Barber Creek (mainstem) or Wolverine Gulch that would constitute the limit (Downie 1993; Gerstung 1996).

Sacramento pikeminnow, *Ptychocheilus grandis*

The Sacramento pikeminnow is a large piscivorous cyprinid (minnow) that was introduced into the Eel River system in Pillsbury Lake 1979 (Brown and Moyle 1997). Pikeminnow are native to the Sacramento-San Joaquin drainage and several smaller coastal drainages in California. They usually live in clear low to mid-elevation streams and rivers with deep pools and slow runs. High winter discharge appears to limit their upstream extent (Harvey and Nakamoto 1999). Undercut banks and aquatic

vegetation are good cover. Pikeminnow prefer water temperatures ranging from 64.4 to 82.4°F, though they are capable of withstanding extremes up to 100.4F.

While juvenile pikeminnow feed during the day, adults feed during dawn and dusk in riffles and stay in deeper pools during the day (Harvey and Nakamoto 1999). Pikeminnow are predaceous and move from smaller prey such as aquatic insects to crustaceans and fish as they grow bigger.

Pikeminnow become sexually mature at age three or four. Spawning mainly occurs in April through May, when water temperatures reach a range of 59-68°F. Spawning is in riffles and pool tails with gravel substrate in small tributary streams. Females produce an average of 15,000 to 40,000 eggs each and eggs hatch in four to seven days. Young fish disperse in small schools and to deeper water with time, often occupying protected riffles and fast water. Pikeminnow grow slowly but may reach great lengths and ages in excess of 16 years.

Pikeminnow can create problems for native salmonids and other native fish and amphibians. Pikeminnow can prey upon and compete with juvenile salmonids for food (Brown and Moyle 1981). Pikeminnow prefer warmer water temperatures than native salmonids, therefore changes in the Eel River system that promote warmer water temperatures (such as loss of riparian vegetation, shallowing of streams, and reduced river flows) could promote Sacramento pikeminnow over salmonid species (Harvey et al. 2002). Competitive effects of juvenile pikeminnow on juvenile steelhead were shown to be greater in warmer water temperatures (Reese and Harvey 2002). Additionally, reservoirs that decrease winter discharge may extend the pikeminnow's upstream distribution (Harvey and Nakamoto 1999).

Sacramento pikeminnow are present in the estuary, and were documented in surveys conducted in the mid to late 1990s (Cannata 1995 and USFWS 1997). Pikeminnow have been documented as present in several surveys (Middle Subbasin) beginning in the late 1990s. Pikeminnow were first reported in the mainstem Van Duzen in 1988 and have been observed in tributaries throughout the Upper Subbasin since the late 1990s. Studies have shown that pikeminnow move long distances throughout the Eel River system, thus any small scale local control efforts are likely to be thwarted by individual pikeminnow movements throughout the basin (Harvey and Nakamoto 1999).

Stocking

The Eel River Basin contains a long history of stocking salmonids throughout the basin. With the beginning of commercial fishing in the early 1850s in the estuary, fishing pressure rapidly increased on Eel River stocks. Declining fishery production in the late 1800s gave rise to a hatchery program to augment salmonid stocks (Brown and Haley 1974). Hatchery operations eventually expanded to occur throughout the entire Eel River drainage.

While hatchery operations have varied over the years, a substantial number of salmon and steelhead have been planted throughout the Eel River Basin. Hatchery records indicate more than 39 million Chinook salmon, 9 million steelhead and millions of coho have been planted in the Eel River Basin since 1900 (Steiner Environmental Consulting 1998). However, a century of hatchery operations have only lead to mixed results as their effectiveness in potentially restoring salmonid populations in the Eel River has been unsubstantiated.

Similar to the historic management practices of hatchery programs throughout the state, Eel River salmonid stocks were also supplemented with brood stock raised outside the basin. Other sources of fish planted include hatcheries on Battle Creek, Mill Creek, and McCloud River of the Sacramento River system, Prairie Creek (of Redwood National Park), Klamath River, Mad River, Gibson Creek of Russian River, some eggs from Oregon and Washington and potentially other additional sources.

While fish were stocked throughout the Eel River, this report, however, will only detail the hatchery operations that occurred previously within the Lower Eel River basin.

Hatchery operations became established in the Eel River Basin in the late 1800s. Public perception of declining salmon stocks prompted requests to State Fish and Game for a hatchery on the Eel River. Thus, after general reconnaissance studies the first hatchery was built on Price Creek (RM 15) in 1897. The hatchery was unsuccessful in obtaining ripe eggs from Eel River Chinook or coho salmon stocks; therefore, Chinook salmon eggs were obtained from Battle Creek and Mill Creek of the Sacramento River system (CDFG Commission Report No. 23, 1912-1914 in CDFG 1997). Over most of the following 15 years, the Price Creek hatchery received between 885,000 and 9,000,000 Chinook salmon eggs per year from the Sacramento Basin. The eggs were hatched and

released as fry. In 1910, 47,000 coho salmon fry from Santa Cruz were released into Price Creek (CDFG 1910). The hatchery was eventually abandoned in 1916 due to low water and siltation.

A dam constructed at the Newburg Mill on Strongs Creek, near Fortuna created a fish passage barrier approximately 2.5 miles upstream from mouth. At the close of the mill in 1931, the ponds were used for rearing steelhead trout, since the runs in Strongs had decreased due to the dam. Steelhead and Dolly Varden trout were stocked in the 1930s, followed by cutthroat trout in 1962, 1964, 1965, 1966, and 1972.

More recently, the Pacific Lumber Company (PL) began operating fish-rearing facilities in 1972 to augment Eel and Van Duzen River stocks. Fish were initially raised in concrete ponds in Scotia. A hatchery and rearing facility was built on Cooper Mill Creek (tributary to Yager Creek, tributary to the Van Duzen River) in 1976, and use of the Scotia pond also continued. Additional facilities on Corner Creek and South Fork Yager Creek were built in 1993 for rearing and acclimating fish for release. Fish were released at various locations throughout the Yager Creek drainage such as Lawrence, Cooper Mill, Shaw, Corner, and Blanton creeks. Records from 1990 to 2002 show that in years that fish were released, between 2,973 to 20,360 steelhead trout and 3,400 to 100,350 Chinook salmon were released per year. The facilities ceased operations in 2002.

Currently there are no active hatchery or fish collecting operations in the Eel River Basin.

Fish Rescue

Fish rescue is a technique sometimes used to remove fish from habitat in which they are sure to die and move them to more suitable habitat. Efforts at fish rescue in Del Norte, Humboldt, and Mendocino Counties were catalogued in 1949 (Table 17, Table 20).

The vast majority of rescued fish were steelhead trout. Although, overall, more fish were rescued from the Eel River system and transplanted to other rivers, and more coho salmon and Chinook salmon were planted in the Eel Basin than were rescued within the basin. A total of 391,277 fish were rescued in the basin and 171,934 rescued fish were planted in the basin.

Table 17. Rescued fish in 1949.

Stream	Steelhead	Coho Salmon	Chinook salmon	Total
Eel River – Humboldt	1,560		760	2,320
Cummings Creek	900			900
Baechtel Creek		5,629		5,629
Bloody Run Creek				
Cold Creek (Middle Fork)	43,865			43,865
Short Creek (Middle Fork)	175,220			175,220
Tomki Creek	135,678	16,815		152,493
Town Creek (Middle Fork)	10,850			10,850
Eel River Total	**368,073**	**22,444**	**760**	**391,277**

Table 18. Rescued fish plantings in 1949[1].

Stream	Steelhead	Coho Salmon	Chinook salmon	Total
Eel River – Humboldt	6,125	355	2,400	8,880
Van Duzen River	900			900
Eel River – Mendocino	36,395	19,374		55,769
Middle Fork Eel River	24,713			24,713
Outlet Creek	972			972
Black Butte River (Middle Fork)	11,160			11,160
Asbill Creek (North Fork)	8,280			8,280
Burger Creek	8,990			8,990
Cold Creek (trib to Black Butte River)	8,786			8,786
Hull Creek	10,810			10,810
Shields Creek (trib to Black Butte River)	18,434			18,434
Turners Gulch (trib to Mill, trib to Middle Eel)		3,840		3,840
Woodman Creek	10,400			10,400
Eel River Total	**145,965**	**23,569**	**2,400**	**171,934**

[1] Murphy, G. I. 1950. "Fish rescue and stream improvement work in the north coast area in 1949." California Department of Fish and Game, Sacramento: 11 p.

Habitat Overview

In order to meet the needs of the life stages of anadromous salmonids, the Lower Eel River Basin must provide appropriate diverse stream flow regimes, suitable water quality, high quality gravel substrate for spawning and incubation of eggs, suitable in-channel and riparian conditions, and adequate food supplies within the fish bearing reaches throughout the basin. High quality instream and riparian habitat is most important for coho salmon and steelhead as they spend a year or more rearing in streams.

The advent of timber harvesting in the Eel River Basin in 1850 brought changes to stream channels across the basin due to land use activities. These changes from historic stream conditions resulted in reductions of salmonid habitat quality. Identifying salmonid life history strategies at the basin and regional scales provides clues to the range of stream conditions and environmental requirements for fish. Salmonids display a range of behavioral patterns that are a product of their habitat by their trends of abundance. Some species or life history strategies may already belost or rarely observed due to changes from historic stream conditions. By gaining insight into the relationships between the diverse life history strategies, fishery population dynamics and status, and by assessing stream habitat condition, efficient recommendations for recovery of depressed populations can be made.

Historic Conditions

There are approximately 36 named streams in the Lower Eel Basin. Surveys have been conducted at various points in time on some of 18 creeks from 1938 to 1989 (Table 19). The results of past stream surveys were not quantitative and cannot be used in comparative analyses with current habitat inventories; however, they do provide a description of habitat conditions. The data from these stream surveys provide a snapshot of the conditions at the time of the survey.

Summary tables appear in the subbasin sections of this report. In general, surveys described a range of habitat conditions. The earliest stream surveys were conducted in 1938 on six creeks. These surveys generally indicated good spawning and pool conditions. Surveys in later years described fish passage problems in the Middle Subbasin and silty conditions across the basin.

Table 19. Streams surveyed by CDFG in the Lower Eel Basin from 1938-1989.

