Introduction

The Outlet Creek Basin is part of the Northern California Coast Range located in north Mendocino County. This basin begins at the confluence with the mainstem of the Eel River along Hwy 162 and includes the headwater tributaries ending south of the city of Willits off Hwy 101. It has an area of approximately 160 square miles, (90,527 acres) and represents approximately 4% of the Eel River System, the third largest river in California (Figure X. Location of Outlet Creek referenced to California and the Eel River Basin).

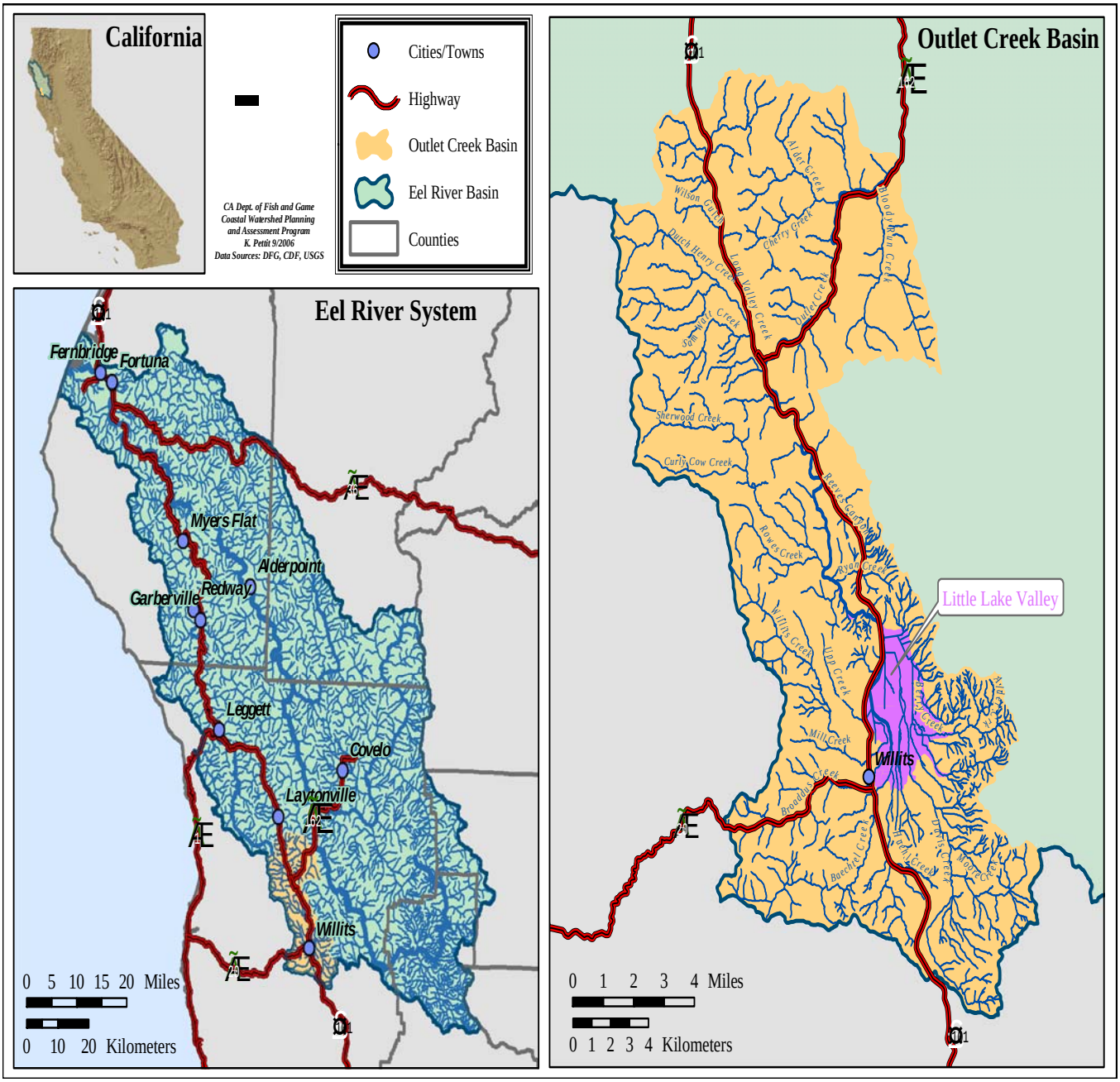

Figure X. Outlet Creek Basin referenced to California and the Eel River Basin.

The Eel River system, including Outlet Creek Basin was inhabited by Pomo Native Americans long before the first European settlers arrived in the early 1840s. The Pomo men in this area were well known for their ingenious basketry fish traps and weirs (Barrett 1952) which they used to catch the plentiful salmon and steelhead for their sustenance. In the 1850s, early settler Sam Baechtel described Little Lake Valley in his journal, stating that "During our rainy season the water collects more rapidly than the outlet can carry it off, consequently it forms a lake in its northern end which is usually drained off by May." This early reference to Little Lake and its outflow is probably the reason behind the naming of Outlet Creek.

Today, Willits is the only city in the basin, and is located in the south end of Little Lake Valley at the junctions of U.S. Highway 101 and State Highway 20, approximately 148 miles north of San Francisco, 158 miles northwest of Sacramento, and 36 miles east of Fort Bragg.

The dominant geology in the basin includes outcrops of both the Central and Coastal belts of the Franciscan Complex, Pliocene-Pleistocene valleys fill, and Quaternary alluvium. The headwaters are steep (>20% gradient) headwaters and drain into the mainstem of Outlet Creek or the long flat (0-1% gradient) Little Lake Valley. Open grasslands, oak woodlands, ponderosa, gray pines and redwoods vegetate the slopes and hills. Mediterranean climate characterized by cool, wet winters with high runoff and dry, warm summers with reduced or absent flows in some streams. The air temperatures range from 14F to104F. The west side is commonly influenced by summer coastal fog which insulates streams from the higher air temperatures experienced by other geographically oriented streams. The average precipitation is approximately 45 inches per year which mainly falls as rain, although it is fairly common to receive up to 3 inches of snow each year. The main stem of Outlet Creek is about 118 miles long and receives water from over 13 tributary streams. There are approximately 67 miles of blueline stream and 150 perennial stream miles in the basin. Elevation ranges from 1,000 and 3,000 feet. The land use include grazing, timber production, and large rural residential and commercial properties. The geology, topography, climate and land use combine to cause high erosion contributing fine sediment to Outlet Creek which moves downstream into the Eel River system.

