# SF Eel River Northern Subbasin

## Table of Contents

## Table of Figures

## List of Tables

# Northern Subbasin

## Introduction

The Northern Subbasin of the South Fork (SF) Eel River Basin is the smallest of the three subbasins, covering an area of 149 square miles, or 22% of the total basin area (*Table 1*). This subbasin includes the drainage area south of the South Fork Eel River from its confluence with the Eel River (RM 0) to the confluence with Ohman Creek (RM 22.9) and is located entirely in Humboldt County. The subbasin includes 23 miles of the SF Eel River mainstem and 190 miles of tributary stream (116 miles of perennial or blue line stream, and 74 miles of intermittent stream). The largest towns in the subbasin, located along the mainstem SF Eel River, are Weott, Myer's Flat, Miranda, and Phillipsville.

Most of the land in the northern part of the subbasin is owned by the CA State Parks, and in the southern and eastern parts of the subbasin, the primary land uses are residential and timber production. The dominant vegetation type is mixed conifer and hardwood forest (*Figure 1*).

This Subbasin is characterized by a forested landscape of rugged, steep, sharp-crested ridges and narrow stream valleys. Stream elevations range from approximately 85 feet at the confluence to approximately 3,200 feet in the headwaters of the tributaries. The climate is dominated by the coastal marine layer, giving this area mild, foggy summers and wet winters.

Large tributaries with documented salmonid distribution in this subbasin include the Bull Creek drainage in the north and the Salmon Creek drainage in the south. Coho and Chinook salmon, and steelhead trout have been documented in Northern Subbasin streams.

General attributes of this subbasin are listed in *Table 1*. *Figure 2* is a map of the Northern Subbasin location in relation to other subbasins within the SF Eel River watershed.

*Table 1. Attributes of the SF Eel River Northern Subbasin.*

| | |
|---|---|
| Area (square miles) | 149 |
| Privately Owned (square miles) | 71 |
| Publicly Owned (square miles) | 78 |
| Principal Land Use | Open space/parks |
| Primary Vegetation Type | Mixed conifer and hardwood forest |
| Mainstem Miles | 22.9 (RM 0-22.9) |
| Tributary Miles | 190 |
| Total Stream Miles | 213 |
| Low Elevation (feet) | 85 |
| High Elevation (feet) | 3,200 |

*Figure 1. Canoe Creek, flowing through mixed conifer and hardwood forest in Humboldt Redwoods State Park, located in the SF Eel River Northern Subbasin.*


*Figure 2. South Fork Eel River and Northern, Eastern, and Western Subbasins.*

## Hydrology

The Northern Subbasin is made up of eight CalWater Units: North Fork Bull Creek, Upper Bull Creek, Decker Creek, Canoe Creek, Elk Creek, Headwaters Salmon Creek, South Fork Salmon Creek, and Ohman Creek (*Figure 3*). There are 46 named and 62 unnamed tributaries with more than 130 perennial and 75 intermittent stream miles in this subbasin (*Figure 4*). The mainstem SF Eel River is a fifth order stream using the Strahler (1964) classification, and the tributaries are first through fourth order streams. Stream drainage areas in this subbasin range from less than one square mile to 42 square miles (*Table 2*). Bull Creek is the largest tributary to the SF Eel River in the Northern Subbasin with a drainage area of approximately 42 square miles and a stream length of 15 miles. Salmon Creek, in the southern part of the subbasin, is the second largest tributary, with a drainage area of 37 square miles and a stream length of almost 13 miles.

The Northern Subbasin has the highest amount of average annual precipitation in the South Fork Eel River basin, ranging from 60 inches near Miranda and Phillipsville to 115 inches in the headwaters of the Bull Creek drainage. Approximately 70 percent of this precipitation occurs from November to March and generates significant runoff during this five month period.

Other hydrologic attributes of the Northern Subbasin include:

- A drainage area of 149 square miles.
- More than 110 mapped streams.
- 213 miles of stream (133 perennial and 75 intermittent);
- The highest peak flow of 199,000 cubic feet per second (cfs) was recorded at the USGS gage in Miranda during the flood of 1964;
- The lowest peak flow recorded at the same station was in 1977 at 2,260 cfs;
- The highest average annual flow of 7,300 cfs was recorded in 1981;
- The lowest average annual flow was in 1977 at 563 cfs.

Two USGS stream gages currently capture information in the Northern Subbasin. The gauge at Miranda is located in the mainstem SF Eel River at RM 17, and is fed by all streams in the SF Eel River Basin upstream from this point (78% of the total SF Eel River drainage area, or 537.5 square miles). The gauge in the Bull Creek drainage, located approximately 5 miles upstream from the confluence of the SF Eel River, is fed by a much smaller drainage area (28.1 square miles), so discharge is much lower (*Figure 5*). Data were available at the Miranda gauge from 1940-2010, and were available in Bull Creek from 1961-2010. Although average annual discharge was considerably higher for the Miranda gauge due to the much larger drainage area, discharge patterns were similar at the two locations, with extremely low flows in 1977 (10 cfs at Bull Creek and 156 cfs at Miranda), and peak flows in 1983 (287 cfs at Bull Creek and 4393 cfs at Miranda) and in 1974 (249 cfs at Bull Creek and 3,929 cfs at Miranda). Peak flows at these locations occurred during the 1964 flood, with recordings of nearly 200,000 cfs at Miranda and 6,520 cfs at the Bull Creek gauge.

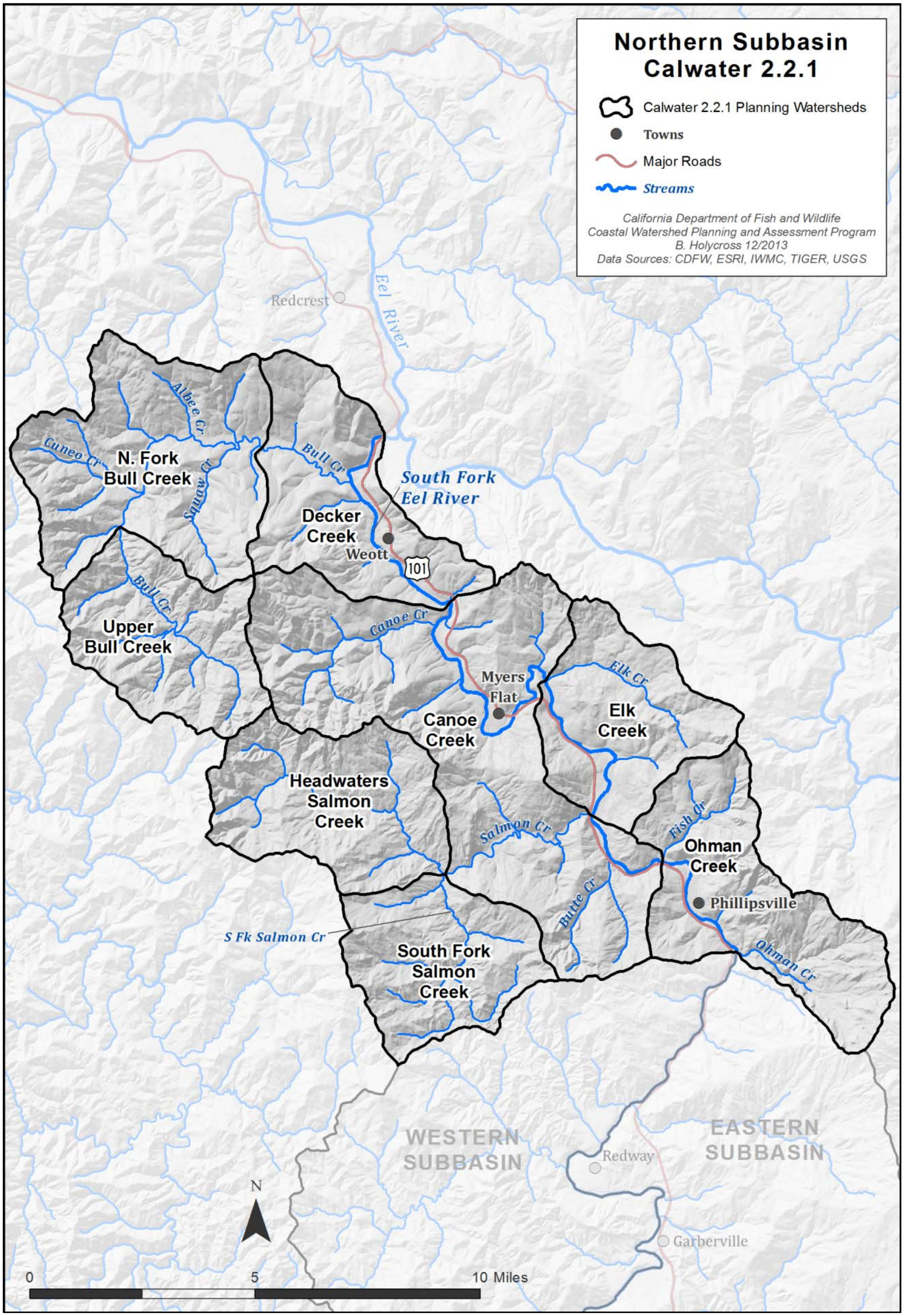


*Figure 3. Calwater planning watersheds in the SF Eel River Northern Subbasin.*

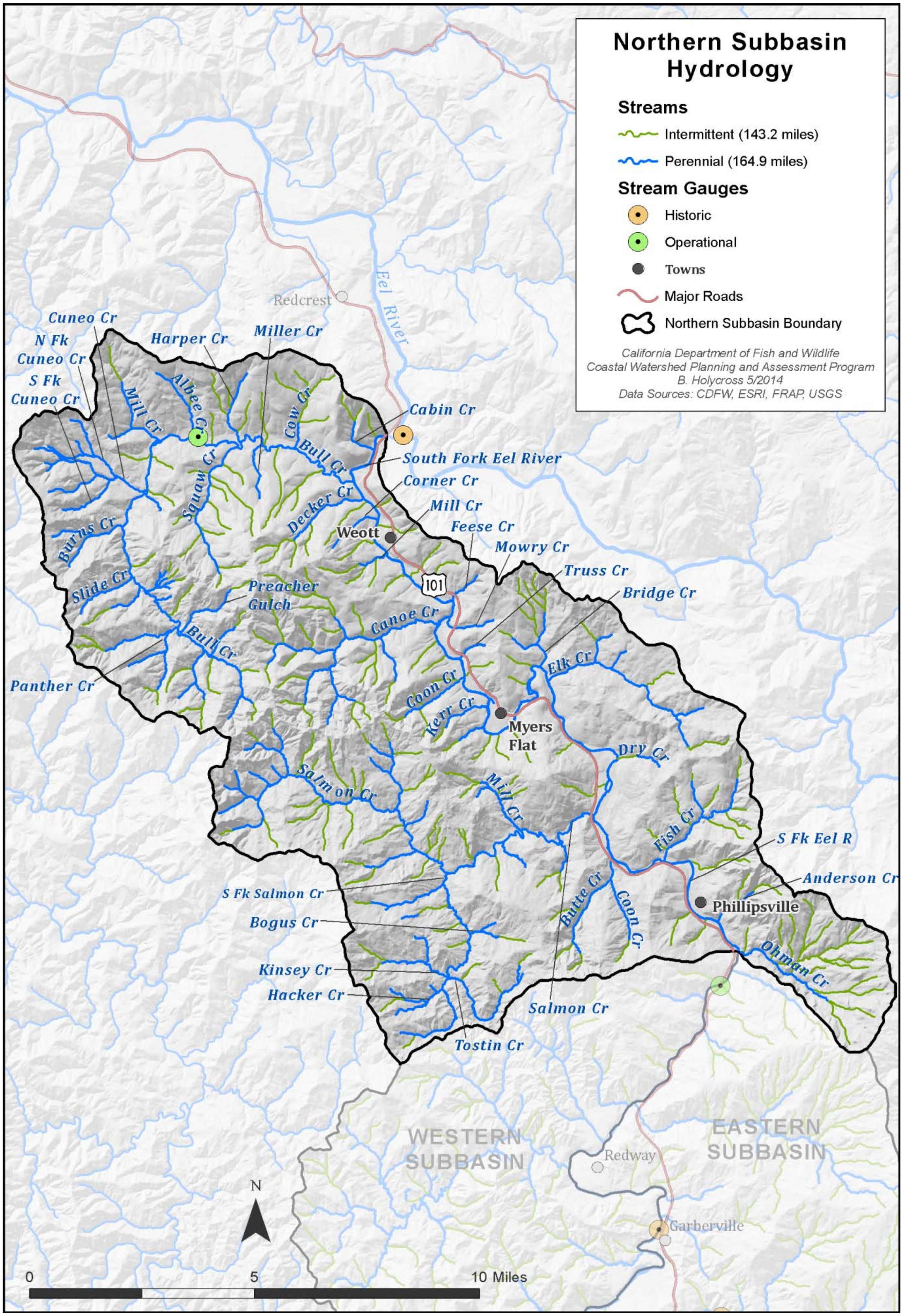


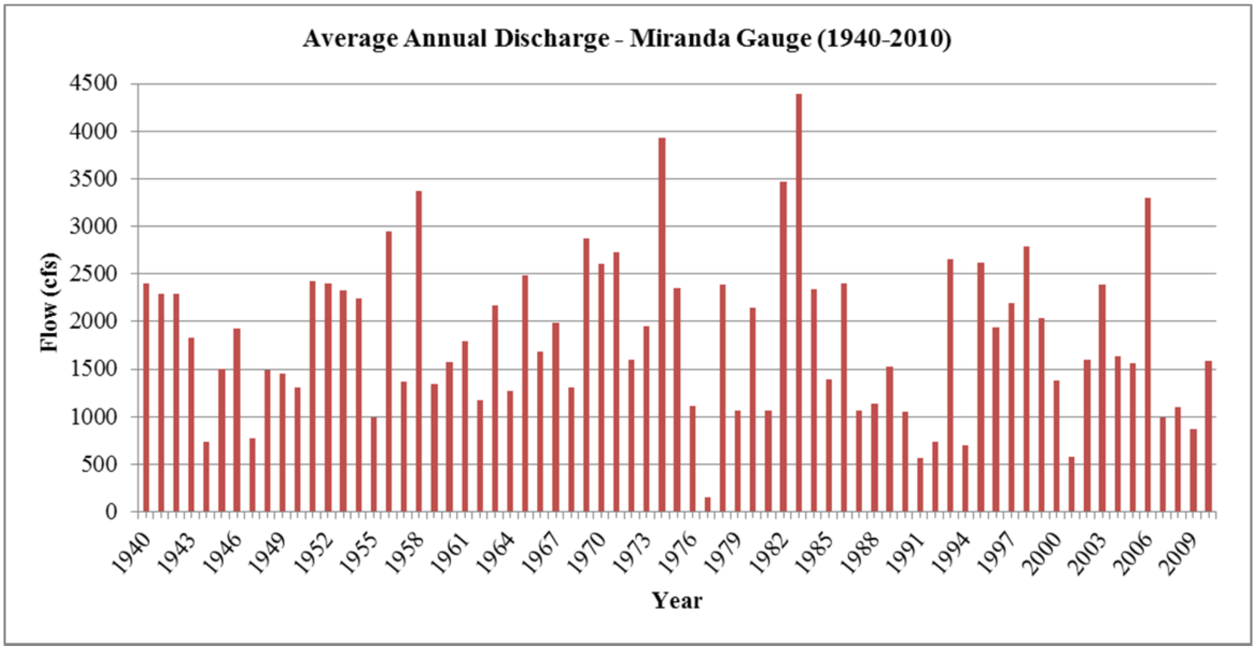

*Figure 4. SF Eel River Northern Subbasin streams.*

*Table 2. Northern Subbasin tributaries and statistics (int. = intermittent stream).*

| Stream | Tributary to: | Length (miles) | Perennial miles | Intermittent miles | Drainage Area miles$^2$ | Stream order |
|---|---|---|---|---|---|---|
| S.F. Eel River | Eel River | 22.9 | 22.9 | 0.0 | 149.0 | 5 |
| LB trib | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.4 | int. |
| LB trib | S.F. Eel River | 0.6 | 0.0 | 0.6 | 0.5 | int. |
| Cabin Creek | S.F. Eel River | 1.7 | 1.0 | 0.7 | 0.7 | 1 |
| Bull Creek | S.F. Eel River | 15.2 | 14.7 | 0.4 | 41.5 | 4 |
| Tepee Creek | Bull Creek | 1.6 | 0.0 | 1.6 | 0.8 | int. |
| Cow Creek | Bull Creek | 2.1 | 0.7 | 1.4 | 2.3 | 1 |
| Connick Creek | Bull Creek | 2.0 | 0.0 | 2.0 | 2.6 | int. |
| Calf Creek | Bull Creek | 1.3 | 0.0 | 1.3 | 0.5 | int. |
| Miller Creek | Bull Creek | 1.4 | 1.4 | 0.0 | 0.6 | 1 |
| Harper Creek | Bull Creek | 1.8 | 1.8 | 0.0 | 1.6 | 1 |
| Squaw Creek | Bull Creek | 3.9 | 3.5 | 0.4 | 4.7 | 1 |
| Golpher Creek | Bull Creek | 0.8 | 0.0 | 0.8 | 0.2 | int. |
| Albee Creek | Bull Creek | 1.8 | 1.8 | 0.0 | 1.3 | 1 |
| Mill Creek | Bull Creek | 2.7 | 0.9 | 1.8 | 3.0 | 2 |
| RB trib | Bull Creek | 0.8 | 0.0 | 0.8 | 0.3 | int. |
| Cuneo Creek | Bull Creek | 3.0 | 3.0 | 0.0 | 4.4 | 3 |
| North Fork Cuneo Creek | Cuneo Creek | 1.9 | 1.9 | 0.0 | 1.7 | 2 |
| South Fork Cuneo Creek | Cuneo Creek | 1.4 | 1.4 | 0.0 | 0.7 | 1 |
| RB trib | Bull Creek | 0.6 | 0.6 | 0.0 | 0.4 | 1 |
| Burns Creek | Bull Creek | 1.7 | 1.7 | 0.0 | 1.8 | 2 |
| RB trib | Bull Creek | 0.7 | 0.0 | 0.7 | 0.1 | int. |
| Slide Creek | Bull Creek | 1.6 | 1.6 | 0.0 | 1.2 | 1 |
| LB trib | Bull Creek | 1.7 | 1.0 | 0.8 | 0.7 | 1 |
| RB trib | Bull Creek | 0.9 | 0.8 | 0.1 | 0.5 | 3 |
| RB trib | Bull Creek | 0.4 | 0.4 | 0.0 | 0.1 | 1 |
| RB trib | Bull Creek | 1.0 | 0.0 | 1.0 | 0.3 | int. |
| Panther Creek | Bull Creek | 1.5 | 1.5 | 0.0 | 3.2 | 2 |
| LB trib | Panther Creek | 2.5 | 1.7 | 0.8 | 1.6 | 1 |
| RB trib | Panther Creek | 1.3 | 1.0 | 0.3 | 1.1 | 1 |
| Preacher Gulch | Bull Creek | 2.3 | 1.8 | 0.6 | 0.9 | 1 |
| LB trib | Bull Creek | 1.4 | 1.4 | 0.0 | 0.3 | 1 |
| RB trib | Bull Creek | 1.5 | 1.0 | 0.5 | 0.6 | 1 |
| LB trib | Bull Creek | 1.0 | 0.0 | 1.0 | 0.3 | int. |
| RB trib | Bull Creek | 0.5 | 0.0 | 0.5 | 0.2 | int. |
| LB trib | Bull Creek | 0.6 | 0.6 | 0.0 | 0.5 | 1 |
| Decker Creek | S.F. Eel River | 3.1 | 2.0 | 1.1 | 7.0 | 1 |
| LB trib | S.F. Eel River | 1.4 | 0.0 | 1.4 | 0.2 | int. |
| RB trib | S.F. Eel River | 0.5 | 0.0 | 0.5 | 0.0 | int. |
| Corner Creek | S.F. Eel River | 1.3 | 1.3 | 0.0 | 0.3 | 1 |
| LB trib | S.F. Eel River | 1.0 | 0.0 | 1.0 | 0.3 | int. |
| Mill Creek | S.F. Eel River | 1.8 | 0.8 | 1.0 | 2.4 | 1 |
| LB trib | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.3 | int. |
| Robinson Creek | S.F. Eel River | 1.1 | 0.0 | 1.1 | 0.5 | int. |
| RB trib | S.F. Eel River | 1.1 | 0.0 | 1.1 | 2.4 | int. |
| Feese Creek | S.F. Eel River | 0.9 | 0.9 | 0.0 | 0.8 | 1 |
| Mowry Creek | S.F. Eel River | 1.3 | 1.3 | 0.0 | 0.8 | 1 |
| Canoe Creek | S.F. Eel River | 5.1 | 4.5 | 0.6 | 10.6 | 2 |
| North Fork Canoe Creek | Canoe Creek | 2.7 | 2.1 | 0.6 | 1.9 | 1 |
| RB trib | S.F. Eel River | 0.9 | 0.0 | 0.9 | 0.2 | int. |
| RB trib | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| LB trib | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.1 | int. |
| Truss Creek | S.F. Eel River | 0.8 | 0.0 | 0.8 | 0.4 | int. |

| Stream | Tributary to: | Length (miles) | Perennial miles | Intermittent miles | Drainage Area miles² | Stream order |
|---|---|---|---|---|---|---|
| RB trib | S.F. Eel River | 0.8 | 0.0 | 0.8 | 0.2 | int. |
| Coon Creek | S.F. Eel River | 2.2 | 0.0 | 2.2 | 1.7 | 1 |
| Kerr Creek | S.F. Eel River | 1.7 | 0.0 | 1.7 | 0.5 | 1 |
| LB trib | S.F. Eel River | 1.1 | 0.5 | 0.7 | 0.5 | int. |
| LB trib | S.F. Eel River | 0.8 | 0.0 | 0.8 | 0.5 | int. |
| LB trib | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| LB trib | S.F. Eel River | 1.0 | 0.0 | 1.0 | 0.5 | int. |
| RB trib | S.F. Eel River | 0.5 | 0.0 | 0.5 | 0.2 | int. |
| RB trib | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| Bridge Creek | S.F. Eel River | 2.5 | 1.7 | 0.7 | 2.7 | 1 |
| Elk Creek | S.F. Eel River | 5.6 | 4.6 | 0.9 | 6.7 | 2 |
| RB trib | S.F. Eel River | 0.5 | 0.0 | 0.5 | 0.2 | int. |
| Dry Creek | S.F. Eel River | 1.1 | 0.0 | 1.1 | 1.3 | int. |
| LB trib | S.F. Eel River | 1.3 | 0.0 | 1.3 | 0.3 | int. |
| Salmon Creek | S.F. Eel River | 12.8 | 12.1 | 0.8 | 36.9 | 4 |
| RB trib | Salmon Creek | 1.4 | 0.8 | 0.7 | 1.4 | 1 |
| Mill Creek | Salmon Creek | 2.5 | 0.9 | 1.6 | 2.0 | 2 |
| RB trib | Salmon Creek | 0.9 | 0.9 | 0.0 | 1.9 | 1 |
| RB trib | Salmon Creek | 0.6 | 0.0 | 0.6 | 0.4 | int. |
| LB trib | Salmon Creek | 0.9 | 0.0 | 0.9 | 0.4 | int. |
| South Fork Salmon Creek | Salmon Creek | 6.1 | 5.6 | 0.5 | 12.5 | 3 |
| LB trib | S.F. Salmon Creek | 0.7 | 0.0 | 0.7 | 1.5 | int. |
| Bogus Creek | S.F. Salmon Creek | 1.3 | 0.6 | 0.7 | 1.5 | 1 |
| LB trib | S.F. Salmon Creek | 0.5 | 0.0 | 0.5 | 0.1 | int. |
| Kinsey Creek | S.F. Salmon Creek | 2.4 | 1.7 | 0.8 | 2.5 | 2 |
| Tostin Creek | S.F. Salmon Creek | 3.7 | 3.2 | 0.4 | 2.3 | 2 |
| Hacker Creek | S.F. Salmon Creek | 1.4 | 1.4 | 0.0 | 1.3 | 2 |
| RB trib | S.F. Salmon Creek | 0.4 | 0.0 | 0.4 | 0.3 | int. |
| LB trib | Salmon Creek | 0.6 | 0.0 | 0.6 | 0.1 | int. |
| RB trib | Salmon Creek | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| LB trib | Salmon Creek | 1.1 | 0.0 | 1.1 | 0.3 | int. |
| RB trib | Salmon Creek | 1.8 | 1.3 | 0.5 | 1.4 | 1 |
| LB trib | Salmon Creek | 0.9 | 0.9 | 0.0 | 0.3 | 1 |
| RB trib | Salmon Creek | 1.1 | 0.0 | 1.1 | 0.3 | int. |
| LB trib | Salmon Creek | 2.2 | 1.7 | 0.5 | 2.4 | 2 |
| LB trib | Salmon Creek | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| LB trib | Salmon Creek | 1.6 | 0.0 | 1.6 | 0.8 | int. |
| RB trib | Salmon Creek | 1.2 | 0.0 | 1.2 | 0.4 | int. |
| RB trib | Salmon Creek | 1.1 | 0.0 | 1.1 | 0.9 | int. |
| RB trib | Salmon Creek | 1.1 | 0.0 | 1.1 | 0.3 | int. |
| RB trib | Salmon Creek | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| LB trib | Salmon Creek | 0.6 | 0.0 | 0.6 | 0.2 | int. |
| LB trib | Salmon Creek | 1.2 | 0.0 | 1.2 | 0.4 | int. |
| LB trib | Salmon Creek | 1.6 | 1.2 | 0.4 | 1.4 | 2 |
| LB trib | Salmon Creek | 0.4 | 0.4 | 0.0 | 0.2 | 1 |
| LB trib | Salmon Creek | 0.6 | 0.6 | 0.0 | 0.3 | 1 |
| LB trib | Salmon Creek | 1.0 | 1.0 | 0.0 | 0.9 | 2 |
| RB trib | Salmon Creek | 0.8 | 0.0 | 0.8 | 0.3 | int. |
| Butte Creek | S.F. Eel River | 3.2 | 2.7 | 0.5 | 4.6 | 2 |
| Coon Creek | Butte Creek | 2.1 | 0.0 | 2.1 | 1.9 | 1 |
| Fish Creek | S.F. Eel River | 3.4 | 2.9 | 0.5 | 4.5 | 2 |
| RB trib | S.F. Eel River | 1.6 | 0.0 | 1.6 | 0.9 | int. |
| LB trib | S.F. Eel River | 1.0 | 0.0 | 1.0 | 0.8 | int. |
| LB trib | S.F. Eel River | 0.8 | 0.0 | 0.8 | 0.5 | int. |

| Stream | Tributary to: | Length (miles) | Perennial miles | Intermittent miles | Drainage Area $miles^2$ | Stream order |
|---|---|---|---|---|---|---|
| Anderson Creek | S.F. Eel River | 1.9 | 1.9 | 0.0 | 4.3 | 1 |
| Ohman Creek | S.F. Eel River | 3.8 | 2.7 | 1.1 | 7.2 | 1 |



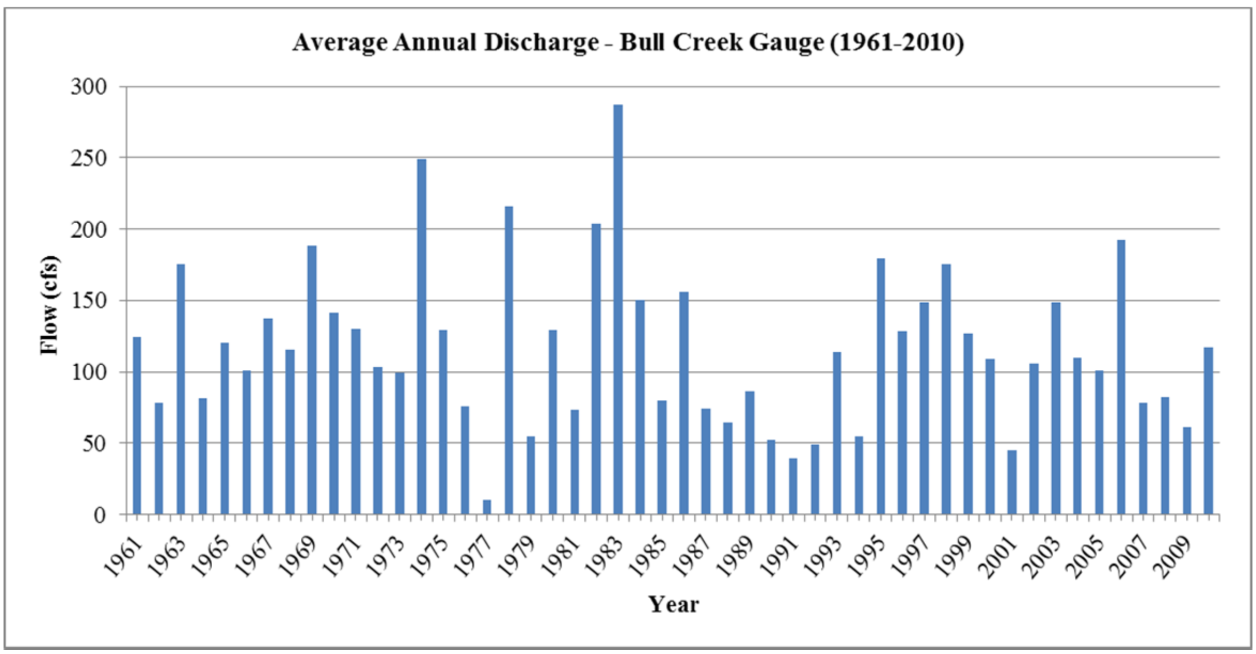




*Figure 5. Average annual discharge at the Miranda (top) and Bull Creek (bottom) gauges, located in the SF Eel River Northern Subbasin.*

## Floods

Large floods occur nearly every decade and typify the storm flows of the South Fork Eel River Basin (*Table 3*). The most infamous floods in recent memory occurred in 1955 and 1964. The effect of these floods on the watershed was exacerbated by extensive logging due to the advent of post-WWII tractor technology, historical changes in local vegetation, and prior seismic events that further destabilized the hillslopes. The extensive road network also disrupts natural runoff rates and routes. The 1964 flood also involved a large accumulation of snow in the higher elevations that was melted by a warm storm with sustained, heavy rains. Landslides and resulting sedimentation of the streams were unprecedented - these floods washed away whole towns, reset river patterns, and changed stream morphology for decades. In some cases the lingering effects are still apparent upon the landscape. In the Northern Subbasin the towns of Dyerville, Bull Creek, Weott, Myers Flat, and Phillipsville were severely damaged or completely destroyed. The 1955 flood had a peak flow (at Miranda) of 173 thousand cubic feet per second, and exceeded 22 million dollars in damages, flooded 43,000 acres, and killed at least one person in the Eel River Basin. The 1964 flood had a peak flow (at Miranda) of 199 thousand cubic feet per second, exceeded 100 million dollars in damages, and killed at least 19 people in the Mad and Eel River watersheds (Dyett and Bhatia 2002).

*Table 3. Flood dates and discharges at USGS Miranda gauge.*

| **Humboldt County Floods – Miranda Gage** ***(italicized discharge is approximated by extrapolation from the Scotia gage)*** | |
|---|---|
| **Year** | **Discharge, cfs** |
| *Jan 22, 1914* | *97,300* |
| *Feb 2, 1915* | *112,300* |
| *Feb 25, 1917* | *90,500* |
| *Dec 11, 1937* | *117,300* |
| *Feb 28, 1940* | *91,500* |
| Dec. 22, 1955 | 173,000 |
| Feb 8, 1960 | 117,000 |
| Dec. 23, 1964 | 199,000 |
| Jan 4, 1966 | 107,000 |
| Jan 16, 1974 | 122,000 |
| Dec 19, 1981 | 123,000 |
| Feb 17, 1986 | 123,000 |
| Source: USGS Gage 11476500 | |

The Northern Subbasin's stream canyon topography is typified by narrow flood zones that cause rapid inundation of streamside towns and features such as Weott, Myers Flat, Miranda, Phillipsville, and the Avenue of the Giants (Humboldt Co. 2012). During events that cause large amounts of sediment to enter creeks, or in tributaries that are heavily diverted, streams that have historically been perennial may become intermittent.

## Dams, Diversions, and Hydrologic Disturbances

There are presently no functioning, legal, man-made dams on the streams of the Northern Subbasin. There are some legal water right diversions within this subbasin and as with most watersheds in Humboldt County there are a significant number of illegal water diversions associated with residences, ranches, and industrial marijuana agricultural practices that remove water from the streams, especially during the dry times of the year.

The towns of Weott, Myer's Flat, Miranda, and Phillipsville have all been developed along the SF Eel River and use water extracted from the river, its tributaries, or shallow groundwater wells that draw from "surface water underflow" (water that has permeated through the soil layer into the weathered bedrock layer on top of the coherent bedrock). This water provides dry season base flow to the streams.

Reaches flowing through towns have often been modified to accommodate development. Modifications include bank armoring, construction of stream crossings such as culverts and bridges, and channelization. These modifications often decrease or eliminate natural stream floodplains. This can increase the volume and velocity of flows during the rainy season. Increases in impervious cover (parking lots, roads, and buildings) associated with development can increase runoff to streams and aggravate flooding problems (http://www.coastal.ca.gov/nps/watercyclefacts.pdf).

There are small remote residences, ranches, and agricultural areas scattered throughout the Northern Subbasin, in areas that are not owned by large timber companies or the CA State Parks. These residences and agricultural operations depend on water extracted from private wells or diverted directly from springs or creeks, which affects the overall subbasin hydrology.

No drainage issues were noted in any of the towns within the Northern Subbasin in the 2012 Humboldt

County General Plan and no specific drainage plans were made. However, the following applicable policies were developed:

- Natural drainage courses, including ephemeral streams, shall be retained and protected from development impacts which would alter the natural drainage courses, increase erosion or sedimentation, or have a significant adverse effect on flow rates or water quality. Natural vegetation within riparian and wetland protection zones shall be maintained to preserve natural drainage characteristics consistent with the Biological Resource policies. Storm water discharges from outfalls, culverts, gutters, and other drainage control facilities that discharge into natural drainage courses shall be dissipated so that they make no significant contribution to additional erosion and, where feasible, are filtered and cleaned of pollutants;
- Peak downstream storm-water discharge shall not exceed the capacity limits of off-site drainage systems or cause downstream erosion, flooding, habitat destruction, or impacts to wetlands and riparian areas. New development shall demonstrate that post-development peak flow discharges will mimic natural flows to watercourses and avoid impacts to Beneficial Uses of Water;
- Drainage design standards for new development shall be adopted by ordinance. The design standards shall ensure that storms of specified intensity, frequency, and duration can be accommodated by engineered drainage systems and natural drainage courses;
- Create storm drainage development guidelines with incentives to encourage low-impact development standards to reduce the quantity and increase the quality of storm-water runoff from new developments. Formulate and require the use of Low-Impact Development (LID) standards to reduce the quantity and increase the quality of storm-water runoff from new developments in watersheds with known significant cumulative impacts from storm-water runoff. For all other watersheds, design storm drainage development guidelines with incentives to encourage Low-Impact Development (LID) standards to reduce the quantity and increase the quality of storm-water runoff from new developments;
- Minimize chemical pollutants in storm-water runoff such as pesticides, fertilizers, household hazardous wastes, and road oil by supporting education programs, household hazardous waste and used oil collection, street and parking lot cleaning and maintenance, use of bio-swales and other urban storm-water best management practices described in the California Storm-water Best Management Practices Handbooks or their equivalent;
- Work with federal and state agencies and local watershed restoration groups to retrofit existing drainage and flood control structures and design new structures to facilitate fish and other wildlife passage in partnership with these agencies;
- Ministerial and discretionary development in Critical Water Supply or Watershed Areas where maintenance of groundwater recharge is determined to be necessary to maintain sustainable groundwater demands or surface water flows shall maintain or increase the site's pre-development absorption to recharge groundwater or be conditioned to reduce effects to water supplies to below levels of significance;
- The design, construction, and maintenance of County roads, bridges, drainages, and other facilities shall minimize stormwater runoff erosion and discharge of sediments and other pollution by following best management practices in accordance with the Five County Water Quality and Stream Habitat Protection Manual for County Road Maintenance in Northwestern California Watersheds (5Cs Manual 2002) or its equivalent;
- Development within stream channels may be approved where consistent with Policy BR-P4, and is limited to the following projects:
    - A. Fishery, wildlife, and aquaculture enhancement and restoration projects;
    - B. Road crossings consistent with Standard BR-S9 - Erosion Control;
    - C. Flood control and drainage channels, levees, dikes, and floodgates;
    - D. Mineral extraction consistent with other County regulations;
    - E. Small-scale hydroelectric power plants in compliance with applicable

County regulations and those of other agencies;

F. Wells and spring boxes, and agricultural diversions;

G. New fencing, provided it does not impede the natural drainage or wildlife movement and does not adversely affect the stream environment or wildlife movement;

H. Bank protection, provided it is the least environmentally damaging alternative; and

I. Other essential projects, including municipal groundwater pumping stations, provided they are the least environmentally damaging alternative, or necessary for the protection of the public's health and safety.

# Geology

## Bedrock

The Northern Subbasin is composed of metamorphic, marine sedimentary and igneous rock types of the Franciscan Complex and their associated overlap assemblage of sediments and sedimentary rock types. The Northern Subbasin is made up of predominantly the Yager Terrane of the Coastal Belt, but also consists of some areas of the juxtaposed Central Belt. Descriptions of bedrock, including composition, depositional history, landscape morphology, strength, and erosional characteristics of each rock type represented on the geology map (*Figure 6*) will be briefly discussed below in order of their abundance within the subbasin. *Table 4* contains a brief summary of Northern Subbasin geology types and their attributes.

### The Yager Terrane

Folded and faulted interbedded layers of well consolidated sandstone, argillite, and in some places pebble conglomerate of the Yager Terrane of the Coastal Belt dominate the geologic landscape of this subbasin.

This terrane, named by Burdette Ogle in the early 1950s because of its excellent exposure along Yager Creek in the Van Duzen River drainage, makes up 68% of this subbasin. It is considered a tectonostratigraphic terrane because it has been faulted into its current location by tectonic processes as part of the accretionary wedge and contains a stratigraphic history of deposition, age, and metamorphic grade that set it apart from neighboring terranes.

Sediments of the Yager Terrane were originally deposited between 65 and 34 million years ago and transported by rivers from as far away as Idaho (Underwood and Bachman 1986) and accumulated along the continental shelf to the deep ocean floor. The accumulation of sediment that makes up the Yager Terrane is more than 10,000 feet thick in places (Ogle 1953). The sequence of interbedded argillite and sandstone represents marine deposition of sediments during calm periods, punctuated by large underwater landslide events. These subaqueous landslides were likely triggered by large seismic events, tsunamis, storm wave loading, and sediment loading (Goldfinger et al. 2003) attesting to the abundant seismic activity in this region.

The Yager Terrane forms steep, sharp-crested ridges and associated valleys that give the landscape a steep and rugged appearance. The relative stability of the Yager Terrane results in the development of soils that typically support lush forest growth.

The Yager Terrane is relatively stable; however, it has many areas where it is faulted and/or sheared, which typically causes zones of weakness within the bedrock that are prone to large-scale landsliding. Furthermore, the argillaceous interbeds of the Yager Terrane tend to crumble when exposed to water and air, and undercutting of the stream bank along bedrock reaches and movement along bedding planes may result in translational landslides. Excessive crumbling of argillite can also be a source of fine sediment input into streams. The beds of the Yager Terrane are tilted by folding and faulting of this region. In areas where the dip of the beds inclines with the hillslope into the stream valley, large translational block landslides are more likely to occur. Yager Terrane is especially prone to debris sliding on steep stream banks (Kelsey and Allwardt 1975).

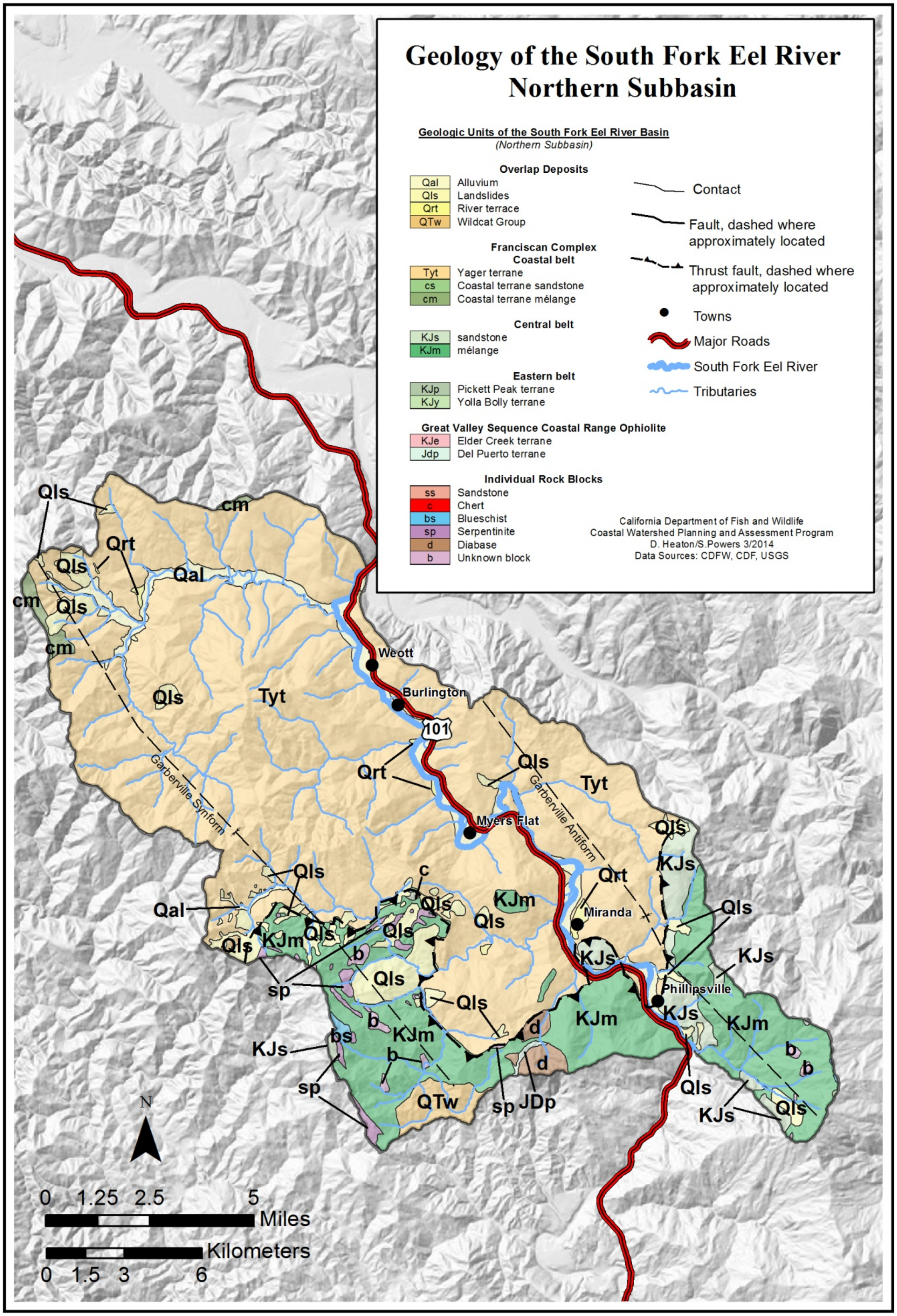



*Figure 6. Geologic map of the Northern Subbasin.*

*Table 4. Geologic formations and unit descriptions in the SF Eel River Northern Subbasin (ma = millions of years before the present).*

| Unit | Belt/Rock Type | Formation / Terrane | Composition | Morphology/Erosion | Age (ma) | % Sub-basin Area |
|---|---|---|---|---|---|---|
| **Overlap Deposits** | Alluvium | | Unconsolidated river deposits of boulders, gravel, sand, silt, and clay. | Flat to gently sloping, bare, river banks, beds, and floodplains. Raveling of steep slopes. Sediment trnasport by fluvial and aeolian processes. | 0-0.01 | 4.2 |
| | Landslide | | Large, disrupted, clay to boulder debris and broken rock masses. | Rumpled, disordered hillslopes. Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare. | 0.01-2 | 5.2 |
| | River Terrace | | Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel. | Flat to gently sloping, vegetated, uplifted terrace benches bordering streams. Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes, gullying, debris slides, small earthflows. | 0.01-2 | 0.3 |
| | Wildcat Group | Carlotta Formation | Partially indurated, nonmarine conglomerate, sandstone, and clay. Minor lenses of marine siltstone and clay. | Steep slopes/cliffs and prominent "Flat Irons". Shallow landslides, debris slides, and block slides along inward dipping bedding planes. Toppling along joints. Some rock-falls and ravel. | 0.78-1.8 | 1.2 |
| | | Scotia Bluffs Sandstone | Shallow marine sandstone and conglomerate. | Steep slopes/cliffs. Friable, typically fails in numerous small debris slides. | 1.8-3.6 | |
| | | Rio Dell Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes/cliffs. The Rio Dell Formation is one of the most susceptible to landsliding. Especially in zones between mudstone and sandstone beds with inward dip during saturation. | 1.8-3.6 | |
| | | Eel River Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes/cliffs. Debris slides/flows, slaking. | 3.6-5.3 | |
| | | Pullen Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes, forested and highly dissected with sharp ridge crests and V-shaped canyons. Debris slides/flows, rotational slides, slumps, slaking. | 5.3-11.6 | |
| **Franciscan Complex** | Coastal Belt | Coastal Terrane | Slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate, and mélange with limestone lenses, and exotic blocks of rock. | Tends to form forested, sharp-crested ridges with well-incised sidehill drainage; susceptible to debris sliding especially upon steep stream banks. Mélange of the Coastal Terrane tends to form oak and grassland, rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows and secondary debris flows. | 1.8-99.6 | 0.5 |
| | | Yager Terrane | Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate. | Steep, straight, forested slopes, sharp ridge crests, V-shaped canyons. Prone to debris slides along stream banks. Translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers. | 33.9-65.5 | 67.6 |
| | Central Belt | Sandstone | Large blocks of metasandstone and | Forms forested, moderate to steep, straight to convex slopes, sharp ridge crests, and V- | 65.5-161.2 | 2.7 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | metagraywake, interbedded with meta-argillite. | shaped canyons. Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages. | | |
| | | Mélange | Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, metachert. | Oak and grassland, rolling, hummocky terrain. Boulders protrude from surrounding mélange forming knockers. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation. | 1.8-65.5 | 16.3 |
| | Eastern Belt | Yolla Bolly Terrane | Metagraywacke, argillite, and conglomerate with minor metachert and metavolcanic rocks. | Develops sharp-crested, forested ridges generally with V-shaped canyons. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation. | 99.6-199.6 | 0.01 |
| | | | Mélange – sheared matrix of argillite, sandstone, and conglomerate with blocks of greenstone, metachert, and metagreywacke. | Rolling, hummocky terrain. Boulders protrude from surrounding mélange forming knockers. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation. | | |
| **Great Valley Sequence** | Coast Range Ophiolite | Del Puerto Terrane | Highly sheared mudstone. | Present locally in the southwestern part of the subbasin. | 161.2-145.5 | 0.1 |
| | | | Dismembered Ophiolite: chert, basalt, diabase, serpentinite mélange, gabbro, and peridotite. | Correlated with a more extensive ophiolite 300 km to southeast, in the Del Puerto Canyon area near San Jose, California and forms Bear Buttes, approximately 6 miles northwest of Garberville. | 145.5-175.6 | |
| Sources: Kilbourne, 1985, Ogle, 1953, McLaughlin, 2000, Kelsey and Allwardt 1975, Kilbourne 1985. | | | | | | |

## Central Belt Mélange

Mélange (French for "mixture") of the Central Belt of the Franciscan Complex is the second most abundant rock type within this subbasin, making up approximately 16% of its aerial extent. Mélange can be described as a completely sheared matrix of argillite and sandstone containing very small (gravel sized) to very large (city block sized) mappable, relatively resistant blocks of sandstone, limestone, blueschist, greenstone, serpentinite, and chert.

The mélange of the Central Belt formed from 65.5 through 199.6 million years ago within the subduction trench between the Farallon and North American plates as material from the oceanic crust and its overlying sediments were tectonically mixed with sediments washing off of the continent (Aalto 1981). This mélange was then accreted to the western edge of the continent beginning around 88 million years ago (McLaughlin 2000).

Mélange has undergone such a degree of internal shearing that it has lost much of its internal strength and tends to behave like an extremely viscous liquid, slowly "flowing" over time, mostly in the form of large earthflows. Mélange typically creates a hummocky, rolling landscape with prairies and grasslands occupying the areas of least competence. The Central Belt mélange is considered one of the most unstable rock types in the subbasin and is highly prone to erosion and mass movement, especially when saturated with water and/or disturbed by land use. Mélange is especially prone to earthflows as well as subsequent debris flows.

## Central Belt Sandstone

Sandstone of the Central Belt makes up roughly three percent of the surface of this subbasin. The Central Belt sandstone exists as very large blocks of slightly metamorphosed greywacke ("dirty" sandstone), and argillite (McLaughlin 2000). These blocks most likely formed from 65.5 through 161.2 million years ago as sediment eroded from the continent as far away as Idaho (Underwood and Bachman 1986), washed off the continent, and blanketed the subduction trench between the Farallon and North American plates. Although they have been metamorphosed, folded, and sheared to some extent, they are more coherent than the mélange. The Central Belt sandstone is generally stable, forming forested, sharp-crested ridges and V-cut valleys. It is prone to debris sliding along steep stream banks and in steep headwater drainages (Kelsey and Allwardt 1975).

### Wildcat Group

Relatively young, soft, shallow marine mudstone, siltstone, and sandstone grading upwards through nonmarine sandstone and conglomerate, compose the bedrock of the Wildcat Group which overlaps the Franciscan Complex and makes up around 1% of this subbasin.

The sediments of the Wildcat Group were deposited within the last 11 million years in environments ranging from a deep to shallow seas, to estuaries and river systems. The Wildcat Group was originally divided into five formations by Burdette Ogle in the early 1950s (downstream of the confluence of the SF Eel River). These were the Pullen Formation, Eel River Formation, Rio Dell Formation, Scotia Bluffs sandstone, and Carlotta Formation. These divisions of the Wildcat Group did not, however, carry over into the SF Eel River Basin and are mapped as either "Wildcat undifferentiated" or as "Tertiary marine deposits".