Year	Salt River Subbasin	Middle Subbasin	Upper Subbasin
1938	Russ Creek		Cummings Creek, Oil Creek, Price Creek, Howe Creek, Sweet Creek
pre-1951			Price Creek
1952		Rohner Creek	Cummings Creek
1961			Cummings Creek
1962			Cummings Creek
1963			Wolverton Gulch, Cuddeback Creek
1964			Fiedler Creek, Cummings Creek, Price Creek
1965			Barber Creek (Van Duzen), Wolverton Gulch, Fiedler Creek
1966			Cummings Creek
1972	Reas Creek	Rohner Creek	
1973	Coffee Creek		Barber Creek (Eel), Nanning Creek
1977			Oil Creek
1979			Nanning Creek
1980		Unnamed Trib to Strongs Creek	Howe Creek
1981			Price Creek, Sweet Creek
1982		Rohner Creek, Strongs Creek	
1984	Reas Creek	North Fork Strongs Creek	Barber Creek (Van Duzen), Wolverton Gulch
1985			Cummings Creek
1986			Price Creek
1987			Cuddeback Creek, Price Creek, Fiedler Creek, Howe Creek, Cummings Creek
1988			Barber Creek (Van Duzen), Cuddeback Creek, Cummings Creek
1989			Cummings Creek

Current Conditions

Within the Lower Eel Basin, CDFG inventoried 21 tributaries between the years of 1991 and 2004. The data collected during these inventories are compared to the target values defined in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) to determine if habitat conditions within the streams are limiting to salmonid production. Data collected during these habitat inventories describe the canopy density, cobble embeddedness of pool tails, length of primary pools, and mean pool shelter coverage along surveyed reaches within the Lower Eel Basin. Additionally, the CWPAP evaluates these habitat data using the Ecological Management Decision Support (EMDS) system software. The EMDS system can evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. More details of how the EMDS functions are in NCWAP Methods Manual. Habitat data collected in the Lower Eel Basin that can be used in the EMDS are: canopy, pool quality, pool depth, pool shelter, and embeddedness (Figures 26–34). Calculations and conclusions made in the EMDS are pertinent to surveyed streams and are based on conditions existing at the time of survey. Tributary EMDS results are presented in the subbasin sections.

Three of the four Lower Eel subbasins have had habitat inventories completed by the CDFG over the past fifteen years (Table 20). Based on USGS 7.5 minute topoquads, the Estuary Subbasin does not contain any permanent freshwater tributaries, and therefore has no completed habitat inventories. The Upper Subbasin, which has the longest length of stream miles, has had the most inventories completed; three streams in this subbasin have had repeat surveys.

Table 20. Habitat surveys completed in the Lower Eel River Basin from 1991 to 2004.

Subbasin	Years of survey	Number of streams surveyed	Number of surveys	Total length of survey (miles)	Percent of permanent stream surveyed
Estuary	N/A	0	0	0	0
Salt River	2003, 2004	4	4	9.2	29
Middle	1993, 2004	3	3	2	10
Upper	1991-2002	14	17	30.3	58

Canopy

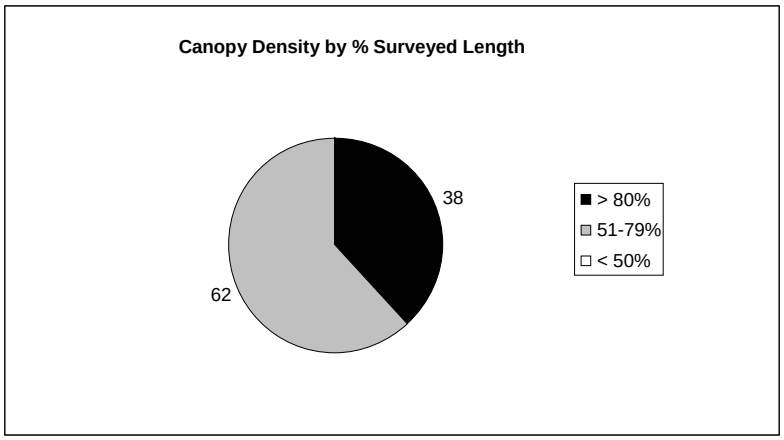

Figure 26. Canopy density in the Lower Eel Basin.

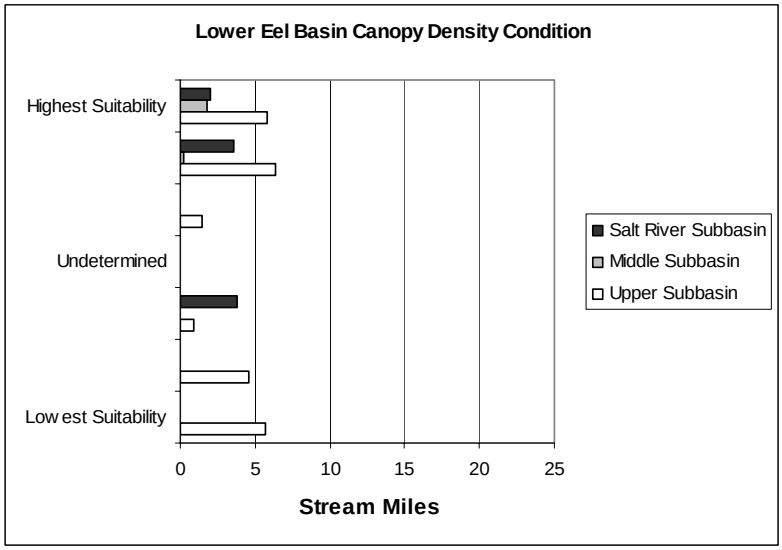

Figure 27. EMDS canopy results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: Canopy density is one of the measurements estimated during CDFG habitat surveys. These measurements, which are given as a percentage of shade canopy over the stream, provide an indication of potential recruitment of organic debris to the stream channel, as well as insulating capacity of the stream and riparian areas during winter. Canopy density may also contribute to microclimate conditions that help moderate air temperature, an important factor in determining stream water temperature. Stream canopy relative to the wetted channel normally decreases in larger streams as channel width increases due to increased drainage area. The CDFG Restoration Manual establishes a target of 80% for shade canopy along coastal streams (Flosi et al. 1998). The CDFG recommends areas with less than 80% shade canopy as candidates for riparian improvement efforts.

Findings: All of the surveyed streams recorded measured canopy above 50%. Nine streams (10 surveys) did not meet the target value of 80% measured canopy and are therefore evaluated as lower suitability by the EMDS. Streams with lower suitability scores were in the Upper and Salt River subbasins.

Pool Depth

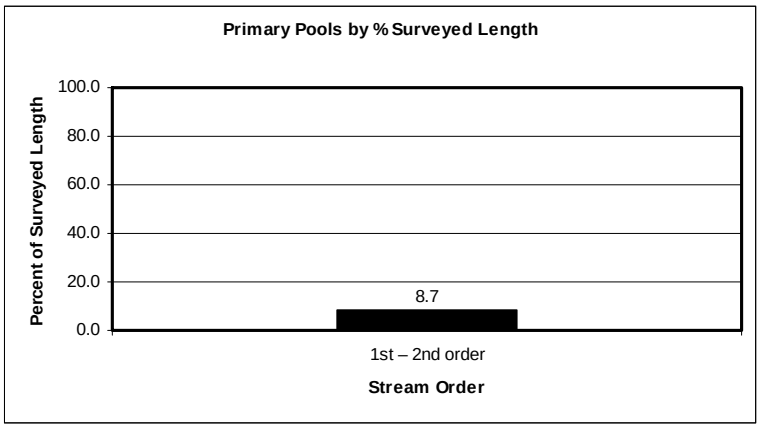

Figure 28. Primary pools in the Lower Eel Basin.

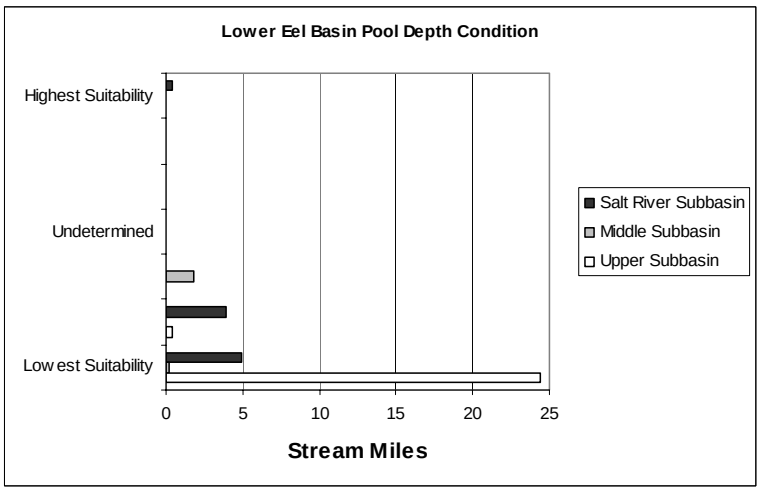

Figure 29. EMDS pool depth results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: Primary pools provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas. Generally, a stream reach should have 30 – 55% of its length in primary pools to be suitable for salmonids. In first and second order streams, a primary pool is described as being at least 2 feet deep.

Findings: The percent of primary pools by length in the Lower Eel Basin is generally below target values for salmonids. The majority of stream miles with the lowest suitability scores for pool depth as evaluated by the EMDS were in the Upper Subbasin. Some stream length with suitable scores for pool depth was in the Salt River Subbasin.

Pool Shelter

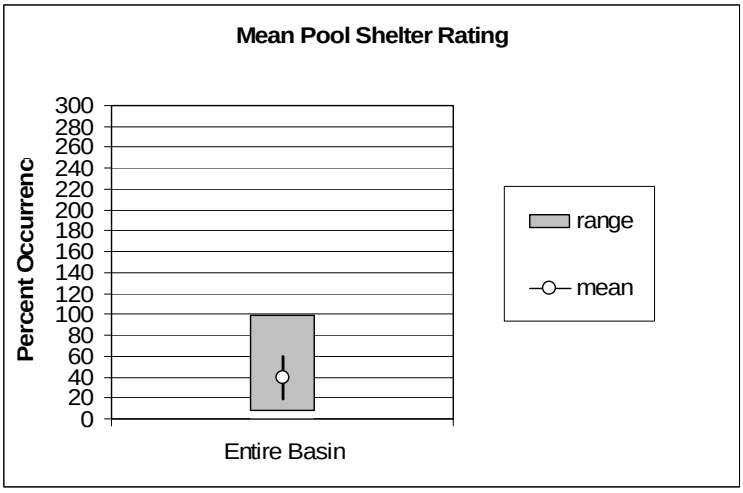

Figure 30. Pool shelter in the Lower Eel Basin.