Historically, the lower Eel River supported a substantial fall run of Chinook and coho salmon which began to be commercially fished in 1853. By the close of the decade there were seven packing plants along the lower Eel River which supplied cured fish to the miners and townspeople of northwestern California as well as for export. The Eel River became the second most important salmon producer in California. By the 1880s, the canning industry became unprofitable due to the lack of salmon in both the Eel and the Sacramento rivers (McEvoy1986). By 1900, the first documented decline of the salmon in the Eel River system was recorded. This decline was likely mirrored further upstream in the Outlet Creek Basin since all of the adult salmonids migrate from the Pacific Ocean through the Eel River System on their way to their natal spawning grounds in the Outlet Creek Basin, some 160 river miles upstream each fall and winter. Steelhead trout were recorded as the most abundant anadromous species in both Outlet Creek and Eel River Basins after the 1890s (DWR 1965; Ferndale Enterprise 1893). The winter run of steelhead trout into Little Lake in the late 1890s was called “phenomenal” by the locals (Mendocino Dispatch Democrat 1897).

Today, Chinook salmon and steelhead trout inhabit the basin with a few tributaries having small infrequent coho salmon populations. These remnant populations still represent the longest migration of wild, non-hatchery influenced coho salmon left in California. The distribution of salmonids in the Basin has been reduced due to the building of six dams. Impounding this flow inhibits the upstream adult Chinook and coho salmon spawning migration to the Eel River System, and up into Outlet Creek and its tributaries. During late summer and early fall, flows become subsurface in some of the tributaries and Outlet Creek, stranding and causing mortality to juvenile salmonids. Natural low flow conditions are severely reduced by legal and illegal dewatering.

Most salmon and steelhead stocks in California streams have decreased to levels which led to the listing of coho, Chinook, and steelhead under the authority of the Federal or State Endangered Species Acts and are State listed species. Basins like Outlet Creek are vital in protecting remaining native stocks of salmonids from extirpation and are important to recovering viable populations.

Subbasin Scale

Terminology can become confusing when discussing different scales of watersheds involved in monitoring and assessment activities. The convention in this Outlet Basin assessment follows those used in the North Coast Watershed Assessment Program reports established by the Pacific Rivers Council. The descending order of scale is from *Basin* level (e.g., Outlet Basin), *Subbasin* level (e.g., Middle Subbasin), *watershed* level (e.g., Ryan Creek) and *sub-watershed* level (e.g., unnamed tributary of Ryan Creek) (Figure X. Watershed Hierarchy highlighting locations in the Outlet Creek Basin).

General Attributes

For the purpose of this assessment, the Outlet Creek Basin has been divided into three subbasins based on the Super Planning Basins (SPW) as defined by the CalWater 2.2a: Longvale, Reeves Canyon and Davis creeks. The subbasins were renamed to simplify geographical orientation: Northern, Middle, and Southern (Figure X. Outlet Creek and Tributaries showing the subbasin delineations). The general attributes of the Outlet Creek Basin (Table X. General attributes for Outlet Creek Basin and subbasins) and the land ownership (Figure X. Ownership Map showing parcel sizes in the Outlet Creek Basin.) follow:

- The Outlet Basin encompasses 160 square miles and 90,527 acres, which is 95% privately owned. The only post office town is Willits with a population of 5,073 in 2000. An additional 7,500 people live in the surrounding areas. The basin is dominated by Coastal Belt. The vegetation on the west side includes redwood, bay, and tan oak species, while the east side is composed of Douglas fir, ponderosa and gray pines, with tan and valley oaks, madrone and manzanita. The streams are dominated by gravel with bedrock, small and large cobble, and sand present. The stream banks are dominated by sand and gravel with some areas composed of small cobble and bedrock;
- The Northern Subbasin encompasses 62 square miles and 39,832 acres which is 90% privately owned and has a human population of 282. This subbasin makes up 44% of the basin. It includes the area from the confluence of Outlet Creek and the mainstem Eel to the confluence with Long Valley Creek. Bloody Run, Cherry, and Long Valley creeks are the perennial streams:
- The Middle Subbasin encompasses 34 square miles and 9,958 acres which is 99% privately owned and has a human population of 1,065. This subbasin makes up 11% of the basin. It includes the area above confluence with Long Valley Creek to the bridge on Highway 101 which crosses over Outlet Creek just north of Willits. Ryan, Reeves Canyon, Sherwood and Rowes creeks are the perennial streams;
- The Southern Subbasin is 64 square miles and 40,960 acres which is 99% privately owned and has a human population of 11,239. This subbasin makes up 45% of the basin. It includes Little Lake and the headwaters of the tributaries. Baechtel, Broaddus, Davis, Haehl, and Mill/Willits creeks are the perennial streams. The city of Willits is located in this subbasin. There are six impoundments in this subbasin.

Table X. General attributes for Outlet Creek Basin and subbasins.

Attribute	*Northern*	*Middle*	*Southern*	*Basin*
Square Miles	62	34	64	160
Acreage Total	39,832	9,958	40,737	90,527
Percent of Basin	44	11	45	100

Private Land (Acres)	~35,902	~9,858	~40,327	~86,087
Public Land(Acres)	~3,930	~100	~410	~4,440
Communities	Longvale	Sherwood Reservation	Willits, Brooktrails	4
Human Population	282	1,065	11,239	12,580
Geology	Coastal Belt	Coastal Belt	Coastal Belt, Alluvium	Coastal Belt
Vegetation	Grass, Brush, Oak, Fir, Pine	Brush, Oak, Fir, Redwood	Grass, Oak, Fir, Pine, Redwood	Deciduous Dominant
Land Use	Grazing, timber, rural	Grazing, timber, rural	Grazing, timber, rural, urban	Grazing, timber, rural, urban
Rainfall (Inches)	~45	~45	~45	~45
Blue Line Stream (Mi)	28	12	27	67
Elevation Range (Feet)	1,000-3,000	1,150-2,400	1,310-2,400	1,000-3,000
Salmonid Species	Chinook, coho, steelhead	Chinook, coho, steelhead	Chinook, coho, steelhead	Chinook, coho, steelhead