The Wildcat is highly prone to erosion, especially when disturbed by land use. Erosion of the soft, fine-grained, sedimentary rock types of the Wildcat contribute fine sediments to stream channels. While the sediments that make up the Wildcat are considered bedrock, they are quite loosely cemented and friable, meaning that the sediment crumbles under light pressure. Landsliding is most common in zones between mudstone and sandstone beds with inward dip, especially during episodes of saturation caused by heavy rain.

Streams within Wildcat bedrock tend to form steep to vertical canyon walls which are prone to undercutting, and subsequent rock falls and translational rock-block sliding.

### Quaternary Landslides

Although not technically bedrock, large landslide features (tens to hundreds of acres) influence landscape and erosion, and may indicate how bedrock and overlying soils may behave over time. Quaternary landslides occupy at least 5% of the subbasin (based on GIS mapping). Landslide deposits are typically a jumble of debris, soil, and underlying bedrock consisting of clay to boulder-size debris and broken rock masses that have moved down slope.

Landslide deposits produce rumpled, jumbled hillslopes and may develop subsequent debris slides and rotational slumps on steep slopes or eroding toes. Surface erosion and gullying is usually prevalent where vegetation has been stripped (McLaughlin 2000).

Landslide deposits are sensitive to land uses such as timber harvest, development, and road construction because the coherency of the slide material has been disrupted. The toes of these landslides are typically eroded by stream channels causing subsequent, prevalent small-scale sliding and bleeding of fine sediments into the river system. If the toes of these large landslides erode far enough, become saturated by heavy seasonal rain, or if there is a large, local seismic event, they may reactivate.

Earthflows typically form in mélange due to its very low shear strength, and are capable of contributing immense amounts of sediment to the streams. Large scale GIS mapping shows only a small percent of the probable extent of landslides within this subbasin. It is estimated, based upon topographic diversity, that approximately 70 percent of the landscape in areas of mélange or extensively sheared zones has likely moved (Ellen et al. 2007).

### Alluvium

Like landslides, alluvium is also not technically bedrock. Alluvium includes any active stream channel sediments as well as unconsolidated bank deposits and floodplain deposits. This deposit type covers just over 4% of this subbasin.

### River Terrace Deposits

River terrace deposits blanket less than 1% of the Northern Subbasin. They consist of unconsolidated through poorly consolidated cobbles, gravels and fine sediments. These terraces were once river-channel and flood-plain deposits, which were subsequently raised during the last 2 million years by regional tectonic uplift above the hundred-year-flood level.

River terrace deposits make up extensive flat areas bordering the stream. Most of the towns (Weott, Myer's Flat, Miranda, and Phillipsville) within this subbasin are built on these terraces due to their gentle topography and proximity to the river.

### Del Puerto Terrane

The Del Puerto Terrane occupies less than 1% of this subbasin. This terrane is associated with an ophiolite complex and its overlying sedimentary rocks about 190 miles away in the Del Puerto Canyon near San Jose, California (McLaughlin et al., 2000).

In the Northern Subbasin the Del Puerto Terrane occurs as blocks of fine through coarse-grained diabase and some gabbro within the Central Belt mélange. This block forms Bear Buttes northwest of Garberville.

Diabase is an intermediate rock between volcanic basalt and plutonic gabbro, which differ in the pressure and time period under which they cooled and solidified from their magmatic state. Gabbro cooled over a long period of time under immense pressure, producing rocks exhibiting large crystals. Diabase cooled over more moderate time scales and pressures nearer the surface, not allowing crystals to grow as much. Basalt cooled very quickly at the surface, allowing only extremely small crystal growth.

### Coastal Terrane

The Coastal Terrane is a division of the Coastal Belt of the Franciscan Complex and consists mainly of slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate. The Coastal Terrane has been folded, faulted, sheared, and shattered, sometimes to such an extent that it is considered mélange: a highly sheared matrix of the former rock types containing limestone lenses and exotic blocks of rock (McLaughlin et al 2000).

The sedimentary sequences (sandstone, argillite, and conglomerate) are interpreted to be turbidites (sedimentary deposits left from sub-aqueous landslides) and other mass-flow type deposits that accumulated in an east-dipping subduction zone along the western margin of North America between 140 and 28 million years ago. In contrast, the limestone units and exotic blocks are interpreted to be the remnants of rocks and sediment that were carried into the trench and faulted into place within the Coastal Terrane sediments.

Sandstone/argillite/conglomerate of the Coastal Terrane tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding, especially on steep stream banks.

Mélange of the Coastal Terrane tends to form a rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows as well as secondary debris flows.

## Faults, Folds, and Shear Zones

The Northern Subbasin is located to the east of the north-northwest trending boundary between the Pacific Plate and North American Plate. At present, most movement between the plates consists of grinding past one another at a rate of approximately 5 centimeters per year. The plate boundary also has a component of compression that causes uplift and the formation of mountain ranges. The plate boundary is not a single or narrow seam, but is better characterized as a region of crustal deformation that is approximately 65 miles wide. The Northern Subbasin lies within this region of deformation and is sandwiched between two of the most active fault rupture zones in north coastal California: the San Andreas that lies just off the coast to the west, and the Maacama Fault Zone that lies several miles to the southeast. Both of these faults are right-lateral strike slip faults and are considered active by the State of California which means they exhibit evidence of displacement within the past 11,000 years. Estimations of the recurrence interval between large seismic events for the northern segment of the San Andreas Fault range from 250–100 years. The Northern Subbasin is underlain by major, mapped, active faults, the Garberville Fault being the most prominent, which makes ground displacement probable within the basin. Strong seismic shaking should be anticipated to occur if the San Andreas, Garberville, or Maacama faults rupture.

A brief description of faults within the Northern subbasin follows, with summary information included in *Table 5*.

*Table 5. Northern Subbasin fault descriptions (M = magnitude; R. Int. = recurrence interval).*

| | Active Faults: | Fault Type | M | R. Int. | Description |
|---|---|---|---|---|---|
| Mendocino Triple Junction | Cascadia Megathrust | Thrust | 8.3-9.2 | 500-600 | The Cascadia Megathrust allows subductive movement of the Gorda Plate beneath the North American Plate. This fault is capable of generating very large earthquakes (~M9) and usually produces uplift or subsidence of the coastal area adjacent to the Van Duzen River Basin. Several prehistoric seismic events that produced significant tsunamis and sudden uplift or subsidence along this area of the coast have been documented. In 1992 an earthquake of magnitude 7.1 (Richter) occurred that uplifted the coast at Cape Mendocino by about five feet. |
| Mendocino Triple Junction | Eastern Mendocino Fracture | Dextral | 6.5 | 17 | This high-angle, east-west trending fault represents the plate boundary between the Gorda and Pacific plates. It generates predominantly right-lateral strike-slip earthquakes. |
| Mendocino Triple Junction | San Andreas Fault (Northern Segment) | Dextral | 7.3-8.3 | 200-300 | The San Andreas fault (Northern segment) is an active dextral fault that runs just off shore, southwest of the Van Duzen River Basin. It is capable of large earthquakes (~M 7) that can significantly affect the basin by seismic shaking, deformation, and their associated mass wasting/erosion effects. Although not well documented within the Van Duzen River Basin, the 1906 northern San Andreas fault seismic event (the San Francisco earthquake) caused significant damage to the surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments. |
| Mendocino Triple Junction | Gorda Plate | Deep-seismic | 7.3 | 50 | This relatively small plate remnant is breaking up as it approaches thesubduction zone. Frequent earthquakes are generated along left-lateral strike-slip faults within the plate itself. The plate is subducting in a northeastward direction. |
| Mendocino Triple Junction | Garberville Fault | Dextral | 6.9 | | Consists of several widely spaced, steeply dipping reverse faults with components of dextral slip. |
| | Briceland Fault | Dextral | 6.9 | 220 | Is associated with the Garberville Fault and consists of several widely spaced, steeply dipping reverse faults with components of dextral slip. |
| | **Inactive Faults:** | **Fault Type** | **M** | **R. Int.** | **Description** |
| | Coastal Belt Thrust (Freshwater Fault) | Thrust | | | The Coastal Belt Thrust Fault is the major fault that juxtaposes the Coastal Belt and the Central Belt. It trends north by northwest through the Van Duzen River Basin. It is most likely the zone which accommodated movement between the subducting Farallon Plate and the North American Plate before accretion of the Coastal Belt when the active subduction moved west to its present location along the Cascadia Megathrust. |
| | Piercy fault | | | | Mapped fault segment near Piercy. |
| Sources: USGS 2011, McLaughlin et al. 2000 | | | | | |

## The Mendocino Triple Junction

The structure of the Northern Subbasin is induced by tectonic forces generated by the Mendocino Triple Junction, which consists of the interaction of the North American, Pacific, and Gorda plates. The movement of these plates has set up three major fault systems that influence the structure and landscape of this subbasin: the San Andreas Fault Zone between the Pacific and North American plates, the Cascadia subduction zone between the North American and the Gorda plates, and the Mendocino Fracture Zone between the Pacific and the Gorda plates. Of these, the convergent plate boundary of the Cascadia Megathrust and the translational plate boundary of the San Andreas Fault Zone are most influential on the tectonic regime within this subbasin.

The Franciscan Complex was accreted to the western edge of the continent by processes related to the subduction of the Farallon Plate in this region during the geologic past. As northward movement of the Pacific Plate brought the San Andreas fault system northward, this region went from being controlled by compression set up by convergence and subduction of the Farallon under the North American plate to transpression and translation between the Pacific and North American plates. Under compression, a series of north-west trending folds and thrust faults were set up, and these features controlled the landscape such as the Coastal Belt Thrust and the Garberville synform and antiform. As the San Andreas system became dominant and stress on this area became transpressive, faults acting on this landscape became right-lateral strike-slip (dextral) such as the Garberville/Briceland fault.

In addition to the landscape of this subbasin being controlled by the tectonic regime, folds, faults, and shear zones have affected the area in many ways. Folding of rock layers can create unstable zones of inward dipping increasing the likelihood of landsliding. Seismic activity can destabilize hillslopes, causing widespread landsliding; fault movement can change stream morphology, and faults and shear zones can locally weaken rock strength, enhancing erosion.

### Coastal Belt Thrust

The Coastal Belt Thrust fault cuts through this Subbasin, juxtaposing the Coastal Belt and the Central Belt of the Franciscan Complex. The Coastal Belt thrust is likely the zone which accommodated movement between the subducting Farallon plate and the North American plate before accretion of the Coastal Belt when active subduction moved west to its present location along the Cascadia Megathrust.

### Garberville Fault Zone

The Garberville fault zone consists of several widely spaced, steeply dipping reverse faults with components of dextral slip that bound elongate northwest-oriented slivers of marine and nonmarine overlap assemblage strata. Earthquakes along the Garberville fault have deep epicenters (greater than 10-12 km) and may be generated from the underlying Gorda plate (McLaughlin 2000).

#### *Garberville Synform*

The Garberville synform is a prominent downward-arching fold within the rock strata running north by northwest along the west side of the Northern Subbasin.

#### *Garberville Antiform*

The Garberville antiform is a prominent upward-arching fold within the rock strata running north by northwest along the east side of the Northern Subbasin.

## Uplift

The coastal area to the west of this subbasin is undergoing high rates of uplift (1 to 5 millimeters per year) which translates into uplift in all three SF Eel River subbasins. Studies of river terraces along the mainstem Eel River indicate that at least 1 millimeter per year of uplift reaches past Garberville (Bickner 1985, Merritts and Bull 1989, Merritts and Vincent 1989, Merritts and others 1994). Northeast-southwest compression seems to be generating this region of uplift within the subbasin and has been termed the Mendocino Uplift (McLaughlin and others 1992).

Uplift in this area has increased the potential energy of the streams, allowing them to incise and erode the landscape at high rates leaving steep canyon walls above the streams. As tectonic forces push the land up, gravity tries to pull it down, and the result is usually landslides and rock falls. Landsliding is further exacerbated by heavy seasonal rainstorms that saturate the hillslopes, making them unstable and even more prone to landsliding.

## Earthquakes

The Northern Subbasin is within one of the most seismically active regions in the world. Its juxtaposition to the Mendocino Triple Junction to the northwest, the San Andreas fault zone to the west, and the Maacama fault zone to the southwest places this subbasin in a very precarious seismic regime which is susceptible to periodic strong seismic shaking (*Table 6*).

This shaking can trigger rockfalls, landslides, and earth/debris flows as well as increasing erosional processes in the area of surface rupture or liquefaction. Fault movement can result in uplift of the local landscape, increasing the potential for erosion, or may cause the local landscape to subside, increasing the potential for deposition. Faults may deform, break, or weaken rock, leaving the immediate area unstable and more prone to erosion.

*Table 6. Significant earthquakes near the SF Eel River.*

| Large historic earthquakes in proximity to the South Fork Eel River Basin | | |
|---|---|---|
| **Date** | **Magnitude** | **Location** |
| 1899 April | 7.0 | West of Eureka |
| 1906 April | 8.25 | Great 1906 earthquake |
| 1922 January | 7.3 | West of Eureka |
| 1923 January | 7.2 | Cape Mendocino |
| 1980 November | 7.2 | West of Eureka |
| 1991 August | 7.1 | West of Crescent City |
| 1992 April | 7.2 | Cape Mendocino |
| **Source: USGS 2011** | | |

## Landslides and Erosion

The Northern Subbasin is underlain by weak and erodible rock types of the Coastal and Central belts of the Franciscan Complex. The Yager Terrane composes the majority of the subbasin and while it is relatively hard and more resistant to erosion than many of the other rock types in the subbasin, it still erodes and contributes sediment at high rates. The majority of natural sediment entering the streams is produced by landslides. The term "landslide" is used in a general sense to refer to the various processes of mass wasting of soil, unconsolidated sediment, or bedrock within this subbasin.

There are both benefits and disadvantages of natural landslides on salmonid populations. Landslides typically contribute large woody debris, large boulders, and spawning gravels from the hillsides and create stream channel diversity like plunge-pools, riffles, meanders, and side channels. However, landslides can also contribute an abundance of fine sediments, strip riparian vegetation, and fill channels and pools. Fish have evolved over time to thrive in the delicately balanced, highly unstable, natural landscape of this area, but anthropogenic activities that result in additional fine sediment input may disrupt this balance.

The likelihood of landslides occurring in an area is related to numerous variables. Major factors that tend to increase the likelihood of landsliding are: steep hillslopes, high pore pressure between grains (water saturated ground), bedding planes and/or planes of weakness within the soil or bedrock, undercutting of slopes, poor vegetation cover, seismic shaking, and weak hillslope material. In the Northern Subbasin, weak rocks in conjunction with high amounts of rainfall and the dynamic tectonics of the northwestern California create a landscape prone to landsliding.

The Yager Terrane is prone to debris slides along stream banks and translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers. Argillite (shale) within the Yager Terrane becomes very friable when repeatedly exposed to cycles of hydration and desiccation (wetting and drying) and can perpetuate these rock slides as well as contribute fine sediments to nearby streams. Areas where faults have disrupted the coherency of the bedrock are prone to rockslides, debris flows, and enhanced surface erosion.

Central Belt mélange, while less abundant than Yager Terrane, is more susceptible to erosion. The high degree of internal shearing within mélange has turned it into an incoherent matrix of its parent rock type (completely smashed and sheared argillite, sandstone, and conglomerate). This sheared matrix, which comprises most of the volume of mélange, has very little internal strength and flows downhill over time via deep-seated earthflows. Mackey and Roering (2011) estimated that while only about 7 to 8 percent of mélange terrain might be active at a given time, approximately 70 to 80 percent of the landscape moves over geologic time. Large, active, deep-seated earthflows are capable of delivering tens of thousands of tons of sediment per square mile of surface area each year (Kelsey 1977). Even when dormant, the toes of these earthflows erode, providing a constant source of fine sediments to the streams. If erosion of the toe progrades far enough, if heavy rainfall saturates the earthflow, or if there is local seismic shaking, dormant earthflows may reactivate.

Surface erosion affects recent earthflows by forming rills and gullies, as well as secondary slumps and small debris flows which wash additional sediments into streams.

Five percent of this subbasin has been mapped with large Quaternary landslide features. These landslides reflect only what has been mapped on a large scale without detailed field investigation. Many smaller and/or less obvious landslides most likely exist that have not been mapped, or have been mapped as part of landslide inventories at a much more detailed scale.

The most notable, historical slide in the Northern Subbasin is located in Salmon Creek (*Figure 7* and *Figure 8*). This slide occurs in Central Belt mélange and is the largest mapped Quaternary landslide. Salmon Creek follows the Coastal Belt Thrust (fault) separating Yager Terrane to the east and the Central Belt mélange to the west. This large earthflow has conveyed many large Franciscan boulders to the stream, creating boulder-run/cascade/pool reaches in many areas. It has been estimated that the entire landscape in this area is eroded at a rate of about one millimeter every two-and-a-half years (Gendaszek et al. 2006).


*Figure 7. Pseudo-aerial-oblique of Salmon Creek Earthflow 2011.*

*Figure 8. Salmon Creek Earthflow 2011. View is from the earthflow looking west, across the stream to the Yager Terrane.*

## Fluvial Geomorphology

The overall fluvial geomorphology of the Northern Subbasin may be described by moderately steep tributaries with steeply incised valleys draining into a low gradient (<1%) mainstem. The geology of this landscape is subject to high rates of tectonic uplift, and the streams incise at similar rates, creating geologically young ridge/valley morphology.

Two basic types of geology control the landscape: relatively resistant sandstone units (including shale and conglomerate) and mechanically weak mélange units (sandstone, shale, and conglomerate sheared and fractured to the point where it loses coherency). Coastal Belt sandstone geology of the Yager Terrane dominates this subbasin and typically produces a rugged landscape with steep sharp ridges and valleys whose trend is predominantly controlled by regional folding and faulting induced by Mendocino Triple Junction and San Andreas tectonics.

Mélange geology exists in the southern portion of this subbasin and typically produces a hummocky topography with a landscape of rolling hills and grassland. Ridge-valley sets of mélange units are strikingly less steep and sharp compared to sandstone units. Exotic rock blocks within mélange protrude, forming knockers jutting out from the terrain. Mélange, lacking coherency, tends to move downhill, over time, in large earthflows. Where active earthflows terminate at streams they usually deliver large amounts of fine sediment and deposit sizeable boulders of exotic rock types. This creates chronic turbidity in streams as well as boulder-runs and cascade reaches, both of which are possible barriers to fish passage.

### Sediment Transport

Processes of stream sedimentation are controlled by stream power, which is a combination of discharge and the slope over which a stream runs (velocity). Streams are typically divided into a source reach (channel gradient of >20%), a transport reach (channel gradient 4-20%), and a depositional reach (channel gradient <4%) in terms of sedimentation based on channel steepness. Sediment is eroded from steep headwater reaches as well as steepened knick-zones, transported along moderately steep reaches, and deposited within gentle gradient reaches. Although streams are broadly divided into these three regions, forms of erosion, transport, and deposition occur on all reaches of a stream at any given time, and seasonal variations in stream flow modify where and when such processes occur.

Large storm events trigger more erosion and recruit more sediment to the streams than smaller events. Sediment pulses from large storms migrate slowly downstream and tend to affect the stream for tens of years. Anthropogenic land use can greatly increase the rate of erosion and sediment input to streams, and it may take upwards of a century for the stream to naturally flush out the sediment pulse.

Terrace deposits are present at several places along the mainstem of the SF Eel River and in some of its tributaries. Stream terraces can be formed in a variety of ways. In a period of tectonic quiescence, stream valleys widen and sediment is deposited within the flood plain; if regional uplift occurs the stream will respond by incising and eventually the flood plain will be left perched above the active stream channel.

Large flood events can trigger widespread bank erosion and landsliding, recruiting excess sediment into the stream and redepositing it. This can cause aggradation of the stream valleys in decades following the flood event. In time, the channel typically incises through these sedimentary deposits and back to its former level, leaving terrace deposits along its banks. Large landslides may block the stream from time to time causing a landslide dam. Water backing up behind the dam typically triggers many smaller streamside landslides, contributing large amounts of sediment which are impounded behind the dam. Eventually the dam is breached and worn away and the stream responds by incising into the impounded deposit, leaving behind terraces along the banks of the stream.

During high stands of sea-level, base-levels of streams also become raised. Streams usually respond to a raised base-level by depositing sediment and decreasing their slope. Eventually as the seas recede, streams will readjust and incise, leaving behind extensive terrace deposits.

Large river floodplain/terrace deposits bordering the mainstem of the SF Eel River have been developed due to their flat morphology, which is easy to build on, as well as the sediment itself which usually supports good crop growth and forest cover. Weott, Myer's Flat, Miranda, and Phillipsville are all built on terrace deposits.

The tributaries of the SF Eel River are mostly bedrock controlled: streams create their fluvial-geomorphology from the gradual wearing away of the containing bedrock. Local geology will dictate channel slope, bedforms, pool-riffle-run morphology, bars, flood-planes, and terraces. Regional uplift, folding and faulting, and the mechanical strength and behavior of bedrock control the overall morphology of the streams in the Northern Subbasin.

Although controlled by bedrock, Northern Subbasin streams are still subject to influence from available sediment input. The input of sediment is typically from various hillslope processes such as landsliding and erosion that are often enhanced by land use and management activities. The 1955 and 1964 floods recruited massive amounts of sediment into the streams, aggrading the channels and completely burying bedrock within them. Filling-in of the channels with sediment effectively forced the water up and out of the channel, causing excessive streambank erosion channel widening to accommodate flow.

### Bull Creek

The Bull Creek drainage is a good example of the effect of sediment input on the fluvial geomorphology in Northern Subbasin streams. Prior to the 1955 flood the lower reaches of Bull Creek consisted of a deep, meandering channel that was roughly 50 feet wide. After the 1964 flood segments of this channel had widened to approximately 400 feet (Jager and LaVen 1981). Flood-flows, aggradation, and subsequent lateral erosion removed riparian vegetation, hundreds of old-growth redwoods, roads, and bridges, as well as complete stream-side towns.

These two flood events deposited vast amounts of sediment into the channel of Bull Creek and its tributaries. The lower reaches of Bull Creek aggraded by about 15 to 20 feet.

Sediment was deposited to a depth of approximately 40 feet in the lower reaches of Cuneo Creek (a tributary to Bull Creek). The 1955 flood completely buried a bridge across Cuneo Creek with sediment, after which a new bridge had to be built. The 1964 flood completely buried the new bridge with sediment, after which a third bridge was constructed. Presently the channel in the vicinity of the bridges has degraded back to a point where the second bridge has become exposed.

## Knickzones

Knickzones are the actively propagating areas of base-level fall throughout the basin. Knickpoints are more numerous on first order streams where stream power is weaker and the knickpoints effectively become trapped. Subsequent base-level fall within the basin will induce a new series of knickpoints which will typically migrate upstream over time and "bunch-up" against the previous knickpoints in areas where the stream power becomes too weak to propagate them further. Knickzones record various bouts of regional uplift or base-level lowering within the basin, and may create gradients steep enough to become obstacles or barriers to fish passage.

Of the 20 named SF Eel tributaries in the Northern Subbasin, 12 were surveyed for salmonid habitat, and the probable end of anadromy was identified in the field. The end of anadromy of eight of these streams (67%) was associated with a knickzone and usually located towards its downstream end.

## Channel Type

The fluvial geomorphology of individual streams within a system can be used to help understand current as well as past fluvial regime changes. Some basic morphologic stream patterns were defined by D.L. Rosgen, and were based on entrenchment, sinuosity, and slope of streams (*Figure 9*). In the most recent (1987 to 2010) Northern Subbasin stream surveys (n = 29), crews documented A, B, C, D, E, F, and G Rosgen channel types (*Table 7*). Type B streams were the most common (39% of Northern Subbasin stream length surveyed), followed by type F (27%), type C (15%) and type A (13%).

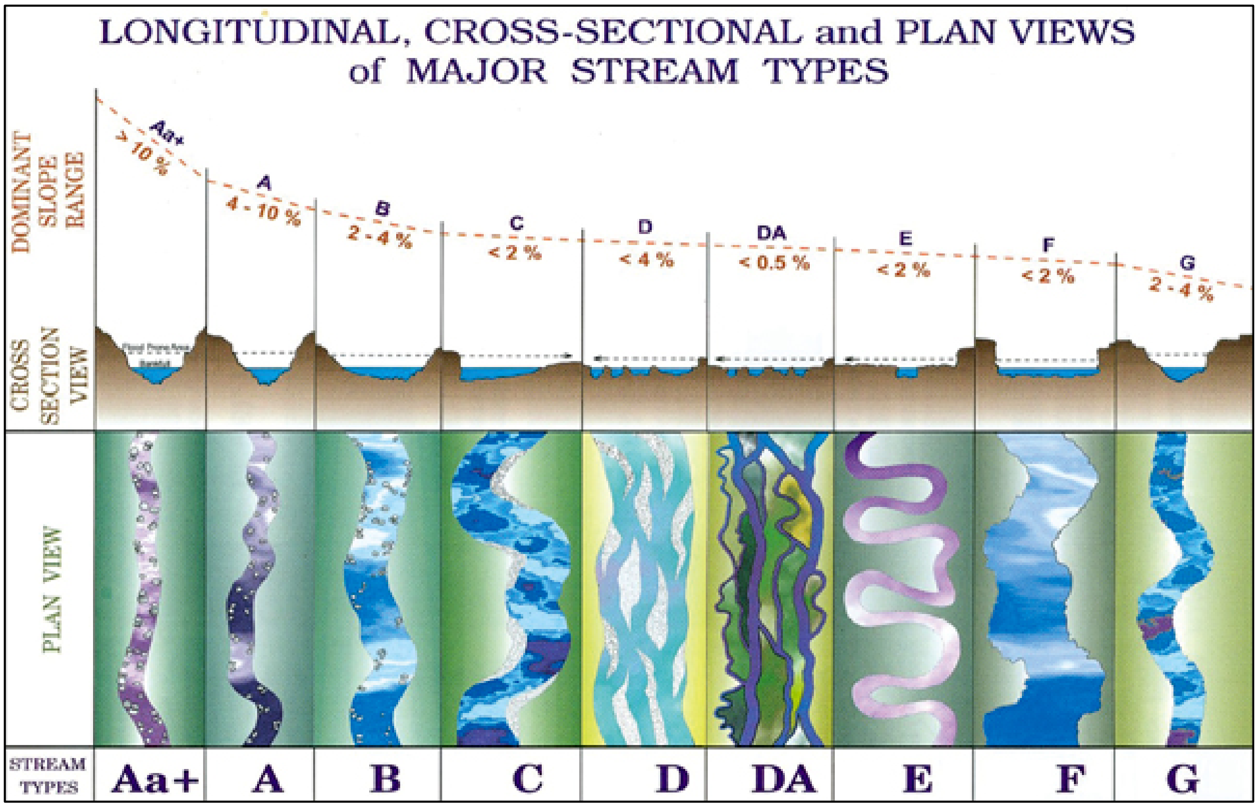



*Figure 9. Illustration of channel types A-G (Rosgen 1996, courtesy of Wildland Hydrology).*

*Table 7. Surveyed channel types by percent of subbasin*

| Northern Subbasin General Channel Types | | |
|---|---|---|
| **Type** | **%** | **Description** |
| **A** | 13% | Type A reaches have a moderate to steep slope (4-10%), flow through steep V- shaped valleys, do not have well-developed floodplains, and have few meanders. |
| **B** | 39% | Type B stream reaches are wide, shallow, single thread channels. They are moderately entrenched, moderate gradient (2-4%) reaches, which are riffle-dominated with step/pool sequences. Type B reaches flow through broader valleys than type A reaches, do not have well-developed floodplains, and have few meanders. |
| **C** | 15% | Type C stream reaches are wide, shallow, single thread channels. They are moderately entrenched, low gradient (<2%) reaches with riffle/pool sequences. Type C reaches have well-developed floodplains, meanders, and point bars. |
| **D** | 1% | Type D streams are wide, have Multiple channels with longitudinal and transverse bars, eroding banks, and have gravel substrates. They are not entrenched and have less than a 2% gradient. |

| | | |
|---|---|---|
| **E** | 1% | Type E channels are low gradient (<2%), meandering, riffle/pool streams with a gravel, sand, or silt substrate. |
| **F** | 27% | Type F stream reaches are wide, shallow, single thread channels. They are deeply entrenched, low gradient (<2%) reaches and often have high rates of bank erosion. Type F reaches flow through low-relief valleys and gorges, are typically working to create new floodplains, and have frequent meanders. |
| **G** | 4% | Type G, or gully stream reaches, are similar to F types but are narrow and deep and have a steeper gradient (2-4%). With few exceptions, type G reach types possess high rates of bank erosion as they try to widen into a type F channel. They can be found in a variety of landforms, including meadows, developed areas, and newly established channels within relic channels (Flosi, et al. 2010). |

In addition to channel type, Rosgen's system includes a "level II" classification, which describes the size of channel material or D50 (median particle size). Material size classes include: (1) bedrock (>2048 mm); (2) boulder (256-2048 mm); (3) cobble (64-256 mm); (4) gravel (2-64 mm); (5) sand (0.062-2 mm); and (6) silt/clay (<0.062 mm). The most common Northern Subbasin stream types using the level II classification system were F4 and B2 channel types (47,785 and 43,233 ft respectively) (*Table 8*).

*Table 8. Surveyed Channel types of the Northern Subbasin by stream reach.*

| Stream | Length (feet) | Channel Type |
|---|---|---|
| Bull Creek | 12885 | B2 |
| | 13301 | B3 |
| | 12261 | B4 |
| | 12359 | C4 |
| | 2218 | D4 |
| Cow Creek | 1263 | A3 |
| | 1137 | B3 |
| | 3038 | F3 |
| Connick Creek | 11866 | C1 |
| Harper Creek | 3186 | A2 |
| | 1494 | G3 |
| Squaw Creek | 5638 | A2 |
| | 6327 | B2 |
| | 2516 | F3 |
| Albee Creek | 1938 | A3 |
| | 988 | B3 |
| Mill Creek | 676 | A3 |
| | 2006 | B2 |
| | 1190 | E3 |
| | 2553 | F4 |
| Cuneo Creek | 1742 | A3 |
| | 1108 | B3 |
| | 4590 | C2 |
| N.F. Cuneo Creek | 428 | A2 |
| | 3721 | B2 |
| Burns Creek | 3674 | A2 |
| Brain's Creek | 3352 | A3 |
| Slide Creek | 3349 | A3 |
| Panther Creek | 2980 | A2 |
| | 696 | B4 |
| Preacher Creek | 2700 | B1 |
| Decker Creek | 1831 | A3 |
| Mill Creek | 1765 | A3 |
| Mowry Creek | 243 | A3 |
| | 2281 | C3 |
| Canoe Creek | 3444 | B2 |
| | 2347 | F2 |
| | 4553 | F4 |
| Coon Creek | 3006 | A3 |
| Bridge Creek | 2816 | B2 |
| | 2356 | B4 |
| Elk Creek | 4396 | B2 |
| | 1082 | B3 |
| | 2126 | B4 |
| | 7722 | F4 |
| | 6536 | G3 |
| Salmon Creek | 7638 | B2 |
| | 8114 | B4 |
| | 7361 | C4 |
| | 15488 | F4 |
| Mill Creek | 2735 | B4 |
| S.F. Salmon Creek | 17226 | F3 |
| | 3547 | F4 |
| Butte Creek | 6567 | B3 |
| | 738 | B4 |
| Coon Creek | 2731 | F4 |
| Fish Creek | 3651 | B3 |
| | 2047 | B4 |
| Anderson Creek | 978 | E4 |
| | 11191 | F4 |
| Ohman Creek | 1929 | C4 |

## Stream Channel Geometry

### Longitudinal Stream Profiles

A stream in a topographically steady state of slope (at equilibrium) tends to form a convex slope that exponentially gets steeper towards its headwaters. A stream that is out of equilibrium tends to deviate from this basic pattern along various portions of its length. In Northern Subbasin streams, reasons for deviance from profile equilibrium are typically caused by changes in underlying geology, regional uplift, movement along fault lines, large landslides, and large amounts of sedimentation (aggradation of the stream channel). These processes generally cause the longitudinal profile of a particular stream to become progressively convex (*Figure 10*). Changes in the natural resistance of the bedrock to erosion may also cause variations in the longitudinal profile. Sections of the stream channel that are significantly out of equilibrium may become too steep (>10% channel slope) to allow passage of fish and will decrease the length of anadromy. In Northern Subbasin streams, only two out of 12 (17%) of the surveyed tributaries of the SF Eel River with identified probable ends of anadromy have profiles that are consistent with the basic pattern of equilibrium. Uplift or basal lowering has created multiple knickzones that are apparent on longitudinal stream profiles of tributaries are out of equilibrium. These areas may be considered sensitive to disturbance and fish passage over time. Land use and management practices should be studied closely when planning activities that may alter the fluvial morphology or regime of each stream.

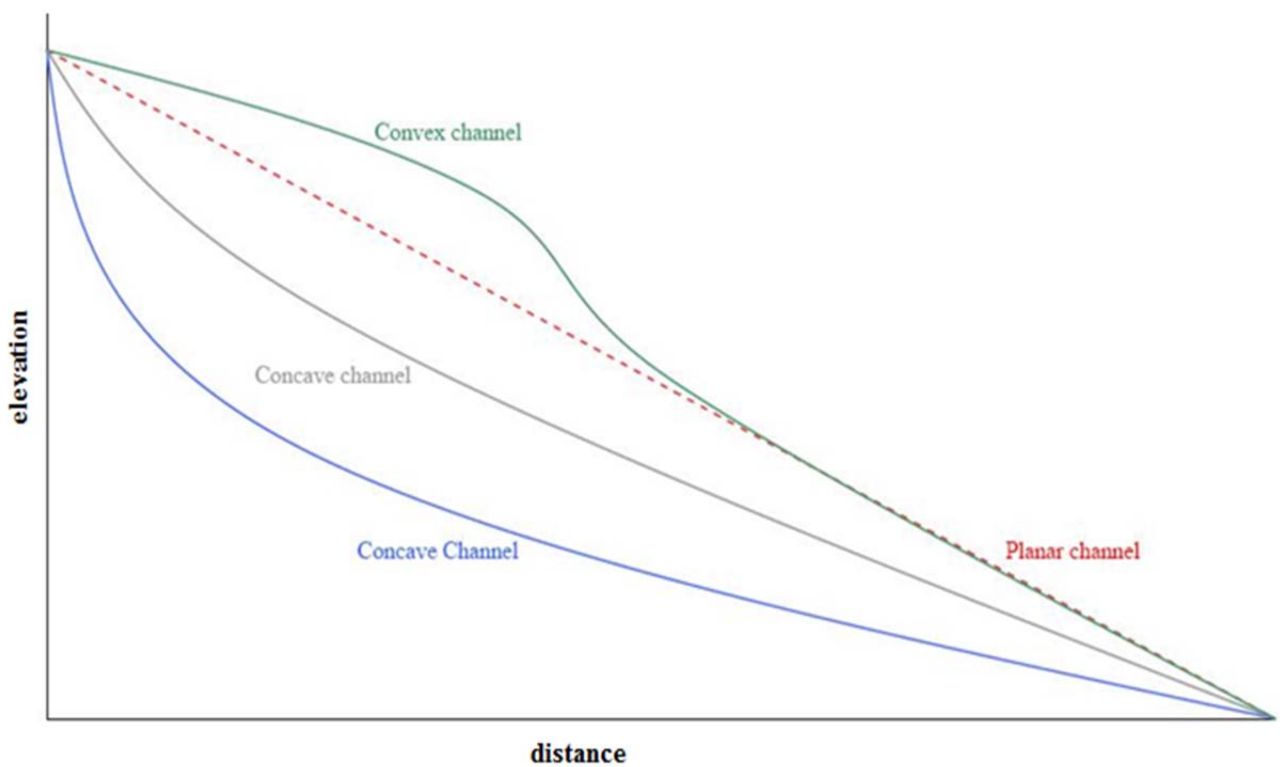



*Figure 10. Basic channel profile shapes.*

### *Profiles of Northern Subbasin Streams*

Stream profiles were completed for 20 Northern Subbasin streams (*Figure 11*). Knickzones and ends of anadromy (EOA) were included on profiles where applicable; 12 of the 20 streams had EOAs identified in habitat typing reports. Of these 12, 67% had EOAs associated with knickzones (7 were located at the downstream end of a knickzone, and 1 was located in the middle of a knickzone). Thirty three percent (4 of 12) of EOAs were not associated with a knickzone.

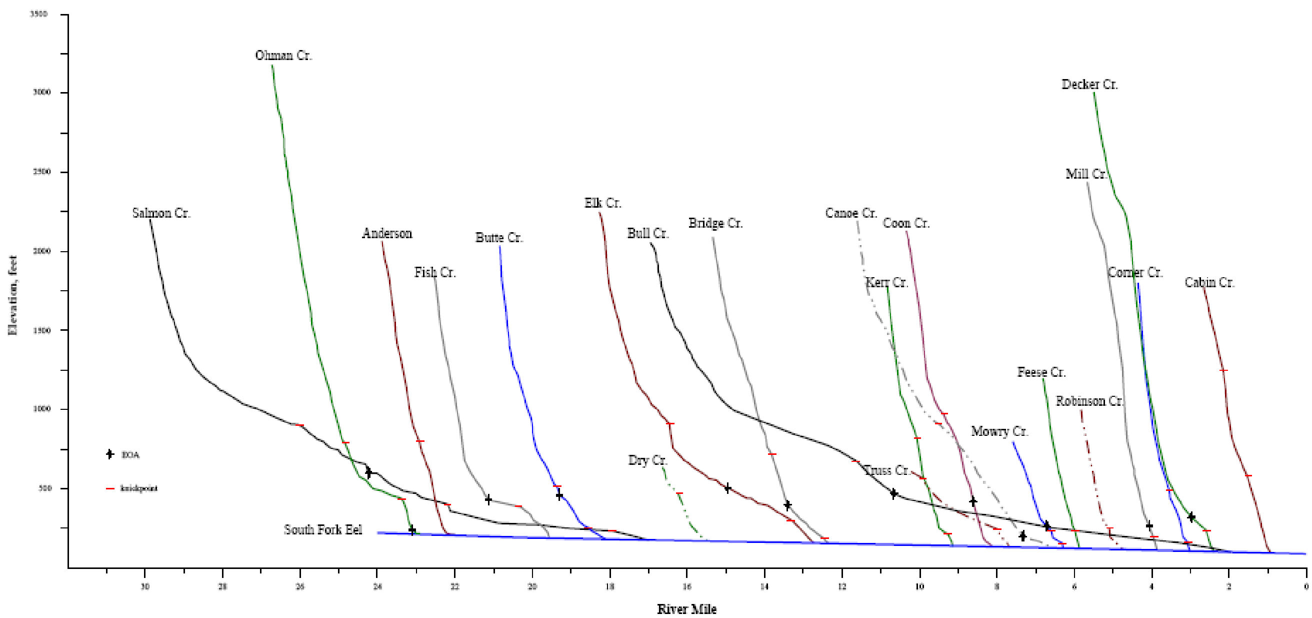



*Figure 11. Longitudinal stream profiles of SF Eel River Northern Subbasin streams.*

## Soils

In this assessment the term "soil" refers to any loose material derived from the weathering of bedrock and mixed upward by biogenic, chemical, and/or mechanical processes. Like the other SF Eel River Subbasins, bedrock of the Northern Subbasin is mantled with unstable soils.

The majority of bedrock throughout the subbasin is composed of sedimentary rock types of the Coastal Belt, producing associated soil types ranging from silt loam to very gravely loam that are prone to mass wasting, hillslope erosion, and transport by fluvial processes. The dominant soil series in the Northern Subbasin is Vandamme-Tramway-Irmulco-Hotel-Dehaven soil series, covering approximately 67% of its area (*Figure 12*). The Vandamme-Tramway-Irmulco-Hotel-Dehaven soil series is associated with and mantles steep, rugged ridges and valleys of Yager Terrane bedrock (sandstone, shale, and conglomerate) of the Coastal Belt (*Table 9*).

The Northern Subbasin receives high levels of rainfall between October and May (up to 115 inches in the Bull Creek headwaters). Rainfall initiated soil movement varies with storm intensity, most noticeably during short-duration, high-intensity storms but still significant during long-lasting, less intense storms. As soil becomes saturated, pore-pressure between grains increases, which lowers its ability to resist downslope movement. A healthy cover of vegetation helps stabilize the underlying soil through root-strength, which increases soil cohesion and evapotranspiration; this can prevent or at least delay soil saturation. Tree cover on hillslopes can increase the soil shear-strength by more than 60%. The soils in this subbasin support a lush growth of redwood and Douglas-fir.

Forest cover in this subbasin reinforces hillslope soils, with roots mechanically reinforcing soils by transferring shear stress in the soil to tensile resistance in the roots (Menashe 2001). Humboldt Redwoods State Park occupies approximately 52% of the subbasin, mainly within the Bull Creek watershed and Grasshopper Mountain, and maintains its forest and vegetation cover in a close-to-natural or recovering state (from wide-spread, intensive logging before the late '60s) with the exception of access roads, trails and campgrounds. Detrimental effects on soils of compaction and lack of vegetation are not considered widespread within this subbasin.

The Northern Subbasin has periodically experienced fires throughout history. One of the most notable and recent fires was the Canoe Fire of 2003, located in the Canoe Creek drainage within Humboldt Redwoods State Park. Wildfires can weaken soil slope-strength and increase erosion by: decreasing or removing the root mass tensile strength; removing vegetation and duff; decreasing inception and evapotranspiration rates; creating hydrophobic soils which reduce infiltration, absorption, and subsurface hydraulic flow; and increase surface runoff. The negative effects of burned soils can last from years to decades.

Gradual downslope movement of soil caused by gravity, weathering, saturation and rain-splash, and biogenic activity (soil creep) is also present within the soils of this subbasin and delivers sediment to the streams (Stillwater Sciences 1999).

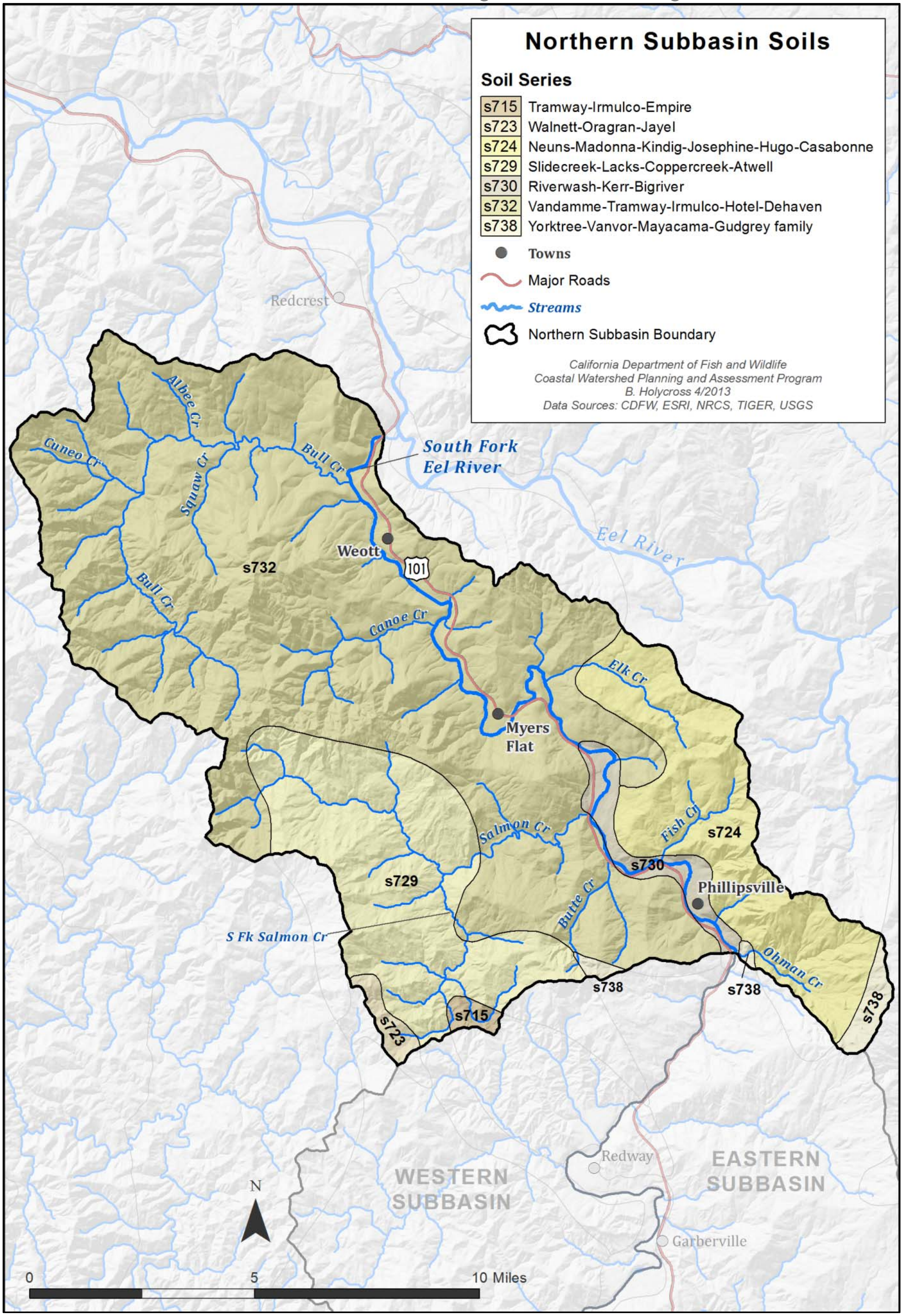



*Figure 12. Soils map of the Northern Subbasin.*

*Table 9. Northern Subbasin soil descriptions.*

| Soil series | Texture | Description | Parent Bedrock | Slope % |
|---|---|---|---|---|
| **Vandamme-Tramway-Irmulco-Hotel-Dehaven (67%)** | | | | |
| VANDAMME SERIES | loam | Deep, well drained soils formed in material weathered from sandstone or mudstone. | Coastal Belt Yager Terrane. | 2 - 75 |
| TRAMWAY SERIES | loam | Moderately deep, well drained soils formed in material weathered from sandstone. | | 9 - 75 |
| IRMULCO SERIES | loam | Deep or very deep well drained soils formed in material weathered from sandstone. | | 9 - 75 |
| HOTEL SERIES | very gravelly loam | Moderately deep, well drained soils that formed in material weathered from sandstone. | | 30 - 100 |
| DEHAVEN SERIES | gravelly loam | Deep, well drained soils formed in material weathered from sandstone. | | 30 - 99 |
| **Slidecreek-Lacks-Coppercreek-Atwell (16%)** | | | | |
| SLIDECREEK SERIES | gravelly loam | Very deep, well drained soils that formed in colluvium and residuum weathered from sandstone and mudstone. | Central Belt Mélange. | 9 - 75 |
| COPPERCREEK SERIES | loam | Very deep, well drained soils that formed in colluvium and residuum from schist, sandstone, and mudstone. | | 9 - 75 |
| ATWELL SERIES | silt loam | Very deep, moderately well drained soils formed in material from sheared sedimentary rocks | | 15 - 50 |
| **Neuns-Madonna-Kindig-Josephine-Hugo-Casabonne (13%)** | | | | |
| NEUNS SERIES | gravelly loam | Moderately deep, well drained soils that formed in slope alluvium and colluvium from metamorphosed igneous and sedimentary rocks. | Central Belt Sandstone and Mélange. | 15 - 80 |
| MADONNA SERIES | loam | Moderately deep, well drained soils that formed in material weathered in residuum from sandstone and shale. | | 15 - 75 |
| KINDIG SERIES | gravelly loam | Deep, well drained soils that formed in residuum and colluvium from metamorphosed igneous and sedimentary rocks. Kindig soils are on mountains. | | 15 - 80 |
| JOSEPHINE SERIES | gravelly loam | Deep, well drained soils that formed in colluvium and residuum weathered from altered sedimentary and extrusive igneous rocks. | | 2 - 75 |
| HUGO SERIES | gravelly sandy clay loam | Deep, well drained soils that formed in material weathered from sandstone, shale, schist, and conglomerate. | | 9 - 75 |
| CASABONNE SERIES | Gravelly loam. | Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale. | | 9 - 75 |
| **Riverwash-Kerr-Bigriver (2%)** | | | | |
| KERR SERIES | loam | Dark olive gray recent moderately well drained alluvial soils without profile development that are formed in material derived mainly from micaceous schists. | Alluvium and river terrace deposits. | 0 - 5 |
| BIGRIVER SERIES | loamy sand | Very deep, well drained soils formed from alluvium derived from mixed sources. | | 0 - 5 |
| **Yorktree-Vanvor-Mayacama-Gudgrey family (1%)** | | | | |
| YORKTREE SERIES | loam | Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone. | Central Belt Sandstone. | 15 - 75 |
| VANVOR SERIES | very gravelly sandy clay loam | Moderately deep, well drained soils on mountains. These soils formed in colluvium from metavolcanic rock. | | 30 - 75 |

| Soil series | Texture | Description | Bedrock | Slope % |
|---|---|---|---|---|
| MAYACAMA SERIES | very gravelly sandy loam | Moderately deep, somewhat excessively drained soils formed in material derived from sedimentary and metasedimentary rocks. | | 9 - 75 |
| GUDGREY SERIES | gravelly sandy clay loam | Deep, well drained soils formed in material weathered from sandstone, schist or shale. | | 8 - 75 |
| **Walnett-Oragran-Jayel (1%)** | | | | |
| WALNETT SERIES | stony loam | Very deep, well drained soils formed in material weathered from serpentinized peridotite. | Central Belt Mélange – peridotite block. | 5 - 75 |
| ORAGRAN SERIES | very stony loam | Shallow, well drained soils formed in material weathered from peridotite or serpentinite. | | 5 - 75 |
| JAYEL SERIES | stony clay loam | Moderately deep, well drained soils formed in material weathered from serpentinized peridotite. | | 5 - 75 |
| **Tramway-Irmulco-Empire (<1%)** | | | | |
| TRAMWAY SERIES | loam | Moderately deep, well drained soils formed in material weathered from sandstone. | Wildcat Group. | 9 - 75 |
| IRMULCO SERIES | loam | Deep or very deep well drained soils formed in material weathered from sandstone. | | 9 - 75 |
| EMPIRE SERIES | loam | Deep, well to moderately drained soils formed in material derived from soft sedimentary rocks. | | 10 - 40 |

## Vegetation

Two main factors in the decline of salmonids within the SF Eel River Basin over the past century are an overabundance of fine sediments and increasing temperatures in the streams. Vegetation on the landscape has a direct influence on both of these conditions. Hillslope vegetation intercepts and slows the velocity of rainwater and also provides leaf litter and duff layers to the surface of soils, which intercepts and disperses rainwater and increases resistance to surface erosion. Leaf and duff layers also provide an intricate irregular, permeable interface that allows surface water to pond and be absorbed rather than flow downhill as runoff. Vegetation also increases transpiration, decreasing pore pressure between soil grains and reducing slope failure. Root systems increase the tensile slope strength of unstable soils, reducing landslides, erosion, and sedimentation.