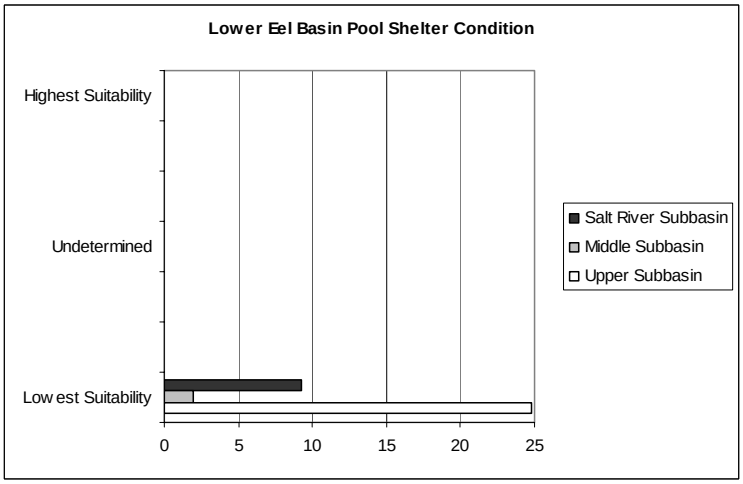

Figure 31. EMDS pool shelter results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: Pool shelter provides protection from predation and rest areas from high velocity flows for salmonids. The pool shelter rating is a relative measure of the quantity and percent composition of small and large woody debris, root wads, undercut banks, bubble curtains, and submersed or overhanging vegetation in pool habitats. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

Findings: The average mean pool shelter rating for the Lower Eel Basin is 39.2. This is below the shelter target value for salmonids. All surveyed stream miles across the basin had the lowest suitability ratings for pool shelter as evaluated by the EMDS.

Cobble Embeddedness

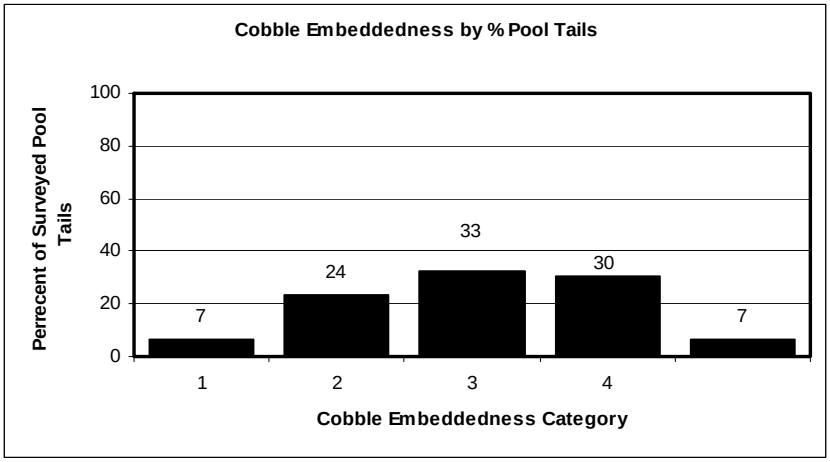

Figure 32. Cobble embeddedness in the Lower Eel Basin.

Cobble embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included.

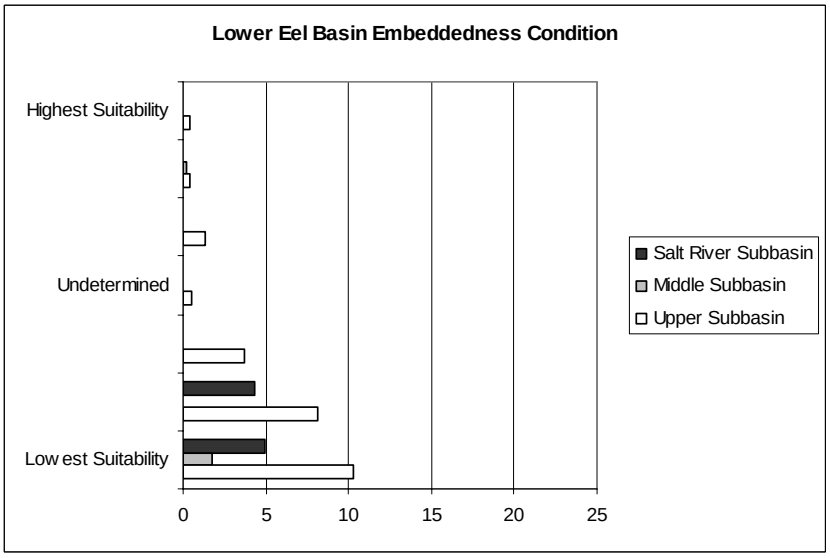

Figure 33. EMDS cobble embeddedness results for the Lower Eel Basin by surveyed stream miles.

Where there was more than one year of survey data, the most recent data was used for this graphic.

Significance: Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments decrease successful spawning and incubation. Cobble embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded, and category 4 is 76-100% embedded. Cobble embeddedness categories 3 and 4 are not within the fully supported range for successful use by salmonids. The bar furthest to the right in Figure 32 represents tail-outs deemed unsuited for spawning due to inappropriate substrate like sand, bedrock, log sills, boulders or other considerations.

Findings: Only 7% of pool tails in the Lower Eel Basin have cobble embeddedness in category one, which meets spawning gravel targets for salmonids. Streams miles evaluated as suitable by the EMDS were located in the Upper and Middle subbasins.

LWD

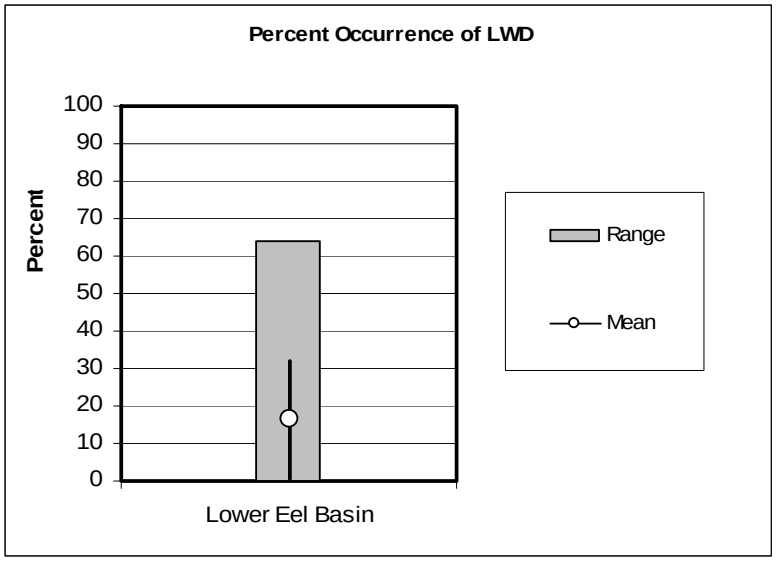

Figure 34. Large Woody Debris (LWD) in the Lower Eel Basin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, etc.) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

Significance: Large woody debris shapes channel morphology, helps a stream retain organic matter, and provides essential cover for salmonids. There are currently no target values established for the percent occurrence of LWD.

Findings: The percent occurrence of LWD in a stream as calculated by CDFG in the Lower Eel Basin represents a measure of the amount of woody debris that was found in the wetted width of a stream channel during stream surveys that can be used by fish for cover as compared to other types of fish cover present. The average percent occurrence of LWD for the Lower Eel Basin is 16.4%. The dominant shelter type recorded in most stream reaches was boulders, while small woody debris was the second most common dominant shelter type. This average percent occurrence of LWD is higher than that recorded for the nearby Mattole River Basin (6.6 +/- 6.2 percent).

Barriers

During their freshwater life phases, salmonids need free access to a variety of stream habitats from the headwaters to the mouth, as both migratory corridors and habitat for rearing and spawning. Barriers to migration between these habitats have proved disastrous to salmonid populations throughout their range. Types of barriers include dams, culverts, diversions, flood control channels, flow dynamics, water quality, and natural features such as waterfalls and bedrock chutes. Barriers lead directly to the fragmentation of salmonid habitat and may completely eliminate anadromous salmonids from accessing a stream to spawn.

Fifty structures considered potential barriers to fish passage were evaluated within the Lower Eel Basin, and reported in the Passage Assessment Database (2005) (Figure 35). The majority of these are road crossings; four are described as flow diversions, two are tide gates, and one is a grade control bedrock chute. From this total, sixteen structures were considered partial barriers, meaning they are only barriers to certain species, or life stages, three were considered temporal and/or partial barriers, meaning it is only a barrier to certain species, or life stages, and only at certain times of the year. Eleven structures were determined to not pose a threat to fish passage, while eighteen are described as “unknown.” Two structures were assessed as total barriers, which is a complete barrier to all anadromous fish species, at all life stages at all times of the year. More details about barriers are presented in the Subbasin sections of this report.

All tide gates in the Eel River estuary were not evaluated in the fish passage study. The USFWS is currently assessing tide gates in the Humboldt Bay watershed. A similar assessment within the Eel River estuary is both pertinent and necessary, as many of the tide gates are non-operational and may function as barriers to fish migration and lead to loss of high quality estuarine habitat.