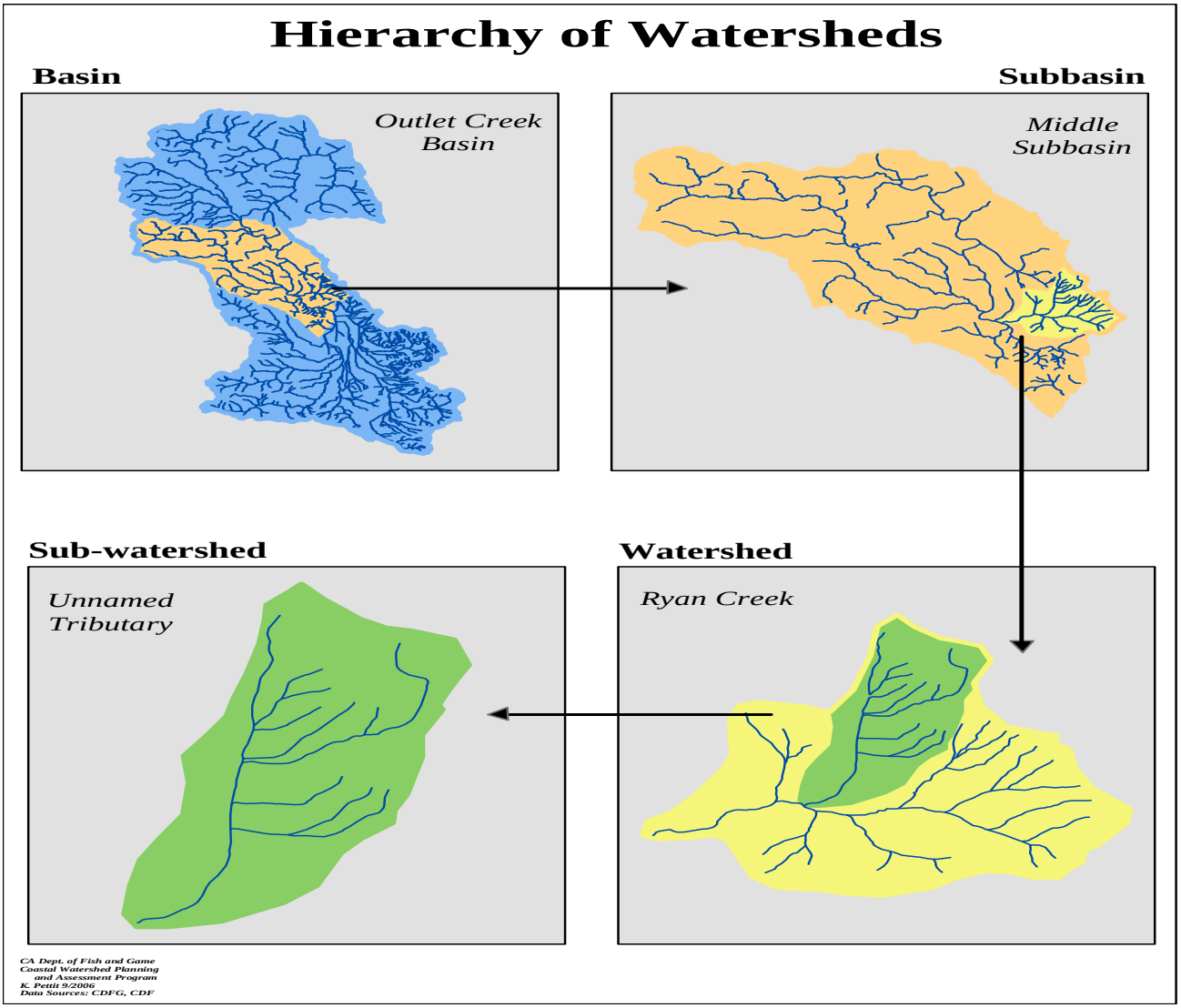

Figure X. Watershed Hierarchy highlighting locations in the Outlet Creek Basin.