Riparian vegetation shades streams and reduces solar radiation and corresponding stream temperatures. Stream bank roots and low hanging branches provide cover for fish. Large woody debris generated by riparian vegetation and recruited by the stream provides habitat and stream channel diversity. Stream bank root systems increase the tensile slope strength of unstable soils, reducing bank failure and subsequent sedimentation.

The predominant vegetation cover type as described by the USFS CALVEG data is mixed conifer and hardwood forest, which covers approximately 55 percent of the Northern Subbasin (*Figure 13*). This vegetation type includes forests and woodlands where conifer is the primary vegetation type and hardwoods are present secondarily. Pacific Douglas-Fir is the primary vegetation type (61%) in this classification, followed by mixed Redwood – Douglas-Fir (36%) and Redwood (3%) (*Table 10*). Conifers are prevalent throughout this subbasin and occupy nearly all areas except river floodplains, some river terrace low lands, and hillside meadows where the underlying geology is too unstable to support forest growth.

Conifer forest is the next most abundant vegetation type in this subbasin, covering approximately 28% of the subbasin area (*Figure 13*). Conifer forests and mixed conifer forests, when combined, are the major vegetation in the Northern Subbasin, making up nearly 85% of the total vegetation.

Grassland/prairie (herbaceous) vegetation, primarily composed of annual grasses, is the next most abundant vegetative cover, making up 9% of the total subbasin area. This vegetation is found in small, interspersed hillside prairies in the southern part of the subbasin, overlying earthflows within geology of the Central Belt mélange. Herbaceous vegetation is also found along some of the low-lying areas on the mainstem SF Eel River. Historically, grasslands were composed of native prairie bunch grasses with relatively deep root systems. In the late 1800s ranchers began seeding European short-rooted annual grasses for grazing and these soon replaced the bunch grasses. Replacement of the deeper rooted grasses with shallower rooted annual grasses is believed to have increased surface erosion and hillslope soil stability (Kelsey 1980).

Hardwood forest is the fourth most abundant vegetation category, covering about 6% of the Northern Subbasin area.

GIS data indicate that less than one percent (0.01%) of the subbasin area is covered by agriculture, however this may be an under-representation because pastures used for grazing of livestock may not be included in this vegetation designation since land use is often difficult to ascertain remotely. For this reason, it can be assumed that areas mapped as annual grasslands may also be agricultural in nature and the overall percentage of agricultural lands is likely to be greater than depicted.

Many agricultural practices in this region are covert and undocumented; both legal and illegal marijuana cultivation are becoming large-scale problems when considering water diversion and contamination of streams within the basin. Illegal grow sites are periodically established in remote areas of State Park lands, which make up more than half of the Northern Subbasin area, and on privately owned timberland which includes nearly a quarter of the subbasin area.

To supply a constant, reliable source of water to their plants, growers will typically divert water through plastic pipes from nearby streams or springs to their cultivation sites. The warm, dry portion of the season is when plants require the most water, including plants in the surrounding forest as well as those that are cultivated. Consequently, this is the time period when stream base flows are at their lowest. When low base-flow conditions exist, the

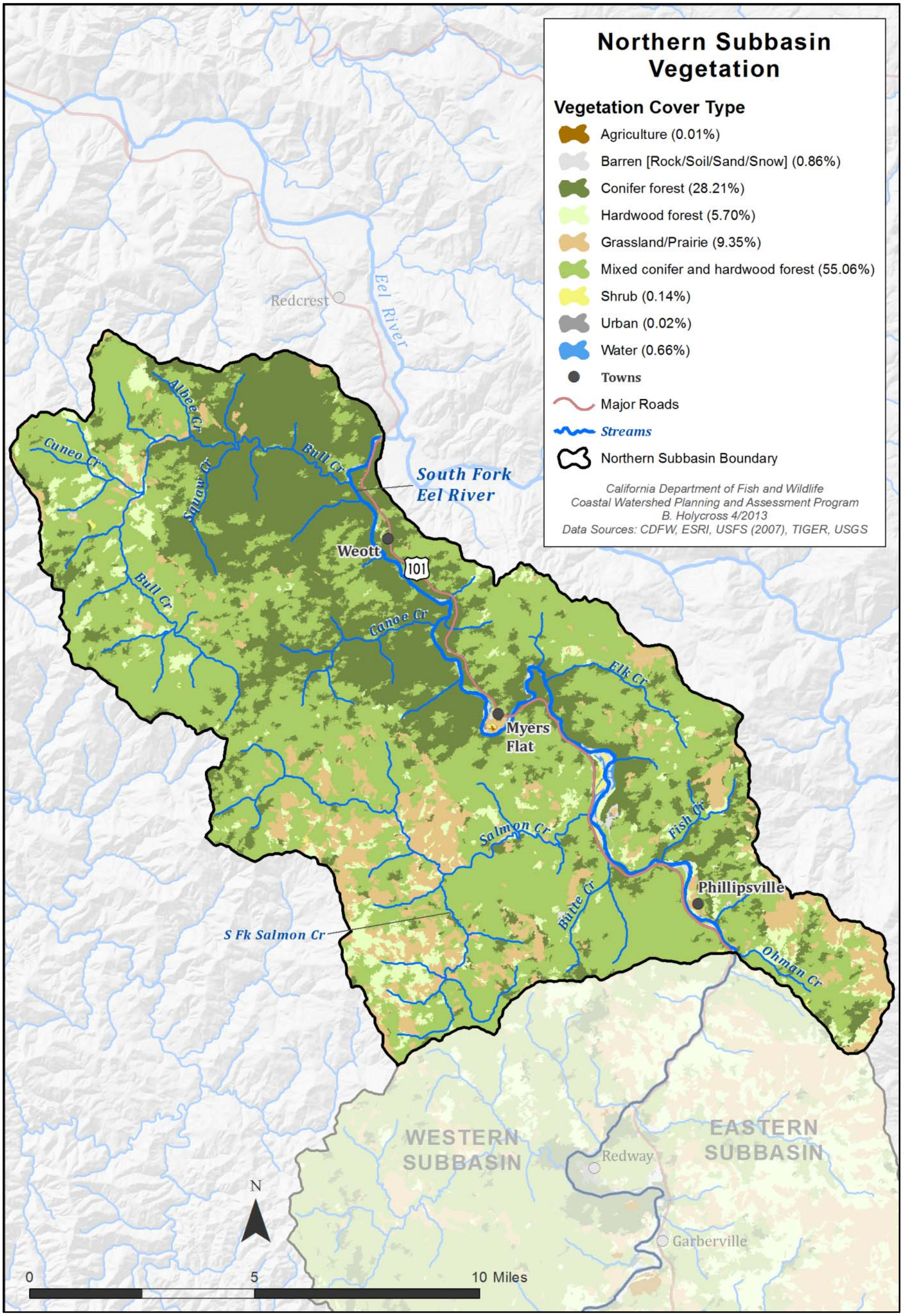



*Figure 13. Vegetation map of the Northern Subbasin*

*Table 10. Vegetation of the Northern Subbasin (USFS CALVEG).*

| Vegetation Cover Type | % of Subasin | Primary Vegetation Type | % of Type |
|---|---|---|---|
| Mixed conifer and hardwood forest/woodland | 55.06% | Pacific Douglas-Fir | 61.1% |
| | | Redwood - Douglas-Fir | 36.0% |
| | | Redwood | 2.5% |
| | | Jeffrey Pine | 0.3% |
| | | Incense Cedar | 0.1% |
| Conifer forest/woodland | 28% | Redwood - Douglas-Fir | 45.1% |
| | | Redwood | 39.1% |
| | | Pacific Douglas-Fir | 15.3% |
| | | Jeffrey Pine | 0.2% |
| | | Non-Native/Ornamental Conifer | 0.2% |
| | | Incense Cedar | 0.2% |
| Grassland/Prairie | 9.35% | Annual Grasses and Forbs | 99.5% |
| | | Pastures and Crop Agriculture | 0.3% |
| | | Non-Native/Ornamental Grass | 0.1% |
| | | Perennial Grasses and Forbs | 0.1% |
| Hardwood forest/woodland | 5.70% | Tanoak (Madrone) | 53.0% |
| | | Oregon White Oak | 14.3% |
| | | Montane Mixed Hardwood | 13.5% |
| | | Canyon Live Oak | 5.7% |
| | | Black Oak | 5.0% |
| | | California Bay | 3.1% |
| | | Riparian Mixed Hardwood | 1.9% |
| | | Red Alder | 1.4% |
| | | Interior Mixed Hardwood | 1.2% |
| | | Willow | 0.6% |
| | | Black Cottonwood | 0.2% |
| | | Coast Live Oak | 0.2% |
| Barren | 0.86% | Barren | 62.4% |
| | | Urban-related Bare Soil | 37.6% |
| Shrub | 0.14% | Willow (Shrub) | 69.8% |
| | | Lower Montane Mixed Chaparral | 8.7% |
| | | Wedgeleaf Ceanothus | 8.6% |
| | | Scrub Oak | 6.8% |
| | | Blueblossom Ceanothus | 5.0% |
| | | North Coast Mixed Shrub | 1.3% |
| Urban | 0.02% | Urban/Developed (General) | 100.0% |
| Agriculture | 0.01% | Agriculture (General) | 100.0% |
| Statistics exclude classification of water | | | |

streams become shallow and warm, and stressors on salmonids increase. During these times when water flow is minimal (usually in the late summer through early fall), even a single diversion can significantly reduce stream flow. Because these diversions are purposefully covert, especially for grows on public parkland or privately owned timber land, they cannot be managed and the cumulative impacts are unknown other than observations of significantly lower streamflows and some streams going dry during relatively wet years. Sedimentation and pollution associated with grow operations are also increasing and becoming a greater concern.

Additional vegetation types are barren, shrub, and urban (all covering <1% of the total subbasin area).

## Fire

Historically, fire has shaped ecosystems throughout California, and there are three periods where human influences have managed both fire and fire environments differently: 1) prior to European settlement (before 1700); 2) the settlement period (1700 to 1920); and 3) the suppression era (1920 to present). Fire patterns in pre-European times resulted in many millions of acres burning in California each year, with fire acting as a major cause of ecosystem change (CalFire 2003). Fires renewed mature vegetation communities that required fire to restore vegetation life cycles.

Habitat structure and composition, climate, weather, prior fire history, land management activities, and physical properties such as elevation and aspect influence the frequency, size, and severity of fires (Flannigan et al. 2000, Pilliod et al. 2003). Most fires are effectively suppressed using advanced technology and increased early efforts to protect resources, commodities, and people. To reduce the potential for severe, widespread fires, fuel treatments are considered the only practical means of altering potential wildfire behavior (CalFire 2003). In some areas where cutting and removal of fuel is controversial, infeasible, or prohibitively expensive, fire has been used as a tool to reduce fuel loads. The extent, effects, and severity of subsequent fires may be limited by these prescribed burns (Collins et al. 2008).

Fire is one of the primary natural disturbance factors influencing vegetation structure in the Northern Subbasin. Natural post-fire stands are usually a mosaic of burn severities, from unburned to stand-replacing, within a watershed. Historically, Native Americans and settlers used fire to manage grasslands and prairies, and to maintain the ratio of conifers to oaks in tanoak stands (BLM et al. 1996).

Twenty four percent (35 $mi^2$) of the Northern Subbasin has burned, with 19 fires on record since the early 1900s (*Figure 14*). This percentage is the largest of the three subbasins, with 20% of the Eastern and 21% of the Western subbasin burned since the early 1900s. However, fires have been more prevalent in the Eastern Subbasin, where the number of fires was greatest (35 fires), and lowest in the Western Subbasin (16 fires).

The largest areas in the Northern Subbasin burned between 1990 and 2012 (17 $mi^2$), and between 1950 and 1969 (15 $mi^2$). The most recent large fire was the Canoe Fire, started by lightning in 2003, which was not a drought year on the north coast. Coastal redwood forest is usually considered fire resistant, and large fires are rare since large-scale acquisition and fire suppression efforts began 1930s (Scanlon 2007). However, the Canoe Fire burned more than 16 $mi^2$ (more than 10% of the total subbasin area) in an old growth redwood stand, and was the most significant fire to have burned in coast redwood during the last half century due to the extent and diversity of vegetation types that were burned. Scanlon (2007) stated that historic fire suppression and exclusion practices in this area resulted in higher burn intensity and duration, which may have contributed to greater mortality of old growth stands (*Figure 15 A, B*).

Fire behavior is strongly influenced by vegetation type and fuel moisture content. More than 80% of the Northern Subbasin area vegetation is made up of conifer forest (28%) and mixed conifer and hardwood forest (55%). Large fires in the subbasin (other than the Canoe Fire) burned in the Bull and Salmon Creek drainages, and in areas east of Phillipsville (*Figure 14*) where vegetation types are a mix of conifer/hardwood forest, hardwood forest, shrub, and grassland/prairie.

Modern land use practices have influenced the likelihood and effects of wildfire throughout the subbasin. Logging on highly erodible hillslopes has altered the natural hydrology, and construction of roads and stream crossings causes additional erosion and sediment runoff at greater levels than would have occurred naturally.

Human settlement has also affected wildland fire patterns and occurrences. Areas where residential communities border parklands or industrial timberlands are known as the wildland-urban interface. In this interface, a combination of fuel, weather, and topographical conditions may create an environment of increased wildland fire risk (Humboldt County 2008). These high risk areas have been identified throughout the county, and in 2005 the CalFire-Del Norte Unit Fire Management Plan added the area between Pepperwood and

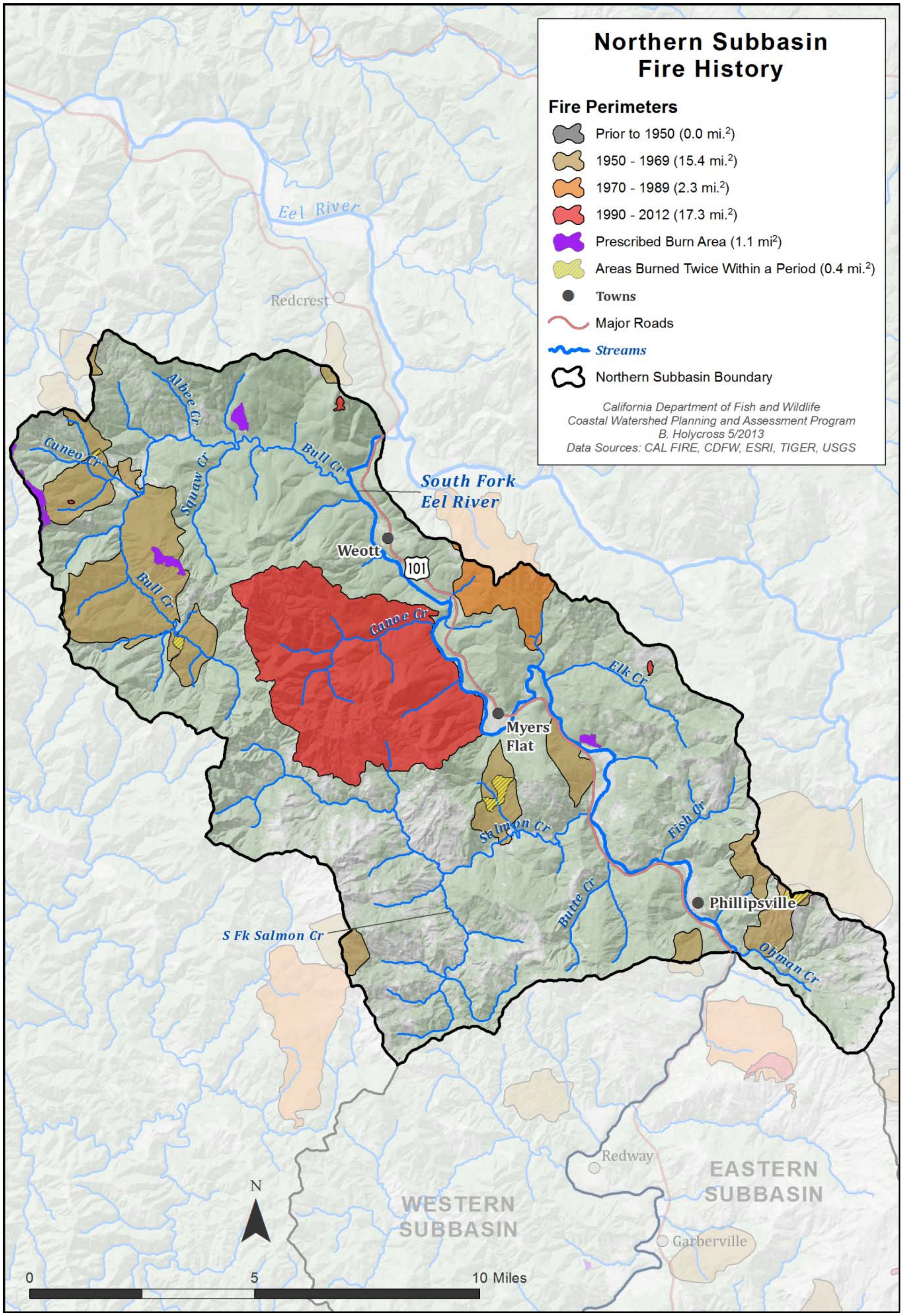



*Figure 14. SF Eel River Northern Subbasin fire history, with total square mileage burned within each time period.*

*Figure 15 A, B. Children's Forest bridge in old growth area of Humboldt Redwoods State Park before (left (A)) and after (right (B)) the Canoe Fire in 2003 (photos courtesy of Dave Stockton, CA State Parks).*

Phillipsville (Cathey road/Avenue of the Giants) as an increased fire risk area due to hazardous fuel buildup, wildland-urban interface proximity, high value assets, and fire history. Most of this added land is within the Northern Subbasin boundary, and land use is a mix of Humboldt Redwoods State Park and private property.

Fire-fighting practices may directly affect the landscape and streams within the subbasin. Actions and their effects include the following:

- Construction of fire roads and fire breaks, which may increase erosion and sediment input to streams;
- Aerial application of fire retardant in upslope and riparian areas (and directly in streams when mis-applied), which may result in the input of toxic chemicals to stream habitats;
- Prescribed burning, which may affect LWD recruitment, soils, and stream habitat (Pilliod et al. 2003).

Land use practices influence the likelihood of and severity of fires throughout the subbasin. Most of the land in the Northern Subbasin is open space/parkland (52%). There is an active prescribed burning program in place on park property that is maintained cooperatively with efforts of Humboldt Redwoods State Park and the Humboldt-Del Norte Management Unit (CalFire 2012). Benefits of prescribed or controlled burns include the following:

- Hazard reduction - fire decreases fuel loads that may destroy young stands in the event of a wildfire;
- Control of understory vegetation;
- Site preparation – to facilitate natural regeneration or prepare sites for tree planting;
- Enhanced wildlife habitat;
- Improved access; and
- Increase quality and quantity of habitat for fire-dependent native species (USDA-NRCS 1999).

Only 1.1 square miles of the basin area was managed using prescribed burns on Humboldt Redwoods State Park land (*Figure 14*), however, regular use of prescribed fire could reduce fuels so that catastrophic fires are less likely to occur.

Reduced rainfall and drier conditions resulting from climate change may affect the natural fire regime (Flannigan et al. 2000, Fry and Stephens 2006). The fire season in Humboldt County generally begins in June, peaks in August, and ends in October. In the future, fire behavior will be less predictable due to changes in temperatures, precipitation, fire frequency and fire severity (Tetra Tech 2013). Despite the generally damp climate prevailing in the county's forests, studies have suggested a fire return interval of 50 to 100 years in the northern part of the County, and 12 to 50 years in the south (CDF 2005).

The effects of wildfire in watersheds may include:

- loss of vegetative cover;
- increased runoff;
- hydrophobic (water repellent) soils;
- severe erosion; and
- increased sediment production.

Post-fire erosion may increase sediment loads in both streams and riparian areas. In some areas where large-scale forest fires have occurred, accelerated sediment production has been documented (Humboldt County 2008). Increased erosion and sediment production following fires are of particular concern in the Northern Subbasin due to very high natural and anthropogenic sediment inputs that already exist.

Depleted vegetation in riparian areas reduces instream shading, resulting in increased water temperatures that threaten fish and other aquatic life (Pilliod and Corn, 2003). Increased water temperatures during low flow times are already a major concern for salmonids in many areas of the Northern Subbasin. Low flows occur during late summer and early fall, which correspond to the times of highest fire danger. Post fire monitoring and the development of management strategies are essential for areas where the loss of riparian vegetation and associated shade results in elevated instream temperatures. Active fuels management in riparian zones, including hazardous fuels reduction and habitat restoration, is increasingly common among Federal land managers (Dwire et al. 2011).

The most recent large fires in the Northern Subbasin occurred in areas of moderate to very high fire threat (*Figure 16*). Thirty eight percent of the land in the subbasin is classified as very high fire threat, and the majority of land (48%) is classified as high fire threat. In a high fire threat area, all fine dead fuels ignite readily and fires start easily from most causes; fires spread rapidly and high intensity burning may develop on slopes or in concentrations of fine fuels; and fires may become severe and their control difficult unless they are attacked successfully while small (National Wildfire Coordinating Group 2002). Thirteen percent of the basin area is classified as moderate fire threat, and one percent as low threat (agricultural regions). Threat rankings address wildfire related impacts on ecosystem health, with ecosystems defined as unique vegetation types by tree seed zones (http://www.fire.ca.gov/index.php). CalFire's Fire and Resource Assessment Program (FRAP) data used to produce fire threat maps are related to:

- stand-level data: estimated fire frequency and fire behavior characteristics at a fine scale, and
- landscape-level data: the risk of widespread landscape-level damage to an entire ecosystem, based on the percentage of an ecosystem at risk of losing key ecosystem components or functions.

Climate change has the potential to affect fire behavior, fuels, ignition, season duration, and management strategies. Global climate change models predict drier conditions for northwestern California, which will result in an increased probability of large fires (Westerling and Bryant 2008). Drier conditions, including warmer temperatures and reduced precipitation, will lead to decreased fuel moisture and increased flammability, both of which increase wildfire spread rate, intensity, and duration. Increased fuel flammability may also result in greater fire frequency in wetter, forested areas, and higher temperatures will extend fire seasons, resulting in larger total burn areas from fires occurring both earlier and later than expected (Fried et al. 2004, McKenzie et al. 2004). Resource management strategies such as the modification of vegetation structure and fuels can help mitigate the effects of climate change throughout the subbasin.

Sudden oak death (SOD) has spread throughout southern Humboldt and is found in the SF Eel River Basin. In one SOD hot spot between Garberville and Miranda, the rate of expansion of diseased areas was approximately1,500 acres per year from 2004 through 2010 (Valachovic 2011) The OakMapper website (http://www.oakmapper.org/oaks/index/4132) shows two clusters within the SF Eel River hot spot area (*Figure 17*). The northern cluster and the four locations to the south are within the boundary of the Northern Subbasin. Affected stands have the potential to seriously impact fuel loading and fire behavior because SOD causes 100% mortality in tanoak, and infected areas have higher fuel loads and trees that are prone to rapid failure during fires (CalFire 2012). The duration of infection in stands is also important when considering fire behavior; late-phase (>8 years) diseased forests may show

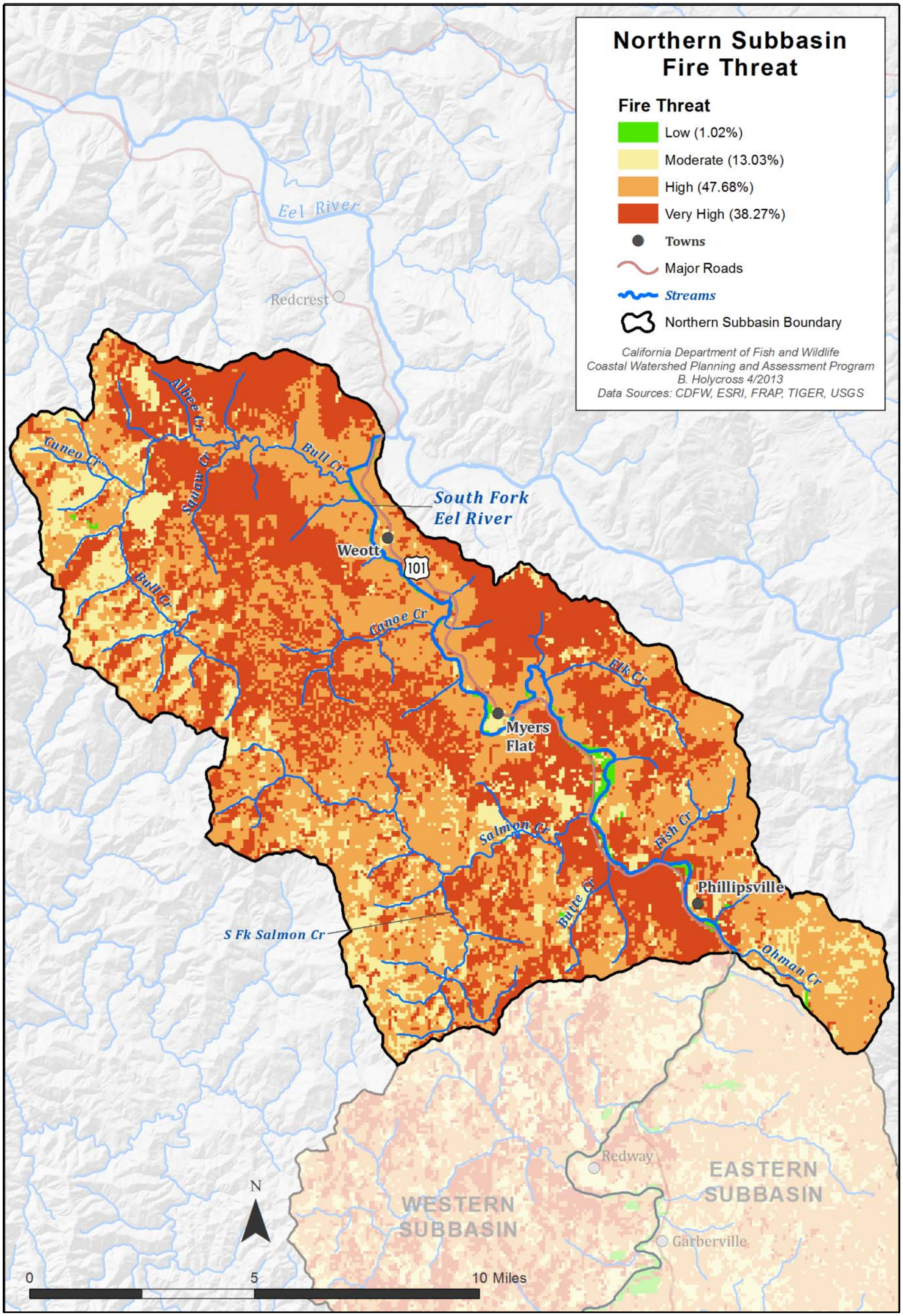



*Figure 16. SF Eel River Northern Subbasin fire threat, with percentage of total basin area in each threat category.*

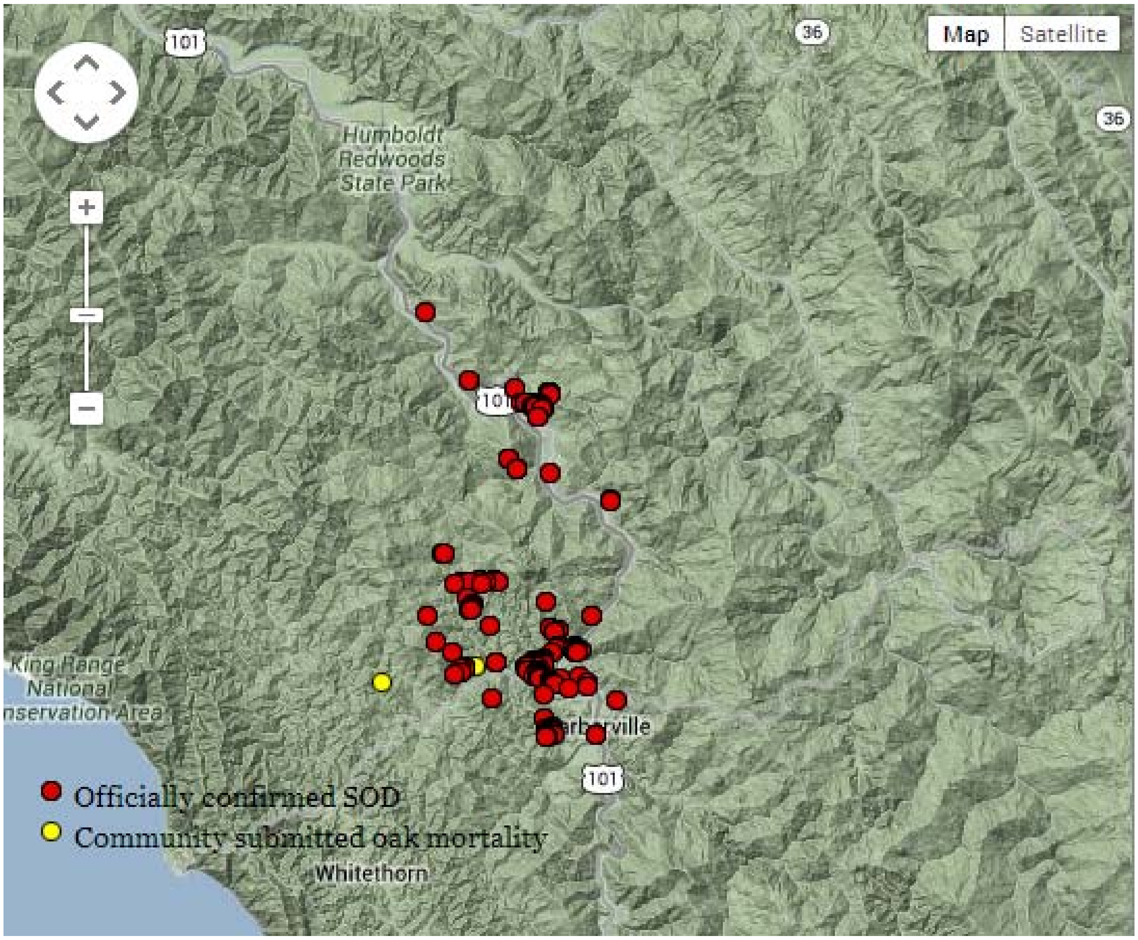



*Figure 17. Confirmed (red) and reported (yellow) cases of Sudden Oak Death (SOD) in the SF Eel River Basin, from Oak Mapper website (accessed 2/27/2014). Confirmed locations in the northern cluster of dots are located within Northern Subbasin boundaries.*

increased rates of fire spreading, flame length, and fireline intensity, which reduces the effectiveness of firefighting strategies and techniques (Valachovic et al. 2011).

In summary, fire is a natural and important part of the disturbance regime of the Northern Subbasin. Direct effects to salmonids, particularly increased sedimentation and reduced riparian canopy resulting in increased stream temperatures, may be compounded in areas where human activities have resulted in increased sedimentation and higher instream temperatures, and where natural sedimentation input from landslides and unstable geology are a concern.

# Land and Resource Use

## Historic Land Use

The Sinkyone, a subgroup of the Coastal Southern Athabaskans, were the first inhabitants occupying the Northern Subbasin of the SF Eel River Basin (BLM et al. 1996). They subsisted primarily on anadromous fish, with secondary resources including upland game and acorns, and their cumulative impact on the environment and natural resources of the Northern Subbasin was relatively minor (Yoshiyama and Moyle 2010). Native Americans occupied the North Coast Ranges for at least 4,000 years (possibly as many as 10-15,000 years) prior to the arrival of the first European settlers in the early 1850s (JMWM 2000). These settlers were primarily trappers who were encouraged by the Homestead Act of 1862 which allowed them to purchase affordable land (160 acre homesteads for $1.25/acre), and also by the disappearance of the Native Americans due to violence, disease, and relocation (JMWM 2000). These homesteaders trapped, farmed, harvested timber, and grazed livestock throughout the Northern Subbasin.

Dyerville, located at the confluence of Bull Creek and the SF Eel River, was the only community of size in the Northern Subbasin in the 1850s and 1860s, although there were small settlements located along the SF Eel in Phillipsville, Myers Flat, and Weott. Dyerville was located where three major wagon roads met: those running along the mainstem Eel, Bull Creek, and the SF Eel (JMWM 2000). In 1912, the Northwestern Pacific Railroad crossed the mainstem Eel at Dyerville and although the rail line did not go up into the SF Eel Basin, the town of South Fork grew up around the depot at Dyerville and became a shipping hub for ranch products, tanbark, and redwood, and also a primary access point for the SF Eel River Basin. In 1923, the Redwood Highway was completed, bringing more people, commerce, and activity to the community of South Fork, and consequently, to the SF Eel River Northern Subbasin.

The tanbark industry was the first large-scale forest management practice in the Northern Subbasin, beginning in the early 1900s and ending in the 1950s with the development of synthetic tannins (JMWM 2000). Peak production of natural tannin occurred between 1900 and 1920. Tanoak bark was peeled from trees (*Figure 18*) and transported out of the area, or sent to a plant in Briceland where the bark was converted to tannin extract. Stripped tanoak trees were left on the ground, and nearly all of the tanoak trees in the Northern Subbasin were harvested during this time (HCRCD 2002).

*Figure 18. Early tanbark harvest (photo courtesy of Humboldt State University).*

Early logging activity resulted in the removal of all accessible old growth redwood along the creek mouths throughout the Northern Subbasin. In the early 1800s, logs were floated down the SF Eel River to mills as far away as Fortuna, but the river was deemed too long and meandering so logs were cut into more manageable rectangular chunks, known as cants, before floating them downstream (O'Hara and Stockton 2012). Due to the long distance between the harvest areas and larger mills near Fortuna and Humboldt Bay, many trees were used for split products such as railroad ties, shingles, and grape stakes (to support the expanding grape industry in Sonoma and Napa counties). These split products were produced at sites where trees were felled, then transported out of the basin more easily than whole logs (O'Hara and Stockton 2012).

Prior to WW II, Douglas-fir was considered unmerchantable timber, but after the war, nearly all Douglas-fir in the watershed was harvested in an effort to keep up with the post-war building boom BLM et al. 1996). New technologies and additional transportation options allowed harvesters to access remote areas with steep terrain, which resulted in an increase in logging operations throughout the basin, particularly in the densely forested Northern Subbasin. In the 1950s, there were at least seven mills in the Salmon Creek drainage alone; some were "brush mills", small temporary mills set up close to stands of fir so that trees could be cut and skidded to the mills easily. The mills were dismantled and moved to new locations when the stands were depleted (JMWM 2000). In the Bull Creek drainage in the 1950s, there were four mills, one of which was the Bee Creek mill (*Figure 19*). This mill alone produced 50 million board feet of timber in 1956 (O'Hara and Stockton 2012), and was dismantled in the early 1960s.

*Figure 19. Bee Creek Mill in Bull Creek drainage (photo courtesy of Humboldt Redwoods State Park).*

Roads, skid trails, and landings were often located in creeks so logs could be skidded downhill easily. During this time, extensive damage to streams and poor road building techniques combined with unstable geology led to increased sedimentation in streams throughout the subbasin (JMWM 2000).

Improvements in timber harvest techniques and equipment led to increased harvest efficiency, and there was an increase in timber harvest activity in 1956, when the Humboldt County Supervisors levied a tax on standing timber. As a result, most landowners were forced to harvest timber rather than leave it standing for financial reasons (O'Hara and Stockton 2012). The peak timber production year was 1959 in Humboldt County, and although timber harvest levels have declined recently, the timber industry is still an important component of the economy (Downie 1995).

The major flood events of 1955 and 1964 exacerbated the impacts of intensive timber harvest and poor road building practices in a naturally fragile landscape, resulting in large-scale soil erosion and sedimentation throughout the SF Eel River Basin (Yoshiyama and Moyle 2010). Major aggradation during the floods also buried or destroyed the natural armoring of stream banks which allowed high flows to scour banks, causing more bank failures and slides (JMWM 2000). In the Northern Subbasin, following the 1964 flood, clearcutting on upper slopes in the Bull Creek drainage was cited as the primary cause for increased sedimentation and subsequent severe damage to the river environment that extended downstream past the confluence of Bull Creek and the SF Eel River (CA State Parks 2012). These damage assessments prompted the State Park to purchase all of the private land in the Bull Creek drainage, and by the 1970s, the State Park owned more than 25,000 acres, including the damaged watershed.

Almost all merchantable timber had been removed from the Northern Subbasin by the late 1960s, and land developers bought up large tracts of land, subdivided the smaller parcels (40-80 acres), and sold them to "new settlers", also known as "back-to-the-landers". Significant changes to the watershed from these activities included the development of roads to access every parcel, an increase in the number of diversions, and an increase in the total amount of water diverted from streams in the basin to supply additional residences. Many of these "back-to-the-landers" also started cultivating marijuana, and these operations have expanded in both size and number; development of this underground industry beginning in the 1970s has provided an economic boost throughout the subbasin (JMWM 2000). These activities and their impact on the ecosystem and economy are discussed in greater detail in the Industrial Marijuana Agriculture section of this subbasin report.

## Current Land and Resource Use

The four principal land uses as of June, 2013 in the Northern Subbasin of the SF Eel River are: open space/parks, commercial timber production, residential, and grazing/timber (*Table 11*).

*Table 11 Four principal land uses in the Northern Subbasin.*

| Northern Subbasin Land Use | Square Miles | Acres | % of Total Subbasin Area |
|---|---|---|---|
| Open space/parks | 77 | 49,280 | 52 |
| Timber production | 36 | 23,040 | 24 |
| Residential | 21 | 13,440 | 14 |
| Grazing/timber | 13 | 8,320 | 9 |

## Open Space/Parks

Humboldt Redwoods State Park encompasses more than 53,000 acres, including greater than 17,000 acres of old growth coast redwoods. The park was created in 1921 and with the help of the Save the Redwoods League (SRL), has grown to become the third largest in the California State Park system (Humboldt Redwoods State Park 2012). Shortly after the park's creation, new land acquisitions slowed during the Great Depression, but park staff and SRL representatives continued to plan for park expansion. The end of World War II marked the beginning of a logging boom due to the demand for timber (both redwood and Douglas-fir) to support the postwar building boom. During this time, SRL and CA State Parks rushed to acquire tracts of land before the timber companies could purchase them, especially those in the Bull Creek drainage, in order to protect the Rockefeller Forest (known as the Bull Creek-Dyerville Forest until 1951).

The catastrophic floods of 1955 and 1964 temporarily halted logging operations in the Bull Creek drainage, and many landowners who had previously held out selling their land to the State Parks did so after the damage incurred from the 1964 flood (Humboldt Redwoods State Park 2012). Humboldt Redwoods State Park currently includes the entire Bull Creek watershed (*Figure 20*) and the Rockefeller Forest, the largest remaining old-growth redwood forest in the world. The park and SRL are currently working together on an active reforestation program, replanting thousands of trees in previously logged areas.

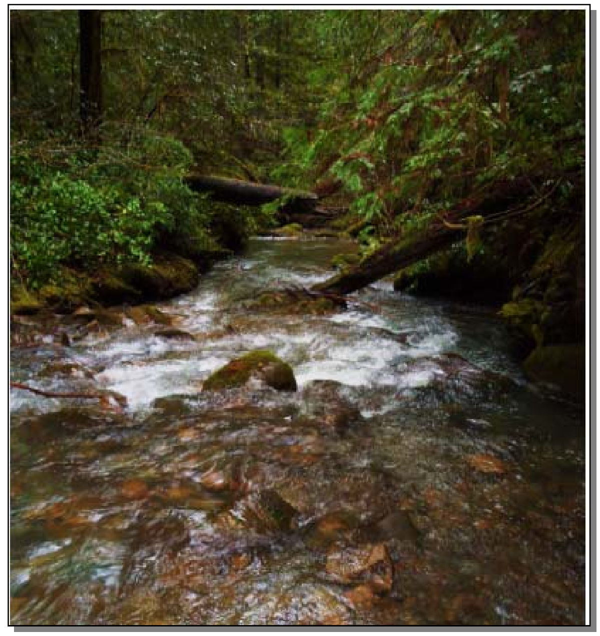


*Figure 20. Squaw Creek, a tributary to Bull Creek, located in Humboldt Redwoods State Park.*

Tourism, camping, fishing, and river-related recreational activities are increasingly popular throughout the SF Eel River Basin, particularly in the Northern Subbasin where most of the land is owned by the CA State Parks. These public areas are easily accessible to recreationists and tourists, and some landowners sell hunting and fishing rights to organizations or individuals, increasing recreational activities on private lands throughout the subbasin (Downie 1995).

## Timber Production

Due to the large amount of land owned by State Parks, large timber companies own a relatively small portion (24%) of the land in the Northern Subbasin (*Table 11*) compared to other subbasins in the SF Eel River Basin. Timber harvest, while less of an issue because of the reduced potential harvest area, still occurs in the headwaters of all of the creeks in this subbasin except those owned by the State Parks (*Figure 21*). Water drafting, which is used by industrial timber companies as a dust abatement measure, will be discussed further in the Water Use: Diversions, Dams, and Hydrologic Disturbances section of this report.

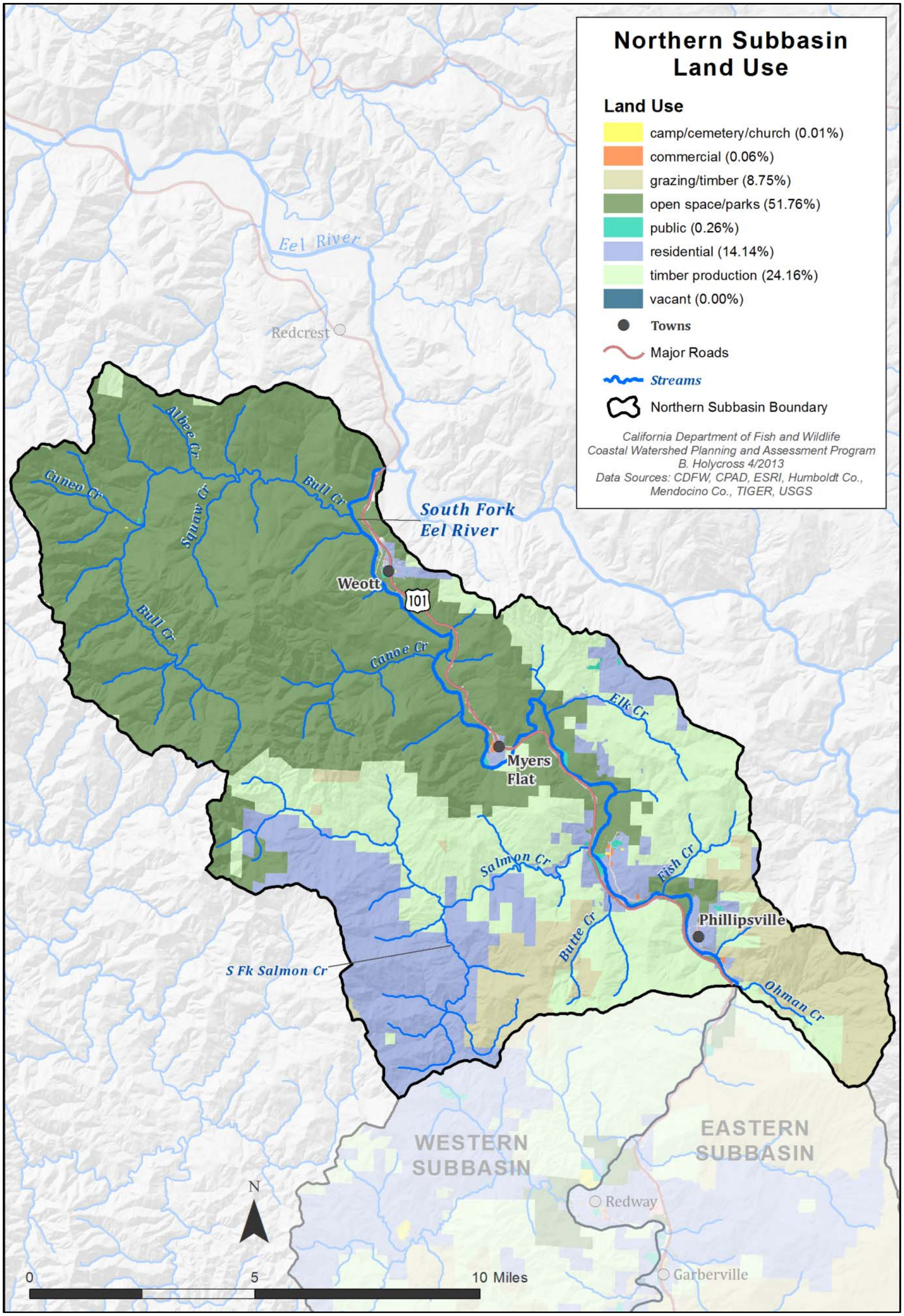



*Figure 21. Land use in the Northern Subbasin of the SF Eel River Basin*

The most recent timber harvest activity has occurred in the southern and eastern portions of the Northern Subbasin. Since 1995, there have been numerous harvests in the Salmon, Fish, Elk, and Butte creek drainages. All timber harvest activities require the development of plans detailing the amount and method of proposed harvest, and there are different plans based on the area of timberland owned and whether or not the landowner is an individual/family or a corporation. Non-industrial timber management plans (NTMPs) allow non-commercial landowners with less than 2,500 acres of timberland to develop harvest plans that are not as expensive and time-consuming as THPs (CalFire 2003). Once an NTMP has been approved, the actual harvest is reported in a notice of timber operations (NTO). Commercial harvest by timber companies and private landowners with more than 2,500 acres of timberland requires the development of a timber harvest plan (THP).

Based on CalFire data collected between 1995 and 2012, most timber harvests were commercial (THPs), as opposed to non-commercial (NTOs), and occurred primarily in the southeastern part of the Northern Subbasin (*Figure 22*). The total area of timber harvested in the subasin between 1995 and 2012 was 11,074 acres (*Table 12*). THP harvest area totaled 7,208 acres and individual operations ranged in size from 982 acres to less than one acre. NTO harvest area in the basin totaled 3,866 acres and ranged in size from 1,240 acres to less than one acre. Only one of the NTO harvest amounts (n=52) was greater than 400 acres.

*Table 12. Timber harvest by plan type (THP or NTO) for South Fork Eel Northern Subbasin (data from CalFire 2012).*

| Northern Subbasin | Plan Type | Acres | County |
|---|---|---|---|
| | THP | 7208 | Humboldt |
| | NTO | 3866 | Humboldt |
| | **Subbasin Total** | **11074** | |

The main silviculture methods used in the subbasin from 1991-2011 were selection (32% of harvested area; 2768 acres), transition (16% of harvested area; 1360 acres), and clearcut (12% of harvested area; 1062 acres) (*Figure 23*). Selection is defined as a method used to regenerate a forest stand, maintaining an uneven-aged structure, by removing trees in all size classes singly, in small groups, or in steps (Adams et al 1994). The transition method is defined as the removal of trees, either individually or in groups, from irregular or even-aged stands to create a balanced uneven-aged stand structure. Clearcutting is defined as the removal of all trees in one operation, producing a fully exposed microclimate for the development of a new age class/even-aged stand (Adams et al. 1994). Slash and ground vegetation left behind following a clearcut is frequently burned to prepare the site for artificial regeneration.

Of the three primary silvicultural methods used in the Northern Subbasin, clearcutting is the most damaging to the environment, resulting in the highest level of disturbance to both terrestrial systems (through soil exposure and instability due to tree removal) and aquatic ecosystems (through removal of shade and reduced large woody debris contribution) (USFS 1985, EPA 2005). All three methods result in increased fine sediment input compared to non-logged areas due to road construction and hauling practices.

There are varying levels of soil disturbance related to yarding techniques. Megahan (1980, in EPA 2005) summarized the results of soil disturbance from logging using different yarding methods in the Pacific Northwest:

- Tractor and skidder yarding had the highest disturbance level, and this method is generally limited to gentle slopes to reduce the potential damage of machine tracks on the soil. A tractor or skidder's weight plus the weight of logs will cause soil compaction, resulting in increased runoff; equipment treads will cause soil disturbance, introducing sediment into the runoff.
- Cable yarding, where logs are pulled uphill by a cable to a road or landing, resulted in the second highest level of soil disturbance. This technique is commonly used in areas where slopes are too steep for tractors or skidders.
- Skyline cable logging had the third highest percent soil disturbance.
- Aerial harvest methods such as helicopter and balloon yarding have the lowest impact on forest soils.