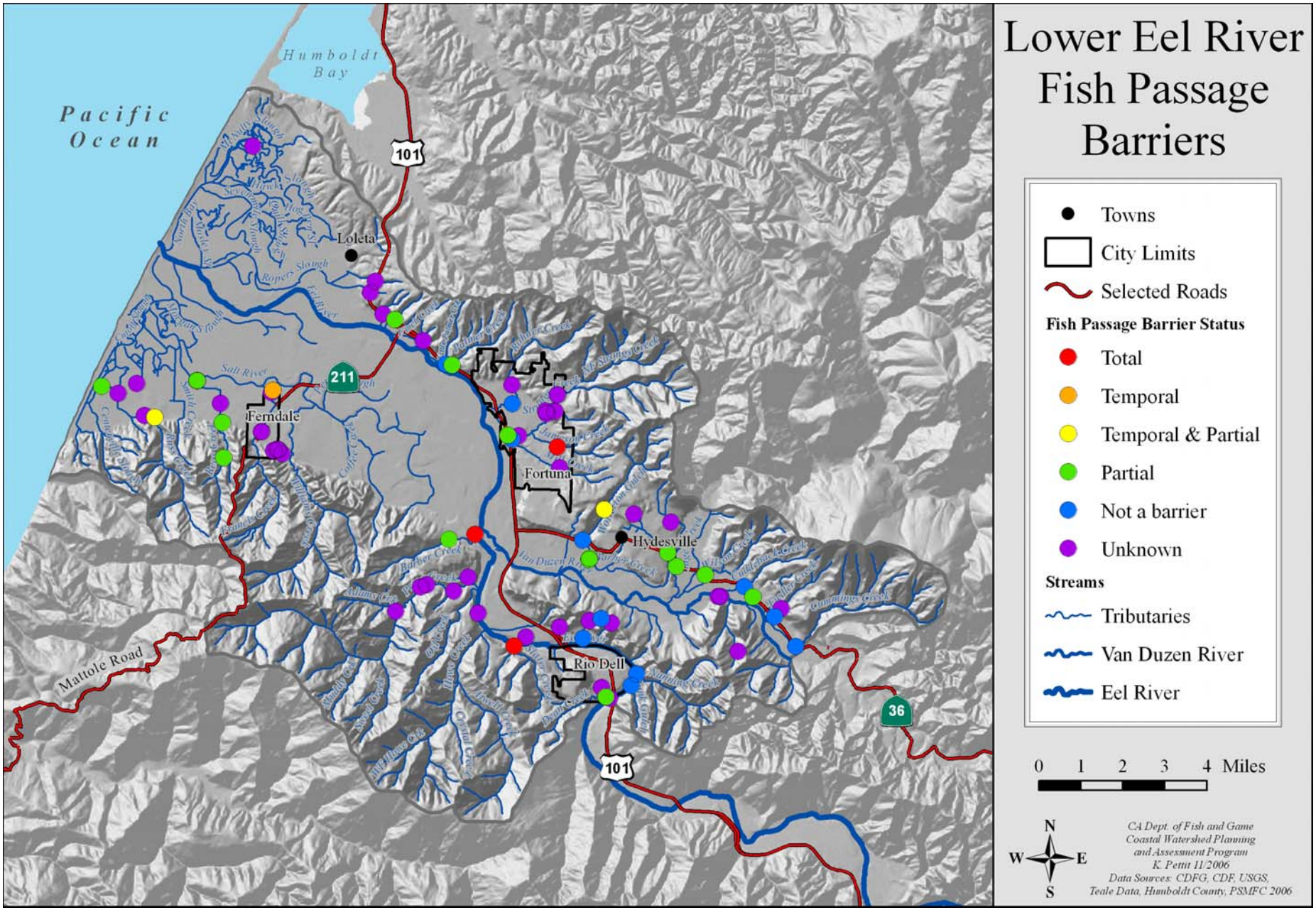

Figure 35. Fish passage barriers in the Lower Eel River Basin.

Water Quality

The EPA has recognized portions of the Lower Eel River watershed as impaired due to sediment and temperature as defined by Section 303(d) of the Clean Water Act. Because of this, the EPA and Water Board are implementing a total maximum daily load (TMDL) process in order to determine the watershed's capacity to assimilate pollution, in this case sediment and temperature sources. This process results in the creation of numerical targets, and provides the state with information on how to reduce pollution within the watershed in order to meet water quality standards. Some entities, like the HCRCD, are collecting and housing data in order to support this effort; those data are presented here.

Beneficial uses related to fisheries that are to be protected by the TMDL process in the Lower Eel and Van Duzen Rivers include:

- Cold freshwater habitat;
- Migration of aquatic organisms;
- Preservation of rare, threatened, or endangered species;
- Aquaculture;
- Commercial and sport fishing;
- Spawning, reproduction and/or early development potential.

In 1992, the Van Duzen River was listed under 303(d) as impaired due to sediment. A sediment source analysis was completed, and results were reported in the Van Duzen River and Yager Creek TMDL in 1999 (PWA 1999). Several beneficial uses were determined to be affected by sediment within the watershed, and were described in the Van Duzen River Basin plan produced by the NCRWQCB. (USEPA 1999)

Water Temperature

The CWPAP has created suitability ranges for maximum weekly average temperatures (MWATs) considering temperature's effect on salmonid viability, growth, and habitat fitness (Table 21). This metric is calculated from a seven-day moving average of daily average temperatures. The maximum daily average is also used here to illustrate possible stressful conditions for salmonids. The instantaneous maximum temperature that may lead to salmonid lethality is ≥75°F.

Table 21. CWPAP-defined suitability ratings for MWATs.

MWAT Range	Description
50-60°F	Fully suitable
61-62°F	Moderately suitable
63°F	Somewhat suitable
64°F	Undetermined
65°F	Somewhat unsuitable
66-67°F	Moderately unsuitable
≥68°F	Fully unsuitable

Water temperatures were continuously measured at 27 locations within the basin (Table 24). The locations of these stations are indicated in the subbasin sections of this report. Data loggers were generally deployed from June through October, and include most years from 1996 to 2005. Background data for temperatures collected in 1996 and 1999 for example site location and condition are incomplete. Because of this, exact locations of temperature loggers are not available, and were derived from recorded field descriptions of the site. Not all sites were sampled in every year; some sites have only one season of data.

In general, most tributaries in each subbasin obtained temperatures within the suitable range, and no seasonal maximum temperatures reached lethal limits. However, 10 locations did record temperatures considered unsuitable in the MWAT range. The highest logged temperatures were recorded in the Middle Subbasin. These data are expected, as three of the five monitors were located in the mainstem. The Upper Subbasin, which was consistently surveyed over the longest period of time, had the highest percentage of tributary locations with data that fell within the unsuitable range. Estuary locations had the greatest MWAT range, with 2 of the 8 stations reaching fully unsuitable temperatures. These data are discussed in further detail in the subbasin profiles.

The USEPA (EPA) has set TMDL targets for temperature in the Lower Eel Basin. The EPA defined the Lower Eel Basin as the area from the confluence with the South Fork Eel River to the ocean, except for the Van Duzen River which is a separate TMDL study area. The EPA concluded that a temperature TMDL was not needed for the main channel of the Lower Eel River. However, the EPA did find that tributary streams did not meet water quality standards for temperature, therefore temperature TMDLs were established to achieve those standards (USEPA 2007).

Table 22. Ranges of MWATs and seasonal maximum temperatures collected throughout the Lower Eel Basin.

Subbasin	Water Body	Number of Sites	Years of Sample	MWAT Range (°F)	Seasonal Maximum Range (°F)
Estuary	Major Sloughs and Mainstem	7	1996, 2005	56-71	57-72
Salt River	Slough and Tributaries	6	2000-2002, 2004	58-74	NA
Middle	Tributaries	2	2002-2003	57-59	58-59
	Mainstem	3	1996	68-72	69-73
Upper	Tributaries	8	1996-2003	59-67	58-68

The EPA set TMDLs based on natural shade for two distinct tributary areas: the tributary reaches in the Salt River subbasin and all the remaining tributary reaches. The shade allocation for tributary reaches for the Salt River subbasin is a 59% reduction of total global solar radiation, or the equivalent of a minimum 59% shade. This is approximately 14% more shading than existed under 2005 conditions. Shade allocation for all remaining tributary reaches is 83% shade (approximately 3% more shading than existed under 2005 conditions) (USEPA 2007).

Water Chemistry

Water quality studies have been undertaken in the basin to address issues associated with the dairy and cattle industry, turbidity and sedimentation, and nutrients. As a follow up to the Animal Waste Assessment Project in the Eel River Delta (Anderson 1997), the Eel River Delta Animal Waste Demonstration Project (Q&A Agriculture Service 2001) monitored water quality at twelve locations: two in the Estuary Subbasin and ten in the Salt River Subbasin. The sites were tested to see if there was any change to water quality after improvements had been made to waste management. Often, due to the season or because the waste was diverted elsewhere, the sites were too dry to test post-project. However, multiple sites showed high levels of ammonia, high pH, and low dissolved oxygen pre-project.

Turbidity and sedimentation have been studied in the Middle Subbasin tributaries, and extensively in the Salt River Subbasin. Turbidity is the muddiness or cloudiness of water caused by individual particles suspended in the water column. These particles will deflect (or scatter) light as it passes through the water. Turbidity increases as more and more light is deflected. Turbidity is often measured by an instrument called a nephelometer, in Nephelometric Turbidity Units (NTU). High turbidities have been associated with negative effects on salmonids (Newcombe and McDonald 1991, Waters 1995). NCRWQB established basin wide regulations that turbidity should not be increased more than 20 percent above naturally occurring background levels (NCRWQCB 2001).

Turbidity and sedimentation have been studied in the Middle Subbasin tributaries, and extensively in the Salt River Subbasin. The Fortuna Creeks Project found that over a six year monitoring period, turbidity levels in Strongs, Mill and Rohner creeks were higher than 30NTUs for most of the year and were associated with high flows. Salmon Forever has been monitoring Francis Creek since January 2007, and preliminary results show maximum turbidity levels have reached 2200NTU during a single storm. Combined with flow data, 2200 NTU is equivalent to 8.5 tons of sediment moving downstream every 10 minutes (Fenton, Salmon Forever, personal communication).

In the Salt River and Estuary subbasins, nutrients were studied to determine the amount of mixing that occurs in the estuary to understand what type of habitat was available throughout the year (i.e. mostly saline, brackish mostly freshwater, or stratified). The estuary appears to be mixing during the dry months and is stratified, or creates a “salt wedge” during wetter months (Gossard 1986). Nutrients were also studied indirectly by the HCRCD via macroinvertebrate surveys. Williams and Francis creeks in the Salt River Subbasin, Strongs Creek in the Middle Subbasin and Cummings, Price, and Howe creeks in the Upper Subbasin were sampled in the spring and fall of 1996. Francis and Strongs creeks scored consistently in the impaired ranges, and Williams, Price and Howe creeks were rated as highly impacted in terms of invertebrate diversity (HCRCD 1998).

The Lower Eel Basin was also listed by the EPA as an impaired water body for sediment (USEPA 2007). Significant sources of sediment found in the watershed included roads, timber-harvest related activities, and natural sources.

A sediment TMDL was set for all stream reaches as equal to the sediment load that corresponds with

125% above natural sediment loading. This was calculated to be 898 tons/square mile/year or 2.5 tons/square mile/day on a 15 year running average (Table 23). Overall these load allocations are a 77% reduction of the sediment loading found in a study of levels from 1955 to 2003 (USEPA 2007).

Table 23. United State Environmental Protection Agency sediment load allocations for the Lower Eel Watershed (USEPA 2007).

Sediment Source		Average Annual		Average Daily		Percent Reduction over 1955-2003 Period
		1955-2003 Loading (tons/square mile/year)	Load Allocation (tons/square mile/year)	1955-2003 Loading (tons/square mile/day)	Load Allocation (tons/square mile/day)	
Natural Load Allocation		718	718	2.0	2.0	0
Road	Episodic	43	9	0.1	0.02	80
	Chronic	115	17	0.3	0.05	85
Timber Harvest		590	147	1.6	0.4	75
Skid trail		7	1	0.02	0.5	90
Bank Erosion		21	6	0.1	0.03	70
Total Human-related Load Allocation		775	180	2.1	0.5	77
Total Load Allocations (Natural and Human)		1,493	898	4.1	2.5	

Although nonpoint sources were found to contribute most of the sediment loading within the watershed, point sources also discharged some sediment. Diffuse permitted sources within the watershed, such as municipal and industrial stormwater discharges, California Department of Transportation facilities construction sites, and municipalities have waste load allocations equivalent to the load allocations for nonpoint sources. For current individual point sources within the watershed, waste load allocations were expressed as total dissolved solids (TSS) in mg/l andsettleable solids in ml/l monthly average concentration (Table 24).

For all of these facilities except for Ferndale, the weekly maximum TSS was set at 45 mg/l and for all facilities the daily maximum TSS was set at 60 mg/l.