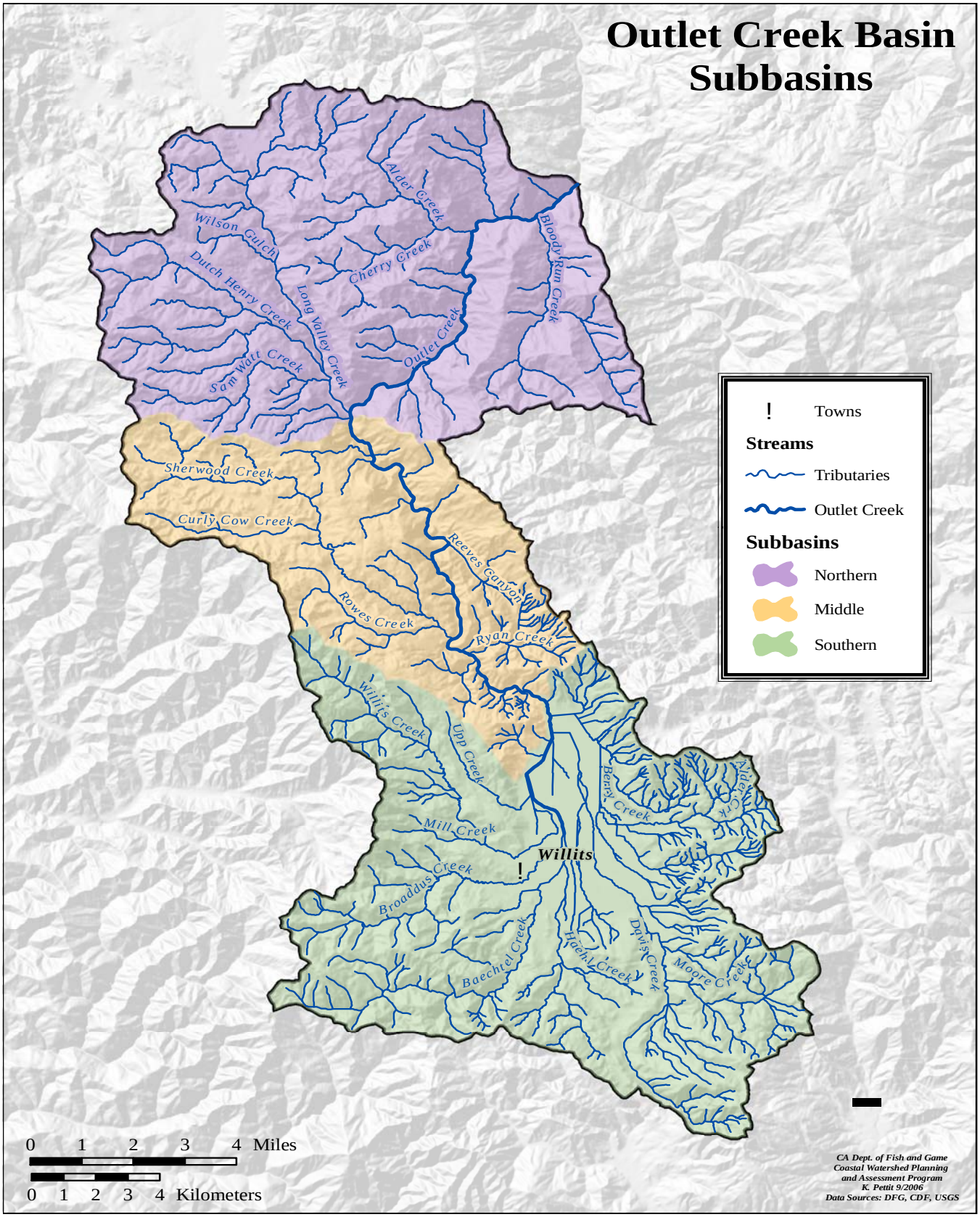

Figure X. Outlet Creek and Tributaries showing the subbasin delineations.

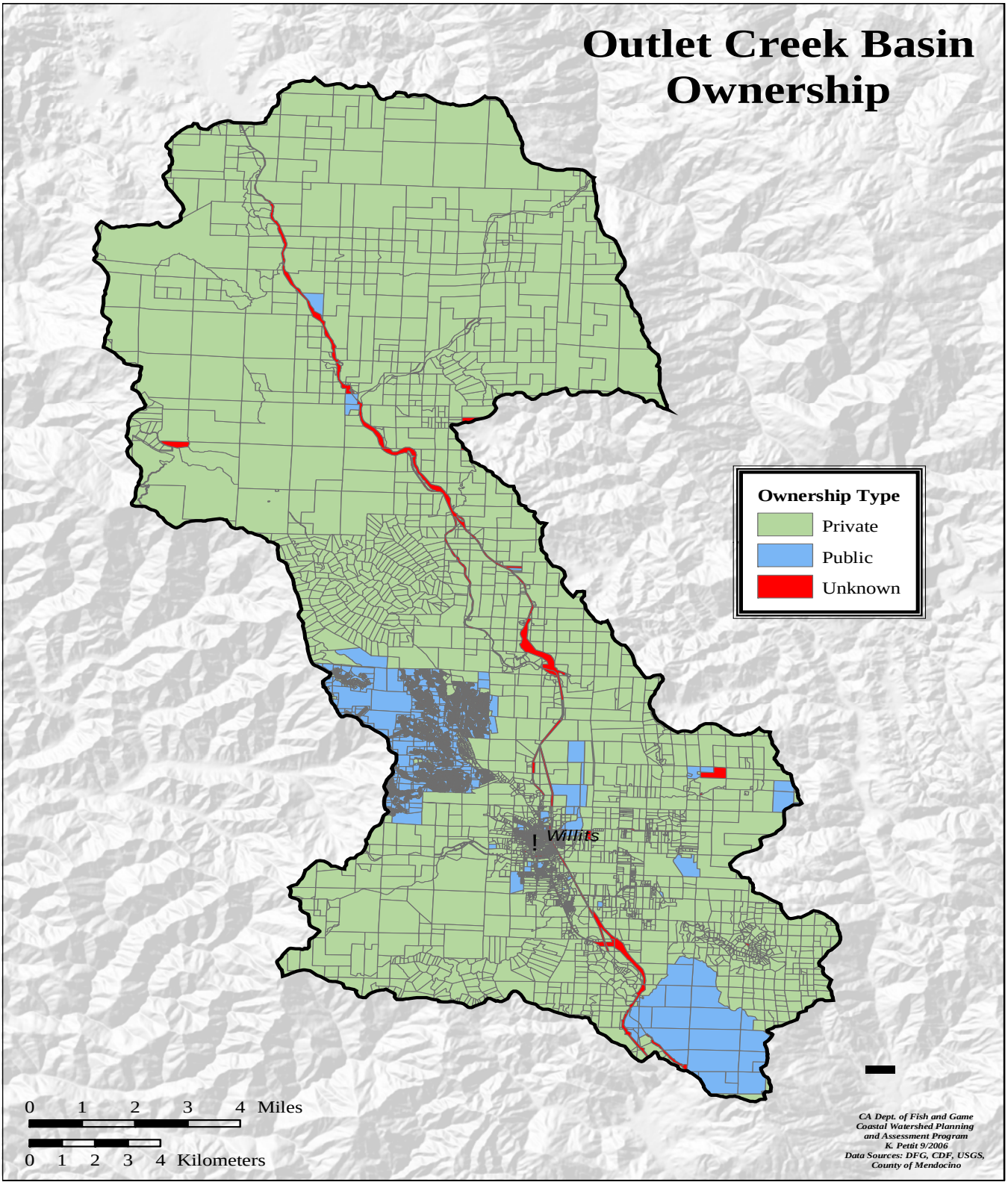

Figure X. Ownership Map showing parcel sizes in the Outlet Creek Basin.

Hydrology

The stream network flows primarily in a northern direction. Six streams flow into Little Lake Valley which form Outlet Creek. Seven additional streams flow into Outlet Creek before reaching the confluence with the main stem Eel River (Figure X).