Yarding techniques vary by harvest, and each THP or NTMP includes a section on harvesting practices and the erosion hazard rating (from low to extreme) associated with the planned harvest. For the largest

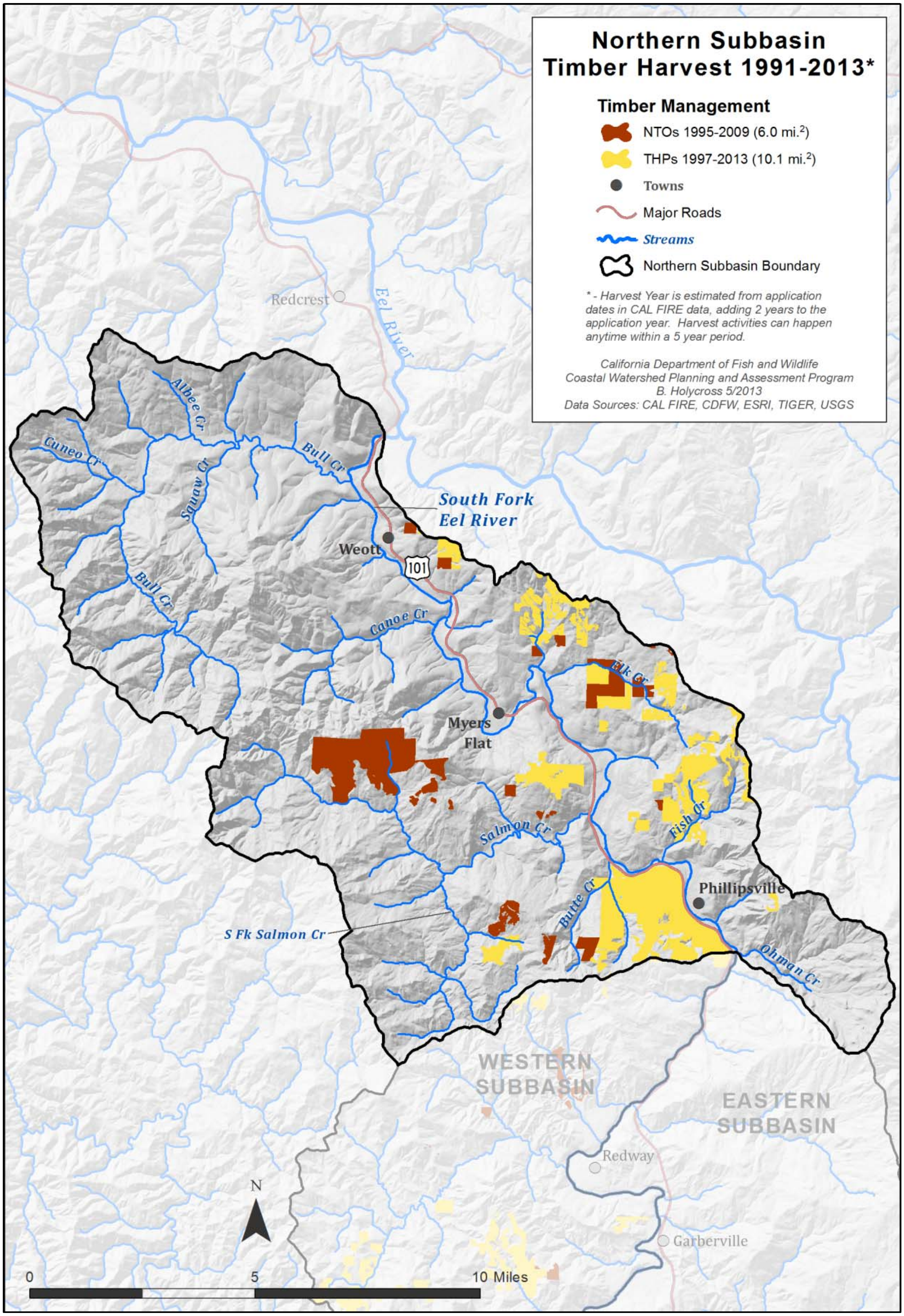


*Figure 22. Timber Harvest (NTOs and THPs) between 1995 and 2012 in the SF Eel River Western Subbasin.*

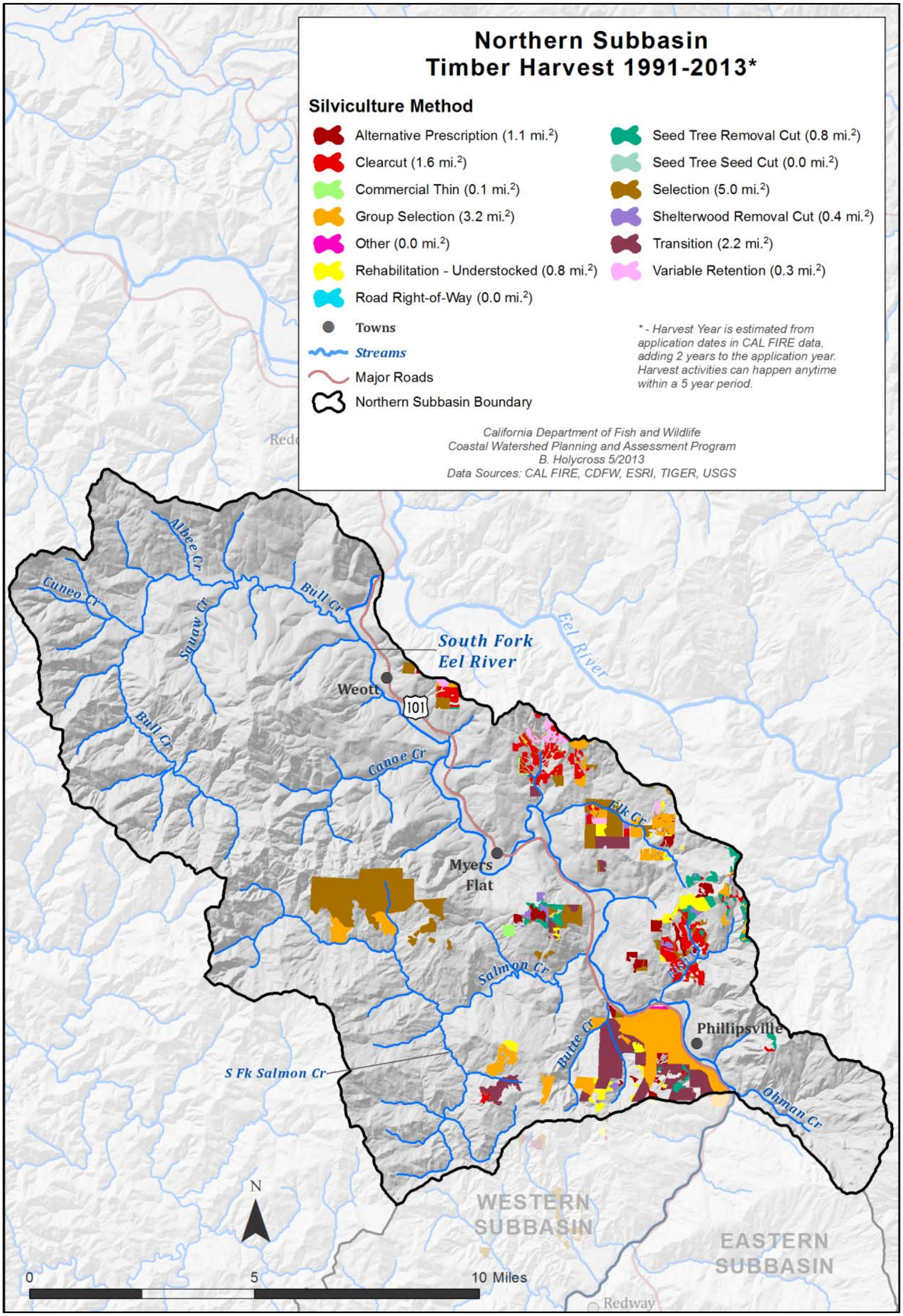



*Figure 23. Timber harvest activity by silvicultural method in the SF Eel River Northern Subbasin.*

THP (approximately 1,500 acres) in the Northern Subbasin (THP No. 1-09-050HUM; available at: ftp://thp.fire.ca.gov/THPLibrary/North_Coast_Region/), tractor cable/skyline harvesting was used, and the associated erosion hazard rating was low. A combination of techniques is often used, for example, NTMP No. 1-05NTMP-020HUM (361 acres) lists three techniques: ground skidder and tractor (ground based) and tractor cable/skyline. Collectively, these techniques had a moderate erosion hazard rating.

## Residential

Approximately 22% of the population of the entire SF Eel River Basin lives in the Northern Subbasin. The population estimate is 1,936 people total (US Census 2010), with a density of 13.17 people/square mile. This population estimate was obtained by adding the population in all the census blocks that were completely within the Northern Subbasin boundary, then identifying blocks partially within these boundaries ("straddling blocks"). The population in these straddling blocks was estimated proportionally based on the amount of each block area that was within the subbasin boundary, and was added to the total population estimate.

The total population and the population density in the Northern Subbasin are lower than in the Eastern Subbasin (population 5,846; density 18.27 people/square mile), and higher than in the Western Subbasin (population 1,175; density 5.37 people/square mile). The population density is relatively low because the majority of land in the Northern Subbasin is owned by the State Park. Miranda is the largest town in the Northern Subbasin, with a 2010 US Census population estimate of 520. Other small towns include Weott (population 288) and Myers Flat (population 146); most towns are located along the SF Eel River. Small towns and dispersed rural residential areas comprise 14% of the Northern Subbasin area (*Table 11*), and are located outside State Park boundaries throughout the southern and western areas of the subbasin (*Figure 21*). Of the 23% of the subbasin area that is privately owned, 17% (15,965 acres) are parcels >40 acres, and 6% (5,983 acres) are ≤40 acres in size.

Improved access and relatively easy water development in the recent past has led to increased settlement of many remote areas in the Northern Subbasin. With this increase in the number of developed parcels, there has been a corresponding increase in the number of roads to access parcels, with additional traffic due to multiple vehicles per family and frequent trips to and from residences, all of which contribute to a larger impact on natural resources throughout the subbasin (JMWM 2000). Residential development and associated activities also increase the possibility of pollution from wastewater, industrial chemicals, fossil fuel spills, fertilizers, and poisons used to control rodents and other pests, and it increases the potential for illegal water diversion for households and unregulated agricultural practices. This is a particular concern in the Northern Subbasin due to an increase in legal and illegal marijuana cultivation since the 1970s (Evers 2010). This will be discussed further in the Industrial Marijuana Agriculture section of this report.

Residential development requires the development of water and wastewater systems. The Humboldt County General Plan Draft EIR (2012) lists two groundwater basins in the SF Eel River planning watershed. In the Northern Subbasin, the Avenue of the Giants Community Planning Area (including Stafford, Redcrest, Weott, Myers Flat, Miranda, and Phillipsville) is associated with the Eel River groundwater basin, with the prime source being at the Eel-Van Duzen delta. Approximately 10,000 acre-feet of the estimated annual yield of 40,000 to 60,000 acre-feet are currently being pumped for agriculture throughout the planning area. Groundwater in rural Humboldt County is generally directed to individual domestic needs and irrigation for farmed areas.

Small Community Service Districts provide water (and some wastewater) services to communities in the Northern Subbasin (*Table 13*). The Humboldt Lafco (2009) and Humboldt County General Plan Update EIR (2012) reviewed existing system services and proposed modifications:

- **Miranda Community Services District** provides water and wastewater services.
  - The water system currently has 143 connections, with a capacity of 220. Water is pumped from two wells (110 and 115 gallons per minute (gpm)) which access SF Eel River subsurface flows and feed a 200,000 gallon storage tank. Average daily use is 55-60,000 gpd and maximum daily use is 200,000 gpd in August and September. The CSD currently operates at 85% capacity and has no

plans to upgrade the water system or modify their sphere of influence boundaries.

- The wastewater treatment system transfers effluent from 143 residences to community septic tanks, where it is chlorinated and stored in a settling pond near the SF Eel River. Treated effluent leaches into gravel layers underlying the river and discharge monitoring reports are submitted to the CRWQCB to insure that water quality of effluent meets acceptable standards. There are no plans to modify the system at this time.

- **Myers Flat Municipal Water Association** provides water to 103 connections; all wastewater is treated in individual septic systems in the service area.
- **Phillipsville Community Services District** provides water service only; all residences in the service area are currently served by individual septic systems. The water system currently serves 65 connections, and the system was recently upgraded to address inadequate storage capacity, limited source capacity, inadequate distribution system materials, and lack of treatment. Construction was completed in 2011 and the system can now serve all existing connections and planned development connections.
- **Weott Community Services District** provides water and wastewater services.
  - The water system currently supplies 140 connections, with no additional connections available. There are two surface water sources, both with separate treatment and distribution systems. Peak daily demands are currently 128% of source capacity, and 210% of existing treatment capacity, and demands are higher during summer months. The district plans to install meters and has completed some system upgrades (including addressing major leaks), but no new treatment equipment has been installed.
  - The wastewater system has 134 connections and is operating at 47% capacity. The system is functioning well and no improvements are planned; planned development connections will be served by the existing facilities.

Since the 1970s, groundwater has been used by residences, and is used increasingly for large- and small-scale marijuana cultivation operations throughout the basin. The water supply has not been adequate to keep up with the demand. As a result, residences and growers supplement the groundwater/well water with direct surface diversion, often pumping water into storage tanks for later use, which is particularly problematic for juvenile salmonids during hot, dry summer months (June through October) when flow is at a minimum (Weiser 2012). Diversions will be discussed further in the Water Use section of this report.

*Table 13. Water and wastewater service providers in the SF Eel River Northern Subbasin (from Humboldt County General Plan Update Draft EIR 2012).*

| Water Provider | Connections | | Capacity | | | Usage | |
|---|---|---|---|---|---|---|---|
| | Existing | Available | Supply (mgd) | Treatment (mgd) | Storage (mg) | Peak Day (mgd) | Connection (gpd) |
| Miranda Community Services District | 143 | 77 | 0.338 | Not required | 0.200 | 0.220 | 1,538 |
| Myers Flat Municipal Water Association | 103 | 0 | Unknown, but limiting | 0 | 0.300 | 0.138 | 1,340 |
| Phillipsville Community Services District | 65 | 0 | Unknown, but not limiting | 0 | 0.075 | 0.085 | 1,308 |
| Weott Community Services District | 140 | 0 | 0.202 | 0.113 | 0.169 | 0.258 | 1,843 |
| **Wastewater Service Provider** | **Subbasin Served** | **Connections** | | **Permitted Capacity (mgd)** | | **Flows (mgd)** | |
| | | Existing | Available | Dry Weather | Wet Weather | Existing Dry Weather | Peak Wet Weather |
| Miranda Community Services District | Northern | 110 | 59 | 0.046 | N/A | 0.030 | 0.10 |
| Weott Community Services District | Northern | 134 | 151 | 0.030 | N/A | 0.014 | 0.03 |

### Grazing/Timber

Approximately 9% of the land in the Northern Subbasin is utilized for livestock grazing and small timber operations. These differ from commercial timber production operations because they are small, usually family-owned ranches that manage their lands using a variety of techniques and grazing schedules. Streams in the Northern Subbasin are affected by these land use practices because all parcels with active management (e.g. logging) require access roads, which are often built using improper construction techniques and in poorly chosen locations. These roads have become a significant source for water quality degradation in rural watersheds (Kocher et al. 2007). In areas where livestock are allowed unrestricted access to creeks, levels of these constituents may exceed water quality standards in areas with extensive livestock use (Knox et al. 2007). This poses a threat to chemical water quality, increases the amount of sediment introduced into the watershed through bank erosion, and may result in the reduction or elimination of riparian vegetation (Hubbard et al 2004).

Grazing was the primary land use in the Upper Bull Creek drainage until the early 1940s, with ranchers harvesting timber to increase pastureland acreage for grazing, and periodically burning grasslands to maintain open areas for grazing cattle and sheep (Stillwater Sciences 1999, JWMW 2000). During this time, most native bunch grasses were replaced by European grasses and invasive weeds (JMWM 2000). Beginning in 1946, ranchers were required to harvest timber on their land in order to avoid taxation, and grazing, burning, and timber harvest practices all resulted in increased sediment delivery to streams. Following the 1955 and 1964 floods, all of the privately owned ranch land in the Upper Bull Creek drainage was sold to the State Parks, and all grazing activity ceased. Current grazing/timber harvest occurs primarily in the southern part of the Northern Subbasin, east of Phillipsville and west in the Butte Creek and South Fork Salmon Creek drainages (*Figure 21*).

## Roads

As the Northern Subbasin was settled in the late 1800s, transportation routes grew and expanded. Wagon trails became roads and roads were upgraded into highways to facilitate transportation of people and resources. In forested upland areas, many logging roads were built to facilitate access to and transport of timber. Most of these logging roads are not paved and many are not mapped.

Cal Fire (CDF) categorizes roads based on capacity, surface material, and frequency of use. Permanent roads include primary (4+ lanes) and secondary (2-3 lanes) paved roads and rocked (improved) roads; seasonal and temporary roads are considered unimproved. There are approximately 500 miles of roads in the Northern Subbasin (road density = 3.33 miles/square mile). Fifty seven percent (285 miles) are existing seasonal roads used for timber harvest and both public and private property access (*Figure 24*). Most of these seasonal roads are located in the Salmon, Elk, Bridge, and Fish Creek drainages for access to timber harvest sites and for residential access to privately owned parcels in the middle and southern areas of the subbasin.

Historically, there was a significant amount of sediment deposited in Northern Subbasin streams due to past land use practices, especially roads associated with timber harvest and residential development (Stillwater Sciences 1999). Although these activities were reduced in the northern part of the subbasin when the State Park purchased much of the land in the Bull Creek drainage, legacy effects of these practices are still concerns throughout most of the subbasin. Twenty four percent of the land in this subbasin is currently used for timber production, with a higher percentage of use historically. Both new and abandoned seasonal roads contribute to the destabilization of hillslopes and increased sediment delivery to streams. Seasonal roads are designed for long-term periodic (dry weather) use, built to lower engineering standards than permanent roads, and have minimal material surfacing (Kocher et al. 2007). As a result, seasonal roads provide more fine sediment input to streams than any other type of road. McCashion and Rice (1983) determined that logging road erosion increases with the slope traversed by the road and with the amount of traffic, and they found that nearly 25% of erosion measured on logging roads in northwestern California could have been prevented with conventional engineering methods. Restoration projects have focused on rehabilitation of seasonal roads throughout the Northern Subbasin.

In the Salmon Creek watershed, timber harvest and residential development, often with more than one residence per parcel and extensive marijuana cultivation operations, have resulted in additional road construction and traffic. Road density in this watershed is greater than 7 miles/square mile, which is more than twice the average density for the subbasin. In 2000, JMWM completed a watershed assessment, with the primary goal of inventorying road, hillslope, and streambank sediment delivered to the creek and its tributaries. They found that the potential sediment delivery from roads in this watershed was lower than that found in comparable watersheds, most likely because many of the high-priority sediment producing sites had been identified and treated (JMWM 2000, HCRCD 2002).

Stillwater Sciences (1999) reported that the highest sediment loading in the SF Eel River Basin occurred in the Bull Creek drainage. This was due in part to high precipitation and uplift rates, but also due to increased sediment from natural process such as earthflow toes and associated gullies, shallow landslides, and soil creep; and from road-related sources including road crossing and gully erosion, road prism sheetwash, and skid trail erosion (Stillwater Sciences 1999). The highest rate of sediment production was due to landslides, and road related sediment input was generally lower in this basin due to park restoration efforts.

Permanent roads make up 23% (117 miles) of the roads in the Northern Subbasin, and the majority of these permanent roads are found in Humboldt Redwoods State Park in the northern part of the subbasin (*Figure 24*). This drainage has few seasonal roads compared to watersheds in the southern and eastern parts of the subbasin, due to reduced commercial timber harvest and residential development.

When developing restoration initiatives the NMFS (1996) classified basins considering the following road densities categories: <2 miles/square mile with no valley bottom roads as "properly functioning"; those with densities of 2-3 miles/square mile with some valley bottom roads as "at risk"; and those with densities of >3 miles/square mile with many valley bottom roads as "not properly functioning". According to this classification system, the Northern Subbasin, with an overall road density of 3.33 miles/square mile, is "not properly functioning", and road rehabilitation projects should be a high priority for watershed managers.

Increased fine-sediment in stream gravel has been linked to decreased fry emergence, decreased juvenile densities, reduced diversity and abundance of invertebrates, loss of winter carrying capacity, and increased predation (Gucinski et al. 2001). Road rehabilitation projects that reduce fine sediment input are a priority throughout the subbasin, particularly in Humboldt Redwoods State Park, where the focus of many restoration projects has been on cleaning up and minimizing the effects of legacy logging roads. For a partial list of projects, go to: ftp://ftpdpla.water.ca.gov/users/prop50/09595_Humboldt/TechnicalDoc_Vol4of8/38_Head_Hunter_Smoke_House_Sediment_Tech_docs/Multi-Year%20Project%20Cost%20Summary.pdf. A more detailed review and discussion of ongoing road rehabilitation projects throughout the Northern Subbasin can be found in the Restoration Projects section of this assessment report.

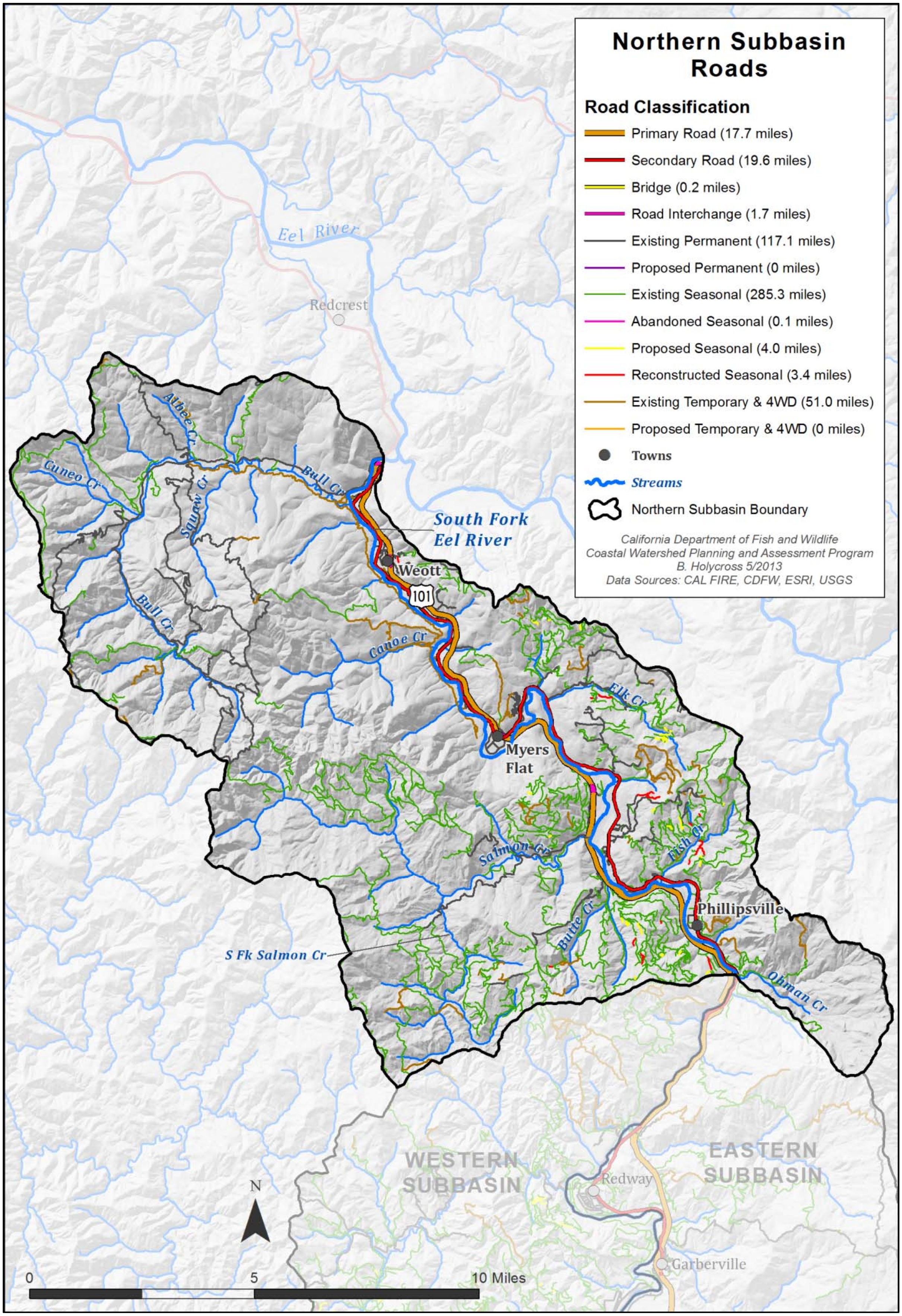



*Figure 24. Roads in the SF Eel River Northern Subbasin.*

## Gravel Mining

Gravel mining activities occur in most north coast rivers, and the primary purpose of these activities is to efficiently supply local markets with construction aggregate while minimizing damaging effects on riverine habitats (CHERT 2011). Aggradation is defined as the increase in land elevation due to deposition of sediment in a streambed. The Eel River Basin has one of the highest natural sediment yields in the world for any river of its size, and channel aggradation from past floods and poor land practices would seem to be more of a concern than downcutting due to over extraction of gravel. Historically, gravel mining activities throughout the Eel River Basin created migration barriers for adult fish, sometimes leading to stranding in shallows and eventual mortality. Problems of over extraction and threats to the fisheries led to a system of monitoring and adaptive management.

Gravel mining occurs in two relatively isolated locations in the SF Eel River Basin between Cooks Valley and Redway (Stillwater Sciences 2008). None of these mining operations are located in the Northern Subbasin. For a complete discussion of gravel mining and its effects on fish and habitat, see the SF Eel River Basin overview, and the Western and Eastern Subbasin sections of this assessment report.

## Water Use: Diversions, Dams, and Hydrologic Disturbances

### Diversions

Water rights are defined as "the legal entitlement authorizing water to be diverted from a specified source and put to beneficial, nonwasteful use" (SWRCB 2013). There are many different types of water rights in CA, including: appropriative (for commercial use), registered (for small domestic or livestock use), and riparian (for use on land adjacent to the water body). Appropriative rights require an application, environmental review, public notification, permit issuance, and finally licensing, providing "beneficial use" of the requested amount has been demonstrated. Registered users divert water from streams for use in non-riparian areas, and are permitted to use a specific amount of water. Riparian rights have a higher priority than appropriative rights, and there are no required permits, licenses, or government approval. Riparian rights apply to water that would naturally flow in the stream, and users are not entitled to divert water for storage, for use during the dry season, or to use on land outside the watershed (SWRCB 2013). Beginning in 2010, riparian users were required to file a statement of use with the SWRCB, but few have complied and the magnitude of the diversions and the impact on fish and wildlife in the SF Eel River Basin remains unknown. For additional information on water rights and diversion, go to: http://www.calsalmon.org/srf-projects/water-rights-education.

In the Northern Subbasin, there are ten appropriative water rights permits for direct diversion currently on file with the State Water Resources Control Board, with total a total maximum diversion amount of approximately 1,204 acre feet per year (*Table 14*). Only one of these includes diversion storage for domestic use and fire protection, with a total storage amount of 2,420 gpd.

*Table 14* does not include diversions that are not registered with the State Division of Water Rights, including illegal diversions for residential and/or industrial marijuana growing operations. Water diversion during dry weather, low-flow times (June through October) and pollution are some of the most devastating results of the rapidly expanding marijuana industry, and are associated with large, irresponsible cultivation operations, often located on public land (Evers 2010). This will be discussed further in the Industrial Marijuana Agriculture section of this assessment.

### Dams

There are no dams located in the SF Eel River Northern Subbasin.

*Table 14. Water rights in the Northern Subbasin of the SF Eel River Basin (WRIMS 2012).*

| Creek | Application Number | Direct Diversion | Maximum Application Direct Diversion | Diversion Storage | Purpose |
|---|---|---|---|---|---|
| UNSP, SF Eel River | A009788 | 970 gpd | 1.1 afy | | Recreation |
| UNSP, Mill Creek | A014029 | 0.09 cfs | 38.4 afy | | Irrigation |
| UNST, Mill Creek | A014076 | 0.03 cfs | 12.8 afy | | Irrigation |
| Pete Creek | A014080 | 0.4 cfs | 289.6 afy | | Municipal |
| UNSP, Bridge Creek | A017465 | | 2.7 afy | 2420 gpd | Domestic and fire protection |
| Feese Creek | A019312 | 9000 gpd | 4.8 afy | | Domestic |
| SF Eel River Underflow | A019923 | 0.89 cfs | 644.3 afy | | Temporary municipal (use by 12/1998) |
| SF Eel River | A022018 | 0.046 cfs | 21.7 afy | | Domestic and irrigation |
| UNST, South Fork Salmon River | A025456 | 4,800 gpd | 2.8 afy | | Irrigation and domestic |
| UNST, Mill Creek | A025677 | 0.39 cfs | 186 afy | | Municipal (use by 12/2005) |
| **TOTAL (n=10)** | | | **1204.2 afy** | | |

## Water Drafting for Dust Abatement

The following section is based on information provided by the North Coast Regional Water Quality Control Board (NCRWQCB) in June of 2014 (J. Burke, Senior Engineering Geologist, Southern Timber Unit, NCRWQCB, personal communication 2014).

Water is used for dust abatement on timber company roads throughout Humboldt and Mendocino counties between May 15th and October 15th. Timber companies draw water from streams near active harvest operations and apply it to unpaved roads to maintain safety and visibility, minimize input of fine sediment to adjacent streams, and to maintain infrastructure. The amount of water used may be substantial at a time when stream flow is already low. Estimates for the amount of water used each harvest season range from 2,000 to 4,000 gallons/mile/day (treating two times each day). Quantities vary depending on the volume of traffic, road surface, exposure/aspect (east side roads tend to be drier and require more treatment than west side roads), and the use of additional treatments such as magnesium chloride, which may reduce the amount of water required by approximately 50%. It is difficult to make generalizations about the amount of water used, but one timber company with approximately 400,000 acres located in Northwestern California estimated an annual use of two million gallons for dust abatement.

Regulations and limitations currently exist for surface water drafting, including the following:

- Lake and Streambed Alteration Agreements – any landowner that is drafting water must notify CDFW and develop a Streambed Alteration Agreement. These agreements generally contain requirements pertaining to water depth, bypass stream flow, and stream velocity. However, there are no consistent region- or state-wide standards regarding the specific conditions of these agreements;
- Anadromous Salmonid Protection (ASP) Rules – these stipulate the following conditions:
  - Bypass flows during drafting shall be at least 2 cubic feet per second;
  - Diversion rates are limited to 10 percent of surface flow; and
  - Pool volume reduction shall not exceed 10 percent.
- Board of Forestry Emergency rules for water drafting – these require users to comply with CDFW Streambed Alteration Agreements, but do not include specific recommendations for bypass flows;
- Statement of Water Diversion and Use – these are required by the State Water Board for all individuals or organizations that divert surface water or pump groundwater. Beginning January 1, 2012, users are required to measure and report the amount of water diverted each month.

Until recently, the amount of water used and the timing and location of withdrawals has not been carefully documented by industrial timber companies. Drought conditions in California, which are expected to persist through the 2014 logging season, will result in reduced water availability in areas throughout the SF Eel River watershed. In February 2014, staff from timber harvest review agencies including CDFW, CalFire, State and Regional Water Quality Control Boards, and the California Geologic Survey met to discuss water drafting on industrial timber harvest lands, limitations associated with these activities that further reduce instream flows, and the impacts of these activities in relation to current drought conditions. The interagency group developed a list of actions that could be developed to ensure the efficient use of water for dust control, including the following:

- Investigate current scope of use by requesting information from large landowners in an effort to quantify amounts used and specific data available on withdrawal locations and applications. This information will be used to determine if current use is significant to warrant changes in practices;
- Education and outreach to address efficient water use and alternatives to current drafting methods;
- Establish a list of best management practices (BMPs) to present in timber review correspondence;
- Develop regulatory solutions and recommendations; and
- Evaluate prudent use of alternatives to water for dust abatement, especially in areas with existing high industrial or agricultural runoff rates.

Existing ASP rules and regulations specifying minimum bypass flows and diversion rates may be adequate to minimize the impacts to water supplies solely from water drafting for industrial timber harvest operations in most situations. However, additional regulations/actions may be required in watersheds throughout the SF Eel River Basin where significant volumes are already diverted in response to high water demands from industrial marijuana cultivation and residential use.

### Industrial Marijuana Agriculture

The permitted water diversions discussed above do not include illegal diversions from the recent proliferation of industrial marijuana agricultural operations throughout the SF Eel River Basin. During the late 1960s and early ‘70s, a large influx of “back to the landers” came to the SF Eel River Basin in search of an independent, peaceful, and rural lifestyle (USBLM et al. 1996). With the decline of the timber and fisheries industries, also in the 1970s, the local economy began to dwindle. With favorable climate conditions and available land, back to the landers, displaced forest workers, and successive generations of homesteaders turned their ingenuity and agricultural talents to cultivating marijuana to accommodate the rising demand both locally and throughout the state. Mendocino and Humboldt Counties are home to the largest marijuana growing operations in the state, and these operations are increasing in both size and number, with a corresponding increase in local revenue currently accounting for nearly two-thirds of Mendocino County’s economy (Evers 2010).

Since the passage of Proposition 215 in 1996 and SB420 in 2003 in California, CDFW field staff, local law enforcement agencies, and other state and federal agency representatives have discovered increasing numbers of large marijuana grows on private lands, presumably for medical purposes.

During an August 29th, 2012 flight over several watersheds in the SF Eel River Basin, Third District Supervisor Mark Lovelace and CDFW staff observed many growing operations that showed evidence of illegal and unpermitted clearcutting, road building, and water diversion (www.arcataeye.com). In the Salmon Creek and Redwood Creek watersheds, two coho salmon strongholds in the SF Eel River Basin, CDFW Biologist Scott Bauer used satellite photography to assess the number of indoor and outdoor grows, then estimated the number of plants grown in greenhouses, and the total amount of water necessary to supply these operations during each growing season (Easthouse 2013). Bauer identified 567 grows (281 outdoor and 286 indoor/greenhouse) in the Salmon Creek drainage (located in the Northern Subbasin) and 549 grows (226 outdoor and 323 indoor) in the Redwood Creek watershed (*Figure 25, Figure 26*). The total number of plants estimated to be associated with these grow operations was: 20,000 (8,700 in greenhouses and

11,300 outdoors) in Salmon Creek; and 18,500 (8,100 in greenhouses and 10,400 outdoors) in Redwood Creek. Bauer estimated that grow operations in Salmon Creek are consuming more than 18 million gallons of water per growing season and more than 16.5 million gallons per season in Redwood Creek. This usage during the growing season is nearly 30% of the total streamflow in these basins (Easthouse 2013). Although Redwood Creek is not located within the boundaries of the Northern Subbasin, information on grows was included in this section because it demonstrates how marijuana cultivation impacts local watersheds throughout the SF Eel River Basin, particularly in those with high percentages of residential land use.

CWPAP staff documented extremely low flow conditions in Salmon Creek in August and September, 2013. These conditions resulted from limited rainfall in the winter of 2012-2013 and an increase in the number of diversions due to extensive marijuana cultivation operations (*Figure 25*). Flows decreased dramatically during the study, due primarily to active diversions supplying water to grow operations throughout the watershed.

While numerous factors may be relevant (wet spring vs dry spring, overall summer temperatures, etc.), a 10,000 square foot outdoor marijuana grow operation uses approximately 250,000 gallons of water in a five-month growing season (T. LaBanca, CDFW, personal communication 2012).

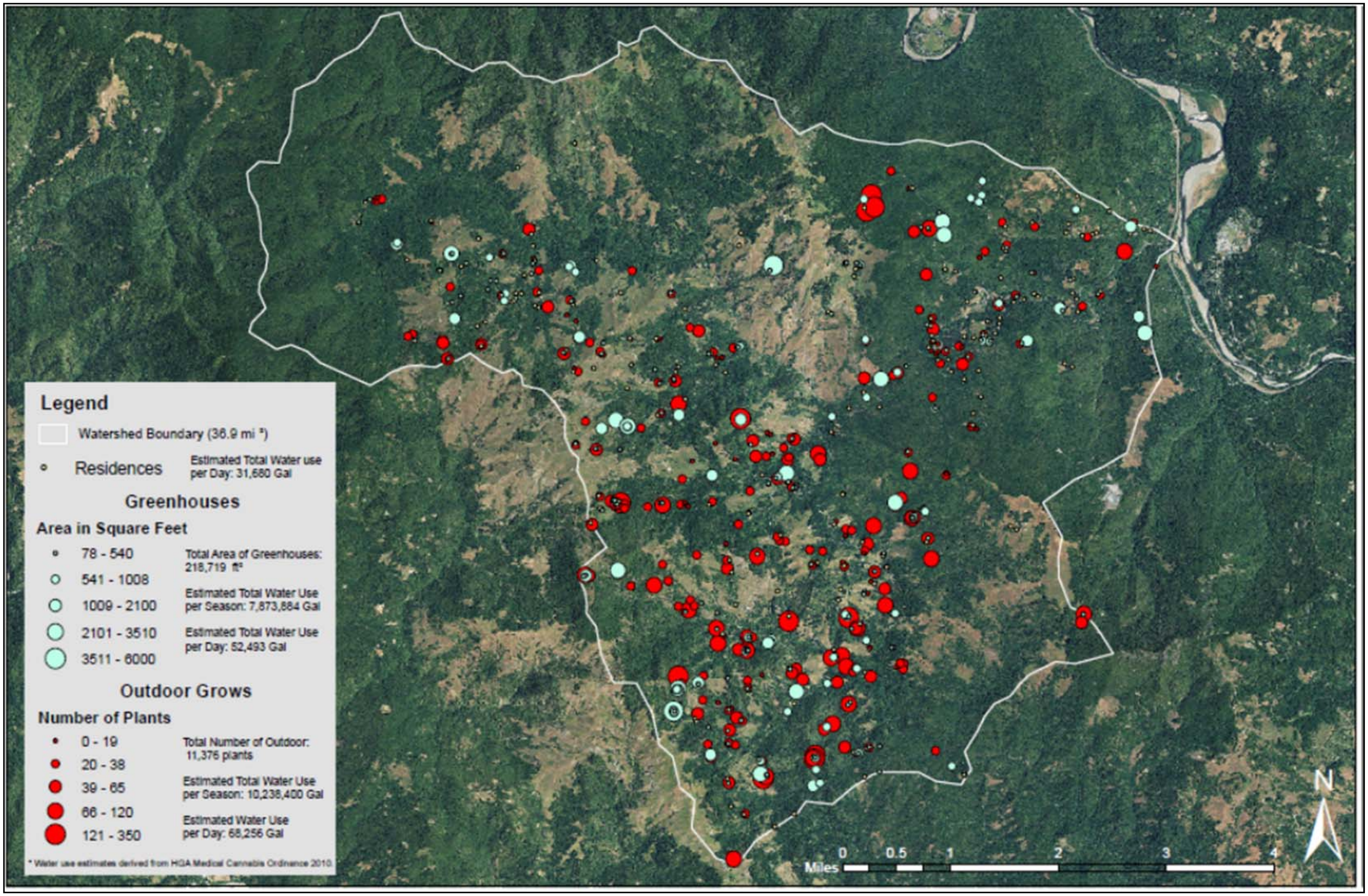



*Figure 25. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Salmon Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW 2013).*

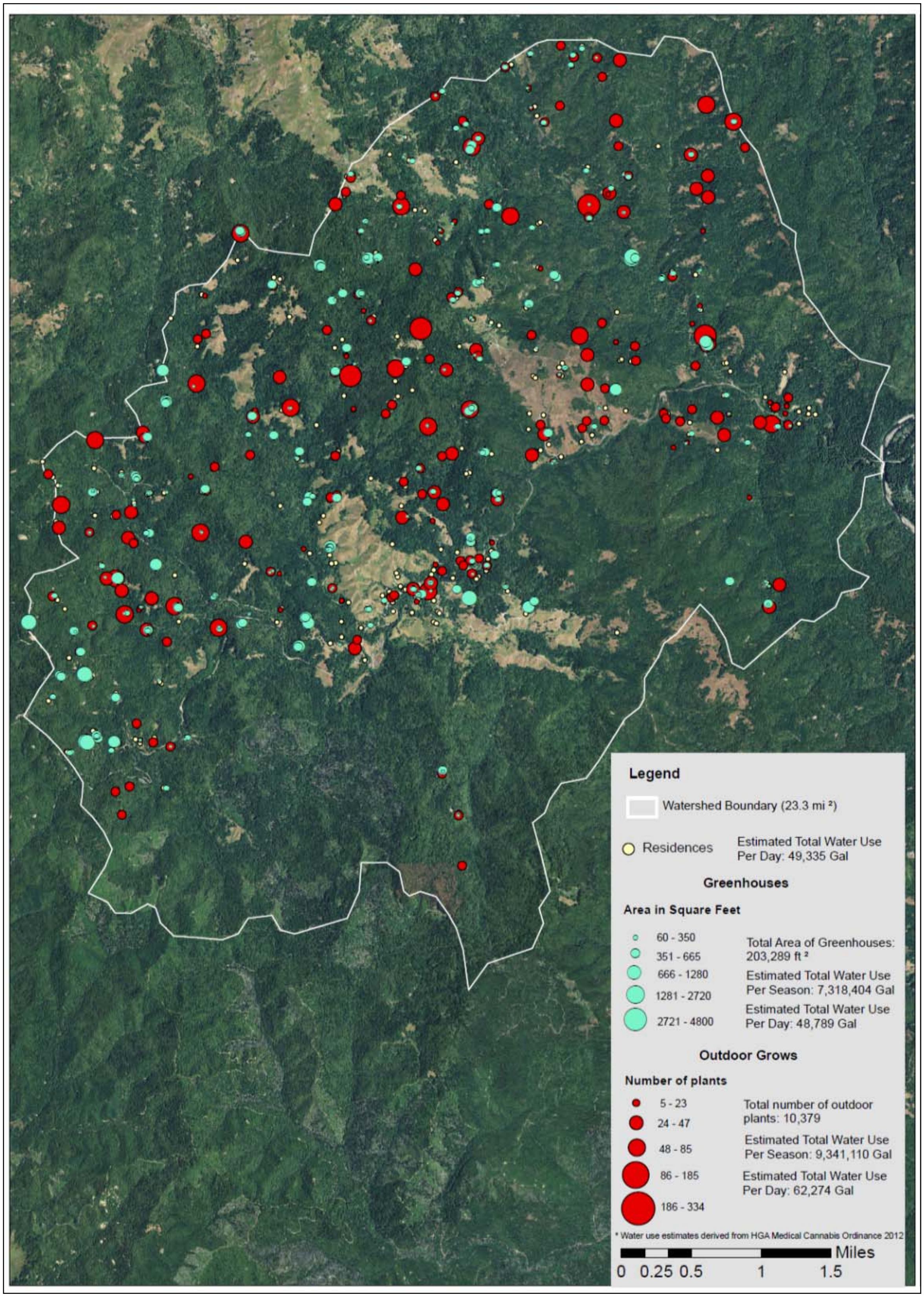



*Figure 26. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Redwood Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW 2013).*

Considering the number of outdoor and indoor operations within the watershed, this industry is having a significant effect on water flows in the SF Eel River and its tributaries. A recent trend has emerged that shows atypical low flows occurring during the late summer to early fall even during wet weather years (T. LaBanca, personal communication 2012). *Figure 27, Figure 28, and Figure 29* illustrate this potential trend using flow data from the USGS SF Eel River gauging stations near Miranda (RM 17), Leggett (RM 66), and Bull Creek (4 miles upstream from the confluence of the mainstem SF Eel River). Daily mean discharge (in cfs) for the 2011 2012, and 2013 water years was plotted along with the median daily statistic (73-year flow average for the Miranda gauge, 40-year flow average for the Leggett gauge, and 52-year flow average for the Bull Creek gauge). 2011 was considered a wet weather year, with above average rainfall throughout Northern California, and 2012 and 2013 were considered dry years, with less than normal rainfall received. *Figure 27* shows a slight decrease in low flows in September and October 2011 at Miranda compared to the 73 year average, and significantly lower discharge from July through November 2012 and July through December 2013, continuing into January 2014, when compared to the 73 year average.

*Figure 28* shows slightly lower flows in September and October 2011 and considerably lower flows in August, September, and October 2012 and 2013 compared to the 40-year average at Leggett. *Figure 29* shows much lower flows in September and October 2011 and 2012, and for nearly all of 2013, compared to the 52-year average flows recorded at the Bull Creek gauge. These atypical low flows (especially during normal water years) support the contention that water diversions by the marijuana industry are affecting streams and tributaries throughout the SF Eel River Basin by increasing water temperatures, reducing flow at critical times for fish rearing and migration, and altering water chemistry in the entire basin.

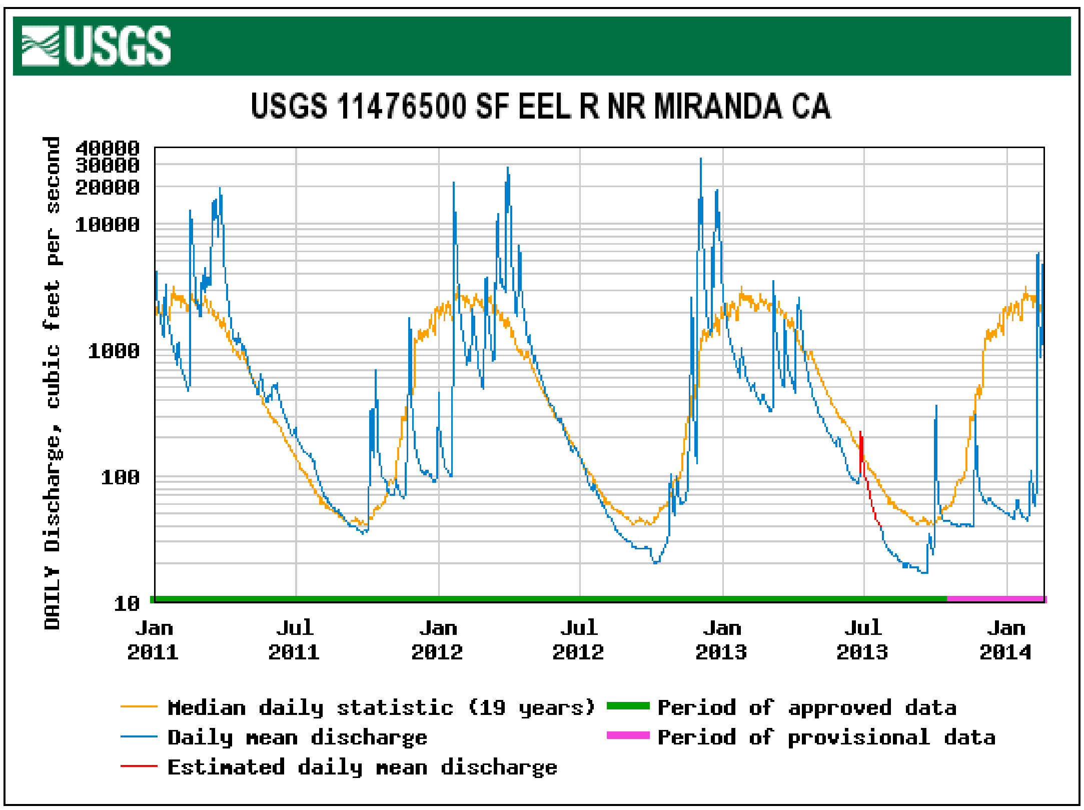



*Figure 27. USGS gauging station near Miranda showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (73-year average in cfs).*

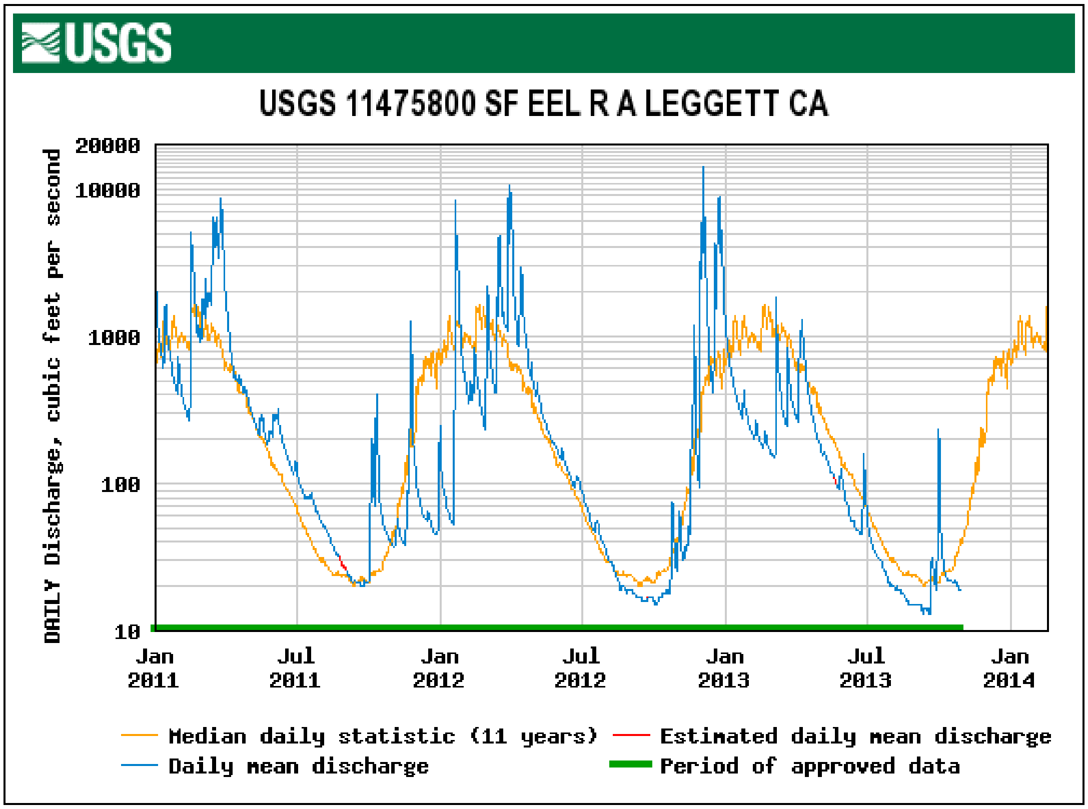



*Figure 28. USGS gauging station near Legett showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (40-year average in cfs).*

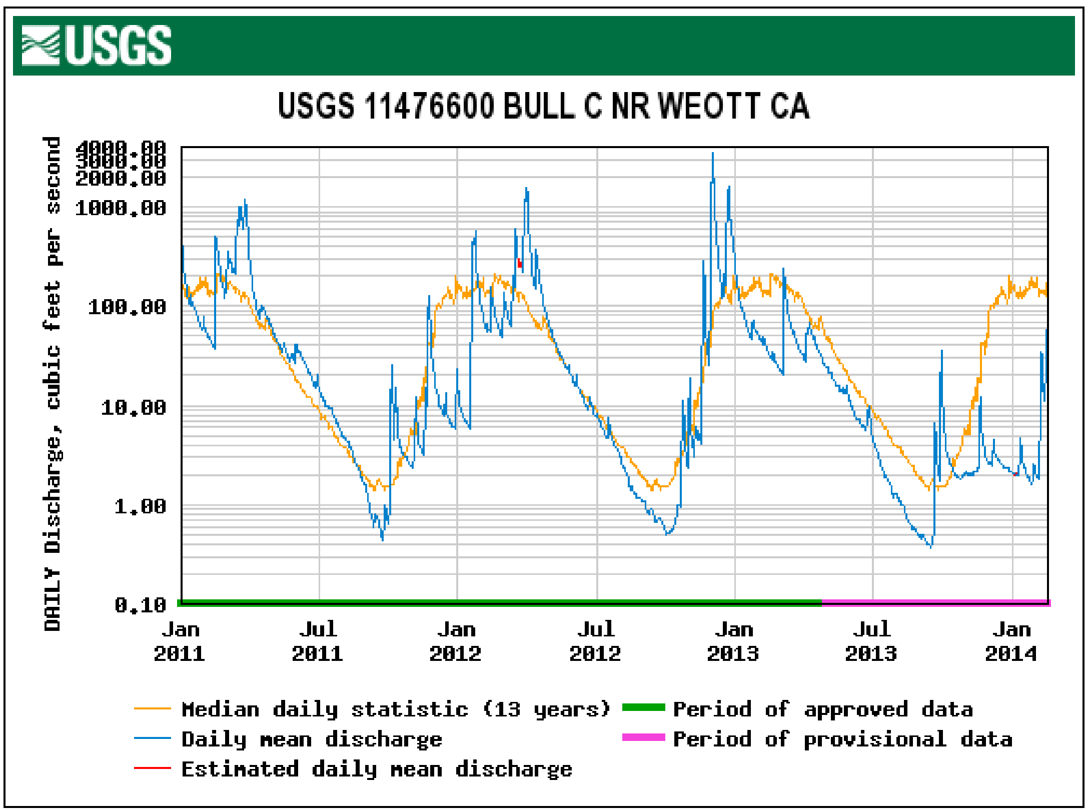



*Figure 29. USGS gauging station at Bull Creek showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (52-year average in cfs).*

Unlike permitted/licensed water diversions and other regulated land use activities such as legal timber harvesting and/or mining operations, there are no established "best management practices" or any review by agencies like CDFW and the State Water Quality Control Board. Therefore, a wide range of effects to watercourses and their aquatic resources are associated with these industrial marijuana agricultural operations. These impacts may include the following (CDFW 2012, T. LaBanca, personal communication 2012):

- Illegal water diversions that draw directly from the streams without screens or bypass, so juvenile fish and amphibian can be pulled from their habitat and die;
- Decreased stream flows due to illegal water diversions, leading to reduced stream depths and diminished pool habitat, possible subsurface flow in streams with excessive sediment recruitment, elevated water temperatures, and concentrated pollutants;
- A wide range of pollutants may be used (*Table 15*), including fuel, fertilizers, herbicides, pesticides, rodenticides, and construction debris. These chemicals and debris may go directly into watercourses or could leach into the soil, eventually being released into the water throughout the year;
- Human waste from camps that could also directly enter or leach into watercourses;
- Sediment from improperly constructed roads and construction around grow sites that enters watercourses throughout the rainy season;
- "Grow trash" such as plastic hose, construction supplies, and gardening waste left on site;
- Conversion and fragmentation of natural wildlife habitats and native ecosystems. Riparian and aquatic habitat may be disturbed or removed, grasslands and hillside habitats cleared and leveled; and
- Unpermitted timber harvests that may occur when an area is cleared for an agricultural grow operation.