Table 24. United State Environmental Protection Agency waste load allocations for non-diffuse point sources in the Lower Eel Watershed (USEPA 2007).

Point Source	TSS (mg/l)	Settleable Solids (ml/l monthly average concentration)
Ferndale	95	0.1
Fortuna	30	0.1
Loleta	30	0.1
Rio Dell	30	0.1
Scotia	30	0.1

The EPA did not set specific watershed indicators for the sediment TMDL in the Lower Eel watershed. However, there are instream indicators with target values (USEPA 2007) (Table 25).

Table 25. United States Environmental Protection Agency sediment indicators and targets for the Lower Eel Watershed (USEPA 2007).

Indicator	Target	Purpose
Substrate composition – percent fines	<14%<0.85 mm ≤30% <6.4mm	Indirect measure of fine sediment content relative to incubation and fry emergence from the redd Indirect measure of ability of salmonids to construct redds
Turbidity and suspended sediment	Turbidity < 20% above naturally occurring background (also included in Basin Plan)	Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities
Riffle embeddedness	<25% or improving (decreasing) trend toward 25%	Indirect measure of spawning support; improved quality & size distribution of spawning gravel
Residual pool filling (V*)	<0.21	Estimate of sediment filling of pools from disturbance
Macroinvertebrate community composition	Improving trends	Estimate of salmonid food availability, indirect estimate of sediment quality
Thalweg profile	Increasing variation from the mean	Estimate of improving habitat complexity & availability
Pools	Increasing trend in the number of backwater, lateral scour pools. Increasing trend in the number of stream reaches where the length of the reach is composed of ≥40% in primary pools	Estimates improving habitat availability

Wastewater Treatment Facilities

There are five wastewater treatment facilities that discharge into the Lower Eel Basin:

- Humboldt Redwood Company;
- The City of Rio Dell;
- The City of Fortuna;
- Humboldt Creamery Association;
- Loleta Community Services District; and
- The City of Ferndale.

In this report we will include the Humboldt Redwood Company treatment facility in Scotia because of its proximity to, and direct influence on, the Lower Eel Basin.

There are no tertiary treatment facilities in the Lower Eel Basin; all wastewater receives secondary treatment only. All six of these facilities are permitted and regulated by the NCRWQCB which enforces federal and state water quality requirements. Permit renewal for surface water discharge occurs every five years as required by the federal Clean Water Act, and groundwater discharge, regulated by state law, is reviewed less frequently. When facilities are re-permitted, requirements on the facility, operations, and monitoring may be amended. A Cease and Desist order may be used to require upgrades between permitting cycles.

The water quality standards used for regulating these wastewater treatment facilities are based on protecting the beneficial uses of the receiving water bodies as determined by the NCRWQCB (NCRWQCB 2006d). An amendment to this region's Basin Plan has been drafted that would take into account the biological requirements of anadromous salmonids in discharge restrictions. The proposed amendment would revise the existing objectives for water temperature and dissolved oxygen to meet requirements of the federal and state Endangered Species Act and the Porter Cologne Water Quality Control Act. The amendment must be approved by the State Water Board before being implemented (draft document summary available at: http://www.waterboards.ca.gov/northcoast/waterissues/programs/basin_plan/basinplan.shtml).

To preserve the beneficial uses of the Eel River, direct surface water discharge may only occur between October 1st and May 14th. During the summer these facilities must use percolation ponds or other terrestrial discharge sites. The wastewater treatment facilities in Scotia and Rio Dell have recently received new permits, and Fortuna's permit was recently drafted and went into effect June 2007. These three facilities discharge summer waste onto gravel bar percolation ponds located adjacent to the Eel River. The new permits prohibit this practice and require an alternative by the next permit cycle. Additionally, all new permits will now require monitoring of receiving waters to ensure that effluent regulations are effective in preserving water quality. Permits for Humboldt Creamery were adopted in September, 2008; the Loleta wastewater treatment facility will be drafted and implemented in 2009. The Ferndale facility is in the process of complying with a Cease and Desist order and will likely be re-permitted once it reaches a

resolution. More detail on each of these facilities is presented in the subbasin sections of this report.

Storm water is also regulated by the NCRWQCB and requires individual permits for any construction or industrial site greater than one acre and municipal permits for cities with populations of 10,000 or greater. Fortuna is the only municipality in this basin that has a city-wide storm water management plan. Storm water runoff can be a major source of pollutants and sediment that impair surface waters.

Conclusions and Limiting Factors Analysis

Although instream habitat conditions for salmonids varied across the Lower Eel Basin, several generalities can be made (Table 29, Figure 36). In general, canopy conditions in the basin are evaluated as suitable in surveyed streams across the basin. However, current canopy density measurements do not take into account differences between smaller, younger riparian vegetation versus the larger microclimate controls that are provided by old growth forest canopy conditions. Water temperature measurements, although not currently evaluated by the EMDS, showed that three tributaries and three locations on the mainstem Eel River and two locations in the estuary had temperatures unsuitable for salmonids. Therefore, water temperature is likely a limiting factor for salmonids at these locations.

Pool quality, pool depth, pool shelter, and cobble embeddedness were generally evaluated as unsuitable across surveyed streams in the basin–thus these habitat factors are likely limiting to salmonid populations.

Fish passage barriers are not currently evaluated by the EMDS. There are sixteen known partial barriers to salmonid passage in the basin and these barriers are likely limiting salmonid production.

Macroinvertebrate data indicate that creeks in the Salt River and Upper subbasins are highly impacted systems. Additionally, farm waste water quality problems have been identified in the Salt River Subbasin and conductivity, turbidity, and dissolved oxygen may be limiting factors in the Middle Subbasin. Therefore, water quality is likely a limiting factor, specifically nutrient enrichment, excess sediment, and dissolved oxygen.

Table 26. EMDS Anadromous Reach Condition Model results for the Lower Eel Basin.

Subbasin	Canopy	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Salt River	+	--	--	---	--
Middle	++	--	-	---	--
Upper	+	--	--	---	--

Key: + ++ +++ = Highest Suitability U = Insufficient Data or Undetermined - -- --- = Lowest Suitability

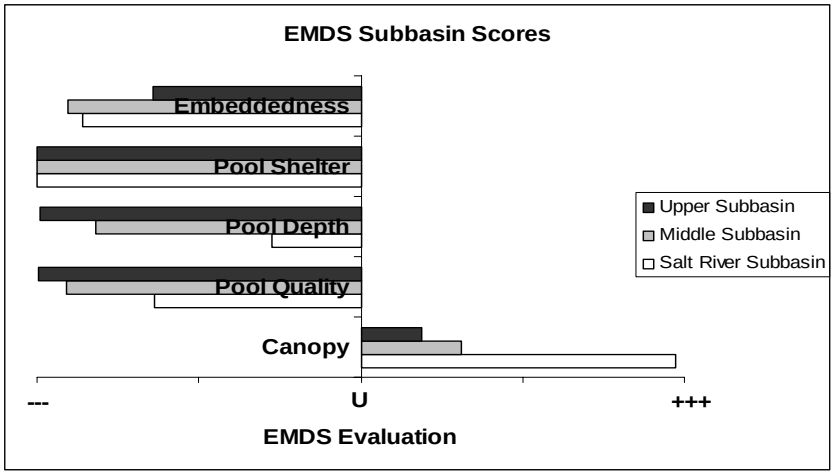

Figure 36. EMDS truth values for the Lower Eel Basin by stream miles.

Table 27. Findings of CDFG habitat inventories for streams in the Lower Eel Basin, and associated target values.

Stream	Survey Year	Survey length (miles)	Mean Canopy Density (%)	Category 1* Pool Tail Cobble Embeddedness (%)	Length of Primary Pools (%)	Shelter Cover Rating
TARGET VALUES			>80	>50	>40	>100
Estuary Subbasin						
No surveys were conducted in the Estuary Subbasin						
Salt River Subbasin						
Francis Creek tributary	2003	0.2	92	0	2	24
Russ Creek	2004	2.2	79	0	16	79
Francis Creek	2003	2.7	87	3	14	32
Williams Creek	2003	4.1	63	14	26	34
Middle Subbasin						
Mill Creek	2004	0.2	80	33	3	27
North Fork Strongs Creek	1993	1.2	93	0	31	55
Strongs Creek	1993	0.6	90	0	29	52
Upper Subbasin						
Muddy Creek	2002	0.8	82	13	1	32
Adams Creek	2002	0.8	88	4	0	20
West Fork Howe Creek	1998	0.4	86	0	<1	8
Oil Creek	1999	0.8	83	0	18	90
	2002	0.5	94	73	19	44
Crystal Creek	2002	0.5	77	0	0	40
Wilson Creek	1991	0.5	80	<1	0	27
Sweet Creek	1999	0.9	60	0	0	43
Dean Creek	1992	1	94	<1	3	45
Wolverton Gulch	1997	2.5	89	0	7	25
Nanning Creek	1992	1.4	71	0	3	58
Atwell Creek	1993	1.6	95	2	8	33
	1998	2.4	83	2	10	22
Cummings Creek	1991	3.4	70	<1	3	66
	1996	2	77	0	3	27
Howe Creek	1998	4	57	2	3	14
Price Creek	1999	6.9	52	12	4	45

Fish Restoration Programs

Restoration efforts throughout the Eel River Basin have been ongoing since the early 1970s. Like many other areas in the region, early efforts included removal of large debris accumulations, small hatchery operations, and riparian tree planting and were largely volunteer (Trees Foundation website). Restoration efforts are now more diverse, inclusive, and better funded. Since 1981, CDFG's Fisheries Restoration Grants Program (FRGP) alone has invested 22.5 million dollars in projects improving watershed conditions in the Eel River Basin (Williams 2007). Currently, within the Lower Eel Basin, watershed improvement projects range from public education to barrier modifications to scientific environmental assessments to instream structure placement and are found throughout the basin.

Cataloging restoration projects has been facilitated by increased funding and the associated tracking requirements. The California Habitat Restoration Project Database (CHRPD) houses spatial data on FRGP projects and other projects with which CDFG has been involved. The CHRP data is available through CalFish (www.calfish.org) and has included some projects from agencies and programs outside of CDFG. In addition, the Natural Resources Project Inventory (NRPI), available through the University of California, Davis (www.ice.ucdavis.edu/nrpi/), receives information on projects from the CHRPD and other sources. Information presented here includes projects from both of these databases (Table 28).

Table 28. Lower Eel Basin projects by subbasin and restoration categories, 1981–present (CHRPD, NRPI).