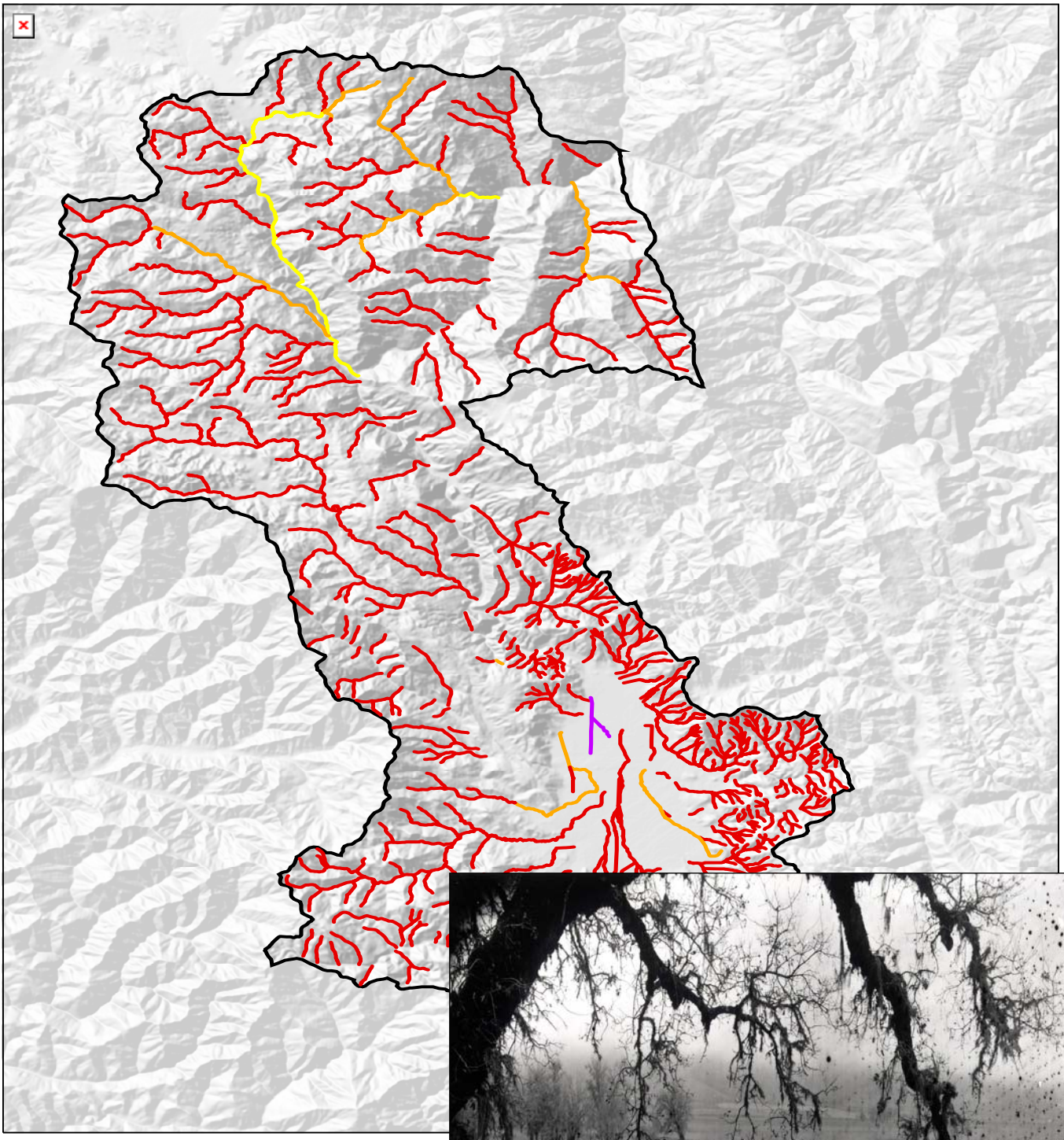

Figure X. Stream Network of the Outlet Creek Basin.

Prior to the relocation and dredging of stream channels in the 1900s, Little Lake functioned as a large, shallow lake and wetland until late spring or early summer dependent upon the amount of rainfall of that given year. The historic photo depicts the large size of Little Lake in 1905. Fishermen were catching the

salmon probably missed by the egg taking weir in the background. In winter, Little Lake provided runoff flow to salmon migrating upstream through Outlet Creek. During spring and early summer, it functioned as a large pool that out migrating juvenile salmonids swam through on their way down to Outlet Creek, into the Eel River and out to the Pacific Ocean. The pool- like conditions provided abundant food for the juvenile salmonids composed of freshwater plankton and aquatic invertebrates, both larvae and adults.

Around 1910, artificial channels were created by ox and plow to facilitate the draining of Little Lake area into Outlet Creek for agricultural purposes such as potato production and grazing (DWR 1965) and railroad construction. The largest channel appears to have been dredged from the confluence of Outlet Creek south through Little Lake where it joined Mill Creek. This channel was straightened and moved east away for the railroad tracks (pers. comm John Ford). One of the original channels through the lake can still be seen and is locally referred to as the Outlet Creek overflow. Later, this channel was continued straight south and merged with the confluences of Broaddus and Baechtel creeks. This dredged channel was named Outlet Creek and is still noted as such on maps today. Historic and current maps indicate that lower Broaddus, Berry and Davis creeks were also straightened to facilitate the draining of Little Lake.

In 1920, U.S. Department of Agriculture conducted a Soil Survey of the Willits area. The survey recorded, "all streams entering the valley are intermittent which include Mill, Broaddus, Baechtel, Haehl, Davis, and Berry creeks. Regional drainage is ample in all except the lower northern end of the Little Lake Valley, where a lake forms every winter."

By the end of the 1930s, Baechtel, Broaddus, Berry, and Davis creeks were straightened, relocated, and /or leveed at least once so the area could be used for the expanding agricultural and transportation activities. These events have changed the hydrology of Little Lake Valley and facilitated the widening of these channels which decreased pool depths and frequencies and increased runoff related stream bank erosion. Outlet Creek's channel has also been relocated and disconnected from it floodplain in several locations for the construction of railroads and later for Highway 101.