There are many pollutants in fertilizers and pesticides that may enter the stream system from grow operations, but one which poses a particular danger to salmonids is copper. Sorenson (1991, in Woody 2007) determined that copper levels below lethal concentrations have been shown to:

- Interfere with normal migration;
- Impair salmonids' sense of smell;
- Impair their ability to fight disease;
- Make breathing difficult;
- Impair their ability to sense vibrations through their lateral line canals, which interferes with their ability to avoid predators;
- Impair brain function;
- Change their blood chemistry and metabolism; and
- Modify natural hatch rates.

Additional research is necessary to determine the concentrations of copper entering the SF Eel River system, and to determine the impacts of other pollutants from pesticides and herbicides on salmonids within this system.

There are some exceptions to the poor land-use practices associated with marijuana cultivation listed above. Local residents with small scale cultivation operations seem to employ more care than larger growers who do not live on site, and may not even own the land. A more comprehensive understanding of the magnitude of the impacts of industrial operations, their effects on fish and wildlife, and consumer and grower education leading to regulation is necessary to address these problems (Weiser 2012).

Although there are no established best management practices for marijuana growing, the Northern California Farmers Guide is a community-based collaborative project that outlines concerns and solutions for many of the issues listed above. This guide is an evolving project that is designed to increase awareness of environmental issues and help cannabis growers protect the environment while growing a high quality, sustainably produced crop. For more information, go to: http://www.norcalfarmersguide.org/.

*Table 15. Pollutants associated with marijuana grows and their effects on fish and wildlife (adapted from Greacen 2012).*

| Pollutant | Application | Result |
|---|---|---|
| Rodenticide | Poison is applied to garden and/or perimeter to keep rodents from harming crop. | Wild animal populations are impacted as poison travels up the food chain. Contamination of fresh stream water. |
| Insecticide | Poison is applied to garden and/or perimeter to keep insects from harming crop. | Toxic to native insects as well as fish. |
| Fungicide | Fungicide is applied to plants to keep fungus from harming crop. | Can be toxic to fish and beneficial soil invertebrates. May contain mercury. |
| Fertilizer | Fertilizer and soil amended with potent nutrients are brought to the grow and used liberally for the growing season then discarded. | Nutrients get into the streams causing problematic algal blooms. Used soil/fertilizer is washed into the streams during the rainy season which adds to the sediment load. Typically leads to a reduction of dissolved oxygen in streams. |
| Sediment | Tractor/dozer work on larger grows is implemented, often with little or no regard for good road/landscape practices in regard to site stability and erosion. | Sediment from dozer work (roads, landings, gardens) gets into streams. |
| Reduced flow | Water is taken from a nearby stream by diversion pipe or water truck and used to water crop (individual plants take 3-5 gallons/day). | Evapotranspiration releases most of the water into the atmosphere resulting in a loss of water available to the stream during the driest, hottest part of the year producing extremely low flows downstream of diversion. |

# Fish Habitat Relationship

## Fishery Resources

### Historical Distribution

Fish presence has been documented in Northern Subbasin streams by anecdotal accounts and observations made during surveys since 1938. Stream survey efforts were neither specific nor standardized until 1991 when the first edition of the *California Salmonid Stream Habitat Restoration Manual (*Flosi et al. 2010) was published. As a result, many early stream survey observations are not quantitative and have limited use.

Historical salmonid presence documentation is available for 33 Northern Subbasin streams. Information sources include CDFW carcass surveys, stream survey and inventory reports, electrofishing and general field notes, downstream migrant trapping data, and spawning stock and escapement reports (*Table 16*). Coho salmon were found in 12 Northern Subbasin streams. Large tributaries to the mainstem SF Eel River with documented historical coho salmon presence included Bull Creek and Salmon Creek. Chinook salmon were documented in 12 Northern Subbasin streams, and steelhead were found in 20 of the 33 tributaries. Eleven creeks had no record of Chinook, coho salmon, or steelhead presence, but unidentified salmonids were observed in ten of these streams (*Table 16*).

*Table 16. Documented fish presence in surveys from 1938 to 2001 in the Northern Subbasin.*

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Anderson Creek | 3/22/1977 | Stream Survey (CDFG 1977) | | | | |
| | 12/22/1988, 1/19/1989 | Carcass Survey Summary (CDFG 1989) | X | X | | X |
| Butte Creek (Bear Butte Creek) | 6/19/1960 | Stream Survey (CDFG 1960) | | | X | |
| | 5/9/1962 | Stream Survey (CDFG 1962) | | | | X |
| | 4/12, 4/23/1968 | Electrofishing Field Note (CDFG 1968) | | X | X | |
| | 4/30/1969 | Field Note (CDFG 1969) | | X | X | |
| | 3/15/1974 | Memorandum (CDFG 1974) | | | X | |
| | 7/6/1977 | Stream Survey (BLM 1977) | | | X | |
| | 4/3/1980 | Stream Survey (CDFG 1980) | | | | X |
| Butte Creek and Coon Creek | 9/19, 9/25/1984 | Stream Survey (CDFG 1984) | | | | X |
| Bridge Creek | 8/3/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 7/6/1961 | Stream Survey (CDFG 1961) | | | | X |
| | 7/27/1967 | Fish Passage Survey (CDFG 1967) | | | | X |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Bridge Creek (con.) | 6/20/1977 | Field Note (CDFG 1977) | | | | |
| | 6/29/1993 | Stream Inventory Report (CDFG 1993) | | | X | |
| | 10/6/1993 | Stream Inventory Report (CDFG 1993) | | | X | |
| Bull Creek | 8/3/1938 | Stream Survey (CDFG 1938) | | X | X | |
| | Circa 1938 | Stream Survey (CDFG no date) | | | X | X |
| | 11/25/1964 | Field Note (CDFG 1964) | X | | | X |
| | 7/16/1968 | Field Note (CDFG 1968) | | | | X |
| | 9/7/1973 | Field Note (CDFG 1973) | | | X | |
| | 8/26/1974 | Field Note (CDFG 1974) | | | X | |
| | 9/16/1982 | Population Estimate (CDFG 1982) | | | X | |
| | 11/27/1982 | Spawning Stock Survey (CDFG 1982) | | | | |
| | 1/13/1984 | Spawner Survey Summary (CDFG 1984) | | | | |
| | 12/23, 1/22/1988 | CWT Recovery Field Note (CDFG 1988) | X | X | | |
| | 1/9/1990 | Carcass Survey Field Note (CDFG 1990) | | X | X | X |
| | 3/22 - 6/1/1988 | Downstream Migrant Trapping (PCFFA 1998) | X | X | X | |
| | 7/24, 7/25/1991 | Stream Inventory Report (CDFG 1991) | | | X | |
| Bull Creek from headwaters forks to Panther Creek | 2/20/1987 | Field Note (CDFG 1987) | | | X | |
| Bull Creek from Cuneo Creek downstream | 1988 | Downstream Migrant Trapping (CDFG 1998) | X | X | X | |
| Bull Creek from Mill Creek downstream | 12/6/1988 | CWT Recovery Field Note (CDFG 1988) | X | | | |
| Burns Creek | 10/27, 11/3/1998 | Stream Inventory Report (CDFG 1998) | | | | X |
| Cabin Creek | 7/4/1962 | Field Note (CDFG 1962) | | | | X |
| | 4/8/1980 | Stream Survey (CDFG 1980) | | | | X |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Calf Creek | 1988 | Personal Communication (CDFG email 2003) | | X | | |
| Canoe Creek | 8/4/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 7/4/1962 | Stream Survey (CDFG 1962) | | | | X |
| | 7/1/1977 | Stream Survey (CDFG 1977) | | | X | |
| | 1/4/1980 | Stream Survey (CDFG 1980) | X | | | X |
| | 3/13/1985 | Field Note (CDFG 1985) | | | X | |
| | 1/25/1988 | Spawning Stock Survey (CDFG 1988) | X | | | X |
| | 9/4/1996 | Electrofishing Field Note (CDFG 1996) | | X | X | |
| Connick Creek | 6/12,6/13/1961 | Stream Survey (CDFG 1961) | | | | X |
| | 12/8/1981 | Spawning Stock Survey (CDFG 1982) | | | | |
| | 7/12/1993 | Stream Inventory Report (CDFG 1993) | | X | X | |
| Coon Creek (tributary to Butte Creek) | 5/10/1962 | Stream Survey (CDFG 1962) | | | | |
| | 4/3/1980 | Stream Survey (CDFG 1980) | | | | X |
| Corner Creek | 5/1/1980 | Stream Survey (CDFG 1980) | | | | X |
| Cow Creek | 8/9/1961 | Stream Survey (CDFG 1961) | | | | X |
| | 7/29/1963 | Stream Survey (CDFG 1963) | | | | X |
| | 7/24/1974 | Stream Survey (CDFG 1974) | | | | X |
| | 3/28/1980 | Stream Survey (CDFG 1980) | | | X | |
| | 12/22/1987 | Carcass Survey Field Note (CDFG 1987) | X | | | |
| | 1/22/1988 | Field Note (CDFG 1988) | X | | | |
| | 12/6/1988 | Field Note (CDFG 1988) | | | | |
| | 1/18/1989 | Field Note (CDFG 1989) | | | | |
| | 1/2/1991 | Stream Inventory Report (CDFG 1991) | | | X | |
| | 1/5/1994 | Field Note (CDFG 1994) | | | | |
| | 11/29, 12/29/1994 | Spawner Survey Summary (CDFG 1994) | | | | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Cow Creek (con.) | 1/2, 2/16/1996 | Field Notes (CDFG 1996) | | | X | |
| | 7/11/1996 | Electrofishing Field Form (CDFG 1996) | | | X | |
| | 12/8/1996 | Field Note (CDFG 1996) | | | | |
| Cuneo Creek | 8/3/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 7/29/1974 | Stream Survey (CDFG 1974) | | | X | |
| | 10/28/1983 | Stream Survey (CDFG 1983) | | | | X |
| | 11/11/1983 | Field Note (CDFG 1983) | | | X | |
| Cuneo Creek (South Fork) | 7/26/1991 | Stream Inventory Report (CDFG 1991) | | | | |
| Cuneo Creek (North Fork) | 7/25/1991 | Stream Inventory Report (CDFG 1991) | | | X | |
| Decker Creek | 7/4/1962 | Stream Survey (CDFG 1962) | | | | X |
| | 1/22/1988 | Spawning Stock Survey (CDFG 1988) | X | | X | |
| | 12/6/1988 | Field Note (CDFG 1988) | | | | |
| | 1/9/1990 | Field Note (CDFG 1990) | X | | | |
| | 6/29/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| Dry Creek | 6/29/1977 | Stream Survey (CDFG 1977) | | | | X |
| | 4/8/1980 | Stream Survey (CDFG 1980) | | | | X |
| | 1/17/1985 | Stream Survey (CDFG 1985) | | | | X |
| Elk Creek (tributary to SFER) | 8/3/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 6/27, 6/28/1962 | Stream Survey (CDFG 1962) | | | X | |
| | 6/29/1977 | Stream Survey (CDFG 1977) | | | X | |
| | 1/23/1990 | Field Note (CDFG 1990) | X | | | |
| | 8/27/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| | 1/6/1994 | Field Note (CDFG 1994) | | | | |
| | 1995 | Personal Communication (CDFG email 2002) | | X | | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Feese Creek | 7/17/1961 | Field Note (CDFG 1961) | | | | X |
| Fish Creek (tributary to SFER near Miranda) | 4/12/1968 | Field Note (CDFG 1968) | | X | X | |
| | 4/30/1969 | Field Note (CDFG 1969) | | X | X | |
| | 6/29/1977 | Stream Survey (CDFG 1977) | | | | X |
| | 6/28/1993 | Stream Inventory Report (CDFG 1999) | X | X | X | |
| | 1/6/1994 | Field Note (CDFG 1994) | | | | |
| Harper Creek | 7/29/1963 | Stream Survey (CDFG 1963) | | | | X |
| Mill Creek (tributary to Salmon Creek) | 1/19/1989 | Stream Survey (CDFG 1989) | | | X | |
| | 6/12/1990 | Electrofishing Field Note (CDFG 1990) | | | | |
| Mill Creek (tributary to Bull Creek) | 7/30/1974 | Stream Survey (CDFG 1974) | | | | X |
| | 6/28/1983 | Spawning Stock Survey (CDFG 1983) | | | | |
| | 2/13/1986 | Activity Report (CDFG 1986) | | | X | |
| | 12/22/1987, 1/14/88 | Carcass Survey Field Note (CDFG 1988) | X | | | |
| | 1/18/1989 | Field Note (CDFG 1989) | | | | |
| | 1/19/1990 | Field Note (CDFG 1990) | | | | X |
| Mowry Creek | 7/17/1961 | Stream Survey (CDFG 1961) | | | | |
| | 4/17/1980 | Field Note (CDFG 1980) | | | | X |
| Ohman Creek | 8/2/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 6/21/1962 | Stream Survey (CDFG 1962) | | | | X |
| Panther Creek | 4/15/1980 | Stream Survey (CDFG 1980) | | | | X |
| Panther Creek (West Fork) | 3/30/1987 | Stream Enhancement Proposal (CCC 1987) | | | X | |
| | 7/9/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| Salmon Creek | 6/1/1938 | Stream Survey (CDFG 1938) | X | | X | |
| | 11/29, 12/18/1966 | Field Note (CDFG 1966) | X | | | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Salmon Creek (con.) | 7/16/1968 | Field Note (CDFG 1968) | | | | X |
| | 6/11/1969 | Electrofishing Field Note (CDFG 1969) | | | X | |
| | 7/29/1971 | Field Note (CDFG 1971) | | | X | |
| | 9/6/1977 | Stream Survey (BLM 1977) | | | | |
| | 1986-1990 | Downstream Migrant Trapping Summary (PCFFA 1990) | X | | X | |
| | 12/30/1987, 1/21/1988 | Field Note (CDFG 1988) | X | | | |
| | 1/18/1990 | Field Note (CDFG 1990) | X | | | |
| | April, May 1991 | Downstream Migrant Trapping Data (PCFFA 1991) | X | | X | |
| | 9/21, 9/25/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| | 1998 | Downstream Migrant Trapping Notes (PCFFA 1988) | X | X | | |
| Slide Creek | 7/7, 7/8/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| Squaw Creek | 6/20/1938 | Stream Survey (CDFG 1938) | X | X | X | |
| | Circa 1962 | Stream Survey (CDFG no date) | | | X | |
| | 8/8/1974 | Stream Survey (CDFG 1974) | | | | X |
| | 4/29, 5/1/1980 | Stream Survey (CDFG 1980) | | | | X |
| | 10/26/1981 | Stream Survey (CDFG 1981) | | | | X |
| | 12/22/1987, 1/20/1988 | Field Note (CDFG 1988) | X | X | X | |
| | 10/21-10/23/1991 | Stream Inventory Report (CDFG 1991) | | | X | |
| | 1994-2000 | Spawning Survey Summary (CDFG 1994-2000) | X | | X | X |
| | 12/18/1996 | Field Note (CDFG 1996) | X | | | |

There is one long-term salmon and steelhead data set for the SF Eel River Basin, with data collected at the CDFW fish ladder at Benbow Dam, located at approximately RM 40 on the mainstem SF Eel River near Garberville. Although this location is not within the boundaries of the Northern Subbasin (the dam is located approximately 20 RM south of the Northern Subbasin's southernmost boundary), these data most likely reflect salmonid abundance and population trends throughout the SF Eel River Basin. Fish counts were conducted between 1938 and 1976, and they show more than an 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the span of the last century (*Figure 30*). Linear regression lines for all three species at Benbow Dam show significant declines in abundance, and it is likely that salmonid populations throughout the SF Eel River Basin declined similarly over this time period.

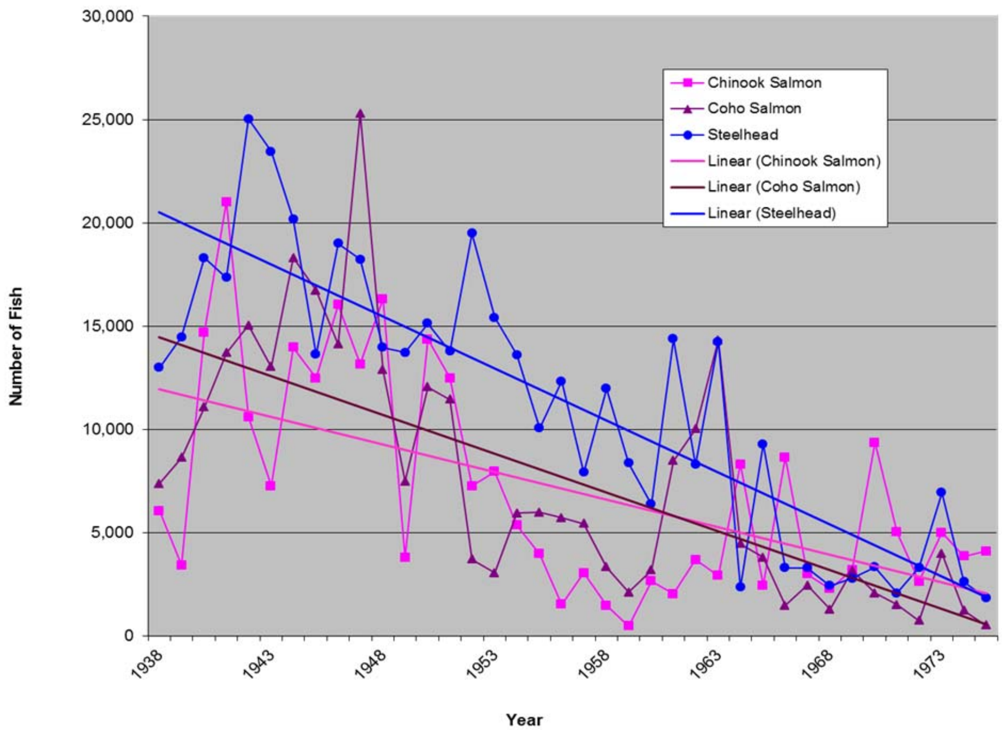



*Figure 30. Counts of migrating Chinook salmon, coho salmon, and steelhead at the Benbow Dam fish ladder between 1938 and 1976. Regression lines for all three species show declines over time.*

In addition to salmonid species, other native freshwater fish that have been observed in the Northern Subbasin include rainbow trout, pacific lamprey, three-spined stickleback, prickly sculpin, and coastrange sculpin (Brown and Moyle 1997, Stillwater Sciences 2010). Invasive species present in the subbasin include Sacramento pikeminnow, which have been detected in the mainstem SF Eel River and many of its tributaries (Nakamoto and Harvey 2003). Pikeminnow abundance is increasing and their distribution is expanding due to the species' high tolerance for warm water and low flow conditions, which have become more prevalent throughout the subbasin in recent years.

## Current Distribution

Current estimated Chinook salmon, coho salmon, and steelhead distributions in Northern Subbasin streams were based on data collected from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) and compiled by the Pacific States Marine Fisheries Commission (PSMFC). Data are available on the CalFish website at: http://www.calfish.org/Programs/ProgramIndex/AnadromousFishDistribution/tabid/184/Default.aspx.

CalFish data is observation-based, meaning that any recorded observation is collected, verified, evaluated, and applied to standard hydrography to develop a linear GIS layer. These layers are overlaid onto local watershed polygons (Calwater Planning Watersheds) to determine distribution ranges, assuming that target species can be found anywhere downstream from the observation point. Distribution layers differ slightly by species:

- Chinook distribution was developed using CDFW reports and the NOAA National Marine Fisheries Service GIS layer, which uses CDFW and PSMFC stream based routed hydrography. This layer was updated in June 2005;
- Coho salmon distribution was developed using CDFW reports and the CalFish observation-based distribution, and was updated in June 2012;
- Steelhead distribution was developed using CDFW reports and the CalFish steelhead distribution layer, and was last updated in June 2012.

Final maps were reviewed by CDFW fishery biologists and distribution lines were added or removed where known distribution was different than gradient and observation-based information. Salmonids in the SF Eel River Basin may be present in areas where they have not been documented due to a lack of data or imperfect sampling techniques.

Proportionally, in terms of total number of streams and stream miles, the Northern Subbasin contains fewer tributaries and stream miles occupied by salmonids than Eastern and Western subbasin streams (*Table 17*). Although there are fewer salmonid occupied streams in this subbasin, air temperatures are cool and riparian cover is generally good. The climate is strongly influenced by the coastal marine layer and is defined by morning fog and overcast conditions, in contrast to the inland Eastern Subbasin which becomes very hot and dry. Ongoing habitat restoration efforts designed to benefit salmonids have been a high priority in many parts of the subbasin, especially in areas owned by the CA State Parks. Unfortunately, there are also many areas with ongoing issues that have resulted in deteriorating habitat for salmonids, such as high sediment input from active landslides in the Upper Bull Creek drainage and substantial diversion from tributaries for marijuana cultivation operations in the Salmon Creek watershed.

Steelhead, like other anadromous salmonids, use the upstream system in their juvenile and adult migrations, but generally prefer habitats that are located farther inland and in smaller streams than Chinook and coho salmon (Moyle et al. 2008). As stream temperature increases in tributaries, steelhead juveniles will move to faster moving water in riffles to feed, and will seek out cold water refugia at tributary confluences and seeps. As a result of these behavioral traits, and due to their superior jumping abilities, steelhead are the most widely distributed of the three species in all SF Eel River Basin streams (*Table 17*). Coho salmon generally have the most limited distribution of the three species, followed by Chinook and steelhead.

*Table 17. Number of tributary streams and approximate number of stream miles currently occupied by anadromous salmonids in SF Eel River Basin and subbasins.*

| Subbasin | Number of Tributaries | Total mainstem miles/tributary miles | SFER mainstem miles currently used by anadromous salmonids* | | | Number of SFER tributaries/miles currently used by anadromous salmonids | | |
|---|---|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Chinook | Coho | Steelhead |
| **Northern** | 109 | 23 / 190 | 23 | 23 | 23 | 14 / 27 | 8 / 13 | 23 / 50 |
| **Eastern** | 167 | 82 / 360 | 80 | 79 | 80 | 27 / 82 | 17 / 25 | 44 / 130 |
| **Western** | 175 | 82 / 312 | 80 | 79 | 80 | 44 / 86 | 34 / 99 | 53 / 128 |

* Mainstem SFER is dividing line between Western and Eastern subbasins; mainstem mileage is counted in both Eastern and Western Subbasin totals.

Coho salmon are present in only 8 Northern Subbasin streams, including the mainstem SF Eel River. Most distribution is limited to areas less than a mile from the confluences of larger creeks (*Figure 31*). Exceptions to this distribution pattern include:

- Bull Creek, with coho salmon presence documented approximately 4 miles upstream from the confluence of the mainstem SF Eel River, and
- Salmon Creek, with coho salmon documented 1-2 miles upstream and into lower Mill Creek.

Current Chinook salmon distribution includes 14 streams, and steelhead trout are found in 23 of the 109 streams in the Northern Subbasin (*Figure 31*). Steelhead are present in more streams currently than in the past, but this may be due to an increase in documentation and sampling effort rather than an increase in actual distribution in Northern Subbasin tributaries.

## CDFW Spawning Ground Surveys

Data on the number of spawning Chinook salmon, coho salmon, and steelhead trout have been collected in SF Eel River streams using two different approaches: index reach sampling (2002 to present) and California Coastal Salmonid Population Monitoring (CMP) program techniques (2010 to present). These methods differ in sampling frequency and intensity, and in the applicability of their conclusions, however, both provide valuable information that can be used to assess the status of salmonid populations in the basin.

### Index Reach Sampling

CDFW survey crews have collected data on the number of redds, live Chinook and coho salmon, and salmonid carcasses in 10 SF Eel River stream reaches, four of which were located in the Northern Subbasin (the remaining six were located in the Western Subbasin and are discussed in the Fishery Resources section in that part of the assessment report). Fifty six surveys were conducted in three Northern Subbasin streams (*Table 18*). Bull Creek sampling reaches were divided into upper and lower sections in 2007. Survey sites were not randomly selected; CDFW biologists selected index reaches based on known salmonid (primarily coho salmon) presence in areas with relatively good quality instream and riparian habitat. Annual surveys also differed in sampling duration and effort, and redds were not assigned to species; however, these data provide a continuous record of spawner survey information in select Northern Subbasin streams. Data collected between 2002 and 2012 show relatively large numbers of Chinook (up to 129 live fish and 6 carcasses per season) spawning in Bull Creek compared to other streams surveyed. There were no live coho salmon or carcasses recorded on any survey in any of the four reaches. The total number of redds (not identified to individual species) observed was greatest in Squaw Creek, with as many as 46 redds counted annually.

Very few steelhead were documented during index reach sampling due to the timing of surveys, which were conducted between November and early March. The peak of steelhead spawning in the SF Eel River usually occurs in late February, but spawning continues through May.

*Table 18. Index reach sampling streams and survey information for Northern Subbasin streams sampled between 2002 and 2012.*

| Stream | Years Surveyed | # of Surveys |
|---|---|---|
| Bull Creek | 2002-2007 (no sampling in 2003-2004 season) | 12 |
| Upper Bull Creek | 2007-2010 | 4 |
| Lower Bull Creek | 2007-2010 | 4 |
| Squaw Creek | 2002-2010 | 18 |
| Cow Creek | 2002-2009 | 18 |

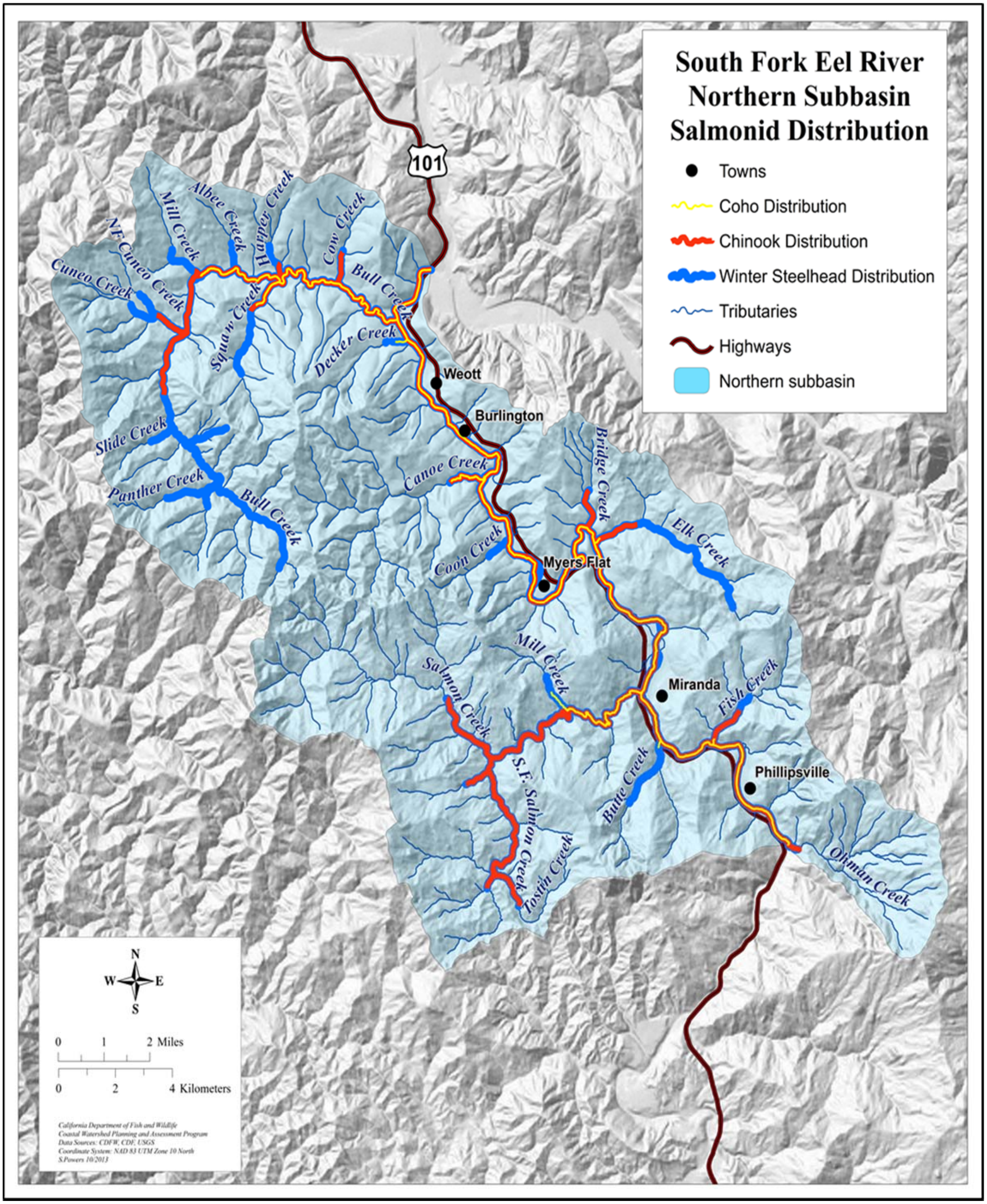



*Figure 31. Distribution of Chinook salmon, coho salmon, and steelhead trout in SF Eel River Northern Subbasin streams.*

## California Coastal Salmonid Monitoring Program (CMP)

Chinook salmon, coho salmon, and steelhead trout spawning ground surveys have been have been completed each year since 2010 in SF Eel River streams, as part of the CMP program. This program is designed to describe the regional status of SONCC coho salmon in coastal watersheds, including the SF Eel River (Adams et al. 2011). The CMP uses the Viable Salmonid Population (McElhaney et al. 2000) concept, with key population characteristics including: abundance, productivity, spatial structure, and diversity, to assess viability. Repeated periodic surveys were conducted on a spatially balanced random sample of stream reaches with possible coho spawning. A total of 818 surveys were completed on 151 stream reaches throughout the SF Eel River drainage between 2010 and 2014 (*Figure 32*). The number of reaches sampled varied slightly by year, and sampling occurred between mid-November and late March.

CMP data were analyzed for the entire SF Eel River Basin, and numbers of live fish, carcasses, redds, and redd estimates were not developed for individual subbasins. Field crews recorded the number of spawning fish, carcasses, and redds observed in each reach, including identifying the salmonid species that constructed each redd where possible (*Table 19*). CDFW biologists then predicted unidentified redds to species using the K-nearest neighbor algorithm (Ricker et al. in review) and estimated the total number of redds constructed across all reaches in the sample frame. Sampling methods and calculations are described in detail in Ricker et al. 2014a - 2014d.

*Table 19. Summary of CMP regional spawning ground surveys and estimates of total salmonid redd construction in the SF Eel River (data from Ricker et al. 2014a - 2014d). UI = unidentified salmonids.*

| | **Report Year** | | | |
|---|---|---|---|---|
| | **2010** | **2011** | **2012** | **2013** |
| # of surveys | 150 | 198 | 224 | 246 |
| # of stream reaches | 31 | 42 | 39 | 39 |
| survey dates | 11/17/2010 - 3/9/2011 | 11/14/2011 - 3/12/2012 | 11/26/2012 - 2/28/2013 | 11/14/2013 - 3/25/2014 |
| # live fish | | | | |
| Chinook salmon | 93 | 63 | 106 | 17 |
| coho salmon | 39 | 293 | 33 | 178 |
| steelhead | 6 | 41 | 29 | 107 |
| UI salmonids | 44 | 142 | 41 | 24 |
| # carcasses | | | | |
| Chinook salmon | 0 | 21 | 53 | 4 |
| coho salmon | 0 | 51 | 25 | 22 |
| UI salmonids | 2 | 2 | 0 | 7 |
| # redds observed | 463 | 495 | 524 | 349 |
| # redds assigned to species | 38 | 65 | 33 | 51 |
| estimate of redds in sampling area | | | | |
| Chinook salmon* | 1316 | 569 | 1045 | 126 |
| coho salmon | 1705 | 1323 | 1346 | 905 |
| steelhead* | 160 | 431 | 148 | 736 |
| * Chinook salmon and steelhead redd estimates represent only the time period and area encompassed by the study (Ricker et al. 2014a - 2014d). | | | | |

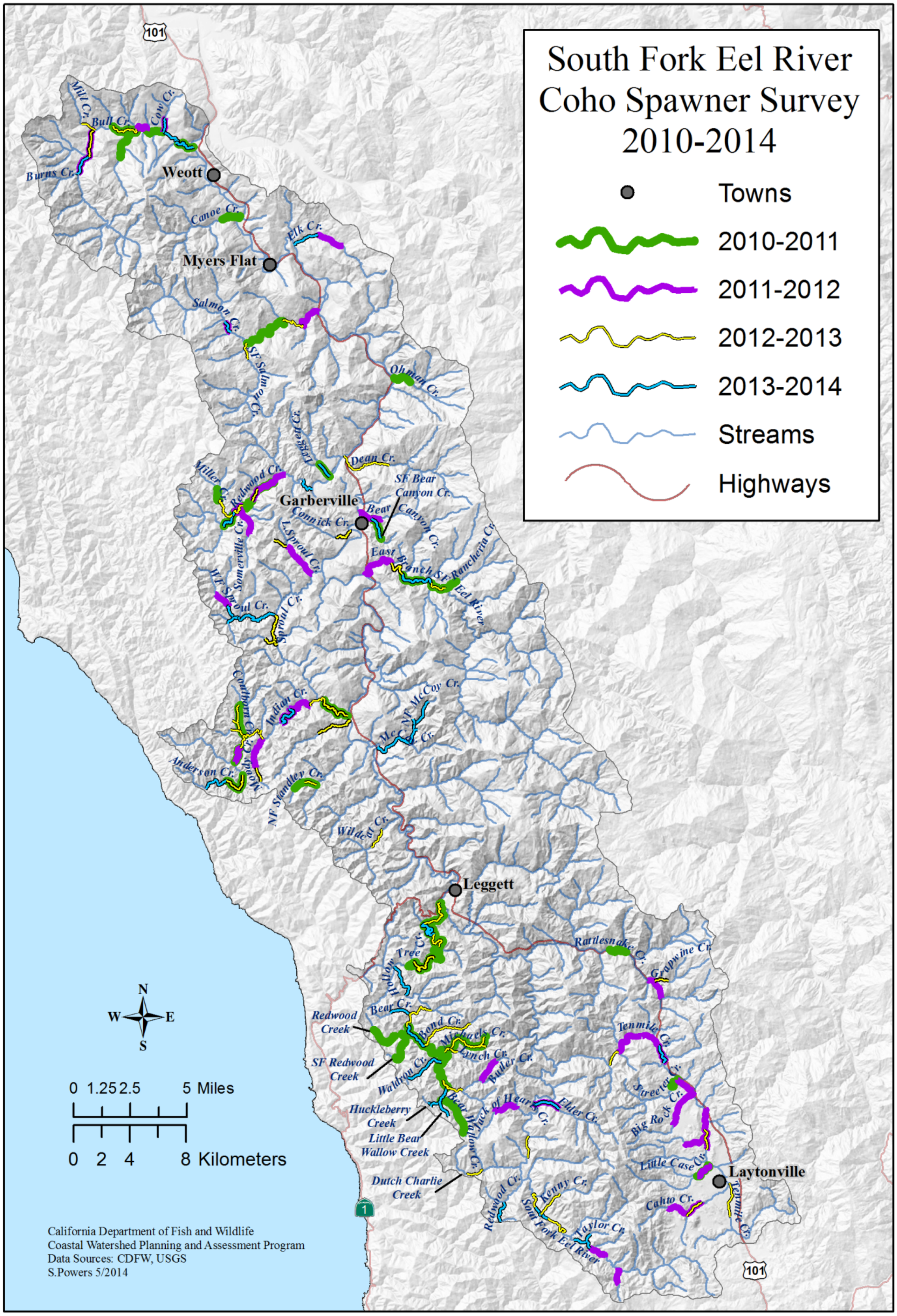



*Figure 32. Location of 2010-2014 CMP spawning reaches in the SF Eel River Basin.*

Chinook salmon and steelhead spawning is extended both spatially and temporally compared to coho salmon. The range of Chinook and steelhead extends further upstream and in more tributaries than coho salmon, and spawning occurs during different peak times and intervals than coho salmon spawning. Therefore, redd abundance estimates for Chinook salmon and steelhead apply only to the time period and physical sampling area used in the study. Redd estimates for Chinook salmon were also not particularly accurate for the first three years (A. Renger, CDFW, personal communication, 2012) due to the following limitations:

- Year 1 (2010-2011) – restricted access from landowners in selected reaches resulted in limited sampling;
- Year 2 (2011-2012) – low flow in tributaries resulted in extensive mainstem and limited tributary spawning;
- Year 3(2012-2013) – heavy rainfall in December, when most spawning occurs, limited spawning surveys (high flow and low visibility in streams).

Population estimates have not yet been developed from redd estimates because there are no redd-to-adult corrections available. These corrections are developed using life cycle monitoring stations, which are established in streams with known coho salmon presence. Essential components of a life cycle monitoring station include:

- A counting station for adults (e.g. a weir);
- Adult escapement surveys in areas above the counting station; and
- Outmigrant juvenile trapping using a fyke net, inclined plane, or rotary screw trap.

Counts of adults and outmigrating smolts are recorded, and these counts are used to calibrate spawning ground escapement estimates and freshwater and ocean survival. CDFW submitted a funding request in 2014 to establish a life cycle monitoring station in Sproul Creek in 2015, and information collected at this station will be used to assess the status of SONCC coho salmon in the ESU.

Data will be collected annually as part of the CMP in SF Eel River streams and at the life cycle monitoring station in order to generate more accurate salmonid population estimates, and results will be available in annual CDFW summary reports.

For additional information on the CMP, see Adams et al. (2011) or go to: http://www.calfish.org/Programs/CaliforniaCoastalMonitoring/tabid/186/Default.aspx/.

# Habitat Overview

## Historic Conditions

Habitat data have been collected in Northern Subbasin streams since the 1930s. Observations were originally collected and recorded in memorandum format, with no established methodology. Beginning in the 1950s, CDFG (now CDFW) used a standard stream survey form to record data, but it was not until the early 1990s that a standard habitat inventory protocol was developed by Flosi et al. (1991) and is outlined in the *California Salmonid Stream Habitat Restoration Manual*. The protocol described specific data parameters, methods of data collection, and training procedures that were designed to reduce potential bias and error while collecting field data at a relatively rapid rate (Albin and Law 2006). The manual has been revised three times since its original publication, and the current (4$^{th}$) edition is available at: http://www.dfg.ca.gov/fish/resources/habitatmanual.asp.

Historic flood events and land use activities (particularly timber harvest and rural residential development) have modified natural stream channels and conditions throughout the subbasin. The most notable changes have been in stream temperatures, flow regimes, and sediment input rates and volumes. These changes from historic stream conditions have resulted in reduced salmonid habitat quality and quantity.

There have been 2 major flood events in the SF Eel River Basin, in 1955 and 1964, both occurring during the month of December. The flood crest in 1955 was 43 feet (at Weott) and in 1964, it was 46 feet (at Miranda) (CA State Parks 2012). During the 1964 flood, channel width increased in the Bull Creek drainage in the Northern Subbasin by up to 400 feet (Jager and LaVen 1981, cited in USEPA 1999), and sedimentation in tributary streams throughout the subbasin reached notable levels. Sediment in Cuneo Creek, a tributary to Bull Creek, buried two bridges with more than 10 meters of sediment since the flood (Dyett and Bhatia 2002). Cuneo Creek has one of the highest sediment yields of any tributary to Bull Creek, due to its location in a zone of high tectonic uplift and shearing, extensive sediment storage, and frequency of landslides associate with natural process and roads (Short 1993, Stillwater Sciences 1999).

Riparian canopy was negatively affected in the past by extensive industrial timber harvesting and flooding. Air photo analysis of canopy openings in Class I and Class II watercourses in the Salmon Creek drainage showed a ten-fold increase between 1947 and 1965, but 1996 air photos show canopy recovery approaching 95% of 1947 photo percentages in upper forested areas (JMWM 2000). Current canopy structure in this drainage has a much higher composition of alder relative to conifers and hardwoods. This new canopy provides shade to stream habitat, but no long term LWD source or multilayered canopy.

Stream surveys were completed by CDFW on 29 Northern Subbasin tributaries, with 106 site visits documented between 1938 and 1990. However, stream survey efforts were neither specific nor standardized until 1990. Most observations in the historic stream surveys are not quantitative and have limited use in comparative analysis with current habitat inventories. However, data from these stream surveys provide a snapshot of conditions at the time of survey (*Table 20*). Streams with relatively consistent good habitat ratings were Albee, Connick, North and Middle Forks of Cuneo, Mowry, and Panther creeks.

Historic habitat surveys included comments on possible barriers to fish passage; log jams were abundant due the input of material from watershed slopes to streams. Intensive logging practices, road building, and the naturally fragile landscape resulted in large amounts of sediment and logging debris entering Northern Subbasin streams, particularly after the major flood events of 1955 and 1964. These land use practices and related input of sediment and woody debris were reduced when Humboldt Redwoods State Park purchased much of the land in the subbasin, however, there were still many log jams inventoried as partial barriers and recommended for removal. Barrier removal can be problematic in these streams due to the large amount of sediment behind barriers that will move downstream after removal.

Historically, this has been an issue in streams with limited spawning habitat; barrier removal upstream increases fine sediment loads, which further diminish spawning habitat quality and quantity of downstream gravels.