Number of projects that include this type of restoration (many projects contain more than one)	Subbasin				Total Number of Projects that include this restoration type (projects will be represented in more than one restoration type)
	Estuary Subbasin	Salt River Subbasin	Middle Subbasin	Upper Subbasin	
Road and Stream Crossing Upgrades		1		63	64
Bank Stabilization		5		53	58
Livestock Exclusion	1	2		46	49
Instream Habitat Improvement			1	37	38
Assessments and Studies	1	20	1	12	34
Re-vegetation	2	4	1	27	34
Public Involvement	2	5	9	7	23
Upslope Management			5	13	18
Fish Passage Improvements			2	3	5
Land Acquisition				1	1
Total Projects	4	28	18	177	
Ongoing Projects as of 2007 (included in Total)	1		5	60	

Three quarters of the restoration projects in the basin have focused on the Upper Subbasin (Figure 37). The Upper Subbasin is the largest subbasin and it has had a large amount of improvement work done associated with the progressive management of Howe Creek Ranch. Many of the issues that the Lower Eel Basin faces relate to high sediment loads, so it is not surprising to see road and stream crossing upgrades are included more times (64) in restoration projects than any other type (Table 28). Under-maintained dirt roads are common throughout most of the subbasins and are a major sediment source. The next most common restoration activities are bank stabilization and livestock exclusionary fencing. These also address sediment input issues and occur 58 and 49 times, respectively, in restoration projects throughout the basin.

Assessments and public involvement projects are not displayed on the map (Figure 37) but make up a large part of the restoration efforts in the basin. Assessments include surveys and studies to determine fish passage barriers, sediment sources and water quality among other parameters and are included in 34 separate restoration projects. Two thirds of these studies and assessments have been conducted in the Salt River Subbasin–mostly to address drainage and fish passage issues. Public involvement can include education, public workshops, and outreach in general and is included in 23 separate restoration projects.

In the Lower Eel Basin, public outreach is focused in the largest population center, Fortuna, and also in the Salt River Subbasin where the impaired state of the watershed affects the majority of the community, including Ferndale.

In addition to the projects listed above that have received funding, many more restoration efforts are occurring throughout the basin as landowners seek to preserve or repair the natural integrity of their property. More detail on the projects that have received funding can be found in the subbasin sections of this report.

Wildlife Habitat Relationships

The value of the Eel River Delta for fish and wildlife is high because of the diversity of habitat types, such as shallow water bays, deep water sloughs, freshwater marshes, salt marshes, tidal mudflats, riparian woodland, sand dunes, gravel bars, well drained pasture, and poorly drained pasture (Monroe et al. 1974). Many of these natural habitat types have been significantly reduced in size and function.

The Eel River Delta is home to more than 200 bird species (resident and migrant), 61 species of mammals, 15 species of crustacean, 40 species of fish, 7 amphibians, and 170 plant species (Gilroy 2002; Bivin, Eicher 1991). The Eel River Delta also serves as an important stopover on the Pacific Flyway for migratory waterfowl, shorebirds, wading birds, and other water-associated birds (Monroe et al. 1974).

The Eel River Delta has a growing residential population, which is concentrated in the communities of Fortuna, Ferndale, Loleta, and Fernbridge. Land area in the Eel River Delta is largely privately owned and predominantly dedicated for agricultural purposes.

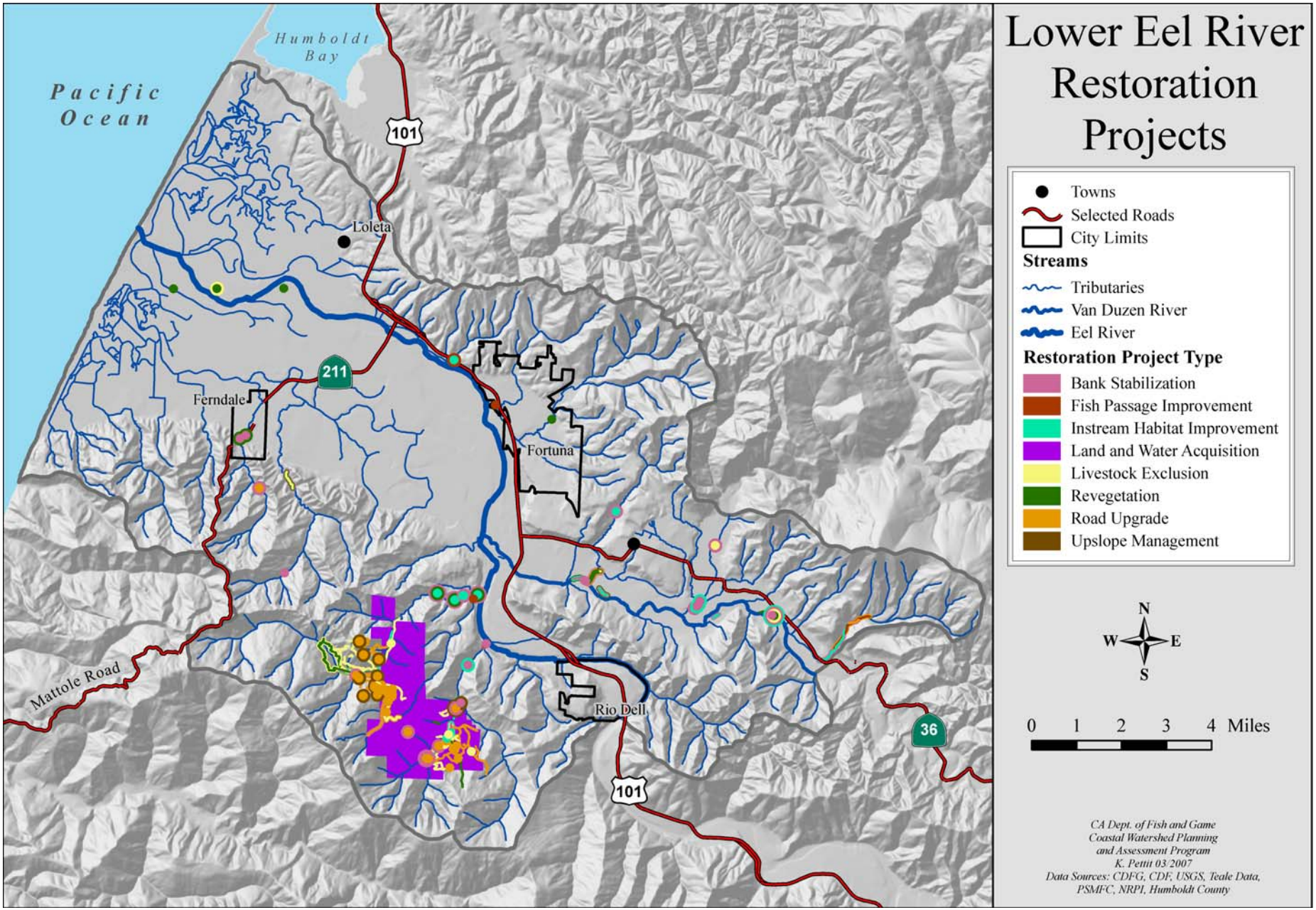

Figure 37. Lower Eel restoration projects locations.

Integrated Analysis

Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFG stream inventories provide a list of recommendations that address those conditions that did not reach target values (see Basin Fish Habitat Section). In the Lower Eel Basin, 24 surveys were conducted on 21 streams, and recommendations for each were selected and ranked by a CDFG biologist (Table 29). The tributary recommendation process is described in more detail in the Fish Habitat Relationship section of each subbasin.

In order to compare tributary recommendations within the basin, the recommendations of each stream were collapsed into five target issue categories (Table 30). The top three recommendations of each stream are considered to be the most important, and are useful as a standard example of the stream. When examining recommendation categories by number of tributaries, the most important target issue in the Middle and Upper subbasins is Erosion/Sediment (Table 31).

However, comparing recommendation categories between subbasins can be confounded by the differences in the number of tributaries and the total length of survey in each. Therefore, the number of stream miles within the subbasin assigned to various recommendation categories was calculated (Figure 38). Erosion/sediment is the most important target issue, both in each of the subbasins, as well as for the basin as a whole. At the basin-level instream habitat and riparian/water temperature were each also important target issues.

Table 29. Occurrence of recommendations in the first three ranks in surveyed streams.

Subbasin	Number of Surveys	Survey Length (miles)	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Live-stock	Fish Passage
Salt River	4	9.2	2	1	1	0	2	3	0	0	0	1
Middle	3	2	2	2	1	0	0	0	0	2	1	1
Upper	17	30.3	12	7	3	2	11	7	1	4	1	1
Lower Eel Basin	24	41.6	16	10	5	2	13	10	1	6	2	3

Table 30. Consolidation of habitat inventory report recommendations into basin-wide target issue categories.

Tributary Report Recommendations	Basin Wide Target Issue Category
Bank/Roads	Erosion/Sediment
Canopy/Temp	Riparian/Water Temp
Pool/Cover	Instream Habitat
Spawning Gravel/LDA	Gravel/Substrate
Livestock/Barrier	Other

Table 31. Distribution of basin-wide recommendation target issues in the Lower Eel River Basin.

Subbasin	Erosion/ Sediment	Riparian/ Water Temperature	Instream Habitat	Gravel/ Substrate	Other
Salt River	3	1	5	0	1
Middle	4	1	0	2	2
Upper	19	5	18	5	2
Lower Eel Basin	23	6	18	7	4

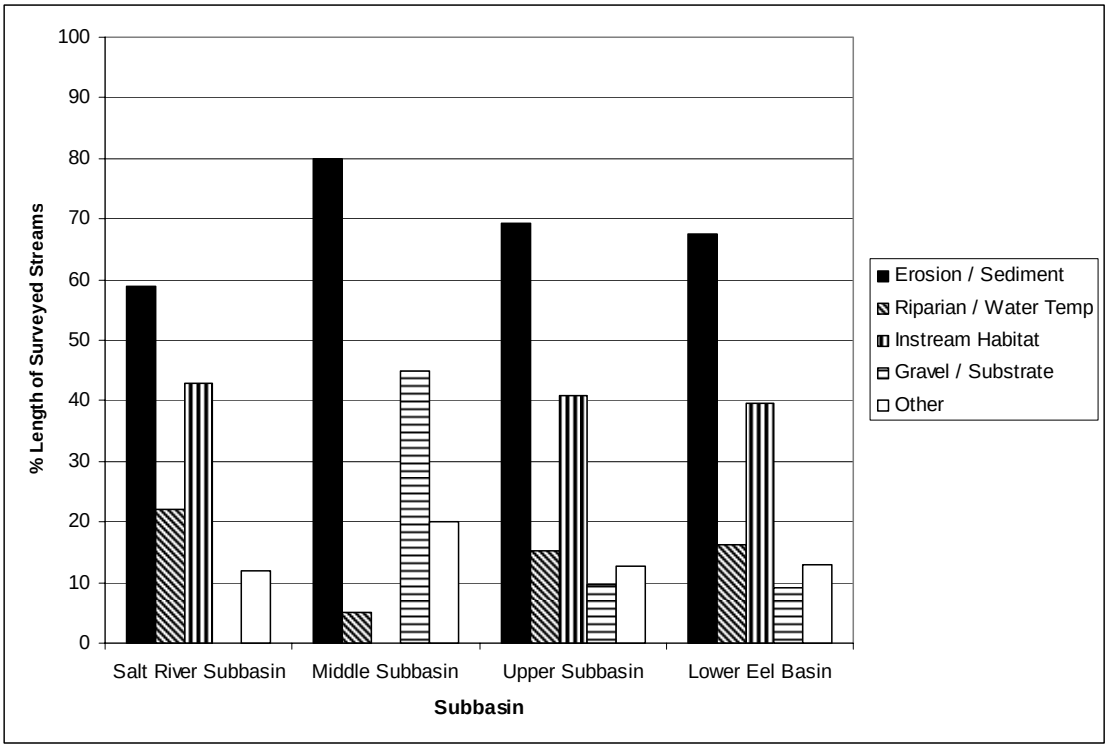

Figure 38. The frequency of recommendation target issues in Lower Eel River Basin surveyed streams.