In order for the Outlet Creek Basin to function properly, the stream channels should contain meanders and have an available and functional floodplain. The levees along many of the channels have excluded over bank flows except for large flood events greater than the 5 to 10 year peak discharge. The straightening, relocation and leveeing of the channels in the lower parts of Davis, Baechtel, Broaddus, and Mill creeks and upper artificial part of Outlet Creek have caused the channels to become undefined and aggraded. This situation leads to the stream flow becoming subsurface which disconnects these streams from the rest of the watershed during the summer and early fall months. The subsurface flow creates dry areas within the stream channel creating barriers to juvenile salmonid's downstream migration. The condition of the channelized and leveed stream banks through Little Lake and the Valley floor has limited and is currently limiting juvenile salmonid survival.

Rainfall and Flow

In the Outlet Creek Basin, most precipitation falls as rain. Rainfall data were collected in the Southern Subbasin near Brooktrails on the west side from 1877-2002 and at CDF's Howard Forest on the east side of the near the headwaters of Davis Creek from 1988-2002. The Brooktrails site averaged 50 inches/year over the 125 year record. The late 1800s had the lowest average annual rainfall with less than 35 inches/year recorded while the 1950s and 1990s had the highest average annual rainfall between 60-65 inches/year. The Howard Forest site average was 56 inches over the 15 year period with a low of 35 inches and a high of 90 inches. Linear regression analysis showed a slight increase in rainfall over the past 125 years in the Brooktrails area. Data from both sites were compared to known El Nino events. The highest rainfall events coincided with El Nino events: 1957-58; 1968-69; 1973-74; 1982-83; and 1997-98. El Nino events increased the normal average rainfall by 120% at both locations.

The California Water Resources Control Board (CWRCB) and the U.S. Geological Survey (USGS) operated a stream gage on the lower main stem of Outlet Creek near Longvale (USGS Station Number 11472200) for water years 1956-94. Complete records exist for the winter months from 1957-93 and for the summer months from

1958-94. In 2003, the USGS installed a stream gage near Lake Emily on Willits Creek(USGS Station Number 11472160).

To further investigate the low flow conditions in the 1990's, we used available data to compare average annual precipitation with average annual discharge by converting all measurements to the same units, acre feet per year (AFY). We expected a simple positive correlation between precipitation and discharge. We did not consider changes in storage, evaporation, subsurface flow, or surface inflo, as we were not trying to develop a complete water budget for the basin. The comparison showed that while annual precipitation increased in the 1990's, stream discharge decreased in the early 1990's in Outlet Creek well below what it had been historically. The data summaries are described below (Figure X. Average annual precipitation and discharge.).

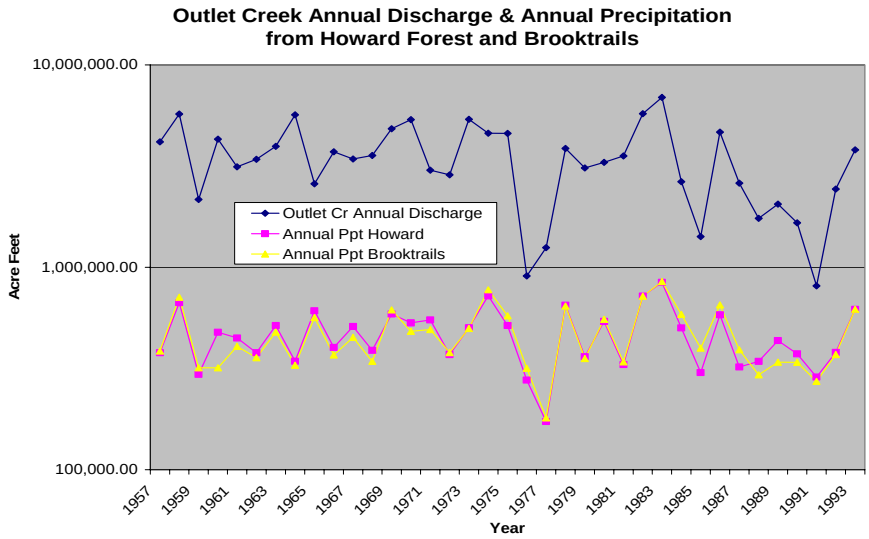

Figure X. Average annual precipitation and annual discharge collected near Brooktrails and Howard Forest.

Stream gage data from Outlet Creek show a decrease in discharge during the period from 1990 through 1993, based on this historical summary of discharge data from 1957 through 1993. Annual discharge was roughly 335,000 AFY (acre feet per year) from 1957 through 1959; 322,000 AFY from 1960 through 1969; 410,000 AFY from 1970 through 1979; and 408,000 AFY from 1980 through 1989. Annual discharge was only 181,000 AFY from 1990 through 1993.

We compared precipitation with discharge by using the same units of measurement, AFY. So as to look for the expected positive correlation, we assumed an even distribution of precipitation over the entire area of Outlet Creek Basin for all the years on record. Notably, we found that precipitation during the 1950's was roughly 60 inches per year, or 512,000 AFY over the entire Outlet Creek basin. Precipitation during the 1990's was 65 inches per year, an increase over the period of the 1950's. Yet, discharge was only 181,000 AFY during 1990-1993. While precipitation increased, discharge decreased in Outlet Creek in the early 1990's. The decrease in discharge coincides with the construction of Centennial Dam in 1989.

Winter rainfall and the resultant discharge were common in November prior to the 1990s. Changing from increased discharge in occurring in November to December and January favor salmonid species which return later (January) like steelhead trout rather than earlier (November) Chinook and coho salmon. Currently, the Outlet Creek Bain is dominated by steelhead. Low winter flow conditions (less than 25 cfs.) in the Eel River System and in the Outlet Basin create barriers to the upstream spawning migration and limit the adult salmonid population's ability to reach their natal spawning grounds (pers. comm. Steiner and Grass). From 1957-93, winter flows were less than 25 cfs eleven times.

The average summer/fall discharge were 15.2 cfs, 4.6 cfs, 1.6 cfs and 2.4 cfs for June, July, August and September, respectively. Low discharges are limiting salmonids during the months of August and September, and zero discharge was recorded during some years in August.

Table X. Average winter and summer monthly discharge by decade from 1950-1990s collected on Outlet Creek near Longvale and by year from 2003-2005 collected on Willits Creek near Lake Emily. Data courtesy of the USGS and U.S. EPA.