*Table 20. Habitat observations made in the SF Eel River Northern Subbasin from 1938-1990 (ND = site visit but no data recorded).*

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Albee Creek | 7/31/1974 | Stream Survey (CDFG 1974) | Spawning habitat good in lower half mile; upper available for residents. Rearing: lower half mile pool riffle ratio 1:1. Cover from partial log jams and small cascades. | Log jam barrier 1/2 mile upstream from mouth. 5 large log jams above first barrier. |
| Albee Creek (mouth to 1.2 mi upstream) | 4/8/1980 | Stream Survey (CDFG 1980) | Lower: Rearing habitat plentiful; spawning habitat good. Upper: Spawning habitat fair to poor; rearing habitat good. Pool riffle ratio 2:3 mouth to culvert; 1:1 culvert to end of survey. Shade 30 - 90% (mouth to culvert) and 60% above. Overall: minimal rehabilitation priority because spawning and rearing habitat area is small; gradient increases just upstream from mouth. | If unnatural obstructions were removed, natural barriers would still inhibit upstream migration. |
| Anderson Creek | 7/6/1961 | Stream Survey (CDFG 1961) | Disregard as anadromous fish stream. | 10-12" metal pipe above Hwy 101 - no fish passage. |
| | 3/22/1979 | Stream Survey (CDFG 1979) | Limited spawning area; small but numerous pools; limited shelter, almost total lack of riparian vegetation. | 6' X 8' box culvert at Hwy 101. Built in 1918; too steep for fish passage. |
| Butte Creek (aka Bear Butte Creek) | 6/19/1960 | Stream Survey (CDFG 1960) | Good spawning substrate and lots of shade from maples and 2nd growth firs. | Small log jam 500 yds below Coon Creek branch could become impassable. |
| | 5/9/1962 | Stream Report (CDFG 1962) | Fair spawning gravel; shelter adequate, primarily log scour pools. | 5 log jams. |
| | 4/12 - 4/23/68 | Field Note: e-fishing (CDFG 1968) | Habitat good - relatively equal pool and riffle habitat. | No passage issues. |
| | 4/30/1969 | Field Note: e-fishing (CDFG 1969) | | No passage issues. |
| | 3/16/1977 | Field Note (CDFG 1977) | Field visit to determine effect of logging on salmonids; steep gradient (20%) with shallow (<1') pools and narrow riffles; unlikely salmonid habitat. | |
| | 7/6/1977 | Stream Report (BLM 1977) | 70% canopy shade from madrone, oak and laurel; invertebrates present but not abundant. | Many log jams stopping migration. |
| | 4/3/1980 | Stream Survey (CDFG 1980) | Shade canopy 50%; pool riffle ratio 2:3 (pools 3' deep); spawning and rearing habitat plentiful and excellent quality. | Possible new log jams forming in Bear Butte Creek as debris moves downstream from Coon Creek. Stream clearance crew working on stream. |
| | 9/19/1984 | Stream Survey (CDFG 1984) | Basin logged in last three years; upper sections of Coon and Butte have slides and other erosion problems; lower areas badly aggraded; pools and rearing habitat filling with fine sediments and gravel; section above Coon Creek managed for resident trout - not anadromous fish. | |
| Bridge Creek | 8/3/1938 | Field Note (CDFG 1938) | Excellent spawning areas; good shelter; many steelhead. | |
| | 6/12/1952 | Velocity Data Form (CDFG 1952) | ND | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Bridge Creek (con.) | 7/6/1961 | Stream Survey (CDFG 1961) | Good spawning gravel and nursery habitat; shelter and cover abundant. | 23 separate log jams documented (none total barriers) |
| | 6/20/1977 | Field Note (CDFG 1977) | Lack of spawning gravel throughout surveyed area; unstable stream banks; creek appears unsuitable for salmonids. | |
| | 3/19/1980 | Stream Survey (CDFG 1980) | Limited spawning and rearing habitat; very short section usable for salmonids; lower section: 85% cover; upper: 10%; pool riffle ratio 1:10 in lower areas. | |
| | 3/16/1983 | Stream Survey (CDFG 1983) | Banks steep and unstable; shade canopy averaged 85% (redwoods and alder). | 6 obstructions (none total barriers) noted but only 2 recommended for removal because of limited spawning habitat. |
| | 10/16 - 10/17/85 | Stream Survey for Enhancement Projects (CDFG 1985) | Spawning habitat fair; good rearing habitat but lack of deep pools; average canopy 60%; bank stabilization and pool forming structures recommended. | |
| Bull Creek | 8/3/1938 | Stream Survey (CDFG 1938) | Good spawning areas, pools, and shelter. | |
| | 9/13/1962 | Velocity Data Form (CDFG 1962) | Water temp 68 degrees F. | |
| | 7/16/1968 | Velocity Data Form (CDFG 1968) | ND | |
| | 4/10/1980 | Stream Survey (CDFG 1980) | Relatively low spawning and rearing habitat due to cascading flow, steep gradient, and natural barriers. Numerous slides. | Barrier removal would increase instability and silt load. |
| | 4/15/1980 | Stream Survey (CDFG 1980) | Poor shade canopy (30-40%); bottom composition poor; no pools or spawning areas available. Not useful for anadromous fish above Preacher Gulch Rd. | |
| | 9/16/1982 | Population Estimate (CDFG 1982) | All salmonids collected were steelhead. Population estimate = 7710 (95% confidence interval). | |
| | 9/9 - 9/11/1985 | Stream Survey (CDFG 1985) | Little canopy; instream cover and habitat diversity needed. Wild pigs are the problem - they damage canopy trees. Critical water temps may be limiting factor for rearing in summer due to lack of canopy shade. Cuneo to Slide Creeks - limiting spawning habitat due to boulder dominated substrate, but improved above Slide Creek. Rearing habitat good. | |
| | 2/20/1987 | Field Note - spawner survey, habitat assessment (CDFG 1987) | Slides abundant; spawning habitat severely limited by amount of fines. | |
| | 12/23/1987; 1/22/1988 | Field Note - CWT recovery (CDFG 1988) | ND | |
| | 12/6/1988 | Field Note – CWT recovery (CDFG 1988) | ND | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Burns Creek | 4/10/1980 | Stream Survey (CDFG 1980) | Unstable banks and numerous active slides. Shade canopy 10%. Limited spawning areas. Stream had continuous riffle habitat. | |
| | 9/5/1985 | Stream Enhancement Work Plan (CDFG 1985) | Good spawning and rearing habitat. Lower section 1:1 pool riffle ratio. | |
| Cabin Creek | 4/4/1962 | Stream Survey (CDFG 1962) | Few suitable spawning areas due to substrate (mainly boulders and rubble). Pools are fair nursery areas; extremely abundant caddisflies. | |
| | 4/8/1980 | Stream Survey (CDFG 1980) | 85% canopy; pool riffle ratio 2:3; aquatic insects plentiful. | Man-made boulder levee at mouth. |
| | 11/15/1984 | Stream Survey (CDFG 1984) | 85% canopy. Only the first 500' is accessible to anadromous fish due to steep gradient in rest of stream. | Low water barrier at mouth - man-made boulder embankment drops 8-10' into SFER. Inadequate sized culvert under Bull Creek Road. |
| | 9/3/1985 | CCC restoration work plan (CDFG 1985) | Canopy averaged 90% - little sunlight may be limiting primary production. | Culvert at mouth is probable barrier. |
| Calf Creek | 4/1/1980 | Stream Survey (CDFG 1980) | No value to anadromous fish - no mouth, and seeps into ground 2000' above confluence with Bull Creek. | |
| | 9/4/1985 | Stream Survey (CDFG 1985) | Stream not flowing during summer and probably only small flows in winter. Limited value for anadromous fish. | |
| Canoe Creek | 8/4/1938 | Stream Survey (CDFG 1938) | Good spawning areas, excellent pools and shelter. | |
| | 7/4/1962 | Stream Survey (CDFG 1962) | Abundant pools provide excellent cover. Good spawning gravel limited to lower reaches. | Cascading falls at end of survey were barriers to anadromous fish. |
| | 7/1/1977 | Stream Survey (CDFG 1977) | Excellent shelter - pools, undercut banks, shaded riffles, etc. Overall canopy of 60-70%. | Potential barrier 15 yards upstream from mouth; small fallen trees and debris. Should be removed. |
| | 1/4/1980 | Stream Survey (CDFG 1980) | Shade canopy 60%; abundant suitable spawning habitat; aquatic insects plentiful; average gradient 2% except at obstruction #18 (5%); pool riffle ratio 1:2. | Low water barrier creating 200' long roughs - end of survey (2.6 mi upstream). |
| | 3/13/1985 | Field Note (CDFG 1985) | Deposition from slide filled in pools - gravels and fine sediment averaged 1' deep; large amounts of gravel on margins of stream and fresh sediment from slide deposited on flood terraces. | Massive slide on LB approximately 1.5 miles upstream from mouth. |
| | 10/7/1986 | Stream Enhancement Proposal (CDFG 1986) | | LDA but no total barriers. |
| | 1/25/1988 | Field Note - CWT recovery (CDFG 1988) | Poor water clarity due to unstable banks and mass wasting. | |
| Connick Creek | 6/12 - 6/13/1961 | Stream Survey (CDFG 1961) | Nursery potential seems good; shelter adequate; salmonids present. | Thirteen separate log jams (33,600 cu ft) recorded but no total barriers. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Connick Creek (con.) | 3/7/1980 | Stream Survey (CDFG 1980) | Good spawning substrate composition; rearing habitat and food supply is excellent. | Remove debris above obstruction in channel; not a total barrier. |
| | 4/1/1980 | Field Note (CDFG 1980) | Annual stream flow insufficient to support anadromous fish. | |
| | 4/9/1981 | Stream Survey (CDFG 1981) | Shade canopy 60%; bank stability fair; pool riffle average 1:7; aquatic invertebrates 10/sq ft; abundant, loose spawning gravel. Good spawning and rearing habitat. | |
| | 12/12/1983 | Field Note (CDFG 1983) | | One probable barrier at upstream end of survey |
| | 9/3/1985 | CCC Salmonid Restoration Work Plan (CDFG 1985) | Excellent spawning areas in lower 300'; debris accumulations and less suitable habitat after 500'. | |
| Coon Creek | 5/10/1962 | Stream Survey (CDFG 1962) | Nursery potential fair; shelter adequate. | 7 separate major log jams but no complete barriers. |
| | 4/3/1980 | Stream Survey (CDFG 1980) | Gradient averaged 10%; canopy averaged 60% (willows, redwood, and hardwoods); spawning and rearing habitat plentiful and excellent quality; invertebrates and salmonids observed in stream. | |
| Corner Creek | 5/1/1980 | Stream Survey (CDFG 1980) | Spawning and rearing habitat plentiful; fry observed (below obstruction #3); substrate 40% rubble, 45% gravel; 15% silt/sand. | 4 possible barriers noted; mouth choked with roots and debris. |
| | 2/21/1985 | Stream Survey (CDFG 1985) | Limited spawning habitat observed; rearing habitat fair; 90% canopy from old growth; 25% gravel & 75% silt/sand. | Two log jams-first on mouth of creek and 270' feet above mouth; recommend not removing log jam, could lose spawning habitat. |
| Cow Creek | 8/9/1961 | Stream Survey (CDFG 1961) | Salmonids observed throughout the area; area has never been logged; gravel, sand, slit present; rubble and small quantities of boulders found in upper portion of survey. | 18 log jams recorded for a total accumulation of 35,800 cubic feet of material; none appear to be a barrier to fish; seven ft. culvert passes under Honeydew road. |
| | 7/29/1963 | Stream Survey (CDFG 1963) | Survey length 830 yards; salmonid fingerlings observed to end of survey; enough gravel to provide adequate spawning area. | Culvert noted 7 feet high, 24 feet long, 200 feet from the mouth; 8100 cubic feet of logs and debris recorded. |
| | 7/24/1974 | Stream Survey (CDFG 1974) | Streambed composed of boulders up to 3 feet, gravel and some silt; stream jammed with logs and active slides; flow 0.5 cfs; active spawning is taking place in the lower 1/4 mile of the stream. | 1/4 mile up choked with log jams; upper reaches jammed with active slides; culvert noted. |
| | 3/28/1980 | Stream Survey (CDFG 1980) | Survey mouth to headwaters (1.5 mile); substrate suitable for spawning throughout entire drainage; good quality DO; insects, canopy and flow throughout stream. | Listed 28 potential barriers and obstructions. Generally logs, chunk and debris with gravel build up. Several slides noted |
| | 5/3/1982 | Stream Survey (CDFG) | Spawning habitat poor throughout due to poor quality gravel beds; fair to good rearing habitat; substrate 10% boulders, 40% rubble, 30% gravel, 20% sand/silt. | Recommend clearing obstructions 1-9; remove chunks and debris. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Cow Creek (con.) | 3/14/1983 | Stream Survey (CDFG 1983) | | 7 obstructions; 400' above mouth Bull Creek Road Culvert - not a barrier; obstructions generally downed trees and chunks and debris; some with silt and gravel build up; recommend clearing or modifying 2a-7 obstructions. |
| Cuneo Creek | 8/3/1938 | Stream Survey (CDFG 1938) | Good spawning, pools, and shelter; steelhead present; heavy fishing. | |
| | 7/29/1974 | Stream Survey (CDFG 1974) | Cuneo Creek drains 281.6 acres of thick steep coastal mountians; the south fork is a wide, boulder-littered sterile stream; the middle and north forks are recovering from flood damage; fish were present in only the middle and north forks. | No jams were observed to present barriers to fish migration; continuous cascades and extreme temperature are natural barriers. |
| Cuneo Creek (Middle Fork) | 3/28/1980 | Stream Survey (CDFG 1980) | Spawning and rearing habitat plentiful; salmonid fry observed. | 9 identified barriers and obstructions; logs, root wads, chunks and debris; gravel behind some logs. |
| Cuneo Creek (North Fork) | 3/27/1980 | Stream Survey (CDFG 1980) | Spawning and rearing habitat plentiful; salmonid fry observed. | 14 identified barriers and obstructions noted; logs, chunks, and debris; rootwads, boulders creating cascades. |
| Cuneo Creek (South Fork) | 4/1/1980 | Stream Survey (CDFG 1980) | Stream banks steep and unstable; gradient variable (10%-20%; at times 42%, end of survey 80%); rearing habiatat available, but spawning habitat scarce; extensive logging above obstruction #22. | Twenty-four barriers and obstructions. |
| Dry Creek | 6/29/1977 | Stream Survey (CDFG 1977) | Good to adequate spawning areas; pool riffle ratio 1:1; good shelter in pools; 60-75% canopy; abundant aquatic insects. | Possible barrier at footbridge. |
| | 4/8/1980 | Stream Survey (CDFG 1980) | Spawning and rearing habitat plentiful; pool riffle ratio 1:4 (2' deep); 3% gradient. | |
| | 1/7/1985 | Stream Survey (CDFG 1985) | Lower area: no good resting pools (pool riffle ratio 1:15); lots of silt in gravels. Middle area: pool riffle ratio 1:4 (depth 1' with good cover); average rearing habitat. Upper area: poor spawning habitat. | Low water barrier at mouth. |
| Elk Creek | 8/3/1938 | Stream Survey (CDFG 1938) | Good pools, shelter, spawning habitat, and abundant aquatic insects. | |
| | 6/12/1952 | Velocity Measurement (CDFG 1952) | 4.12 cfs. | |
| | 6/27 - 6/28/1962 | Field Note (CDFG 1962) | Excellent spawning areas; adequate nursery habitat; pool riffle ratio 1:4. | Log jams (some total barriers), and mill pond water gate (debris jam). |
| | 1962 | Stream Survey (CDFG 1977) | Good to excellent spawning areas; pool riffle ratio 1:2; good to excellent shelter; abundant fish food; creek dry at mouth at time of survey, intermittent along lower mile, and 0.25 cfs in upper areas. | Numerous log jam barriers; the first total barrier is located 0.25 miles upstream from old Hwy 101 bridge. |
| | 3/11/1980 | Stream Survey (CDFG 1980) | Excellent rearing and spawning areas; canopy 10% in lower, 50-60% in middle and upper sections; pool riffle ratios 1:10 in upper and lower, 1:3 in middle section; aquatic insects plentiful. | 63 barriers surveyed; first possible total barrier approximately 2000' from mouth. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Elk Creek (con.) | 12/28/1982 and 2/4/1983 | Stream Survey (CDFG 1983) | Suitable spawning gravel but high amount of siltation; pool riffle ratio 1:10; gradient 2-5%; canopy 20-40%. | 21 barriers; no total barriers. |
| Feese Creek | 7/17/1961 | Field Note (CDFG 1961) | Small, unimportant tributary to SF Eel River; pool riffle ratio 40:60; adequate spawning areas, nursery habitat, and shelter; 3/5 cfs flow. | |
| | 4/8/1980 | Field Note (CDFG 1980) | Stream flow is insufficient to support anadromous fish. | |
| Fish Creek | 6/29/1977 | Stream Survey (CDFG 1977) | Good to excellent spawning areas between log jams; pool riffle ratio 1:4; pools shallow with little cover; water temperature 72 degrees F; flow 0.25 cfs. | 4 log jams, all barriers. |
| | 2/28/1980 | Stream Survey (CDFG 1980) | Banks very unstable; shade canopy 60-70%; pool riffle ratio 1:10. | 450' above mouth is old Hwy 101 box culvert - total barrier. |
| Harper Creek | 7/29/1963 | Field Note (CDFG 1963) | Abundant spawning gravel but somewhat silted; excellent shelter; 5% gradient; food plentiful. | 9 log jams; one complete barrier. |
| | 3/21/1980 | Stream Survey (CDFG 1980) | Lower section: very few pools and little canopy at mouth, increasing to 80% upstream; 6% gradient. Upper section: limited spawning habitat; pool riffle ratio 1:10 (2.5' deep); 60-90% canopy; aquatic insects common; rearing habitat plentiful. | 22 barriers observed on mainstem and West Fork; three total barriers, one possible low water barrier. |
| | 4/4/1982 | Stream Survey (CDFG 1982) | Mainstem and West Fork surveyed. Mainstem: relatively poor spawning habitat; poor quality spawning gravels; significant increase in gradient 3500' above mouth; rearing habitat fair to good until upper section of creek (no good rearing habitat). | 6 barriers on mainstem (2 total); 5 barriers on West Fork (4 total). |
| | 5/4/1982 | Stream Survey (CDFG 1982) | Poor quality spawning gravels; significant increase in gradient 3500' above mouth; rearing habitat fair to good until upper section of creek (no good rearing habitat). | Boulders creating a series of cascades 20' x 100' with 18% gradient - possible low flow barrier. |
| | 12/14/1984 | Stream Survey (CDFG 1984) | Very limited spawning habitat; in lower areas, rearing habitat nearly nonexistent, then adequate in upper areas; canopy 80-90%; pool riffle ratio 1:10; unstable banks and landslides have introduced large amounts of fine sediment. | Probable low water barrier at mouth. |
| Kerr Creek | 7/14/1980 | Field Note (CDFG 1980) | Stream dry to 1000' above confluence with SF Eel River; 1000' above where stream started flowing, natural barrier of boulder cascades with 20% gradient; no anadromous fish or habitat. | |
| Mill Creek (tributary to Bull Creek) | 7/30/1974 | Field Note (CDFG 1974) | Lower half mile: good spawning habitat; upper reaches: available to resident trout only; summer flow 0.29 cfs with average depth 2.82 inches. | Lower half mile: numerous small jams; upper reaches: numerous large jams and dams. |
| | 3/26/1980 | Stream Survey (CDFG 1980) | Lower section of stream good for anadromous salmonids; spawning habitat limited; no shade canopy at mouth but increased to 55% 500' upstream, then increased to 70% in upper reaches; pool riffle ratio 1:2 with average depth 4' in lower section and 1:4 in upper area; rearing habitat plentiful; debris in stream from logging operations. | |
| | 8/22/1985 | Stream Enhancement Work Plan (CDFG 1985) | Mouth had subterranean flows to 90' upstream; no canopy at mouth but increased to 70% upstream; 35% fines in substrate, increasing to 40% in some areas due to sediment input from unstable banks. | Boulder cascades above 3700' makes habitat unusable for salmonids. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Mill Creek (tributary to Salmon Creek) | 10/22/1988 | Stream Survey (CDFG 1989) | No anadromous fishery value due to migration barriers in lower areas; stream inaccessible for adult steelhead in the winter and for juveniles trying to escape warm flows during the summer. | Many debris jams in first mile; 8' falls at 7500' was total barrier to anadromous fish. |
| Mill Creek (tributary to SF Eel River near Weott) | 5/1/1980 | Field Note (CDFG 1980) | Stream gradient 14% at mouth, increasing to 45% 100' upstream; very little if any spawning area. | 10' falls 250' upstream is complete barrier. |
| Miller Creek (tributary to Bull Creek) | 4/1/1980 | Field Note (CDFG 1980) | Annual stream flow insufficient to support anadromous fish. | |
| | 9/4/1985 | Survey Discussion (CDFG 1985) | Canopy 80-90%; gradient 1-3%. No standing or running water in 1300' of stream surveyed; due to lack of consistent flows, no restoration actions recommended. | 3' high gravel bar at mouth not a barrier at high flows. |
| Mowry Creek | 7/17/1961 | Field Note (CDFG 1961) | Stream was dry for 175 yards above mouth; 400 lineal yards of riffle available to anadromous fish; adequate nursery habitat in upper areas; lower portion open and dry at time of survey; pool riffle ratio 70:30; flow 1-3 cfs from 200 yards above mouth. | |
| | 4/17/1980 | Field Note (CDFG 1980) | Excellent habitat in Humboldt Redwoods State Park; excellent spawning substrate; creek is active salmonid producer and should be left untouched. | |
| Ohman Creek | 8/2/1938 | Stream Survey (CDFG 1938) | Excellent spawning areas; good pools and shelter; abundant food; water temperature 63 degrees F; abundant YOY steelhead. | Impassable 0.2 miles above station (100 yards above Hwy 101 bridge). |
| | 6/12/1952 | Velocity Measurement (CDFG 1952) | 3.44 cfs. | |
| | 6/21/1962 | Field Note (CDFG 1962) | Only 0.25 mile of available habitat; spawning areas reduced by siltation in slow water areas below barrier; favorable pool shelter from boulders; adequate nursery habitat evidenced by the presence of many small salmonid fry. | 450 yards above mouth, very steep, huge bouldered, impassable roughs. |
| | 1/31/1980 | Stream Survey (CDFG 1980) | Limited spawning area due to all habitat below barrier being riffle; aquatic insects plentiful; shade canopy averaged 70%. | 200' above mouth, bedrock and boulder cascades; falls average 6' to 20'. |
| Panther Creek | 4/15/1980 | Stream Survey (CDFG 1980) | Spawning and rearing habitat plentiful; gradient averaged 9% in lower section but increased to 30% upstream; pool riffle ratio 1:1; average pool depth 2'; shade canopy 5%; water temperature at time of survey was 50 degrees F but warm water temperatures due to lack of canopy could create a problem for rearing salmonids; plentiful salmonid fry to 3" in length. | |
| Slide Creek | 4/10/1980 | Stream Survey (CDFG 1980) | Stream gradient 10% in lower reaches, increasing to 30% at end of survey; shade canopy 10%; pool riffle ratio 1:1; rearing habitat plentiful; spawning habitat available in lower reaches; possible warm water issues from lack of canopy. | 10 barriers described; three possible low water barriers; no total barriers. |
| | 9/6/1985 | Field Note (CDFG 1985) | First 2000' has limited spawning habitat; siltation and erosion is a problem throughout survey; good rearing habitat. | Boulder roughs and 50% gradient increase is end of anadromy at 4270'. |
| Squaw Creek | 8/8/1974 | Stream Survey (CDFG 1974) | Entire area surveyed (mouth to Grasshopper Creek Rd.) accessible to salmonids; pool riffle ratio 1:1; pool depth 2-4'; good cover and insect food. | Barrier 150 yards long in upper survey area; 7 minor barriers. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Squaw Creek (con.) | 4/29 and 5/1/1980 | Stream Survey (CDFG 1980) | Canopy averaged 90%; gradient 3-4%; pool riffle ratio 3:2; banks generally stable. High priority for restoration (clear obstructions) to release spawning gravel. Excellent salmonid stream. | 37 barriers/obstructions described. |
| | 5/12/1982 | Stream Survey (CDFG 1982) | Bank stability good first mile, then fair to poor; pool riffle ratio 1:3 for lower and 1:2 for upper sections; average canopy 70%. | 17 barriers described (9 possible or total). |
| | 12/11/1984 | Stream Survey (CDFG 1984) | Spawning habitat is limiting factor due to high sediment load degrading gravels; rearing habitat plentiful; canopy good (70-90%). | 12' falls at site #2 is complete barrier. |
| | 8/28 and 9/12/1985 | Field Note (CDFG 1985) | Spawning habitat limited; improvement projects would increase rearing habitat; unstable banks; recommend bank stabilization projects. | |
| | 4/18/1986 | Addendum to Project Improvements (CDFG 1986) | Streambank stabilization project to reduce input of fine sediments. | |

## Current Conditions

Habitat inventories were recently conducted by CDFW on 17 of the tributaries in the Northern Subbasin (*Table 21*). Survey lengths ranged from 13.43 miles (Bull Creek 1991) to 0.12 miles (Bridge Creek unnamed tributary 2007). Survey data were divided into two sampling periods in order to assess changes in habitat factors and suitability of habitat for salmonids over time.

The number of reaches and the total stream length surveyed varied by stream. Habitat typing surveys describe specific stream reaches by Rosgen channel type (see Channel Types section of this report) and sequence. Reaches show characteristics of certain channel types for a minimum distance of 20 bankfull channel widths (Flosi et al. 2010), but are highly variable in overall length.

Some streams were surveyed in multiple years within each sampling period, and if the surveys covered the same area of stream, only the most recent survey information (from 17 streams) was used in the EMDS-based analysis. Only habitat typing surveys completed on perennial streams were used in the analyses. However, some perennial streams contain dry reaches during certain times of the year (usually in late summer) due to variation in annual precipitation, natural aquifer levels, and magnitude of diversion. These dry reaches were categorized as Type 7 (Flosi et al. 2010) in habitat typing reports.

Thirteen of the 17 tributaries were surveyed during both the 1990-1999 and 2000-2010 time periods, but surveys were often completed at different times of the year (e.g. Fish Creek was surveyed in June in 1999 but in August in 2007). For a complete list of the month each survey was completed, see *Table 35* in the SF Eel River Basin Overview. Environmental conditions vary by month and year, and may influence habitat suitability values. For example, flow is reduced between mid-July and early- to mid-September in streams throughout the Northern Subbasin (due to limited rainfall, evapotranspiration by plants, groundwater levels, and the number and magnitude of diversions), so primary pool values and corresponding scores would most likely be lower in creeks where sampling was completed during this time interval. Variability in rainfall received during wet and dry years may also influence flow, and therefore habitat factors and suitability values. According to records from the USGS gauges at Miranda (RM 17) and Bull Creek (four miles upstream from confluence with SF Eel River), average annual flow was very high in 1938 and 1974, and very low in 1977 (*Figure 5*).

CWPAP staff evaluated habitat typing data using an analysis based on the Ecological Management Decision Support (EMDS) model used in previous CWPAP Watershed Assessments. Rating scores were developed from habitat typing data summarized in *Table 21* and were used in the analysis to evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. Additional analysis details can be found in the Analysis Appendix and in the NCWAP Methods Manual, available at:

http://coastalwatersheds.ca.gov/. Calculations and conclusions in the analysis are pertinent to surveyed streams and are based on conditions existing at the time of each survey.

Surveys completed on the same stream during both time periods may also show differences in habitat values because of changing land use practices. For example, in Salmon Creek, there has been a dramatic increase in the number and magnitude of marijuana cultivation operations in the past few decades (see the Industrial Marijuana Agriculture section of this report). Increased diversions from these operations have resulted in lower flows and reduced pool depth suitability in this watershed.

Observer variability and error during habitat typing surveys may also account for changes in habitat variables over time but error and bias can be minimized through use of standards and training. Well-designed sampling schemes, comprehensive observer training, and the use of established operating protocols (e.g. the *California Salmonid Stream Habitat Restoration Manual)* will result in monitoring that effectively detects changing stream conditions (Roper et al. 2002). Because of observer and other error sources, habitat typing is best suited to detecting fundamental changes in Level I or II habitat types (Gerstein 2005), and to identify potential limiting factors for salmonids in specific watersheds for assessment purposes.

Summary values of each factor and the associated target values for these attributes are listed in *Table 21*. Average canopy density, embeddedness, length of primary pools, and pool shelter in Northern Subbasin streams did not meet target values during either sampling period. Primary pools were most limiting for salmonids in this subbasin, with percent lengths well below target values in all streams. The importance of each habitat factor to salmonids, and their effect on habitat suitability will be discussed in detail in the individual factor sections of this subbasin report.

*Table 21. Summary of CDFW habitat inventory data used in analysis for streams in the SF Eel River Northern Subbasin, and associated target values. Averages are weighted by stream length surveyed.*

| Stream | Survey Year | Survey length (miles) | Mean Canopy Density (%) | Category 1 Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|---|
| **TARGET VALUES** | | | **>80** | **>50** | **>40** | **>100** |
| Bridge Creek | 1993 | 0.98 | 60.3 | 4.8 | 1.6 | 48.7 |
| | 2007 | 0.98 | 89.3 | 6.4 | 3.2 | 28.6 |
| Bridge Creek (unnamed tributary) | 2007 | 0.12 | 90.2 | 20.0 | 0.0 | 46.0 |
| Bull Creek | 1991 | 13.43 | 33.1 | 1.4 | 0.8 | 36.4 |
| | 2007 | 9.66 | 64.0 | 22.9 | 6.3 | 38.4 |
| Butte Creek | 1993 | 1.66 | 68.0 | 0 | 4.0 | 38.5 |
| | 2009 | 1.38 | 80.7 | 40.0 | 7.8 | 23.9 |
| Canoe Creek | 1992 | 3.31 | 76.7 | 40.2 | 8.7 | 87.1 |
| | 2007 | 1.86 | 81.0 | 3.6 | 17.1 | 75.8 |
| Coon Creek (SFE) | 1993 | 0.65 | 59.1 | 38.0 | 0.8 | 45.6 |
| | 2007 | 1.09 | 89.0 | 33.1 | 0.2 | 48.8 |
| Cow Creek | 1991 | 0.63 | 67.2 | 2.7 | 0.8 | 53.7 |
| | 2007 | 1.03 | 88.0 | 15.2 | 7.3 | 25.0 |
| Decker Creek | 1992 | 0.79 | 81.0 | 2.2 | 10.4 | 80.6 |
| | 2010 | 0.60 | 93.6 | 46.3 | 5.8 | 22.5 |
| Elk Creek | 1992 | 3.53 | 84.4 | 6.0 | 2.3 | 82.5 |
| | 2007 | 4.14 | 90.2 | 39.2 | 6.6 | 68.8 |
| Elk Creek (unnamed tributary #7) | 2007 | 0.21 | 97.6 | 75.0 | 0.0 | 38.8 |
| Fish Creek | 1999 | 2.36 | 90.0 | 14.0 | 2.9 | 11.4 |
| | 2007 | 1.04 | 96.1 | 15.3 | 2.0 | 23.4 |
| Harper Creek | 1991 | 0.91 | 68.0 | 19.8 | 0.7 | ND |
| | 2007 | 0.89 | 90.0 | 19.7 | 0.7 | 32.8 |

| Stream | Survey Year | Survey length (miles) | Mean Canopy Density (%) | Category 1 Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|---|
| Mill Creek (Bull Creek) | 1991 | 0.76 | 61.3 | 9.0 | 0.7 | 38.7 |
| | 2007 | 1.18 | 86.3 | 17.2 | 3.9 | 71.4 |
| Mill Creek (Salmon Creek) | 2009 | 0.52 | 90.8 | 8.0 | 0.3 | 20.6 |
| Ohman Creek | 1992 | 0.28 | 24.2 | 0 | 5.6 | 20.0 |
| | 2007 | 0.33 | 61.5 | 67.0 | 0.5 | 26.7 |
| Salmon Creek | 1992 | 5.24 | 19.9 | 1.0 | 17.7 | 15.0 |
| | 2007 | 7.28 | 59.7 | 65.7 | 11.9 | 70.4 |
| Squaw Creek | 2010 | 2.74 | 94.6 | 22.9 | 10.0 | 35.9 |
| **AVERAGE** | 1990-1999 | | 50.5 | 7.8 | 5.4 | 43.0 |
| | 2000-2010 | | 75.9 | 33.4 | 7.0 | 49.4 |

## Overall Habitat Suitability

Four factors (canopy density, pool depth, pool shelter complexity, and substrate embeddedness) were used in the EMDS-based analysis to determine overall habitat suitability using habitat typing data collected between 1990 to 1999, and 2000 to 2010. Suitability scores were calculated by assessing how measured values compared to target values for each factor. Overall habitat suitability and suitability of each factor used in the analysis were calculated based on a weighted (by reach or stream length surveyed) average for Northern Subbasin streams in each time period, and change in suitability values between time periods were compared for streams and for individual reaches.

Suitability scores ranged between +1 and -1, and were divided into four categories:

- 1.00 - 0.50 (high suitability);
- 0.49 - 0;
- -0.01 - -0.49; and
- -0.50 - -1.00 (low suitability).

Scores were weighted by survey length to facilitate comparison of habitats between different tributaries based on sampling effort. For a detailed discussion of the analysis framework and calculation of suitability scores, see the Analysis Appendix.

Overall habitat suitability increased in Northern Subbasin streams between the 1990s and early 2000s, but scores were still in low suitability categories (negative values) during both sampling periods (*Table 22*). Overall suitability increased due to increasing embeddedness scores, but also due to a small increase in pool shelter scores between the two sampling periods.

Canopy density scores were higher than any other factor scores used in the EMDS-based analysis. In the model, canopy density (riparian vegetation score) was evaluated with an “in channel score” (a combination of pool depth, pool complexity, and substrate embeddedness factors, all weighted equally), at the final decision node where the lower of the two scores was used to indicate the potential of the stream reach to sustain salmonid populations. In Northern Subbasin streams, in channel scores were almost always lower than canopy density scores, therefore, canopy density scores were often not used as the final indicator of a stream’s potential to support salmonids. Canopy density scores were lower for data collected in the 1990s than in the 2000s, but were only lower than in channel scores 12 times using data collected during the 1990s and only 4 times when using data collected between 2000 and 2010.

*Table 22. Overall suitability scores and suitability scores by factor in SF Eel River Northern Subbasin streams during two sampling periods: 1990-1999 and 2000-2010.*

| Sampling period | Stream miles surveyed | Overall habitat suitability score | Canopy density suitability score | Pool depth suitability score | Pool shelter suitability score | Pool quality score | Embeddedness suitability score |
|---|---|---|---|---|---|---|---|
| 1990-1999 | 34.52 | -0.74 | -0.34 | -0.96 | -0.52 | -0.63 | -0.58 |
| 2000-2010 | 35.05 | -0.24 | 0.33 | -0.99 | -0.42 | -0.76 | 0.20 |

Changes in factor scores over time in specific streams and reaches throughout the subbasin will be discussed further in the individual factor sections of this report.

The overall suitability of habitat for salmonids increased in many Northern Subbasin streams, and in specific reaches in these streams, over time (*Figure 33*). For example, in some larger tributaries, including Bull Creek and Salmon Creek, and in smaller creeks (Mill, Elk, and Butte), suitability in sampled reaches increased over time. Although suitability increased, the majority of reaches were still in the lowest two suitability categories in this subbasin. Two exceptions to this pattern were reaches in lower Salmon and Elk creeks, were in the moderately suitable category in the 2000s.

Although unstable geology in the Northern Subbasin negatively affects pool depth pool and pool shelter (and therefore pool quality), increases in overall suitability may be due to changes in land use and restoration efforts throughout the subbasin. Most of this subbasin was heavily logged in the last century. However, since 1973 with the passage of the Z'Berg-Nejedly Forest Practice Act, environmental regulations have increased and as the CA State Parks purchased additional property, land use patterns changed and environmental disturbance was reduced. Instream habitat and upslope restoration projects are also ongoing, especially in Humboldt Redwoods State Park. Reduced disturbance is reflected in increasing habitat suitability, and with time, management practices and restoration projects that improve salmonid habitat may be expressed by factor values approaching target values, with associated increases in suitability scores.

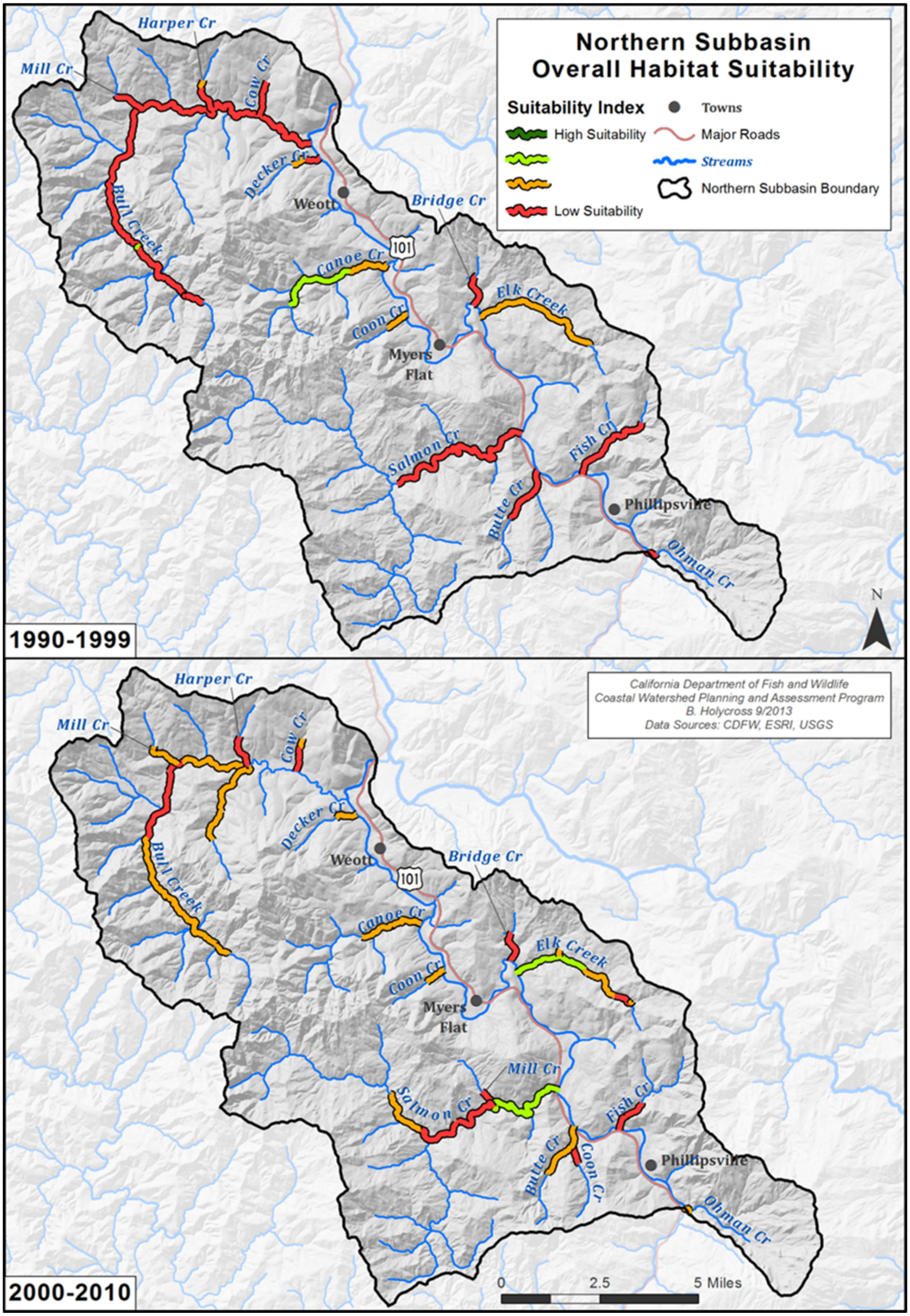
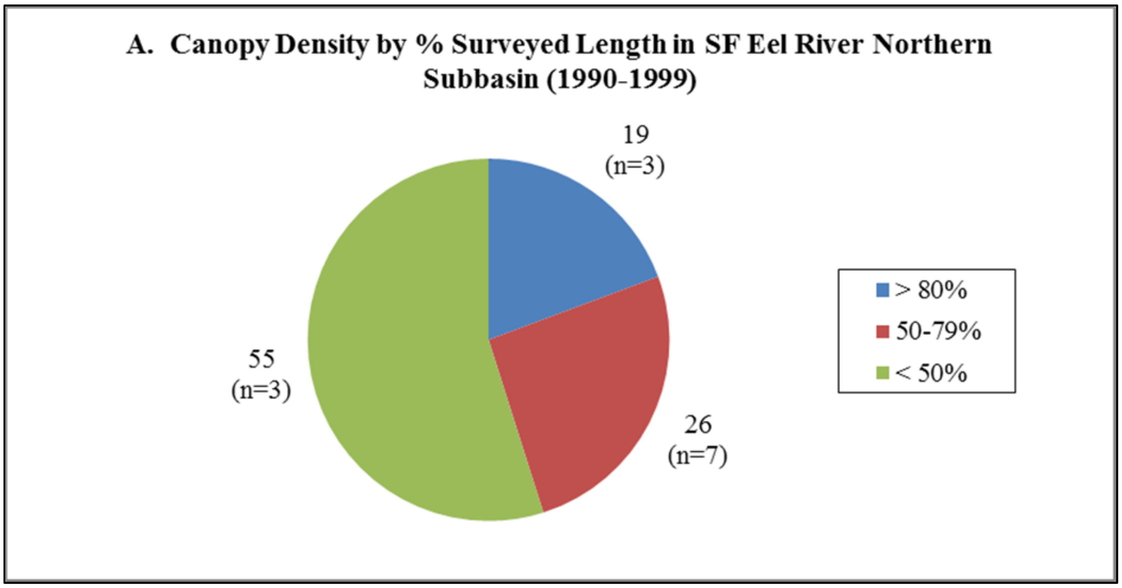



*Figure 33. Overall habitat suitability in SF Eel River Northern Subbasin streams, as determined by the EMDS-based analysis using data from two sampling periods: 1990-1999 and 2000-2010.*

## Canopy Density

Canopy density is one of the measurements estimated during CDFW habitat surveys. These measurements, which are defined as a percentage of shade canopy over the stream, provide an indication of potential recruitment of organic debris to the stream channel, and are a measure of the insulating capacity of the stream and riparian areas during the 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 *California Salmonid Stream Habitat Restoration Manual* establishes a target value of 80% for shade canopy along coastal streams (Flosi et al. 2010). The CDFW recommends areas with less than 80% shade canopy as candidates for riparian improvement efforts.

Canopy density improved over time in Northern Subbasin streams (*Figure 34 A, B*). In the 1990s, 55% of the stream length surveyed had canopy densities below 50% and only 19% met target values of 80% or greater. In the early 2000s, there was no stream length with below 50% canopy density, and 51% of surveyed stream length met target values.



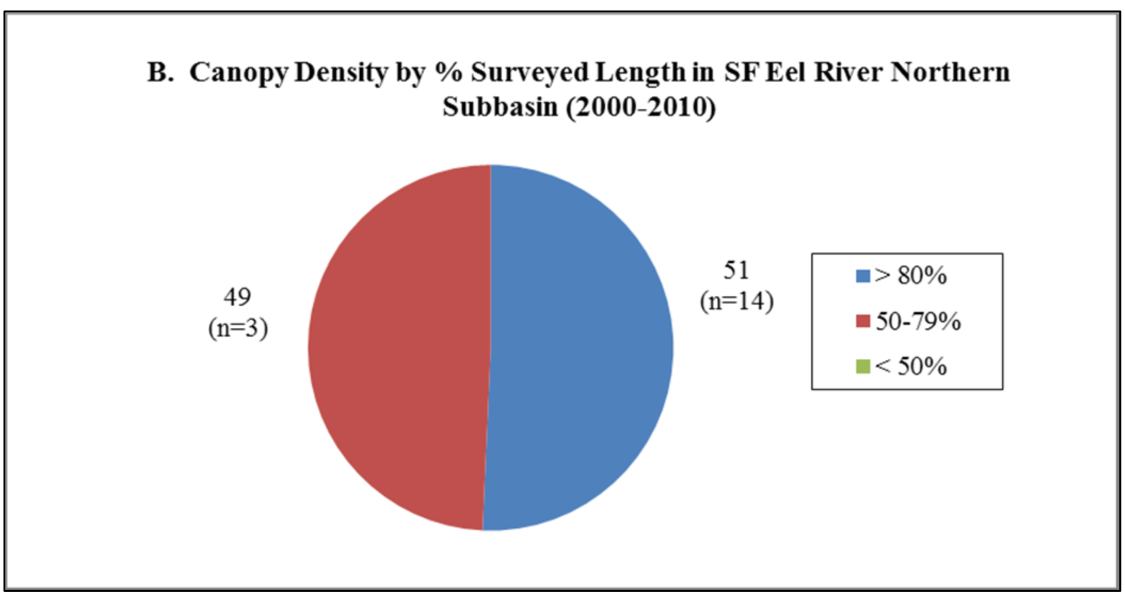




*Figure 34A, B. Canopy Density in the Northern Subbasin using data collected from 1990-1999 (A) and 2000-2010 (B); n = number of streams surveyed.*

Canopy density suitability scores increased in most Northern Subbasin streams between the two sampling periods (*Figure 35*). From surveys completed between 1990 and 1999, the average canopy score for all Northern Subbasin streams was -0.34 (*Table 22*). During this sampling period, two streams had canopy density suitability in the lowest category: the majority of Bull Creek, and the entire surveyed length of Salmon Creek. These are relatively large streams, and we expect canopy density to decrease as channel width increases. However, even in the upper reaches of these creeks, canopy density was poor in the 1990s, most likely due to past land use activities, damage from historic floods, and unstable geology limiting the establishment of riparian habitat.

During the 2000-2010 sampling period, the average canopy density score for all Northern Subbasin streams was 0.33 (*Table 22*). This increase is most likely due to a combination of changes in land use including a reduction in industrial timber harvest (and the associated reduction in detrimental environmental effects), road improvement and rehabilitation efforts, and ongoing restoration projects such as riparian and instream habitat improvement, and upslope watershed enhancement. Canopy density was in the high suitability category in the uppermost reach of Bull Creek, moderately high in the reach above Harper Creek, moderately low near Panther Creek, and low in the reach near Slide and Cuneo creeks. Low canopy suitability is due to highly unstable and erodible banks in this middle stretch of Bull Creek. The entire Bull Creek drainage was heavily logged in the past, and when the State Park purchased nearly all of the land in the watershed, restoration activities became a priority and concentrated on riparian habitat improvement, upslope watershed restoration, and bank stabilization. The middle reaches of both Bull Creek and Salmon Creek remained in the lowest suitability category for canopy density; however, these are both $4^{th}$ order streams, with lower canopy densities expected. Restoration projects designed to increase canopy in those areas with reduced channel width are recommended but overall canopy density may remain low in these reaches due to channel morphology. In the middle reaches of Bull Creek, near the confluence of Cuneo Creek, riparian habitat restoration projects have been completed but canopy densities remain low. Future surveys may show improvement in suitability as a result of these projects.

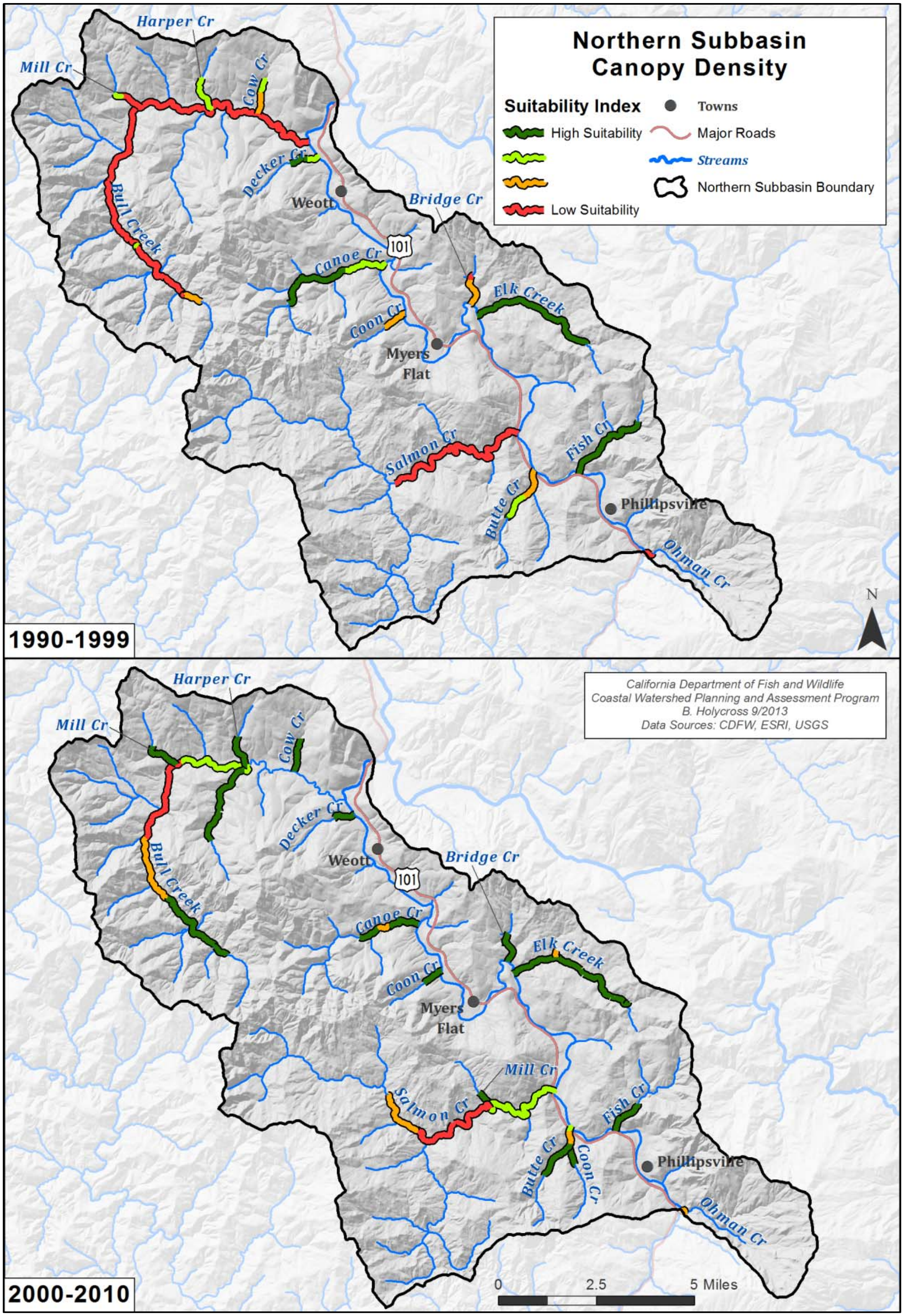



*Figure 35. Canopy density suitability for Northern Subbasin streams, as determined by the EMDS-based analysis using data from two sampling decades: 1990-1999 and 2000-2010.*

In addition to overall canopy density, it is important to consider the contribution of coniferous and deciduous components in the canopy. Dense deciduous riparian vegetation such as alder and maple trees provide excellent canopy closure and habitat/food for macroinvertebrate production, but do not provide the LWD recruitment potential of larger, more persistent coniferous trees (Everest and Reeves 2006). Even in streams with very low coniferous canopy percentages, suitability may be high due to high percentages of deciduous canopy (e.g. Elk Creek); restoration efforts in these areas should concentrate on reestablishing coniferous canopy. CDFW field crews visually estimated the percent contribution of canopy from coniferous and deciduous trees during habitat typing surveys.

Coniferous canopy cover was relatively low (< 50%) in most streams, particularly in creeks that are located outside the boundaries of Humboldt Redwoods State Park. The largest streams in the subbasin, Bull Creek and Salmon Creek, had the lowest coniferous canopy percentages (less than 10%) when sampled in the 1990s.

For streams with survey data available from both time periods, the average percent of coniferous vegetation increased and percent open canopy decreased in most streams over time (*Table 23*). An exception to this pattern was Elk Creek and its unnamed tributary, which showed significant decreases in coniferous canopy coverage and increases in deciduous cover due to significant timber harvest activity in recent years.

*Table 23. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Northern Subbasin.*

| STREAM | AVG% CONIFEROUS | AVG% DECIDUOUS | AVG% OPEN |
|---|---|---|---|
| Bridge Creek 93 | 37.5 | 22.7 | 39.8 |
| Bridge Creek 07 | 44.0 | 45.3 | 10.7 |
| Bridge Creek UT 07 | 46.2 | 44.0 | 9.8 |
| Bull Creek 91 | 4.0 | 29.1 | 66.9 |
| Bull Creek 07 | 16.4 | 47.6 | 36.0 |
| Butte Creek 93 | 21.6 | 46.4 | 32.0 |
| Butte Creek 09 | 21.9 | 58.9 | 19.3 |
| Canoe Creek 92 | 52.4 | 24.3 | 23.3 |
| Canoe Creek 07 | 72.0 | 9.0 | 19.0 |
| Coon Creek 93 | 35.6 | 23.5 | 40.9 |
| Coon Creek 07 | 48.9 | 37.2 | 13.9 |
| Cow Creek 91 | 29.9 | 37.3 | 32.8 |
| Cow Creek 07 | 43.5 | 44.5 | 12.0 |
| Decker Creek 92 | 56.3 | 24.7 | 19.0 |
| Decker Creek 10 | 63.8 | 29.8 | 6.4 |
| Elk Creek 92 | 35.4 | 49.0 | 15.6 |
| Elk Creek 07 | 27.9 | 62.4 | 9.8 |
| Elk Creek UT 1 07 | 27.3 | 60.1 | 12.6 |
| Elk Creek UT 7 07 | 2.7 | 94.9 | 2.4 |
| Fish Creek 99 | 19.6 | 70.4 | 10.0 |
| Fish Creek 07 | 48.6 | 47.5 | 3.9 |
| Harper Creek 91 | 35.6 | 32.4 | 32.0 |
| Harper Creek 07 | 60.4 | 29.6 | 10.0 |
| Mill Creek (Bull) 91 | 13.8 | 47.5 | 38.7 |
| Mill Creek (Bull) 07 | 28.1 | 58.2 | 13.7 |
| Mill Creek (Salmon) 09 | 35.6 | 55.2 | 9.2 |
| Ohman Creek 92 | 17.1 | 7.1 | 75.8 |
| Ohman Creek 07 | 34.8 | 26.8 | 38.5 |
| Salmon Creek 92 | 2.0 | 17.9 | 80.1 |
| Salmon Creek 07 | 21.4 | 38.3 | 40.3 |
| Squaw Creek 10 | 35.9 | 58.7 | 5.4 |

## Pool Depth

Primary pools provide salmonids with 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 to 55% of its length in primary pools to be suitable for salmonids; good coho salmon streams have >40% of total length in primary pool habitat. According to Flosi et al. (2010), in first and second order streams, a primary pool is described as being at least 2.5 feet deep; in third and fourth order streams, primary pool depths are 3 feet and 4 feet, respectively. Because pools are important salmonid habitat even if they are slightly shallower than the established primary pool guidelines, CWPAP staff adjusted primary pool length data for use in the analysis. This adjustment allowed 25% of the length of pool habitat in the depth category below the minimum for each stream order class to be represented in the analyses. For example, in first and second order streams, where pools ≥ 2.5 feet deep are considered primary, 25% of the length of pool habitat between 2 and 2.5 feet deep was added to the total primary pool length to obtain an adjusted percent of primary pool habitat. For third and fourth order streams, 25% of pool habitat between 2.5 and 3 feet, and 3.5 and 4 feet, respectively, was added to the primary pool length. For a complete description of pool depth categories and details of pool depth calculations, see the Analysis Appendix.

*Table 21* lists the percent length of primary pool habitat by stream. Percentages ranged from zero (in unnamed tributaries to Bridge and Elk creeks) to 17% (in Salmon Creek in 1992 and Canoe Creek in 2007). Overall percent primary pool habitat (weighted by surveyed length) was 5.4% for habitat surveys completed in the 1990s, and increased slightly to 7.0% for surveys in the early 2000s. These numbers are well below target values.

The percent of primary pool habitat in first through fourth order streams was very low (10% or less) in both the 1990s and the early 2000s (*Figure 36*). In streams with reaches located in both third and fourth order areas, the larger stream order category was used (e.g. middle reaches in Bull Creek). Although the percent of primary pool habitat is low, it increased slightly over time in all order categories.