Refugia Areas

The CWPAP interdisciplinary team identified and characterized refugia habitat in the Lower Eel Basin by using expert professional judgment and criteria developed for north coast watersheds. The criteria included measures of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. The team also used results from information processed by the EMDS at the stream reach scale.

The most complete data available in the basin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered by the CWPAP team. Salmonid habitat conditions in the Lower Eel Basin are generally better in the Middle and Upper subbasins. The Estuary Subbasin and the Salt River Subbasin, below Reas Creek (RM 3.4) provides critical estuarine rearing habitat. The remaining portion of the Salt River Subbasin provides low quality refugia (Table 32. Figure 40).

Table 32. Subbasin salmonid refugia area ratings in the Lower Eel Basin.

Subbasin	Refugia Categories:				Other Categories:		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area/Function	Data Limited
Estuary						x	
Salt River				x			x
Middle			x				x
Upper			x				x

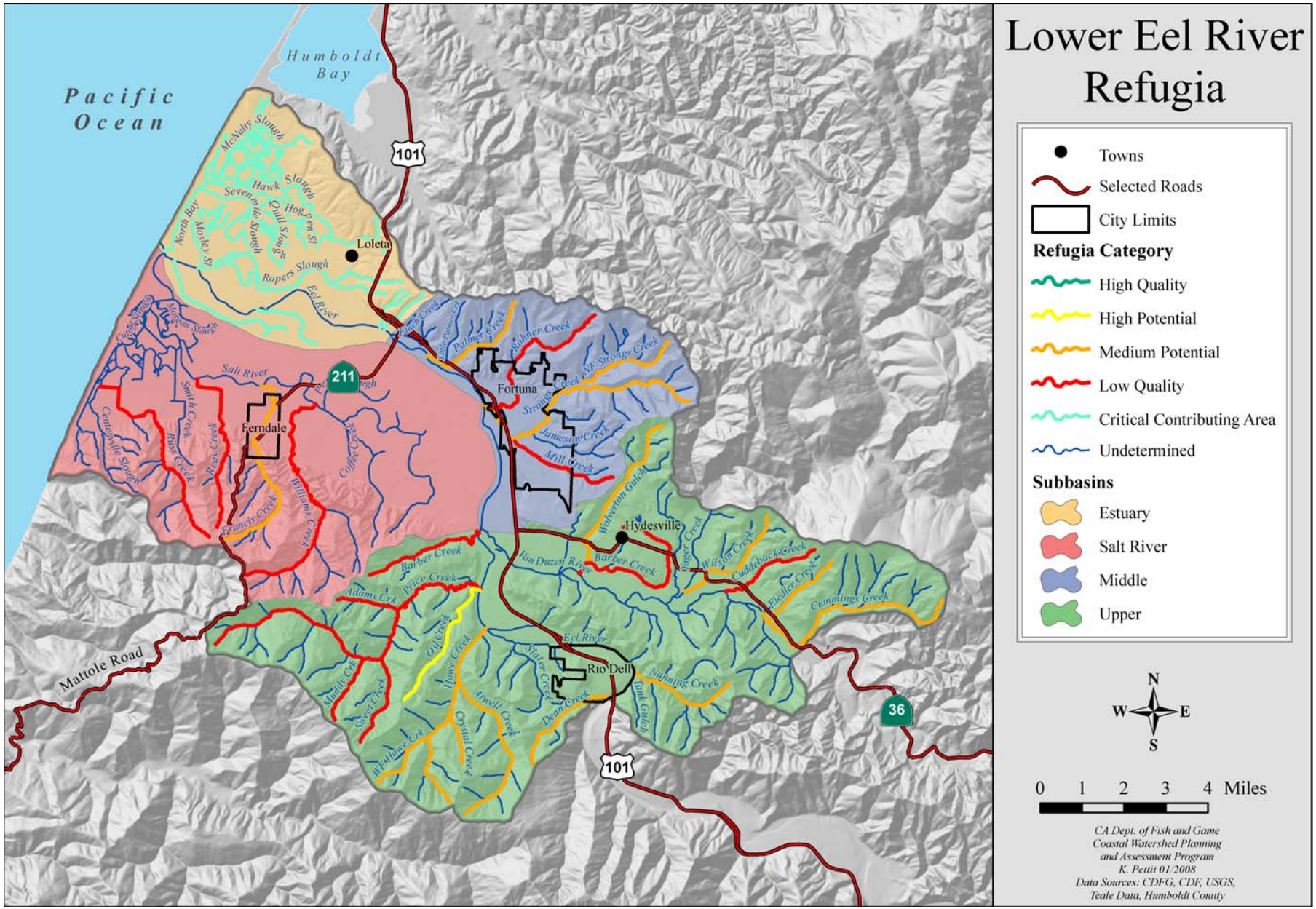

Figure 39. Stream refugia in the Lower Eel Basin.

Key Basin Issues

- The morphology of the Lower Eel River Basin has been changed due to erosion and aggradation;
- Historic and current land use has altered watershed processes and conditions;
- Alterations to watershed processes have affected the basin both socially and economically;
- Fish and wildlife have been adversely impacted by current watershed conditions in the basin.

Responses to Assessment Questions

What are the history and trends of the size, distribution, and relative health and diversity of fish populations in the Lower Eel River Basin?

Findings and Conclusions:

- Historical accounts of the recreational fishery in the Eel River estuary describe excellent salmon and steelhead fishing over the entire delta, with anglers gaining access to catch "from boat to shore" (Haley 1970). Large commercial harvest of salmon and steelhead were taken from the estuary from 1860 to 1926. The commercial fishery has been eliminated and the recreational fishery has been significantly reduced and is now catch and release only (zero bag limit);
- The NMFS has listed northern California runs of coho (1997), Chinook (1999), and steelhead (2000) as threatened under the federal Endangered Species Act. The California Fish and Game Commission also listed coho as threatened in 2005;
- Salmon populations are considerably smaller and less well distributed compared to historic range. Coho salmon have been documented in 13 tributaries across the basin and Chinook salmon in six tributaries. Steelhead trout have been documented in 21 tributaries and cutthroat trout in eight tributaries. In addition, all four species of salmonids use the mainstem Eel River and estuary as critical migration routes and use the estuary as rearing habitat;
- These remaining populations are critical to recovery of salmon and steelhead along the entire North Coast;
- The most comprehensive studies of the estuary were year-long investigations preformed in 1951, 1977, and 1995. These studies indicate the presence of juvenile Chinook salmon from spring to fall (March through November), coho salmon from spring through summer, and year-round presence of steelhead. Adult Chinook salmon and steelhead hold in the estuary until sufficient flows allow upstream migration in the fall;
- Three tributaries in the Middle Subbasin have been inventoried in 1993 and 2004 by CDFG. These data have confirmed, in addition to other fish studies, the presence of coho salmon, steelhead, and coastal cutthroat, among other species. Some historical and anecdotal accounts (dating back to the early 1950s) list the presence of these salmonid species in several Middle Subbasin tributaries;
- Stream inventories conducted by CDFG on fourteen tributaries in the basin between 1991 and 2002, as well as other fish sampling data, have documented the presence of Chinook salmon, coho salmon, and steelhead. Historical recorded data show that these salmonid species were being collected in fish rescue operations in the late 1940s;
- Coastal cutthroat trout were present in a 1984 survey of Centerville Slough, a tributary to the Salt River, indicating presence in the Eel River estuary. Cutthroat trout have also been observed during surveys of the Middle Subbasin between 1984 and 1995, but have not been confirmed present in the Upper Subbasin. The Eel River is the current southern extent of coastal cutthroat trout (Miller and Lea 1972);
- Tidewater goby, a species listed as endangered under the federal Endangered Species Act (ESA), were collected by the United States Fish and Wildlife Service in an unnamed slough of the Eel River estuary near Cannibal Island in August 2004;

- Sacramento pikeminnow, which were introduced into Lake Pillsbury in 1979, have been observed in many surveys of the Lower Eel River Basin from the estuary to RM 21 at Scotia. Pikeminnow predate on juvenile salmonids, particularly outmigrating salmonids (Moyle 2002);
- The Salt River Subbasin once supported populations of coho salmon, Chinook salmon, steelhead, and coastal cutthroat. Recent surveys have found small numbers of these salmonids in a more limited distribution than in the past.

What are the current salmonid habitat conditions in the Lower Eel River Basin? How do these conditions compare to desired conditions?

Findings and Conclusions:

Flow and Water Quality

- Stream and tidal flow has been altered by tide gates and levees constructed along streams and slough channels;
- Water quality is being impacted by cattle waste in estuary sloughs and in streams of the Middle and Upper Subbasins;
- Low summer flows may be stressful to salmonids and dry or intermittent reaches on the Van Duzen River prevent connection with the Eel River and impede passage to spawning grounds;
- In 1992, the EPA listed the Lower Eel River as impaired due to elevated sedimentation/siltation and temperature. The NCRWQCB has continued to identify the basin as impaired in subsequent listing cycles, the latest in 2006;
- Turbidity levels are high during winter rains, which correspond to salmon spawning season.

Erosion/Sediment

- Excessive sedimentation within the watershed has resulted in an overall loss of rearing and feeding habitat for salmonids within the estuary;
- The Van Duzen River is usually isolated from the Eel River by subsurface flows in late summer and early fall due in part to increased bedload materials at the confluence;
- Livestock have unrestricted access to many of the Lower Eel River tributaries and estuary sloughs, resulting in stream bank erosion;
- Soils in surveyed reaches of streams in the Lower Eel Basin are prone to erosion, and slides have been observed to contribute fines to the streams.