WATER YEAR	NOV	DEC	JAN	JUN	JUL	AUG	SEP
Outlet Creek near Longvale measuring flow for the entire Basin							
1950s	1367	407	1,115	19	7	2	6
1960s	306	1,304	1,304	20	4	2	1
1970s	417	700	1,397	12	4	2	2
1980s	485	834	907	13	2	1	2
1990s	28	393	811	12	6	1	1
Willits Creek near Lake Emily measuring flow for one creek only.							
2003	0.5	22.9	ND	ND	ND	ND	ND
2004	0.4	9.61	17.7	0.555	0.247	0.095	0.029
2005	ND	ND	13.9	7.26	1.43	0.399	0.158

Floods

The north coast of California is dominated by intense, short duration rainstorms in the winter with peak flows that are among the highest on record for the western United States (Sommerfield et al. 2002).

Like the Eel River System, Outlet Creek and its tributaries have been and are known to experience flooding in the winter and drying during the summer. Earlier explorers noted that the Eel River had a reputation for flooding. During the winter of 1849-1850, the Gregg party complained about the high water which was recorded in the first written history of Humboldt County:

"*The current during the season is terrific. The canyons are then but conduits for seething flood, bearing on its surface the debris of the forest's huge redwood trees, undermined along the banks and swept along by the flood; old logs dislodged from the drifts, where they lain for years, are carried out into the ocean. These rivers rise very suddenly with heavy rain in the winter*" (Anonymous 1881 as cited in DWR 1965).

Flooding was recorded in the Outlet Creek Basin during 1907, 1938, 1950, 1955, and 1964 with the latter two causing extensive damage. During the winter of 1964, rain fell on the snow pack and triggered the release of a tremendous amount of water in a short period of time, causing a significant increase in flow and velocity. High water in Outlet Creek washed away the railroad embankments along several sections of track during the 1964 flood. This flood was very damaging to the Eel River System, the Eel River estuary, and smaller headwater basins, such as Outlet Creek.

Figure X is a plot of a flood frequency analysis conducted for Outlet Creek near Longvale for the period of record. Peak annual discharge was fit using a Log-Pearson Type III using standard procedures. It is interesting to note that the 1964 flood event (estimated peak discharge of 77,900cfs), which is the largest flow of record, is above the estimated 100-year event of 57,200cfs and has an approximate return period of 385 years (P = 0.0026). Smaller, more recent significant rain events include 1993, 1995, 1997, and 1998.

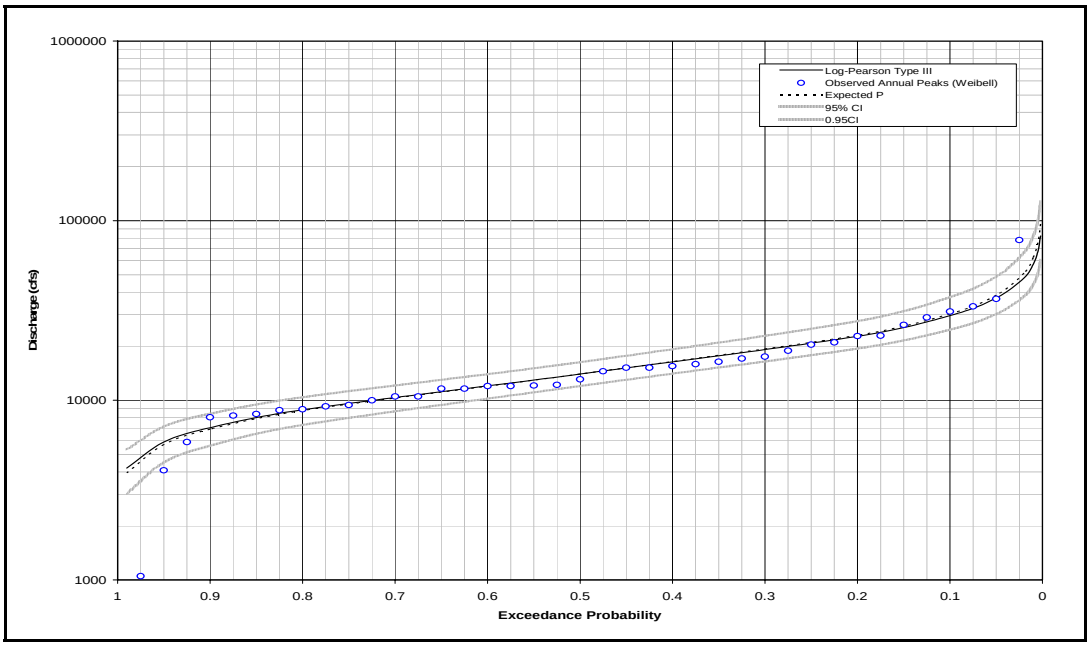

Figure X. Flood frequency analysis of peak annual discharge for Outlet Creek. Data analysis courtesy of Jeff Anderson.

Dams

There are six dams in the Outlet Creek Basin all of which are located in the Southern Subbasin which impound annually a total of 1,670 acre feet of water (Figure X). These dams are filled by rain which falls November through February. There two impoundments on Davis Creek, Morris and Centennial dams, are maintained by the City of Willits for its water supply. Morris Dam was constructed between 1924 and 1927 and is located approximately 3.8 miles upstream from its crossing at Commercial Street. It has a holding capacity of 620 acre-feet which can be increased to 724 acre-feet when the flashboards are installed, which usually occurs March through September. Centennial Dam was built in 1989 and is located approximately 0.9 miles upstream of Morris Dam. It was built to increase the water supply for the growing population of the City of Willits. It has a holding capacity of 512 acre-feet, with an increase to 635 acre-feet with flashboards (Moran pers. comm. 2004). The total maximum impounds from the two dams is 1,359 acre-feet. The two dams on Davis Creek impound over 80% of the total water collected and stored in the Basin.

The two dams on Willits Creek are maintained by the Brooktrails Township Community Service District (BTSCD) for the subdivision's water supply. Lake Emily is located approximately 3 miles from the confluence of Mill and Willits creeks. It was built in 1972 and has a holding capacity of 275 acre-feet. Lake Ada Rose is an off-stream impoundment located on an unnamed tributary to Willits Creek approximately two miles from the confluence of Mill and Willits creeks. It has a holding capacity of 138 acre-feet. Because of accumulated sedimentation, the current holding capacity of both impoundments has been reduced from 413 to 322 acre-feet. BTCSD releases water from Lake Emily to coincide with fall spawning run which helps the returning adult salmonids to migrate upstream. BTSCD also has an active gravel enhancement program which replenishes the spawning substrate on Willits Creek below Lake Emily.