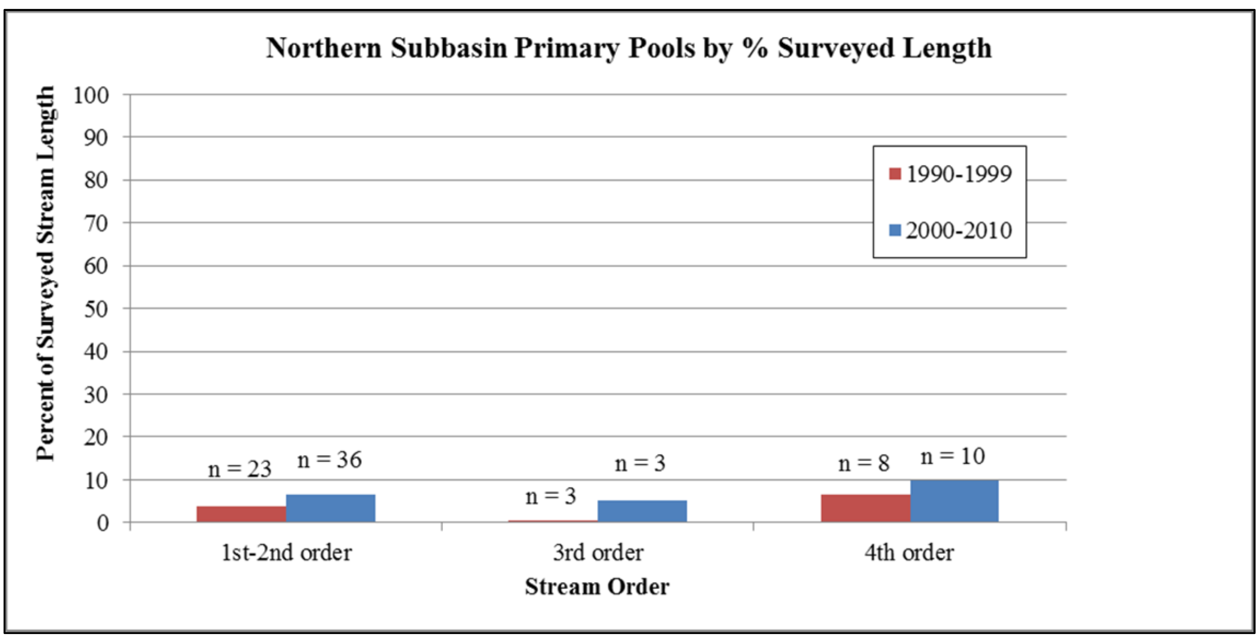



*Figure 36. Percent of surveyed habitat in primary pools in the Northern Subbasin, using data collected from 1990-1999 and 2000-2010 (n = number of stream reaches).*

Pool depth suitability in Northern Subbasin streams was in the lowest category for most streams during both sampling periods (*Figure 37*). Small sections of Squaw, Canoe, and Butte creeks showed improvement between the 1990s and early 2000s, but pool habitat in Salmon Creek deteriorated over time. Northern Subbasin streams receive a tremendous amount of sediment from both anthropogenic and natural sources. Heavy sedimentation rates, especially during large flood events such as the 1955 and 1964

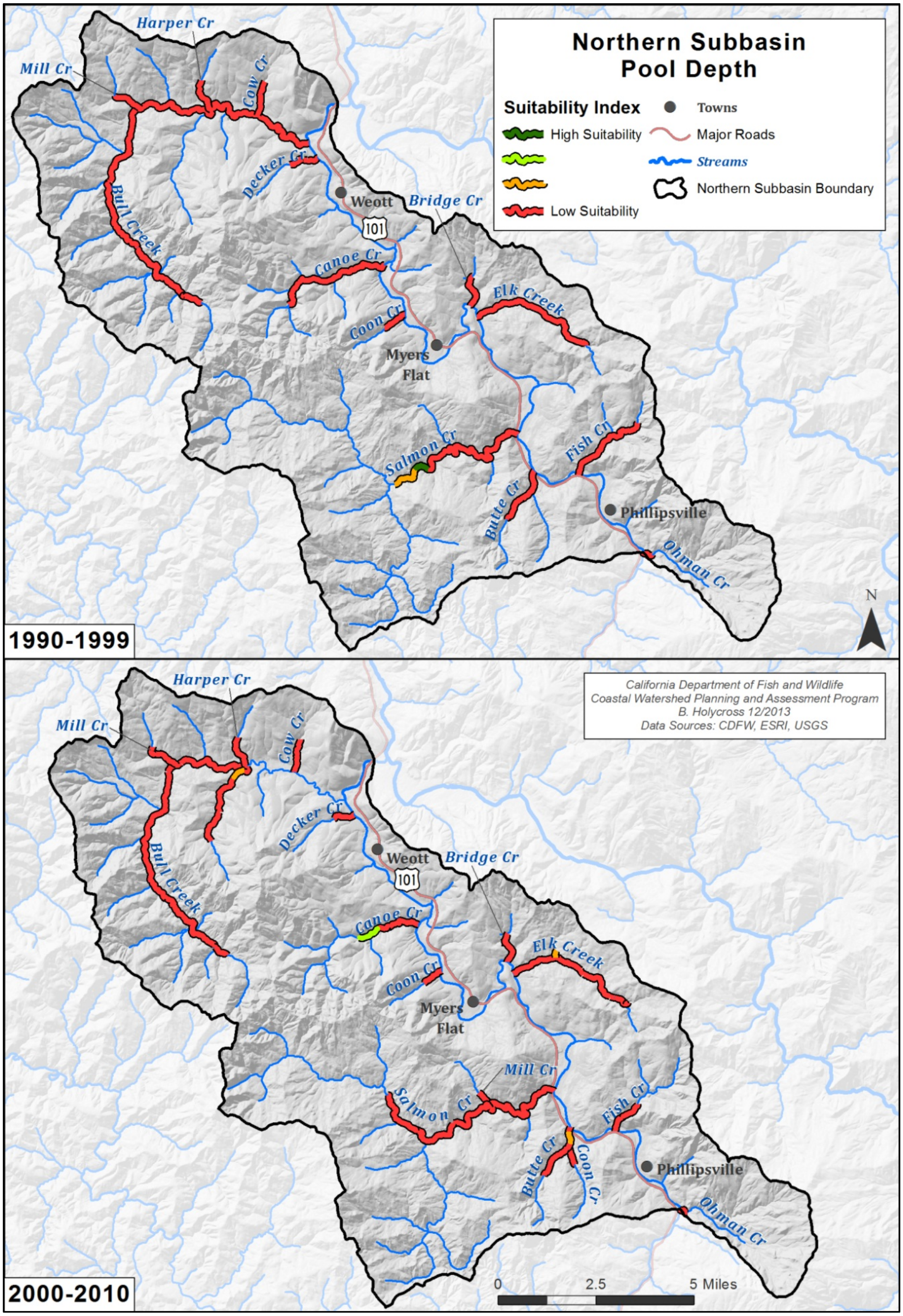



*Figure 37. Pool depth suitability in SF Eel River Northern Subbasin streams, as determined by the EMDS-based analysis using data collected between 1990 and 1999, and 2000 and 2010.*

floods, have modified stream channels from deep, cool and relatively stable, to shallow and relatively unstable by filling in pool habitat and depositing sediment throughout the channel bed. The highest rate of sediment production in this subbasin is from landslides (Stillwater Sciences 1999), but road density is also very high (3.3 miles/square mile), particularly in areas of the subbasin that are outside State Park boundaries. Sediment input sources from legacy and recently constructed roads include road crossing and gully erosion, road prism sheetwash, and skid trail erosion. Restoration activities that will create additional pool habitat and scour existing shallow pools while reducing sediment input from surrounding hillsides and roads are highly recommended throughout this subbasin.

## Pool Shelter

Pool shelter provides protection from predation and rest areas from high velocity flows for all life stages of salmonids. The pool shelter rating is a relative measure of the quantity and percent composition of small and large woody debris, root masses, undercut banks, bubble curtains, and submerged or overhanging vegetation in pool habitats. A standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) is assigned according to the complexity of the shelter. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent covered. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

The average mean pool shelter rating for Northern Subbasin streams was 43.0 in the 1990s and 49.4 using habitat data collected between 2000 and 2010 (*Table 21*). Although these values increased slightly over time, they are still well below the target pool shelter value of 100 for salmonids.

Pool shelter values and corresponding scores for most of the reaches in Salmon Creek increased dramatically between the two sampling periods. In 1992, average pool shelter (weighted by reach length) was 15.0; by 2007, this number increased to 70.4 (*Table 21*). Pool shelter suitability increased in the lower and upper reaches of Salmon Creek, and the uppermost reach, located upstream from the confluence with the South Fork Salmon, was in the highest suitability category in the early 2000s (*Figure 38*). Increased suitability is most likely due to strong community involvement in watershed management and active restoration efforts throughout this watershed (JMWM 2000).

Northern Subbasin streams with slight increases in pool shelter suitability values over time were the middle reaches of Bull Creek, and a few reaches in Butte, Bridge, Coon, Cow, and Mill creeks (*Figure 38*). Pool shelter suitability decreased over time in Decker, Canoe, and Elk creeks, most likely due to land use practices (e.g. recent timber harvests in Elk Creek) and lack of bank stability and LWD recruitment in these streams.

Restoration projects targeting streams with particularly low pool shelter values and potential salmonid presence should be a high priority throughout the Northern Subbasin. These projects could be combined with pool habitat creation/enhancement projects, since both primary pool habitat and pool shelter are limiting factors for salmonids in this subbasin.

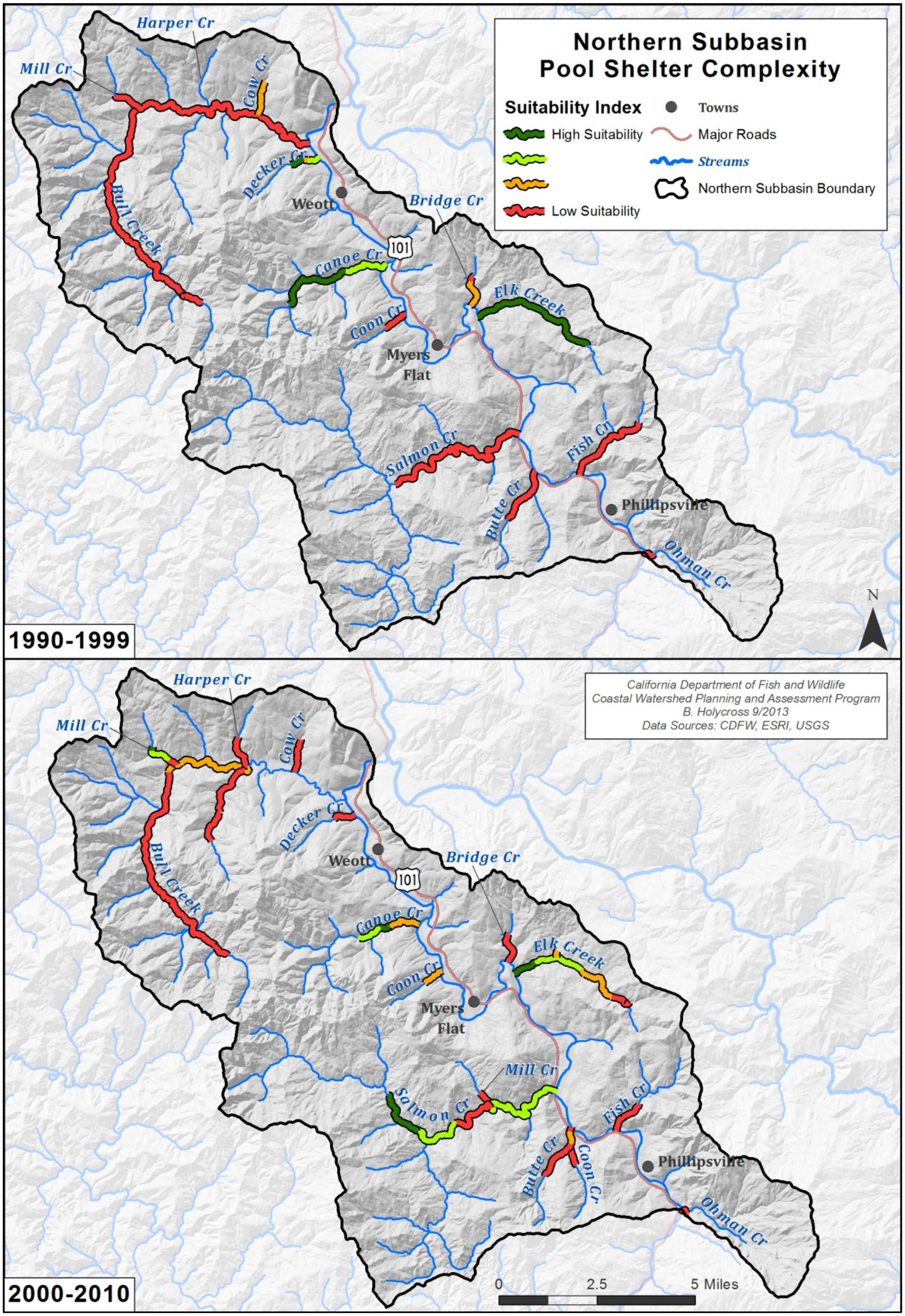



*Figure 38. Pool shelter suitability for Northern Subbasin streams, as determined by the EMDS-based analysis using data collected between 1990 and 1999, and 2000 and 2010.*

## Substrate Embeddedness

Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments in gravels reduce spawning and incubation success. Substrate embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 cobbles are 0-25% embedded, category 2 are 26-50% embedded, category 3 are 51-75% embedded, and category 4 are 76-100% embedded. Embeddedness categories 3 and 4 are not within the fully suitable range for successful use by salmonids. Category 5 embeddedness, represented by the bars furthest to the right in *Figure 39* represent tail-outs deemed unsuitable for spawning due to inappropriate substrate like sand, bedrock, log sills, or boulders, and were not included in the suitability analysis.

Cobble embeddedness condition improved in most Northern Subbasin streams over time, with average percent category 1 embeddedness values of 7.8% for data collected in the 1990s and 33.4% for data collected between 2000 and 2010 (*Table 21*).

While subbasin averages are a good overall indicator of embeddedness, it is valuable to consider the changes in each category type over time, since only categories 1 and 2 are suitable for salmonid spawning. The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled between the 1990s and early 2000s (*Figure 39*). Although nearly 30% of surveyed pool tails were in category 1 in the early 2000s, this is still less than the target value of 50% in category 1 embeddedness established by Flosi et al. (2010).

The percent of pool tails in category 2 stayed nearly the same (35-38%); the percent of pool tails in embeddedness category 3 was approximately 50% less; and the percent of pool tails in category 4 were reduced by about 75% when comparing the two time periods. The percent of pool tails in category 5 increased over time, especially in the Bull Creek drainage where sediment input from slopes and active landslides is widespread.

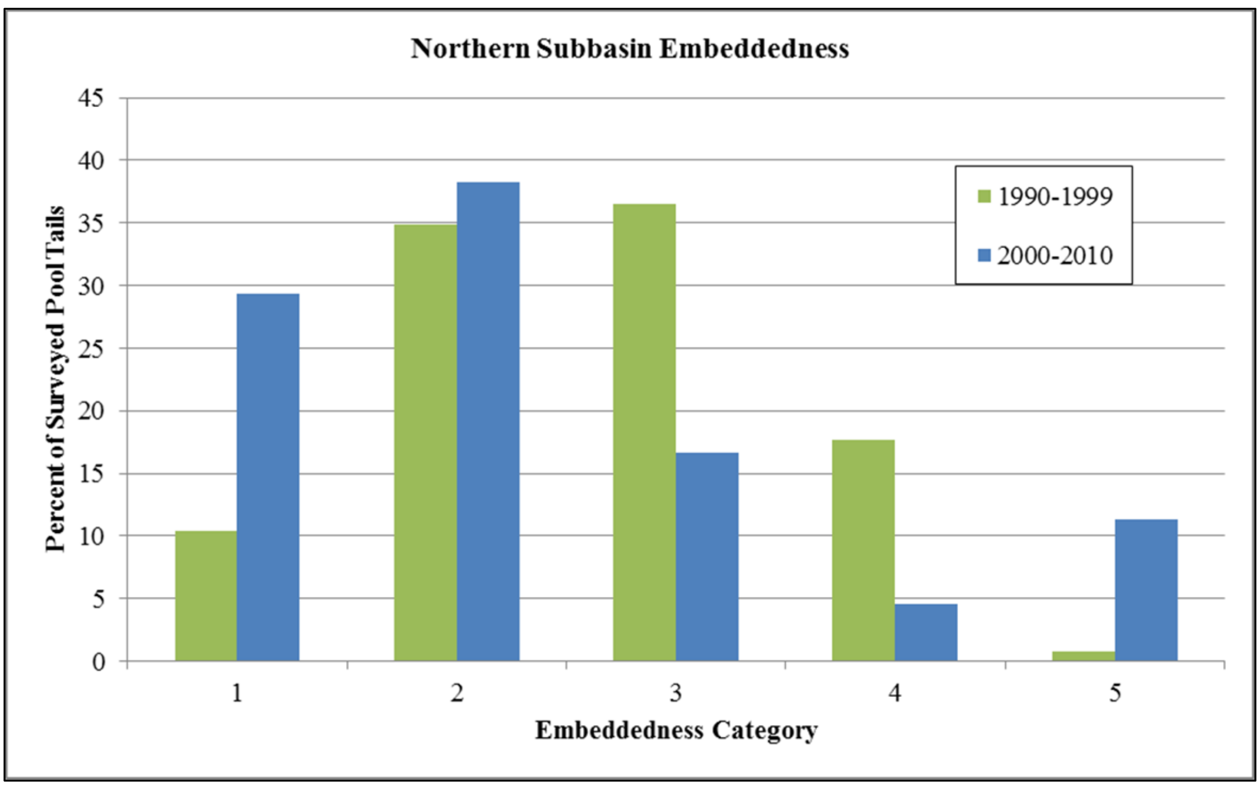



*Figure 39. Cobble Embeddedness in the Northern Subbasin, using data collected from 1990-1999 and 2000-2010.*

The EMDS-based model used a weighted sum of embeddedness category scores to evaluate the pool tail substrate suitability for survival of eggs to emergence of fry. The percent embeddedness categories were weighted by assigning a coefficient to each category. Embeddedness category 1 was rated as fully suitable for egg survival and fry emergence and a coefficient of +1 was assigned to the percent of embeddedness scores in category 1. Embeddedness category 2 was considered uncertain and given a coefficient of 0. Embeddedness categories 3 and 4 were considered unsuitable and were assigned a coefficient of -1. Category 5 values were omitted because they are composed of impervious substrate. The values for each category were summed and evaluated in the analysis.

Embeddedness suitability increased in streams throughout the Northern Subbasin between the 1990s and early 2000s (*Figure 40*). The most dramatic increases were recorded in Salmon Creek, which had overall embeddedness suitability values in the lowest category in the 1990s, increasing to the highest suitability in the 2000s. Other streams with improved embeddedness suitability in some or all surveyed reaches were Bull, Decker, Elk, Ohman, and Butte creeks. These improvements are most likely due to sediment from historical floods moving through the system, and to bank stabilization and upslope watershed restoration projects that have been completed or are in progress throughout the subbasin.

Embeddedness scores decreased in the upper reaches of Canoe Creek between the two time periods. This was due to habitat degradation (in both old and young growth stands) and associated increases in sediment input resulting from the Canoe Creek fire in 2003.

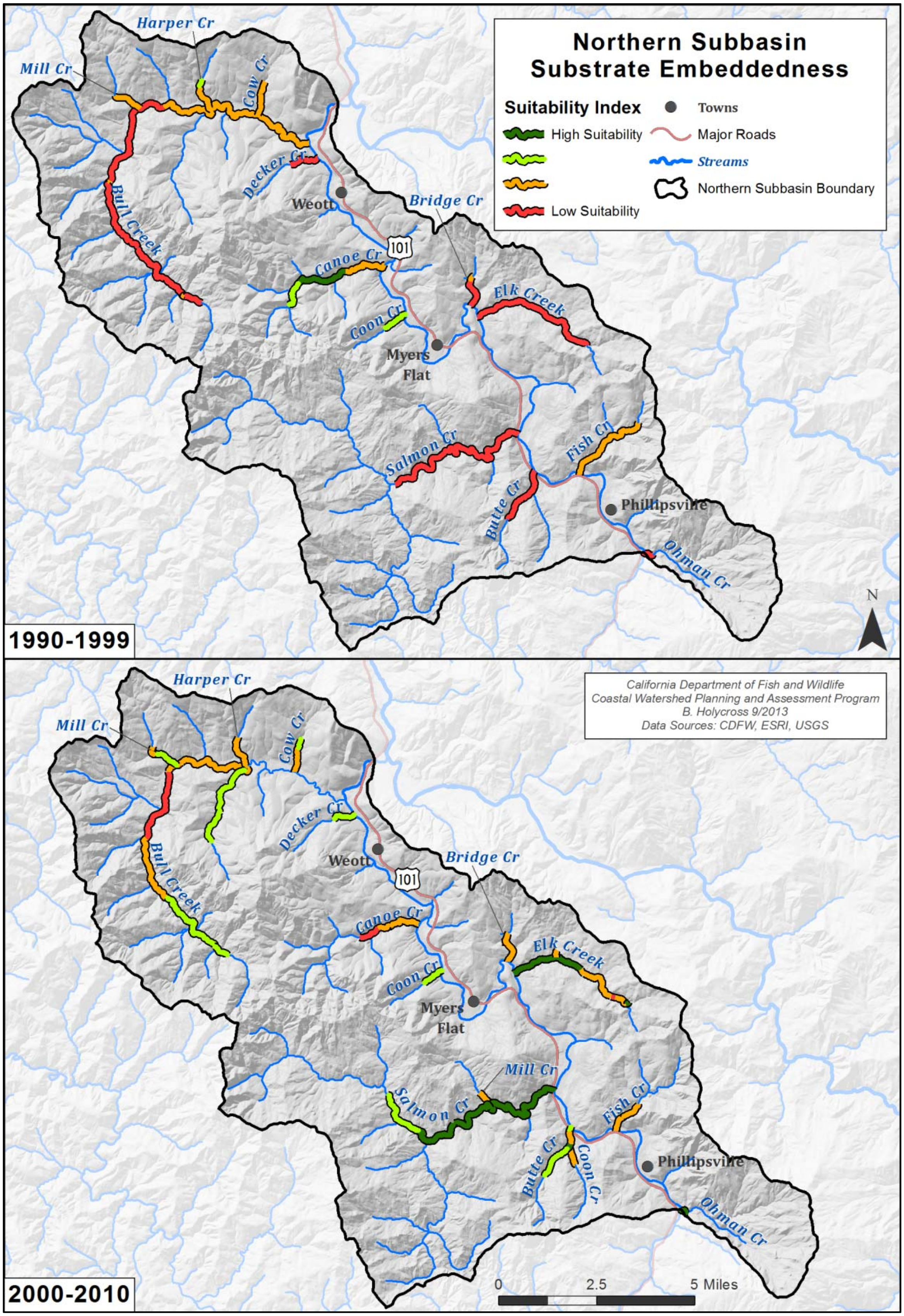



*Figure 40. Embeddedness suitability in Northern Subbasin streams, as determined by the EMDS-based analysis using data collected during between 1990 and 1999, and 2000 and 2010.*

## LWD

Wood recruitment processes vary spatially across landscapes due to differences in forest composition and age, climate, stream size, topography, natural disturbances, and land use history (Benda and Bigelow 2011). Large wood shapes channel morphology, helps streams retain organic matter and nutrients, and provides essential cover for salmonids. It also modifies streamflow, adds habitat complexity and structure, and increases pool formation and available habitat for Chinook and coho salmon and steelhead trout at all life stages during both low and high flow times (Snohomish County Public Works 2002). Natural LWD recruitment is lower in areas where industrial timber harvest occurs (Murphy and Koski 1989, Beechie et al. 2000).

CWPAP staff did not develop reference values for frequency and volume of LWD in the EMDS-type analysis. Other models have used values derived from Bilby and Ward (1989), which are dependent on channel size. Most watersheds in the Northern Subbasin did not have sufficient LWD surveys and channel size measurements for use in the analysis, but existing data were summarized to determine the frequency of LWD as the dominant shelter type and the percent shelter from LWD in pools.

Boulders were the dominant shelter type recorded in Northern Subbasin streams in all subbasin reaches during both time periods (*Table 24*). LWD was the second most dominant shelter type in Northern Subbasin streams during both sampling periods. Large woody debris increased as the dominant shelter, from only 2 reaches in the 1990s to 9 reaches in the early 2000s. This was expected due to the predominance of coniferous and hardwood forest vegetation types, which supply LWD to streams, and due to restoration efforts and management strategies designed to encourage natural LWD recruitment and placement in Northern Subbasin streams.

*Table 24. Dominant pool shelter type by number of reaches surveyed in Northern Subbasin streams.*

| **Dominant Shelter Type** | **1990-1999** | **2000-2010** |
|---|---|---|
| Boulders | 30 | 31 |
| Root masses | 0 | 3 |
| Terrestrial vegetation | 0 | 2 |
| LWD | 2 | 9 |
| SWD | 1 | 1 |
| Aquatic vegetation | 0 | 0 |
| Undercut banks | 0 | 1 |
| Whitewater | 0 | 0 |
| **Total number of reaches surveyed** | **33** | **47** |

The average percent shelter from LWD in pools in Northern Subbasin streams was relatively low during both sampling periods, but increased slightly over time (*Table 25*). These low values may be due in part to past management practices. In the 1960s and 1970s, large wood was aggressively removed from channels, but recent restoration activities have emphasized adding large wood back into streams, especially in areas where wood is readily available in close proximity to the stream. Although the average percent shelter from LWD values increased over time, these values were low (<5%), indicating the need for additional large wood as vital rearing and holding habitat components in all Northern Subbasin streams.

*Table 25. Total length of pool habitat and average percent shelter from LWD in Northern Subbasin streams using data collected during two time periods: 1990-1999 and 2000-2010.*

| **Northern Subbasin** | **Total length of pool habitat (mi)** | **Avg % shelter from LWD** |
|---|---|---|
| 1990-1999 | 6.86 | 2.09 |
| 2000-2010 | 8.57 | 3.31 |

## Pool-Riffle Ratio

Pool-riffle ratio is a measure of the amount of habitat available to salmonids in a stream, specifically the amount of pool habitat for resting and feeding, and the amount of riffle habitat for food production and spawning. Pool-riffle sequences, ratios, and lengths are dependent on channel gradient, resistance of channel boundaries (bedrock walls and bed material), and discharge (Wohl et al. 1993). A 50:50 (1:1) ratio is usually considered optimal, but streams with a slightly lower percentage of pool habitat compared to riffle habitat (0.4:1 ratio) have also been found to support a high biomass of salmonids (Platts et al. 1983). Flosi et al. (2010) recommended that approximately 40% of anadromous salmonid stream length should be pool habitat. Streams with a high percentage of riffles and few pools are generally low in fish biomass and species diversity (Snohomish County Public Works 2002).

The percentages of pool habitat in Northern Subbasin streams were below optimal levels during both sampling periods (*Table 26*). Aggradation from numerous active landslides and unstable geology may have contributed to a decrease in channel complexity and less than optimal pool-riffle ratios in this subbasin, particularly in the Bull Creek drainage near Cuneo, Burns, and Slide creeks.

*Table 26. Percent pool and riffle habitat, and pool riffle ratios for Northern Subbasin streams (from habitat typing data collected between 1990 and 1999, and 2000 and 2010).*

| DATE | % POOL HABITAT | % RIFFLE HABITAT | POOL:RIFFLE RATIO |
|---|---|---|---|
| 1990-1999 | 20 | 40 | 33 : 66 |
| 2000-2010 | 24 | 41 | 37 : 63 |

The ratio of pool to riffle habitat improved slightly in recent years (2000-2010) compared to conditions in the 1990s. This improvement may be due to restoration projects completed in the basin, especially instream and riparian habitat improvement, upslope watershed restoration, and bank stabilization projects, and to large sediment deposits from historic floods moving through the system.

Most pools sampled during both time periods were shallow, resulting in primary pool lengths below target values and corresponding low pool depth suitability scores. This was expected because habitat typing surveys are conducted during summer (relatively low flow) months, and are not a reflection of winter habitat conditions, when flows and pool depths increase. Additional information on pool depths and pool-riffle ratios collected during the winter would be beneficial for future assessments.

# Water Quality

## Water Temperature

Water temperature is one of the most important environmental influences on salmonids at all life stages, affecting physiological processes and timing of life history events (Spence et al. 1996, Carter 2005). Stressful conditions from high temperatures are cumulative and are positively correlated with both the severity and duration of exposure (Carter 2005). Elevated instream temperatures result from an increase in direct solar radiation due to the removal of riparian vegetation, channels widening and becoming shallower due to increased sedimentation, and the transport of excess heat downstream (USEPA 1999).

The Humboldt County Resource Conservation District (HCRCD), with the cooperation of 21 supporting agencies, individuals, and landowners, completed temperature monitoring and biological sampling in the Eel River Watershed, collecting data during eight field seasons from 1996-2003 (Friedrichsen 2003). They collected maximum weekly average temperature (MWAT) in streams throughout the SF Eel River Basin, including 31 sampling locations (30 in tributaries and one in the mainstem SF Eel River) in the Northern Subbasin (*Figure 41*). Data loggers were generally deployed from June through October, and

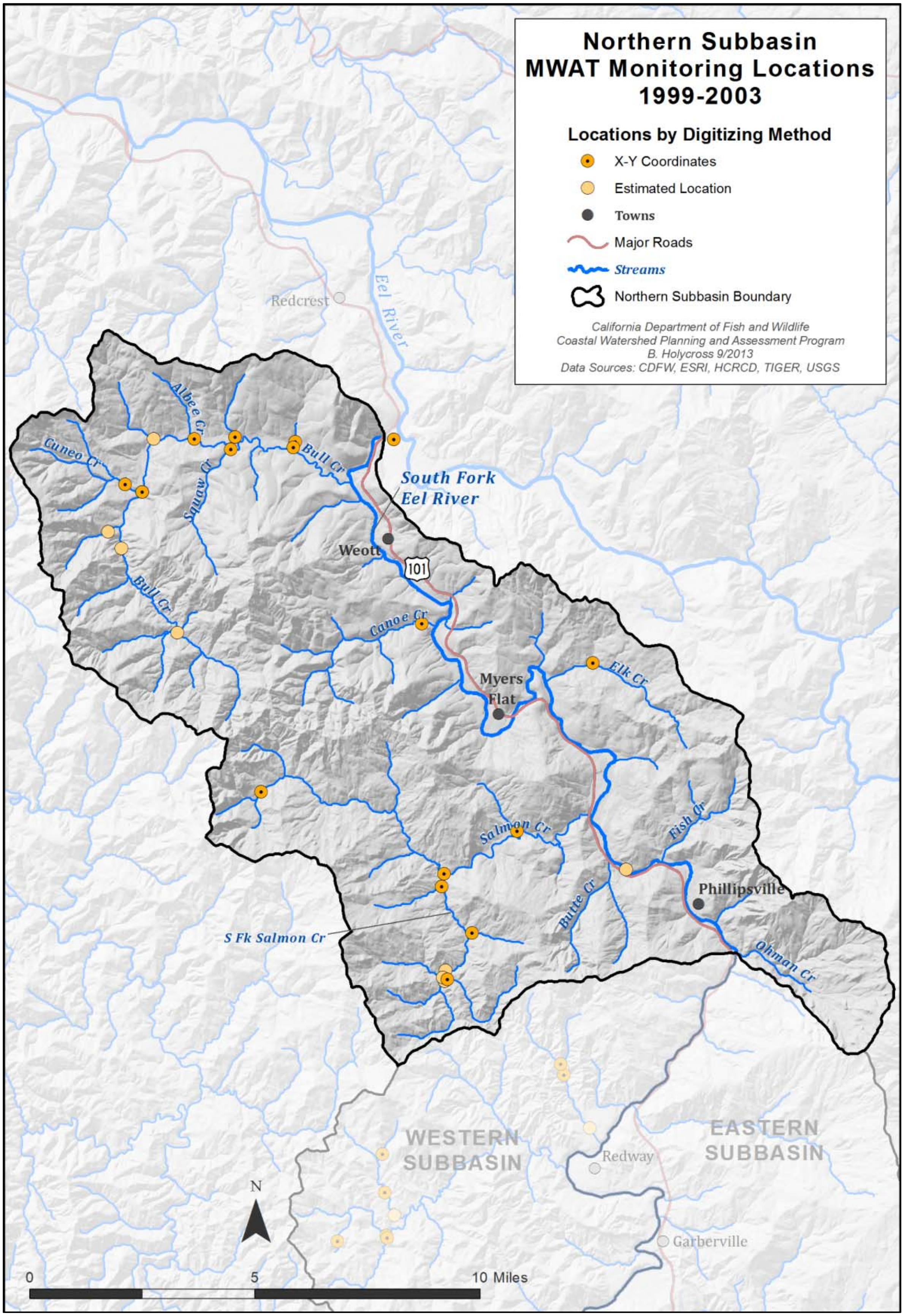



*Figure 41. Locations of temperature monitoring sites in the SF Eel River Northern Subbasin (Friedrichsen 2003).*

not all sites were sampled every year. Some large streams (e.g. Bull Creek) were sampled at more than one location, and site locations are listed for each data point. Friedrichsen (2003) provided X,Y coordinates for most gauge locations, and others were digitized using HCRCD map data where available. Although not all sampling locations are included on the map, missing data points were located in mainstem areas of larger tributaries (S. Downie, CDFW, personal communication 2013).

The CWPAP staff created suitability ranges for stream temperatures based on MWATs, considering the effect of temperature on salmonid viability, growth, and habitat fitness (*Table 27*). This metric was calculated from a seven-day moving average of daily average temperatures. The maximum daily average was used to illustrate possible stressful conditions for salmonids. The instantaneous maximum temperature that may lead to salmonid mortality is ≥75°F; this temperature is potentially lethal for salmonids if cooler refuge is not available.

*Table 27. CWPAP-defined salmonid habitat quality ratings for MWATs.*

| MWAT Range | Description |
|---|---|
| 50-62°F | Good stream temperature |
| 63-65°F | Fair stream temperature |
| ≥66°F | Poor stream temperature |

Using Friedrichsen's data and these suitability ranges, only 8 sites (on 6 creeks) in the Northern Subbasin had good stream temperatures (*Table 28*). Seven sites (on 6 creeks) had fair stream temperatures, and more than half of the sampled sites (16 locations on 11 creeks) had poor stream temperatures (*Figure 42*). Many of the sampling sites in areas with poor temperatures were located in the two largest streams in the subbasin, Bull and Salmon creeks, and at one site in the mainstem SF Eel River. The mainstem Bull Creek above Rockefeller Forest has very little canopy cover and large amounts of sediment entering from upstream sites near Cuneo Creek, resulting in increased temperatures from shallow pools filled in with sediment, and increased direct solar radiation from reduced riparian cover and wide channels. Warm water temperatures in mainstem Salmon Creek are due to reduced riparian canopy and increased water diversion for residential use and industrial marijuana cultivation operations. Researchers obtained a maximum daily average reading at the Miranda Bridge site in the mainstem SF Eel River of 76˚F, which exceeded the lethal temperature for salmonids if cooler refuge areas are not available nearby. Although we expect higher temperatures in mainstem SF Eel River than in tributaries, it is important to capture the duration that salmonids are exposed to these stressful or lethal temperatures, and to document the location and availability of cool water refugia areas near sites where lethal MWAT values have been recorded.

*Table 28. Maximum weekly average temperatures (MWATs) and ranges collected in SF Eel River Northern Subbasin tributaries from 1999-2003 (data from Friedrichsen 2003).*

| Creek | Site | MWAT Range (°F) | Average MWAT (°F) | Years of Data |
|---|---|---|---|---|
| **Good Stream Temperature (50-62°F)** | | | | |
| Cow Creek | 1532 | 60 | 60 | 5 |
| Cow Creek | 9623 | 60 | 60 | 4 |
| Canoe Creek | 1303 | 62 | 62 | 1 |
| Cow Creek | 1305 | 61 | 61 | 1 |
| Cuneo Creek | 1444 | 62 | 62 | 1 |
| Decker Creek | 8065 | 61 | 61 | 1 |
| Harper Creek | 1467 | 61 | 61 | 1 |
| Squaw Creek | 1302 | 61-62 | 61 | 5 |
| **Fair Stream Temperature (63-65°F)** | | | | |
| Bull Creek | 1668 | 57-66 | 63 | 3 |
| Canoe Creek | 9622 | 63 | 63 | 3 |
| Preacher Gulch | 8031 | 63 | 63 | 2 |
| Cuneo Creek | 8048 | 62-66 | 64 | 2 |
| Elk Creek | 8004 | 62-68 | 64 | 4 |
| Mill Creek | 8033 | 64 | 64 | 3 |
| Bull Creek | 1512 | 59-69 | 65 | 5 |
| **Poor Stream Temperature (≥66°F)** | | | | |
| Bull Creek above Kemp | 8064 | 67 | 67 | 1 |
| Burns Creek | 1424 | 67 | 67 | 2 |

| Creek | Site | MWAT Range (°F) | Average MWAT (°F) | Years of Data |
|---|---|---|---|---|
| Panther Creek/Bull Creek | 8066 | 66 | 66 | 1 |
| Salmon Creek (Moeschke's) | 8023 | 62-73 | 67 | 3 |
| Tostin Creek | 8039 | 66-68 | 66 | 3 |
| Bogus Creek | 8037 | 63-73 | 68 | 2 |
| Bull Creek | 1417 | 68 | 68 | 1 |
| Bull Creek | 8047 | 69 | 69 | 1 |
| Cuneo Creek | 1670 | 68 | 68 | 2 |
| Kinsey Creek | 8036 | 66-69 | 68 | 2 |
| Salmon Creek | 1629 | 73-75 | 74 | 2 |
| Salmon Creek, South Fork | 8024 | 71 | 71 | 1 |
| Salmon Creek, lower | 8056 | 73 | 73 | 1 |
| Salmon Creek, South Fork | 8055 | 70-71 | 71 | 2 |
| Salmon Creek, South Fork Estes | 8042 | 69 | 69 | 1 |
| South Fork Eel River (Miranda) | 1415 | 76 | 76 | 1 |

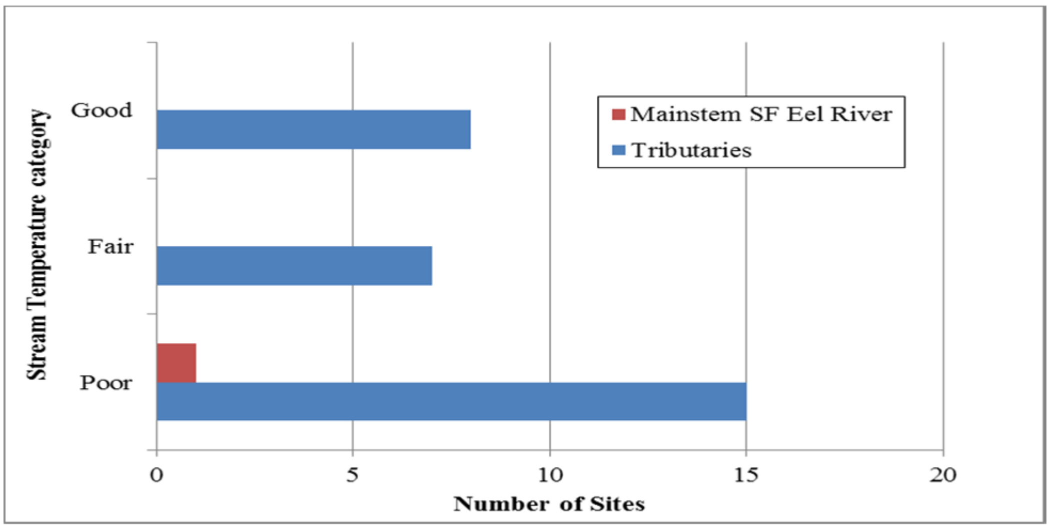



*Figure 42. Number of sites in each suitability rating category for MWATs collected from 1999-2003 (n=31; 30 tributary and 1 mianstem sites) in SF Eel River Northern Subbasin streams (data from Friedrichsen 2003).*

In addition to the HCRCD studies, Higgins (2013) and the Eel River Recovery Project (ERRP) employed a citizen monitoring effort in 2012 to collect water temperature data as an indicator of flow depletion in the Eel River Basin. Higgins compared 2012 stream temperatures with data collected at similar locations by HCRCD between 1995 and 2003, and his conclusions were similar to Friedrichsen's: mainstem SF Eel River temperatures in the upper areas near Branscomb were some of the coolest mainstem conditions in the entire Eel River system, and temperatures became progressively warmer downstream. Mainstem temperatures near Piercy were above optimal for salmonids, and near Phillipsville and Miranda, recorded temperatures were highly stressful for salmonids. Fish in these areas may seek refuge in thermally stratified pools or in localized refugia provided by surface and groundwater interactions when mainstem and tributary temperatures reach stressful or even lethal temperatures (Nielsen et al. 1994, Higgins 2012). These cool water refugia are particularly important in areas where high temperatures result in increased primary productivity (algal blooms), low dissolved oxygen concentrations, and conditions favoring invasive species such as Sacramento Pikeminnow. Both spatial and temporal changes in stream temperatures are concerns in some Northern Subbasin tributaries. Stressful temperature conditions caused by drawing more water out of streams both during dry years and during dry seasons each year have exposed salmonids to extremes that they would not normally encounter. These extremes are particularly problematic for fragmented populations, which are less resilient to variations in stream temperature and other habitat conditions (Poole et al. 2001).

Northern Subbasin streams had more poor temperature conditions compared to Eastern and Western subbasin streams because of the relatively large number of sampling locations (27 of 31) in the Bull and Salmon creek drainages. The mainstem of Bull Creek has very little canopy cover and large amounts of sediment entering from upstream sites near Cuneo Creek, resulting in increased temperatures from shallow pools filled in with sediment and increased direct solar radiation from reduced riparian cover and wide channels. Warm water temperatures in mainstem Salmon Creek are a result of reduced riparian canopy and decreased flow from water diversions.

Temperature data were also collected during the summer of 2013 by UC Berkeley graduate student Keith Bouma-Gregson. Bouma-Gregson sampled cyanotoxins, nutrients (nitrogen and phosphorous), and temperature at 7 Eel River Basin sites, including 4 in the mainstem SF Eel River: Phillipsville (RM 22), Richardson Grove (RM 49), Standish-Hickey State Recreation Area (SRA) (RM 66), and Angelo Reserve (RM 89) (*Figure 43*). Of the SF Eel River sites, daily average temperatures were lowest at Angelo Reserve (64.6-74.7˚F) and warmest at Phillipsville (67.1-79.6˚F). These data are consistent with Friedrichsen's and ERRP's findings. Temperatures recorded at Richardson Grove and Standish-Hickey SRA were intermediate between the other two SF Eel River locations. Lethal temperatures (≥75˚F) were recorded on 15 days in July and August at Richardson Grove, and on 9 days in July at Standish-Hickey SRA. At the Phillipsville site, located within the Northern Subbasin boundary, daily average temperatures were above lethal limits for salmonids on 27 days from mid-July to early September. There were no lethal temperatures recorded at the Angelo Reserve site (Bouma-Gregson, UC Berkeley, personal communication 2014).

Maximum weekly average temperatures are momentary high points, and both MWAT and daily average temperatures are useful for general discussion. However, in order to understand temperature conditions and their effects on salmonids, it would be more informative to capture the duration that salmonids are exposed to stressful or lethal temperatures on a reach by reach basis, and to document the availability of cool water refugia areas near locations where poor MWAT values have been recorded. There are studies in development to address flow and temperature concerns in other parts of the SF Eel River Basin (e.g. Redwood Creek, near Redway (SRF 2013)), but additional studies are necessary in Northern Subbasin streams, particularly in tributaries to larger creeks and in locations further upstream in tributaries sampled by Friedrichsen et al. and ERRP. Studies addressing temperatures during low flow periods are especially important to determine how low flow and diversion are affecting temperatures in tributaries, and the effects of these changes on salmonids throughout the subbasin.

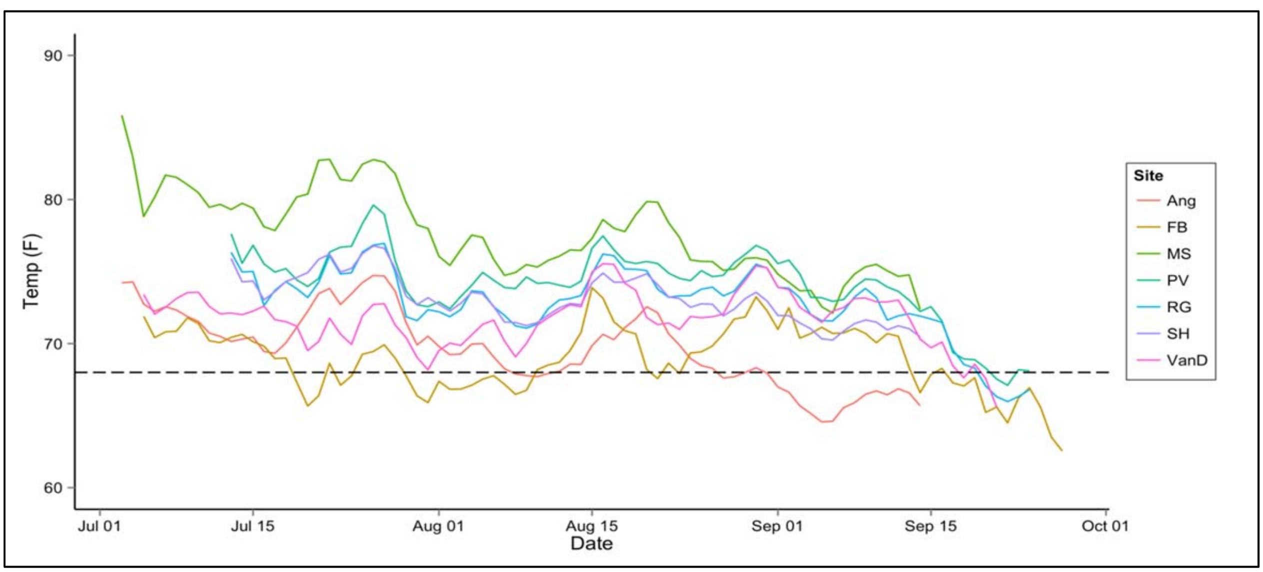



*Figure 43. Daily average temperatures (degrees F) from July 3 through September 24, 2013, recorded at 7 sampling locations in the Eel River Basin. Data and graph provided by Keith Bouma-Gregson (UC Berkeley, 2014). Ang = Angelo Reserve; FB = Fernbridge; MS = Mainstem Outlet Creek; PV = Phillipsville; RG = Richardson Grove; SH = Standish-Hickey SRA; VanD = Van Duzen River.*

## Flow

There are four sources of stream flow in a natural watershed:

- **Groundwater flow** into the channel provides base flow. In perennial streams, the water table is at the height of the stream surface;
- **Interflow** from the soil moisture zone;
- **Direct channel precipitation** at the surface; and
- **Surface runoff** as overland flow (Ritter 2013).

Instream flow is typically measured in cubic feet per second (cfs), and is a measure of how fast the water is moving through a cross-section of the stream. Flow velocity is directly related to the hydraulic radius and channel slope, and inversely related to channel roughness in a stream (Ritter 2013).

River morphology (width, depth, slope, and channel pattern) changes in response to the supply of sediment and water from the surrounding watershed (Pitlick and Wilcock 2001). In Northern Subbasin streams, increased deposition and aggradation from high sediment input rates affect flow, particularly during summer months when natural flow sources are significantly reduced and diversion rates are high. These low flows and the predominance of sediment result in streams with subsurface flow during late summer and early fall months, which decreases the quantity and quality of salmonid habitat in many streams by reducing stream depth and available pool habitat, elevating water temperatures, and concentrating pollutants.

The USGS monitors flow at two locations in the Northern Subbasin: the mainstem SF Eel River near Miranda (RM 17), and Bull Creek (RM 2). The Bull Creek gauge is located approximately 4 miles upstream from the confluence of the SF Eel River, near the confluence of Albee Creek. Records from these gauges show a recently emerging pattern of atypical low flows (compared to the historic running average) occurring during the late summer to early fall months even during wet weather years (*Figure 44, Figure 45*). These low flows may be caused by an increase in both the number of diversions and the quantity of water diverted from subbasin streams and tributaries for agricultural and domestic uses.