Riparian Condition/Water Temperature

- Much of the Lower Eel Basin has been cleared of riparian vegetation to create pasture land for cattle;
- Though water temperatures in CDFG surveyed reaches of streams in the Lower Eel Basin were suitable for salmonids, water temperature data are limited, and therefore inconclusive;
- Water temperatures of the mainstem collected by the Humboldt County Resource Conservation District (1998) in the summers of 1996 and 1997 within the basin, found unsuitable conditions for salmonids (maximum temps ranged from 73ºF–77ºF);
- Water temperatures collected by the Fortuna Creeks Project over a six-year sample period demonstrate stressful (above 68ºF) and occasionally lethal (above 75ºF) conditions, particularly on Rohner Creek;
- The majority of the surveyed tributary reaches in the Lower Eel Basin (70%) met the target value of 80% canopy coverage, but lack larger conifer overstory.

Instream Habitat

- Quality pool structure is generally lacking in streams throughout the basin; no surveyed streams met standards for pool shelter. Eight of the seventeen reaches surveyed obtained ratings considered fully unsuitable;
- On average, pool depths were considered poor for salmonids in all CDFG surveyed streams in the basin;
- Large woody debris is generally lacking in many areas of the basin.

Gravel/Substrate

- Due to increased sedimentation, stream beds have been described as heavily silted in many CDFG habitat inventories throughout the basin;
- Only 7% of pool tails in the Lower Eel Basin have cobble embeddedness in category one, which meets spawning gravel targets for salmonids;
- Areas of suitable spawning gravel are very limited throughout the Basin.

Refugia Areas

- The Middle and Upper subbasins provide medium potential refugia;
- The Salt River Subbasin provides lower quality stream refugia;
- The Estuary Subbasin and lower 3.4 miles of the Salt River provides critical estuarine rearing habitat for juvenile salmonids and other valuable fishery resources.

Other

- When flows are sufficiently high, the Eel River floods into treatment ponds of the Fortuna Wastewater Treatment Plant;
- A culvert on Mill Creek, tributary to Strongs Creek, in the Middle Subbasin does not meet CDFG and NOAA Fisheries fish passage guidelines. Other creeks with possible fish passage problems include Palmer Creek, Dean Creek, Price Creek, Adams Creek, and Barber Creek on mainstem Eel (RM 10).

What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions?

Findings and Conclusions:

- The Lower Eel Basin receives highly variable precipitation throughout the year. High levels of winter precipitation can lead to widespread flooding throughout the basin. The drainage capacity of the Eel River has been drastically altered due to excessive sedimentation, which can exacerbate flood events;
- The floods of 1955 and 1964 catastrophically impacted the basin by depositing large amounts of sediment in the channel;
- Friable soils, steep upstream terrain, and high levels of rainfall result in numerous landslides. Saturated soils are highly vulnerable to sliding during the many earthquakes that characterize the basin;
- The basin is located in a tectonically complex area, resulting in part from compression generated by convergence between the Gorda and North American Plates, underplating and accretionary tectonics along the Cascadia Subduction Zone and further enhanced by accelerated uplift from the encroaching Mendocino Triple Junction;
- Estuarine conditions extend from the mouth to Fernbridge (RM 7); tidal influence, evidenced by water movement, continues beyond this point, possibly to the mouth of the Van Duzen River;
- The basin's vegetation has been historically and is currently composed of primarily coniferous forest,

predominantly of the Redwood Alliance. However, on all surveyed tributaries in the Upper Subbasin, deciduous canopy was more prevalent than coniferous. Reclaimed pasturelands are now also prevalent in the basin.

How has land use affected these natural processes and conditions?

Findings and Conclusions:

- Tideland reclamation and the construction of dikes and levees for agricultural purposes have changed the natural function of the estuary considerably. Slough and creek channels that once meandered throughout the delta are now confined by levees, sufficiently slowing flow to a point that many have become filled with sediment. Remnant slough channels are visible throughout the delta. It is generally accepted that the estuary and tidal prism has been reduced by over half of their original size;
- Riparian vegetation in the basin was cleared, and salt marsh vegetation was converted in order to create pastures for cattle. This change in species of grass has reduced the strength of prairie vegetation, causing soils to be more susceptible to slumping;
- Wastes from the dairy industry, as well as urban storm runoff have affected the water quality;
- Sedimentation and in-filling as a result of urbanization, land subdivision activities, gravel mining, and timber harvesting practices have resulted in an overall reduction in channel area, and consequently in available salmonid habitat;
- Projects related to the expansion of Fortuna's urbanization have adversely affected the area's streams in both water quality and riparian and instream habitats;
- Because of the geologic characteristics within the Lower Eel, the basin is affected by highly variable runoff rates. Disturbance of the basin's already unstable soils by landuse activities has disturbed runoff rates.

Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead production?

Findings and Conclusions:

Based on available information for the Lower Eel Basin, the CWPAP team believes that salmonid populations are limited by:

- Low summer flows;
- High summer water temperatures;
- High levels of fine sediments in streams;
- A shortage of areas with suitable spawning gravel in tributaries;
- Decreased channel capacity;
- A lack of pool shelter and pool-forming LWD;
- Loss of estuarine habitat;
- Competition with Sacramento pikeminnow.

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Recommendations:

<u>Flow and Water Quality Improvement Activities</u>

- Increase the tidal prism to help maintain existing channels and help remove excessive fine sediment accumulations;
- Where feasible, livestock management fencing should be placed in areas where cattle have unrestricted access to streams;
- Protect summer stream flows from diversion.

Erosion and Sediment Delivery Reduction Activities

- The impact of property subdivision on streams of Lower Eel Basin should be minimized through the use of better land management practices;
- Conduct an upslope erosion inventory on streams in the Middle and Upper subbasins in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized and improved in order to decrease sediment contributions within the basin;
- Encourage the use of cattle exclusion fencing along streams where livestock have unrestricted access;
- Opportunities to acquire conservation easements should be examined.

Riparian and Habitat Improvement Activities

- Identify and prioritize locations within the delta where vegetation can be returned to salt tolerant species, thus increasing salt marsh around slough channels and providing a buffer to adjacent lands during inundation;
- Develop a grading ordinance to protect riparian vegetation. Ripparian buffer should be allowed to grow/re-grow along estuarine channels;
- Programs to increase riparian vegetation should be implemented in streams where shade canopy is below target values of 80% coverage. Additionally, those streams that are vegetated with exotic species should be considered for native plant restoration;
- In order to protect riparian vegetation, and decrease stream bank erosion due to unrestricted access of cattle to streams, use of livestock management fencing should be prescribed;
- In creeks where fish spawning and rearing habitat is limited, pool enhancement and instream structures should be added to increase complexity;
- In streams where spawning area is limited, projects should be designed to trap and sort spawning gravels in order to expand and enhance redd distribution;
- Log debris accumulations in streams that retain high levels of fine sediment should be assessed, and carefully removed where appropriate.

Education, Research, and Monitoring Activities

- Improve educational outreach to community;
- Encourage and partner with Fortuna Creeks Project's urban stream clean-up, habitat restoration and monitoring;
- Conduct an inventory of tide gates and levees in the watershed;
- Where necessary, identify barriers to fish migration in the form of large debris accumulations, culverts, etc. and modify them;
- Support the HCRCD in its efforts to monitor and improve habitat and water quality in the basin;
- Because water quality data are limited, monitoring of summer water temperatures should be preformed over at least a three to five year period;
- Water quality data, including temperature and dissolved oxygen, should be consistently collected

throughout the year, for several years, in order to accurately characterize conditions in the streams. Salinities should be collected in the estuary and upstream to determine the extent of brackish conditions;

- Conduct habitat and fish inventories on urban streams of the Middle Subbasin, including Palmer, Jameson, and Rohner Creeks and unnamed tributaries to Strongs Creek;
- Partner with local academic institutions and private agencies as a means to encourage the study of the fish and corresponding habitat.

Basin Conclusions

The California Department of Fish and Game's Coastal Watershed Planning and Assessment Program considered a great deal of information regarding basin processes related to stream conditions in the Lower Eel River Basin. Existing scientific studies and reports that portray physical and biological watershed characteristics were combined with the multidisciplinary investigations and integrated synthesis performed by the CWPAP team. This relatively large data base provided a considerable amount of information for analysis, interpretation and for addressing the CWPAP assessment questions and making recommendations to improve stream habitat conditions.

The Lower Eel River Basin contains runs of Chinook and coho salmon and steelhead and coastal cutthroat trout. Salmon and steelhead populations are considerably smaller and less well distributed compared to their historic range. To maintain or increase these remaining populations is critical to the recovery of salmon and steelhead along the entire North Coast. Opportunities exist in each of the subbasins to help improve habitats and to increase the vitality of salmonid resources of the Lower Eel Basin. These include efforts of local interest groups and programs that provide public education and develop additional concern and actions to preserve one of the most valued assets of Fortuna's urban creeks and the other streams of the Lower Eel River.

Located within the basin is the Eel River estuary, which is a critically important nursery serves as rearing and transition habitat for juvenile and adult salmonids and other valuable fishery resources. Nine fish species that utilize the estuary receive protection under the Federal or State endangered species acts, emphasizing the significance of this unique ecosystem.. Cumulative effects from land use actions in the Eel River Basin and within the estuary coupled with dynamic flood events have altered the morphology of the estuarine channels. The result is a reduction of valuable habitat area, loss of unique habitat complexity and degraded habitat quality for fishery and wildlife resources. The gain of tidal prism by re-establishing functional wetlands is likely the most feasible and practical action to achieve immediate benefits to increase productivity and restore fishery habitats.

The fishery resources in the rest of the basin have also been adversely impacted by land use and resource development. These streams historically provided important spawning and juvenile rearing grounds that enabled salmon and steelhead populations to thrive in the past. Sedimentation and in-filling as a result of urbanization, land subdivision activities, gravel mining, and timber harvesting practices have resulted in an overall reduction in channel area, and consequently in available salmonid habitat. Riparian habitats have been reduced or removed due to agricultural activities and urban development. Moreover, road building as a result of the development and expansion of the city of Fortuna created fish passage barriers, some of which have yet to be properly addressed through mitigation.

Diminishing runs of salmon and steelhead in the Lower Eel River Basin streams are highly susceptible to being reduced to remnant populations. Regulations developed over the years to help protect the basin's salmonid stocks, water resources and associated stream habitats have not provided sufficient protection, been loosely enforced, or in some cases were ignored altogether. While restoration efforts have helped improve certain areas within the basin, they have not been on a large enough spatial or temporal scales to provide significant improvements to the overall habitat conditions and ecosystem function necessary to restore salmonid populations to desirable numbers or range. The Lower Eel River Basin contains critical habitat and runs of salmonids to help in the state wide recovery of salmonids. Basin-wide concerted efforts are needed to improve/expand spawning and rearing habitat for salmonids as well as overall ecosystem function of the lower Eel River watershed.