An earthen dam impoundment on Finney Creek, a tributary to Berry Creek is maintained by the Boy Scouts of America. Boy Scout Lake is located approximately 2.9 miles upstream of the confluence of Finney and Berry creeks. It was constructed in 1962-63 and has a holding capacity of ~80 acre-feet. The impoundment on Moore Creek, a tributary to Davis Creek is maintained by the Pine Mountain Mutual Water Company for the subdivision's water supply. It has a holding capacity of 45 acre feet.

The average monthly flows for November from 1957-93 was 35 cfs with a recorded high of 600 cfs and a low of 21 cfs. Linear regression analysis show a decrease in November flows over the past 36 years. Low and absent

flow conditions were recorded several times during November after 1989 (Figure X). Low and/or absent fall flows are limiting the adult upstream spawning migration and the overall health and productivity of salmonids in the Outlet Creek Basin.

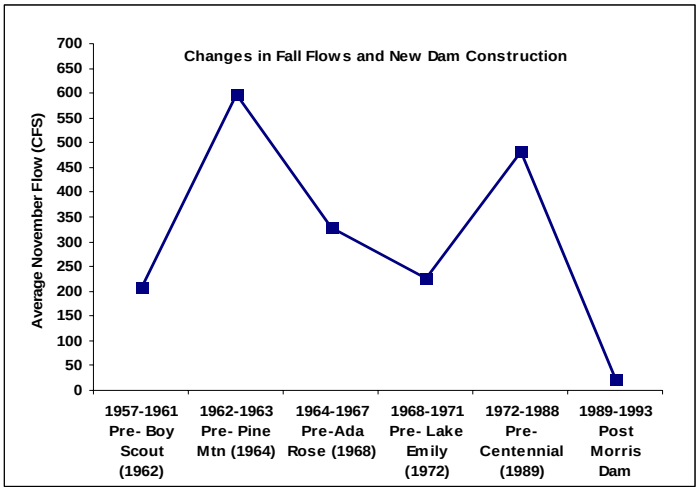

Figure X. Changes in November flow from 1950-1990s correlated with new dam construction. Flow data courtesy of the USGS and US EPA.

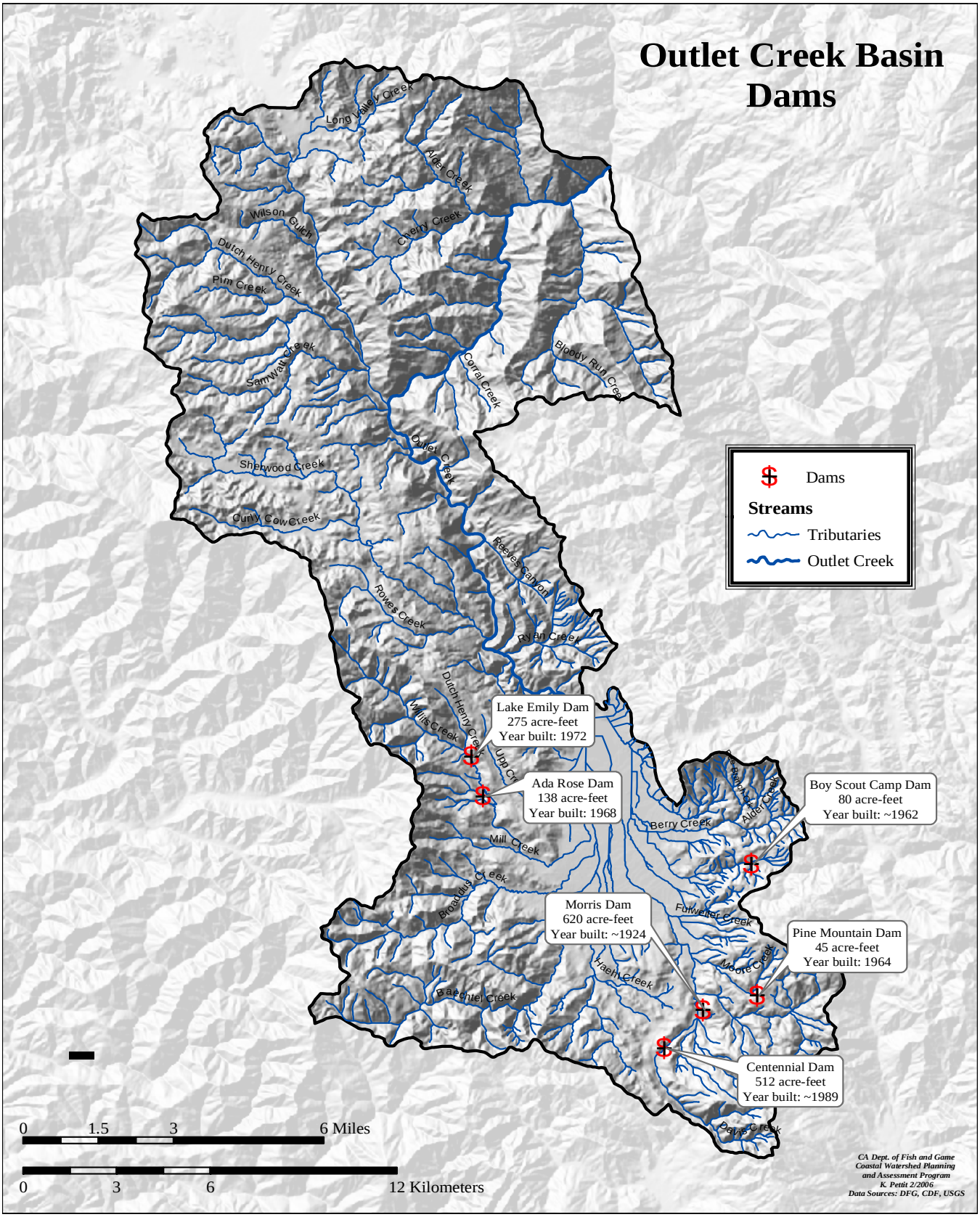

Figure X. Known dams in the Outlet Creek Basin.