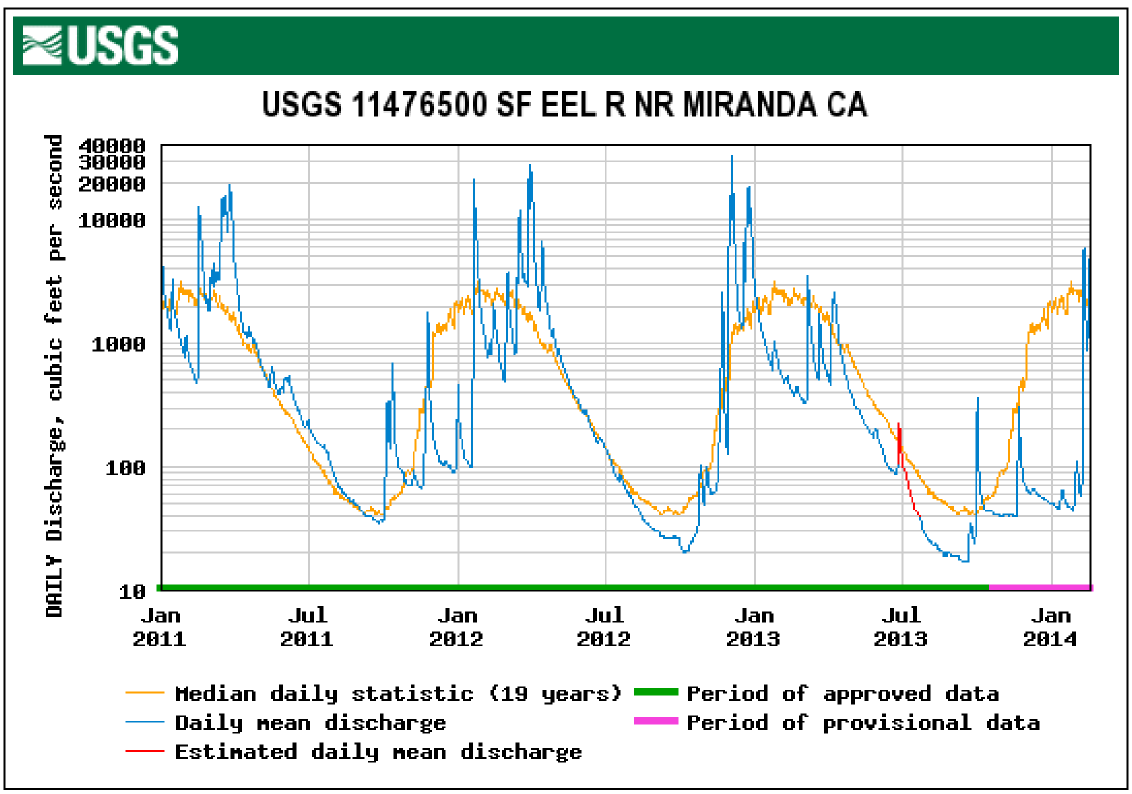



*Figure 44. Daily mean discharge (in cfs) and mean daily discharge (73-year average in cfs) for USGS gauging station at SF Eel River near Miranda, showing 2011-2014 data.*

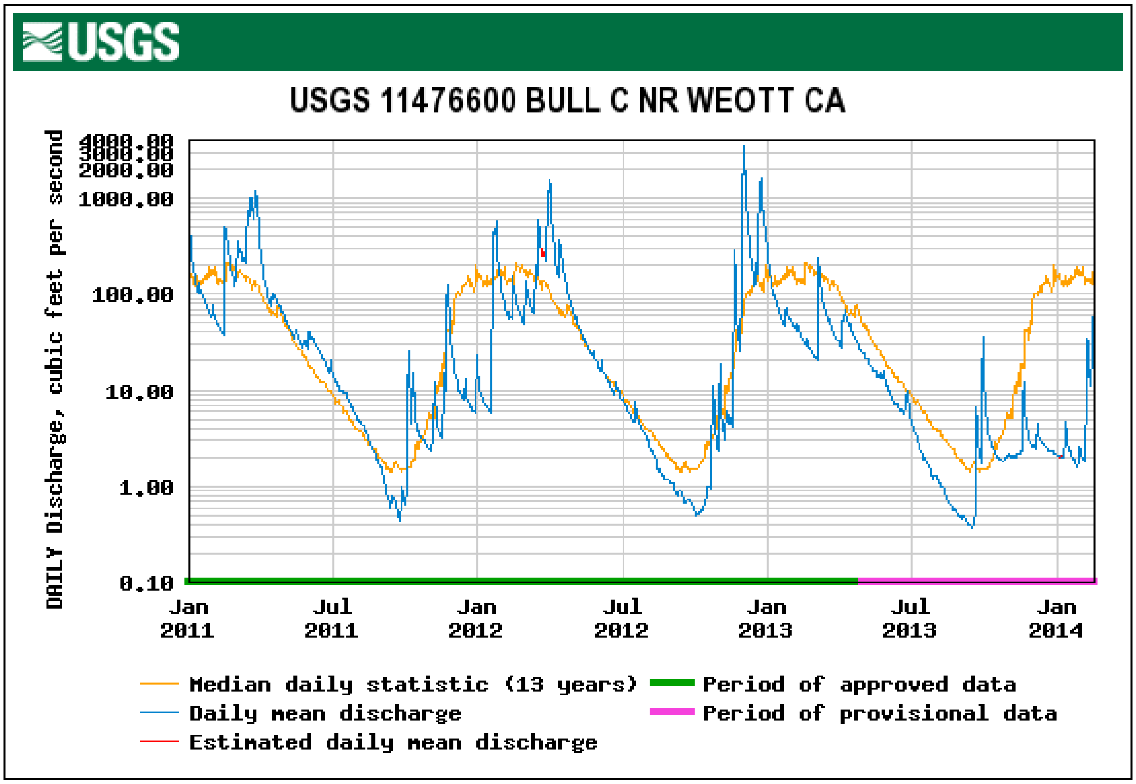



*Figure 45. Daily mean discharge (in cfs) and mean daily discharge (52 year average in cfs) for USGS gauging station at Bull Creek, showing 2011-2014 data.*

In August and September 2013, CWPAP staff conducted a brief low flow study in the SF Eel River Basin, collecting information at 6 mainstem SF Eel River sites and in 37 tributaries with known coho distribution. The purpose of the study was to document extremely low flow conditions (due to limited rainfall in the winter of 2012-2013, and to an increase in the number of diversions for residential use and marijuana cultivation) throughout the basin, and to compare conditions in streams that are heavily diverted with those that are not heavily diverted. In streams that were not impacted by diversion (n = 15) and in streams that were not heavily impacted by diversion (n = 21), flows were typical of those seen in very low water years. In heavily diverted streams, conditions ranged from dry or isolated pools only in some streams, to connected streams with very low flow in others. In Salmon Creek, CWPAP staff noted significant decreases in flow and reduced salmonid habitat between field visits conducted on 8/27/2013 and 9/19/2013 (*Figure 46 A, B*).

*Figure 46 A, B. View of Salmon Creek from Maple Hills Road bridge (RM 0.15) on 8/27/2013 (left (A)) and on 9/19/2013 (right (B)). While flow was diminished, the stream channel was connected in August; however, when field crews returned three weeks later only one isolated pool was present below the bridge.*

The Salmonid Restoration Federation (SRF) initiated a low flow study in Redwood Creek near Redway, located just south of the Northern Subbasin boundary. SRF began collecting baseline streamflow data in the summer of 2013. Data were collected at eleven sites in the Redwood Creek watershed, from upstream areas including Pollock and China Creeks, to downstream sites near the confluence of Redwood Creek and the SF Eel River. Findings included:

- Flow was intermittent in most streams from August through September;
- All sites had less than 1 gallon per minute (gpm) flow in mid-September;
- Bedrock substrate was the main factor in maintaining pools;
- Groundwater recharge was highly variable. After one inch of rain fell on September 20-21, connectivity was reestablished in China and Pollock Creeks. After three more inches of rain fell on September 28-29, all streams throughout the watershed were reconnected and remained flowing until the next rainstorm on November 18.

Although the Redwood Creek watershed is not within the boundaries of the Northern Subbasin, SRF's findings most likely apply to other areas throughout the SF Eel River Basin, particularly in areas with similar land use patterns such as Salmon Creek in the Northern Subbasin. For a full description of the SRF low flow project and results, see the Flow section in the Western Subbasin part of this assessment.

## Water Diversion and Voluntary Conservation

The effects of low flow, diversions, and warm water temperatures on salmonids are major concerns in streams throughout the Northern Subbasin. There are currently no projects in development to address these issues in Northern Subbasin streams, but there are ongoing efforts in Redwood Creek (near Redway), which is located just south of the subbasin boundary. The Redwood Creek watershed has similar land use patterns and low flow concerns as Salmon Creek. A brief overview of the study is presented here, but for a more detailed description of the project and results, see the Western Subbasin section of this report. For additional information and project updates, go to the SRF website: http://www.calsalmon.org/

In 2013, the Salmonid Restoration Federation (SRF) and Humboldt State University (HSU) initiated a study to determine the feasibility of implementing a voluntary water conservation and storage program in Redwood Creek. This study is modeled after Sanctuary Forest's water storage tank and forbearance program in the Mattole River headwaters, where participating landowners store water in tanks during high flows for use during low flow times, thereby reducing diversions and increasing flows to improve fish habitat and water quality during the low flow season. Due to the success of the program in the Mattole River Basin, SRF and HSU applied a similar design when developing the Redwood Creek Water Conservation Project.

SRF and HSU determined that there are landowners who are willing to take part in a voluntary water conservation program, however there are some obstacles. Tank installation requires a financial commitment, including the purchase of a new tank and additional property taxes when water storage is installed, which are currently financial disincentives for residents interested in participating in the water storage program. Several local non-profit agencies are currently investigating options for a new tax policy to provide financial incentives for residents interested in installing water tanks. Water rights are also problematic in the watershed: many landowners currently divert water for domestic and agricultural purposes, but only two residents have established water rights (SRF 2013). SRF, in cooperation with several local non-profit agencies, established a public forum to educate residents about water rights and compliance issues so that they can legally divert and store water.

Preliminary results from the Redwood Creek study indicated the following:

- Flow was intermittent in most streams from August through September;
- All sites had less than 1 gpm flow in mid-September;
- Bedrock substrate was the main factor in maintaining pools; and
- Groundwater recharge was highly variable.

The next steps in the study will include interpretation of data collected in additional low flow studies to develop information that will be used to determine how existing diversions are affecting flow, and to expand the community-led water conservation program that will improve habitat and benefit salmonids in the Redwood Creek watershed.

This study emphasizes the need for specific information on water diversions and flow, and it is an example of successful community involvement in fisheries habitat monitoring and restoration efforts. Similar voluntary conservation programs could be applied in the future in Northern Subbasin watersheds.

## Water Chemistry

### Sediment

Sediment affects salmonids both directly and indirectly by modifying aquatic habitat. Coarse sediment, fine sediment, and suspended sediment may adversely affect adult and juvenile salmonids by altering channel structure and affecting production.

In 1999, the SF Eel Basin was listed by the USEPA as an impaired water body for sediment. In the TMDL analysis (USEPA 1999), the USEPA interpreted water quality standards, calculated existing sediment loads, set loading capacities, and established load allocations. The most significant sources of sediment found in the watershed included roads, timber-harvest related activities, and natural sources. In order to interpret water quality standards and to determine the amount of sediment that will not adversely affect salmonids, USEPA developed a set of indicators: percent fines, turbidity, V star, and the thalweg profile. Stillwater Sciences (1999) then completed a sediment source analysis, which was used to set TMDL loading capacity and allocations for the SF Eel River Basin. TMDL allocations were developed to assess the maximum allowable amount of sediment received by a stream while still meeting water quality requirements (*Table 29*).

*Table 29. USEPA sediment indicators and targets for the SF Eel River Basin (USEPA 1999).*

| Indicator | Target | Purpose |
|---|---|---|
| Substrate composition – percent fines | <14%<0.85 mm | 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 | Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities |
| Residual pool filling (V*) | <0.10 | Estimate of sediment filling of pools from disturbance |
| Thalweg profile | Increasing variation from the mean | Estimate of improving habitat complexity & availability |

The USEPA and Stillwater Sciences did not subdivide the SF Eel River Basin into subbasins, so estimates and recommendations were developed for the entire basin. The USEPA calculated that existing sediment loading was approximately two times the natural rate, or for every t/km$^2$/year of natural sediment, there was one t/km$^2$/year of human-induced sediment (USEPA 1999). Stillwater Sciences (1999) found that sediment loading is variable, and roads are the largest anthropogenic contributors of fine sediment to streams throughout the basin.

The total sediment load was calculated to be 704 tons/km$^2$/year or 1.9 tons/km$^2$/day on a 15 year running average (*Table 30*). The ratio of human-induced sediment is approximately 1:1, but slightly more sediment is from natural sources (54% of total) than anthropogenic sources (46% of total). Earthflows are the primary source of natural sediment, and roads are the primary source of anthropogenic sediment in the basin.

*Table 30. USEPA basinwide estimates of sediment sources for the SF Eel River Watershed from 1981-1996 (USEPA 1999).*

| Sediment Source | Total sediment input (t/year) | Unit area sediment input (t/km2/year) | Fraction of total |
|---|---|---|---|
| Natural Sediment Sources | | | |
| Earthflow toes and associated gullies | 478800 | 269 | 38% |
| Shallow landslides | 132500 | 74 | 11% |
| Soil creep | 62980 | 35 | 5% |
| **Subtotal** | **674280** | **378** | **54%** |
| Anthropogenic Sources | | | |
| Shallow landslides, roads and harvest | 216200 | 121 | 17% |
| Skid trail erosion | 21534 | 12 | 2% |
| Road surface erosion | 67512 | 38 | 5% |
| Road crossing failures and gullying | 276500 | 155 | 22% |
| **Subtotal** | **581746** | **326** | **46%** |
| **Total** | **1256026** | **704** | **100%** |

The loading capacity, or the amount of pollution that a stream can assimilate and still meet water quality standards, was set for all stream reaches in the basin based on a 1:4 ratio of human to natural sediment. Using this ratio, the allowable human-induced loading capacity would be 95 t/km$^2$/year, and the TMDL for the basin would be 473 t/km$^2$/year. Considerable erosion control measures will be required to meet the TMDL and loading capacity. For example, in order to meet the target ratio, road sediment would need to be reduced from current levels by 80%. Sediment from landslides would then require a 55% reduction in input levels.

In the Water Quality Control Plan for the North Coast

Region, NCRWQB established basin-wide regulations that turbidity should not be increased more than 20 percent above naturally occurring background levels (NCRWQCB 2011). Additional prohibitions are included for erosion sources such as logging operations and constructions projects, so that organic material (including soil, bark, slash, sawdust, and other earthen material) from these operations is not directly or indirectly discharged into streams in quantities sufficient to harm fish and wildlife.

Road decommissioning, or the removal and stabilization of unwanted roads to a natural state, is an effective management technique used to reduce sediment input in watersheds with high road densities. McCaffery et al. (2007) found that watersheds with decommissioned roads had lower percentages of fine sediment in streams than those with roads in use. Many CDFW Fisheries Restoration Grant Program (FRGP) projects that have been completed in upslope areas in the Northern Subbasin include road decommissioning and erosion control measures.

Pacific Watershed Associates (PWA) completed an evaluation of CDFW road decommissioning protocols and guidelines used on more than 51 miles of road in Northwestern California between 1998 and 2003 (PWA 2005). The study area included 12.23 miles of decommissioned roads in the Bull Creek drainage in the SF Eel River Northern Subbasin, with 94 treated sites (81 stream crossings, 3 landslides, and 10 “other” sites). PWA determined that at decommissioned stream crossing sites:

- Sediment delivery was approximately 5% of the original pre-treatment fill volume;
- Unexcavated fill was the most common problem; and
- Protocols were effective but were not being uniformly followed at stream crossing sites.

At landslide sites and road drainages, PWA determined that protocols effective and were being followed, but protocols for “other” sites were vague and ineffective. When done properly, road decommissioning projects resulted in decreased fine sediment input at most treated sites. Other sediment reduction projects completed in the basin (see Fish Restoration Programs section) will contribute to a reduction in overall sediment input, and will be monitored over time.

## Nutrients

UC Berkeley graduate student Keith Bouma-Gregson sampled nitrogen and phosphorous concentrations at 7 Eel River Basin sites (one of which is located in the Northern Subbasin at Phillipsville) while collecting cyanotoxin and temperature data in the summer of 2013. He is currently analyzing data and developing conclusions on the relationship between blue-green algae blooms, toxins, temperatures, nutrient levels, and blue-green algae and green algae associations in SF Eel River streams (K. Bouma-Gregson, personal communication 2014).

## Aquatic Invertebrates

Aquatic macroinvertebrates are the primary food source for salmonids, and can be used as indicators of stream health because they are directly affected by physical, chemical and biological stream conditions. They may also show effects of habitat loss and short- and long-term pollution events that may not be detected in traditional water quality assessments (USEPA 1997). High instream temperatures, reduced flow, and increased sediment input may result in decreased macroinvertebrate assemblages and abundance, and populations may be further reduced in watersheds where land use activities have intensified these conditions. Cover et al. (2006) documented decreases in invertebrate abundance in streams with increased fine sediment input from unstable hillslopes and land use activities in Klamath mountain streams, where instream conditions and land use practices were similar to those found in many Northern Subbasin creeks.

In 1996, Friedrichsen (1998) sampled macroinvertebrate communities throughout the Eel River Basin. Sampling locations were selected by Scott Downie (CDFW) and reviewed by the project’s technical advisory committee. Seven of the sampling sites were located within the SF Eel River Basin boundary, with two locations in the Northern Subbasin (Salmon Creek and Elk Creek). Five metrics (explained in detail by Plafkin et al. 1989) of macroinvertebrate assemblages and community structure were used to assess stream condition:

- The Simpson Index (diversity of taxa and evenness of the community);
- Modified Hilsenhoff Index (tolerance values and number of organisms per taxa divided by the total number of invertebrates in the sample);
- EPT Index (number of species of Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies));

- Percent Dominant Taxa (the total number of organisms in the sample divided by the number of invertebrates in the most abundant taxa); and
- Richness Index (total number of taxa).

These metrics may indicate if the stream is healthy or impaired, and can be used to determine how invertebrate assemblages respond to human and natural disturbances. Friedrichsen (1998) found that when all metric results were considered, Salmon Creek invertebrate populations were among the healthiest in the SF Eel River Basin. Conditions have changed in the Salmon Creek watershed since Friedrichsen's study was completed; streams are heavily diverted, and much of the diverted water is used for illegal marijuana cultivation. In addition to reduced instream flow, water entering the stream near grow operations may be polluted with fertilizers, diesel fuel, rodenticides, human waste, and fine sediment, affecting water quality and, therefore, instream invertebrate communities. More information is needed to determine invertebrate species tolerance levels for both pollution and elevated water temperatures, to assess the effects of increased diversions on aquatic invertebrate populations, and to determine how changes in invertebrate populations affect salmonid populations.

### Blue-Green Algae Blooms

Blue-green algae (cyanobacteria) are naturally occurring photosynthetic bacteria present in warm, slow-moving surface waters during temperate months in the late summer and early fall. Some forms of blue-green algae produce harmful toxins which may attack the liver (hepatotoxins) or the nervous system (neurotoxins). These toxins are released into the environment when cells rupture or die, and may be concentrated during algal blooms (Hoehn and Long 2008, Blaha 2009). The relationship between the timing of blooms and the concentration of cyanotoxins in the water column is currently unknown (K. Bouma-Gregson, UC Berkeley, personal communication 2014).

Cyanobacteria are found throughout the SF Eel River, in the water column, living within the cell walls of diatoms, growing directly on the substrate, and growing on certain types of filamentous green algae such as *Cladophora*. The color of *Cladophora* changes as epiphytic assemblages of diatoms, some containing nitrogen fixing cyanobacteria, develop on filaments. New *Cladophora* growth is green (*Figure 47*), turns yellow when colonized by non-nitrogen fixing diatoms, then turns rusty red colored as assemblages are dominated by nitrogen fixing diatoms (Power et al. 2009).

*Figure 47. Cladophora in Elder Creek, June 2013 (photo courtesy of ERRP).*

Rapid accumulations of cyanobacteria cells, or algal blooms, occur during warm summer months, under optimal conditions including elevated stream temperatures, high levels of nutrients (phosphorous and nitrogen, and the ratio of the two), increased periods of sunlight, and low flow. Human activities such as inadequate sewage treatment, or activities that result in increased agricultural and sediment input, lead to excessive fertilization (eutrophication) in water bodies. Eutrophication creates favorable conditions for blue-green algae blooms (WHO 2009) and decreased water clarity and reduced dissolved oxygen levels in streams (Trout Unlimited 2013).

Measures to prevent blooms should be designed to control anthropogenic influences that promote blooms, such as the leaching and runoff of excess nutrients. Management practices for nutrient input, specifically nitrogen and phosphorus, should be designed to reduce loadings from both point and nonpoint sources, including water treatment discharges, agricultural runoff, and stormwater runoff (USEPA 2012). This is especially important in Northern Subbasin drainages where nutrients, sediment, and/or pollutants are entering streams from large marijuana cultivation operations (e.g. Salmon Creek).

The Humboldt County Department of Health and Human Services (HCDHHS) recently issued warnings notifying recreational users of the SF Eel River to avoid exposure to neurotoxins and liver toxins found in blue-green algae in the river (HCDHHS, Division of Environmental Health, 2011). The County provided the following recommendations for homeowners and land managers to reduce conditions favoring the spread of blue-green algae:

- Minimize the use of water, fertilizers, and pesticides;
- Recycle or dispose of spent soil that has been used for intensive growing – it may still contain high levels of phosphorous and nitrogen;
- Operate and maintain your septic system properly; have the system pumped every 3-4 years;
- Encourage the growth of native plants on riverbanks and shorelines to prevent erosion and filter water, with no fertilizers or pesticides required;
- Keep livestock out of surface waters and prevent surface runoff from agricultural areas; and
- Prevent sediment from roads, construction projects, and logging operations from entering streams.

In recent years, blue-green algae blooms have become more common in the mainstem SF Eel River during the late summer, when flows are at a minimum and air temperatures are high (>100˚F). These conditions are prevalent in the lower mainstem areas of SF Eel River in the Northern Subbasin. The ERRP is currently collecting information on algal blooms, flows, pollutants, and temperatures throughout the Eel River Basin, and are currently developing recommendations to improve ecological conditions and reduce pollution. Bouma-Gregson obtained weekly average concentrations of dissolved cyanotoxins, nitrogen, and phosphorous at 7 sites in the Eel River Basin from July-September, 2013 (for a description of sampling locations, see the Temperature section of this subbasin report). The sites with the highest concentrations of toxins were located in the SF Eel River, though cyanobacteria were present at all sites except Fernbridge. *Anabaena* and *Phormidium*, two genera of cyanobacteria that produce cyanotoxins, were frequently observed at all of the monitoring sites except Fernbridge (Bouma-Gregson, UC Berkeley, personal communication, 2014). In the Northern Subbasin, cyanobacteria blooms have been reported only in the mainstem SF Eel River. However, additional studies targeting Northern Subbasin tributaries are necessary to address the following issues: specific locations of blue-green algae blooms; the relationship between blue-green algae and green algae; levels of nutrients and pollutants present; current sources of nutrient input; and ways to reduce the input of these and other harmful substances in order to improve salmonid habitat.

## Fish Passage Barriers

Barriers to fish passage occur on all natural streams, and are usually gradient or flow barriers near the headwaters. Barriers that occur downstream and limit the naturally occurring range and distribution of salmonids can be classified according to the cause (natural or anthropogenic), lifespan (temporary or permanent), and effectiveness (partial or total). Natural barriers include gradient, landslide, flow/habitat, and log debris accumulations (LDA); manmade barriers include culverts and dams. All types of barriers fragment the habitat available to different life stages of salmonids by reducing access to stream reaches that are used as migratory corridors, and spawning and rearing habitat.

Several fish passage barrier issues have been identified in the Northern Subbasin. Most of the barriers are gradient barriers, followed by total and partial culvert barriers (*Figure 48*). In the Northern Subbasin, there were four landslide barriers located in the upper Bull Creek drainage, and three LDA barriers in lower Bull Creek (*Figure 49*). Data used to create the map were collected between 1981 and 2012, but additional barriers may occur as conditions change and information is added to the CalFish Passage Assessment Database.

*Figure 48. Example of total culvert barrier in Feese Creek.*

Improper culvert placement where roads and streams cross can limit or eliminate fish passage (Gucinski et al. 2001). Highway 101, the only primary road in the subbasin, runs along the SF Eel River for the full length of the subbasin, with a secondary frontage road following the highway for its entire length. Many smaller roads, some permanent and some seasonal, connect Highway 101 with headwater areas in most of the larger watersheds. Many roads cross streams multiple times, and at each crossing, passage issues are a possibility. Most culvert barriers are located in Northern Subbasin streams near the mainstem SF Eel River, where Highway 101 and its frontage road cross tributaries. Two partial culvert barriers are located in the Bull Creek drainage, where the Mattole Road crosses Cow and Harper creeks.

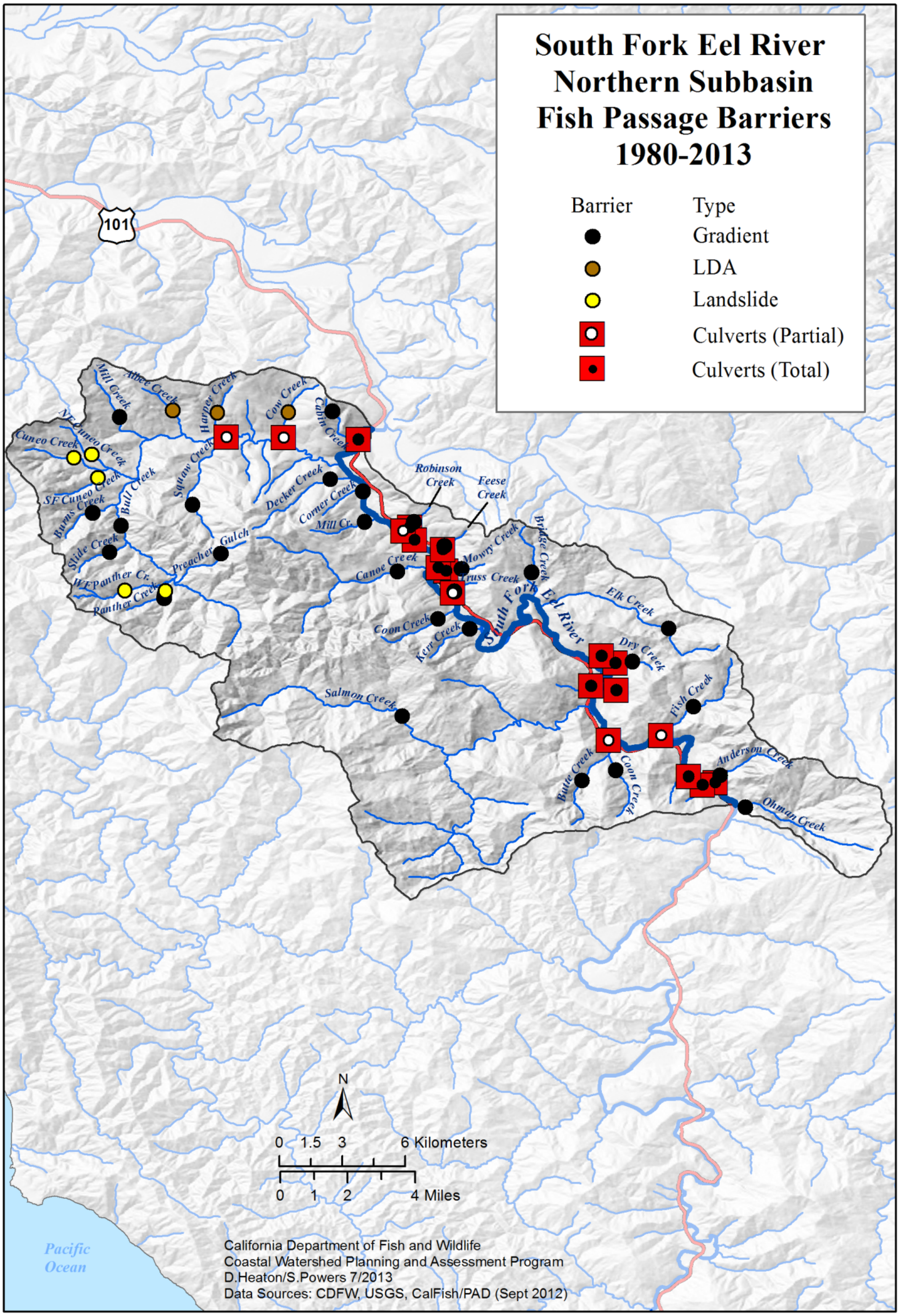



*Figure 49. Fish passage barriers in the SF Eel River Northern Subbasin.*

Gradient barriers caused by boulders or bedrock are found throughout Northern Subbasin streams (*Figure 50*). Most of the gradient barriers mapped in the Northern Subbasin were waterfalls, which are considered extreme examples of gradient barriers. The largest waterfall barrier (30' high) in the Northern Subbasin can be found on Salmon Creek (RM 7.3), and other streams contain smaller waterfalls that are large enough to act as total barriers. Height or vertical drop of falls, plunge pool area and depth, and the jumping ability of each species must be considered when determining whether a waterfall is a barrier to fish passage (Powers and Orsborn 1985). Other gradient barriers included boulder runs and series of cascades.

Log jams, referred to in this report as LDAs in streams can also become fish passage barriers. These are noted in CDFW stream inventories. LDAs are usually temporary barriers, because they shift or break apart during large flow events, but some trap sediment and additional material so that they persist for decades as total barriers. Stream inventories in the Northern Subbasin found LDA barriers in Cow, Harper, and Albee creeks. Historically, large flood events resulted in increased sediment and woody debris (large and small) input to streams. Many large debris jams were documented in stream surveys following the floods, and restoration activities at that time concentrated on removing wood jams, including complete, partial, or potential barriers. These actions, combined with intensive industrial timber harvest activities, resulted in a lack of large wood in streams. Current restoration projects concentrate on adding large wood back into streams to scour pool habitat and provide cover for adult and juvenile salmonids.

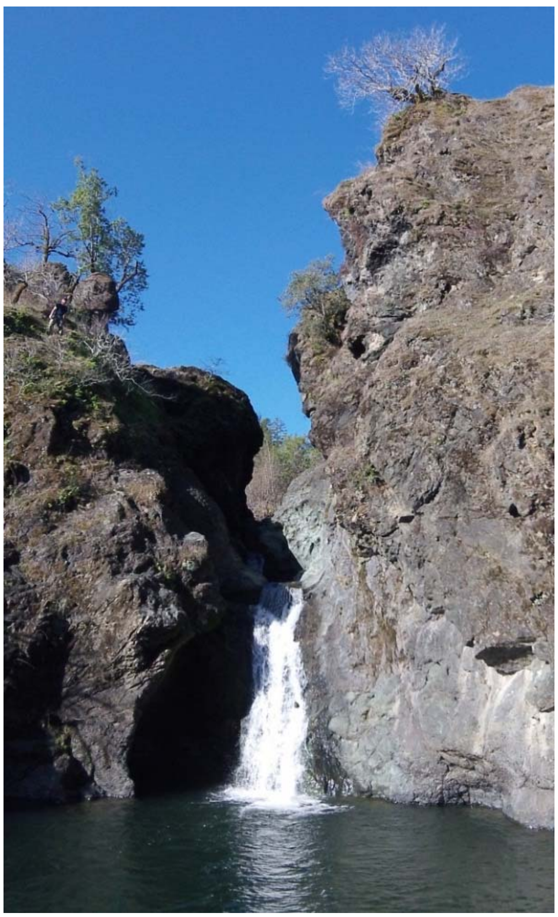


*Figure 50 A, B. Thirty foot bedrock waterfall barrier on upper Salmon Creek (left (A)) and house sized boulder creating a 20' waterfall barrier (right (B)) to fish passage on Ohman Creek, 450 meters upstream of the confluence with the South Fork Eel River.*

# Habitat Conclusions

## Overall Suitability

CWPAP staff assessed changes in Northern Subbasin salmonid habitat using historic data collected on surveys from 1938-1990, and stream habitat typing survey data collected from 1990-2010. Data from older surveys, collected prior to the establishment of a stream survey protocol (Flosi et al. 2010), provided a snapshot of the conditions at the time of each survey. Terms such as excellent, good, fair, and poor were based on the judgment of the biologist or scientific aid who conducted the survey. The results of these historic stream surveys were qualitative and were not used in comparative analyses with quantitative data provided by habitat inventory surveys collected beginning in the 1990s. However, the two data sets were compared to show general trends.

In historic surveys, spawning habitat was generally good in Northern Subbasin streams, but siltation and habitat destruction from past land use practices and flooding was noted following the large flood events in 1955 and 1964. Barriers documented on historical surveys were primarily log jams and landslide debris, with the same large gradient barriers (waterfalls) as those identified in recent habitat typing surveys.

Where habitat data were available from both the late 1990s and early 2000s, average embeddedness and canopy density scores in Northern Subbasin streams increased considerably, and most primary pool length and pool shelter scores increased slightly over time (

*Table* 31). Although some increases in these factor values were seen, average values were below target values for all streams and these habitat factors are likely limiting to salmonid populations.

Canopy density was suitable on most surveyed creeks. However, overall canopy density measurements do not take into account differences between smaller, younger riparian vegetation and the larger microclimate controls that are provided by old-growth forest canopy conditions. CWPAP staff considered the contribution of coniferous and deciduous components in the canopy, and found that the average percent of coniferous vegetation increased and percent open canopy decreased in most Northern Subbasin streams over time.

Pool depth and pool shelter were well below target values, and suitability in most Northern Subbasin streams was in the lowest suitability category for both of these factors. Pool shelter suitability increased slightly in Bull and Salmon creeks, but primary pool habitat was lacking. Both pool depth and pool shelter are likely limiting factors in Northern Subbasin streams.

Cobble embeddedness suitability increased on nearly all Northern Subbasin streams when comparing habitat data collected in the 1990s and early 2000s. Embeddedness scores increased significantly on Ohman and Salmon creeks, where suitability in the 1990s were in the lowest category, and by the early 2000s were in the highest suitability category. Improvements in spawning habitat conditions are due to sediment from large historic flood events moving through the system, and to restoration activities designed to reduce erosion in streams throughout the subbasin.

Summer water temperature measurements showed that water temperatures were good for salmonids in headwaters areas near Branscomb, but were stressful for salmonids at downstream sites near the confluence with the Eel River. Many of the sampling sites in poor habitats were located in the two largest streams in the subbasin, Bull and Salmon creeks, and lethal temperatures were recorded in the mainstem SF Eel River. Mainstem Bull Creek has very little canopy cover and large amounts of sediment entering from upstream sites near Cuneo Creek, resulting in increased stream temperatures from shallow pools filled in with sediment, and increased direct solar radiation from reduced riparian cover and wide channels. Warm water temperatures in mainstem Salmon Creek are due to reduced riparian canopy and increased water diversion for residential use and industrial marijuana cultivation operations. Water temperature is likely a limiting factor for salmonids in surveyed streams in this subbasin, and cold water seeps where springs or tributaries enter the mainstem may provide important patches of cooler water for salmonids during late summer months.

Sediment loading in the Northern Subbasin is extremely high, and primary input sources include natural landslides and earthflows, road erosion and failure, and logging related erosion from skid trails and temporary road construction. Road decommissioning projects have resulted in decreased fine sediment input at most treated sites, however, considerable erosion control measures will be required to meet the established TMDL and loading capacity. Sediment loading and turbidity conditions may be limiting factors for salmonid production.

*Table 31. EMDS-based Anadromous Reach Condition Model suitability results for factors in Northern Subbasin streams (ND = no data available).*

| Stream | Survey Year | Mean Canopy Density (%) | Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|
| Bridge Creek | 1993 | - | -- | -- | - |
| | 2007 | ++ | - | -- | -- |
| Bridge Creek (unnamed tributary) | 2007 | ++ | -- | -- | -- |
| Bull Creek | 1991 | -- | -- | -- | -- |
| | 2007 | - | - | -- | -- |
| Butte Creek | 1993 | + | -- | -- | -- |
| | 2009 | ++ | + | -- | -- |
| Canoe Creek | 1992 | ++ | + | -- | ++ |
| | 2007 | ++ | - | -- | + |
| Coon Creek (SF Eel River) | 1993 | - | + | -- | -- |
| | 2007 | ++ | + | -- | - |
| Cow Creek | 1991 | - | - | -- | - |
| | 2007 | ++ | - | -- | -- |
| Decker Creek | 1992 | ++ | -- | -- | + |
| | 2010 | ++ | + | -- | -- |
| Elk Creek | 1992 | ++ | -- | -- | ++ |
| | 2007 | ++ | + | -- | + |
| Elk Creek (unnamed tributary #7) | 2007 | ++ | ++ | -- | -- |
| Fish Creek | 1999 | ++ | - | -- | -- |
| | 2007 | ++ | - | -- | -- |
| Harper Creek | 1991 | + | - | -- | ND |
| | 2007 | ++ | - | -- | -- |
| Mill Creek (Bull Creek) | 1991 | - | - | -- | -- |
| | 2007 | ++ | + | -- | + |
| Mill Creek (Salmon Creek) | 2009 | ++ | - | -- | -- |
| Ohman Creek | 1992 | -- | -- | -- | -- |
| | 2007 | - | ++ | -- | -- |
| Salmon Creek | 1992 | -- | -- | -- | -- |
| | 2007 | - | ++ | -- | + |
| Squaw Creek | 2010 | ++ | + | -- | -- |
| **Key: ++ = Highest Suitability -- = Lowest Suitability** | | | | | |

## Restoration Projects

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 CDFW's Fisheries Restoration Grants Program (FRGP) projects and other projects with which CDFW has been involved. The CHRP data is available through CalFish (www.calfish.org) and includes some projects from agencies and programs outside of CDFW. 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, but are not comprehensive of all restoration projects completed in the Northern Subbasin.

There have been 68 restoration projects, totaling more than 7 million dollars in funding, completed in the Northern Subbasin from 1982 to the present (*Table 32*). The most common type of project has been upslope watershed restoration, followed by: bank stabilization; watershed evaluation, assessment and planning; and instream habitat improvement. The highest levels of funding have been allocated to upslope watershed restoration (more than half of the overall funding) and bank stabilization projects. Primary historical land uses in this subbasin were commercial timber harvest, residential development, and grazing/non-industrial timber harvest, but much of the land is currently within the boundaries of Humboldt Redwoods State Park, and restoration has been a focus of the CA State Park system.

Upslope watershed restoration projects have been completed in select tributaries of Bull Creek and throughout the Salmon Creek watershed (*Figure 51*). Bank stabilization projects have been done primarily in the Salmon Creek watershed and in some areas of upper Bull Creek. Riparian habitat improvement projects have been completed in middle Bull Creek near Cuneo Creek, Salmon Creek, and in the mainstem SF Eel River. Instream habitat improvement projects have been completed in the mainstem Bull Creek, Tostin Creek, and Elk Creek.

Additional information on specific projects can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/).

*Table 32. Northern Subbasin restoration project type and funding (1982 to 2013).*

| Project Type | # of Projects | Total Project Funding |
|---|---|---|
| Bank Stabilization | 10 | $1,107,529 |
| Cooperative Rearing | 3 | $72,548 |
| Fish Passage Improvements | 1 | $319,848 |
| Instream Habitat Improvement | 8 | $513,810 |
| Land Acquisition | 0 | $0 |
| Monitoring | 3 | $122,412 |
| Other * | 8 | $168,556 |
| Riparian Habitat Improvement | 1 | $35,743 |
| Upslope Watershed Restoration | 24 | $4,389,170 |
| Watershed Evaluation, Assessment & Planning | 10 | $568,939 |
| **Total** | **68** | **$7,298,556** |
| * "Other" includes education/outreach, training, capacity building and public involvement. | | |

While site-specific projects are important at the reach scale, restoration that addresses land use issues, such as timber harvest and illegal marijuana cultivation that result in degradation and reduction of salmonid habitat on a watershed scale is essential for ecosystem recovery. In the northern part of the subbasin, which is nearly entirely owned by the CA State Park system, restoration has been a high priority. Following the 1955 and 1964 floods, the Park purchased the last acreage in the Bull Creek drainage and industrial timber harvest ended in more than half of the subbasin. Current management actions are needed to address diversion, flow, and pollution in residential areas, particularly in the larger watersheds such as Salmon Creek in the southern part of the subbasin.

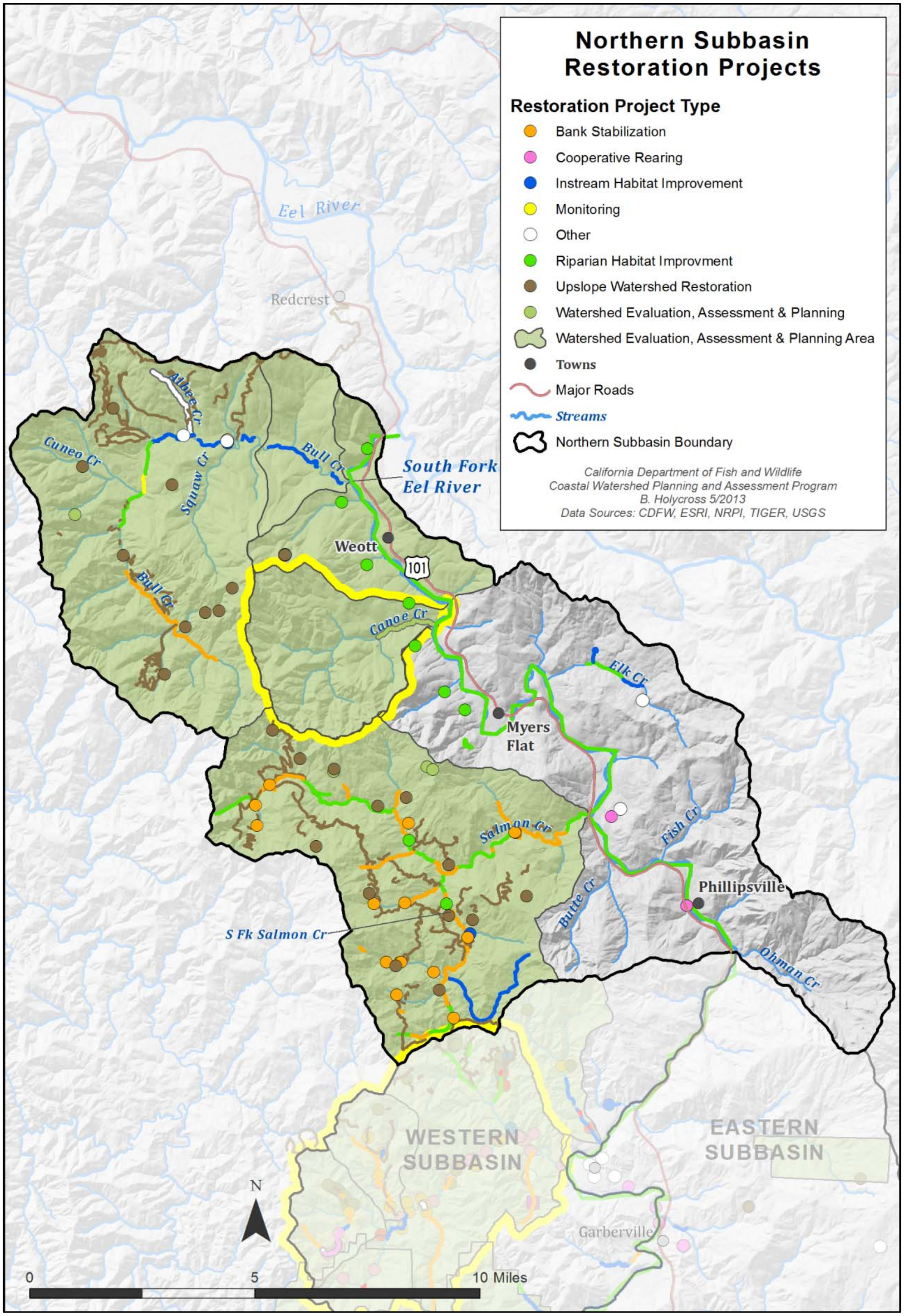



*Figure 51. Restoration projects completed between 1982 and 2013 in the Northern Subbasin.*

# Integrated Analysis

## Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFW stream inventories provide a list of recommendations that address those conditions that did not reach target values (see the Fish Habitat section of this subbasin). In the Northern Subbasin, 34 streams were inventoried (58 surveys; 108 miles total), and recommendations for each were selected and ranked by a CDFW biologist (*Table 33*). The first recommendation in every CDFW stream inventory report is that the stream "should be managed as an anadromous, natural production stream". Because this recommendation is the same for every stream, and because it does not address specific issues, with associated target values, it was not included in the tributary recommendation analysis. The tributary recommendation process is described in more detail in the Synthesis section of the SF Eel River Basin Profile.

In order to compare tributary recommendations within the subbasin, the recommendations of each stream were collapsed into five target issue categories (*Table 34*). 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 occurrence, the most important target issue in the Northern Subbasin is instream habitat: recommendations for pool/cover categories occur more than twice as frequently as both erosion/sediment and riparian/water temperature categories (*Table 34*).

However, comparing recommendation categories in the subbasin by number of tributaries can be confounded by differences in the length surveyed in each tributary. Therefore, the number of stream miles within the subbasin assigned to various recommendation categories was calculated (*Figure 52*). By examining recommendation categories by number of stream miles, the most important target issue remains instream habitat (>150 miles of streams surveyed had this as the primary recommendation). Riparian/water temperature and erosion/sediment recommendations were the second and third most important target issues in Northern Subbasin streams. Because of the high number of recommendations dealing with these target issues, high priority should be given to restoration projects that emphasize riparian improvement or other projects resulting in decreased instream temperatures, and sediment reduction projects addressing input from both natural and anthropogenic sources throughout the subbasin.

*Table 33. Occurrence of stream habitat inventory recommendations for streams of the Northern Subbasin.*

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Albee Creek (1991) | 0.6 | 4 | | | | 1 | 2 | | 3 | | 5 |
| Brian's Creek (1992) | 0.6 | | | | | 1 | 2 | | | | 3 |
| Bridge Creek (1992) | 1 | 3 | 4 | | | 1 | 2 | 5 | | | |
| Bridge Creek (1993) | 1 | 3 | 4 | | | 1 | 2 | | | | |
| Bridge Creek (1999) | 0.9 | 4 | 5 | 6 | A1 | 2 | 3 | | | | |
| Bridge Creek (2007) | 1 | 3 | 4 | | A5 | 1 | 2 | | | | |
| Bull Creek, Lower (1991) | 8.6 | 4 | 5 | 6 | A1 | 2 | 3 | | | | |
| Bull Creek, Middle (1991) | 1.1 | 4 | 5 | | | 1 | 2 | | 3 | | 6 |
| Bull Creek, Upper (1991) | 3.7 | 4 | 5 | 7 | | 1 | 2 | | 3 | | 6 |
| Bull Creek, Lower (1998) | 9 | 4 | 5 | 6 | A1 | 2 | 3 | | | | |
| Bull Creek, Upper (1998) | 3.2 | 1 | 2 | 3 | A8 | 5 | 6 | 4 | 7 | 9 | 10 |
| Bull Creek (2001) | 0.4 | 4 | 5 | 6 | A1 | 2 | 3 | 7 | 8 | 9 | 10 |
| Bull Creek (2007) | 9.7 | 3 | 4 | 5 | A6 | 1 | 2 | | | | |
| Bull Creek Unnamed Trib (1992) | 1.4 | 2 | | 1 | | 3 | | | 4 | | |
| Burns Creek (1991) | 0.6 | 3 | | | | 1 | 2 | | | | 4 |
| Burns Creek (1998) | 0.7 | 2 | | 1 | | | | | | | |
| Butte Creek (1993) | 1.7 | 1 | 2 | 5 | | 3 | 4 | | 6 | | |
| Butte Creek (2009) | 1.4 | 3 | | 4 | A1 | | 2 | | | | |
| Canoe Creek (1992) | 3.4 | 5 | | 3 | A1 | 2 | 4 | | | | |
| Canoe Creek (2007) | 1.9 | | | | A2 | | 1 | | | | |
| Coon Creek (SFE) (1993) | 0.7 | 6 | | 3 | | 4 | 2 | | 5 | | 1 |
| Coon Creek (SFE) (2007) | 0.6 | | | | A2 | | 1 | | | | |
| Coon Creek (Butte) (2007) | 0.5 | 3 | | | A4 | 2 | 1 | | | | |
| Cow Creek (1991) | 0.6 | 3 | | | | 1 | 2 | | | | 4 |

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cow Creek (2007) | 1 | | | | A2 | | 1 | | | | |
| Cuneo Creek (1991) | 1.4 | 2 | 3 | 1 | | 4 | 5 | | | | |
| Cuneo Creek, NF (1991) | 0.8 | 4 | | 1 | | 2 | 3 | | | | |
| Cuneo Creek, SF (1991) | 0.2 | | | | | 1 | 2 | | | | |
| Decker Creek (1992) | 0.8 | | | | | | | | | | 1 |
| Decker Creek (2010) | 0.6 | | | | A1 | | 2 | | | | |
| Elk Creek (1992) | 3.5 | 2 | 4 | | A1 | 3 | 6 | 5 | | | |
| Elk Creek (2007) | 4.1 | 2 | | | A3 | 1 | | | | | |
| Elk Creek, Unnamed Trib #1 (2007) | 0.25 | | | | A1 | | | | | | |
| Elk Creek, Unnamed Trib #7 (2007) | 0.21 | | | | A1 | | | | | | |
| Fish Creek (Miranda) (1993) | 2.5 | 4 | | 5 | A1 | 2 | 3 | | | | |
| Fish Creek (Miranda) (1999) | 2.4 | 5 | | | A1 | 3 | 4 | | | | 2 |
| Fish Creek (Miranda) (2007) | 1 | | | | A4 | 3 | 2 | | | | 1 |
| Harper Creek (1991) | 0.9 | 4 | | | | 1 | 2 | | 3 | | 5 |
| Harper Creek (2007) | 0.9 | | | | A3 | | 2 | | | | 1 |
| Mill Creek (Bull) (1991) | 0.8 | 3 | 4 | | | 1 | 2 | | | | |
| Mill Creek (Bull) (2007) | 1.2 | 4 | | | A1 | 2 | 3 | | | | 5 |
| Mill Creek (Salmon) (2009) | 0.5 | 4 | | | A1 | 2 | 3 | 5 | | | |
| Mowry Creek (1993) | 0.5 | | | | | 1 | 2 | | | | 3 |
| Ohman Creek (1992) | 0.3 | | | 1 | | 3 | 2 | | | | 4 |
| Ohman Creek (2007) | 0.3 | | | 4 | A1 | 2 | 3 | | | | |
| Panther Creek, Main (1991) | 1.5 | 1 | 5 | 6 | A4 | 2 | 3 | | | | 7 |

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Panther Creek, Main (1998) | 0.7 | 3 | | 2 | A1 | 4 | 5 | | | | |
| Panther Creek, SF (1991) | 1.4 | 3 | | | | 1 | 2 | | | | 4 |
| Panther Creek, WF (1991) | 1.4 | 1 | | 2 | | 3 | 4 | | | | 5 |
| Panther Creek, Unnamed Trib (1991) | 1.3 | 1 | | 4 | A5 | 2 | 3 | | | | 6 |
| Panther Creek,Unnamed Trib (1998) | 0.9 | 3 | 4 | 2 | A1 | 5 | 6 | 7 | | | |
| Preacher Gulch (1992) | 0.6 | 1 | | | | 2 | 3 | | | | |
| Salmon Creek (1992) | 5.2 | 3 | 4 | 2 | A1 | | 5 | | | | |
| Salmon Creek (2007) | 7.3 | 2 | | 3 | A4 | | 1 | | | | |
| Salmon Creek, SF (1996) | 3.9 | | | 1 | A2 | 3 | 4 | | | | |
| Slide Creek (1992) | 0.6 | 1 | | | | 2 | | | | | |
| Squaw Creek (1991) | 2.5 | 3 | | | | 1 | 2 | | | | |
| Squaw Creek (2010) | 2.7 | | | | A1 | | 2 | | | | |

**Canopy** = shade canopy is below target values; **Bank** = stream banks are failing and yielding fine sediment into the stream; **Roads** = fine sediment is entering the stream from the road system; **Temp** = summer water temperatures seem to be above optimum for salmon and steelhead; **Pool** = pools are below target values in quantity and/or quality; **Cover** = escape cover is below target values; **Spawning Gravel** = spawning gravel is deficient in quality and/or quantity; **LDA** = large debris accumulations are retaining large amounts of gravel and could need modification; **Livestock** = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; **Fish Passage** = there are barriers to fish migration in the stream.

*Table 34. Top five ranking recommendation categories by number of tributaries in the Northern Subbasin.*

| Northern Subbasin Target Issue | Related Table Categories | Count |
|---|---|---|
| Erosion / Sediment | Bank / Roads | 30 |
| Riparian / Water Temp | Canopy / Temp | 39 |
| Instream Habitat | Pool / Cover | 80 |
| Gravel / Substrate | Spawning Gravel / LDA | 4 |
| Other | Livestock / Fish Passage | 7 |

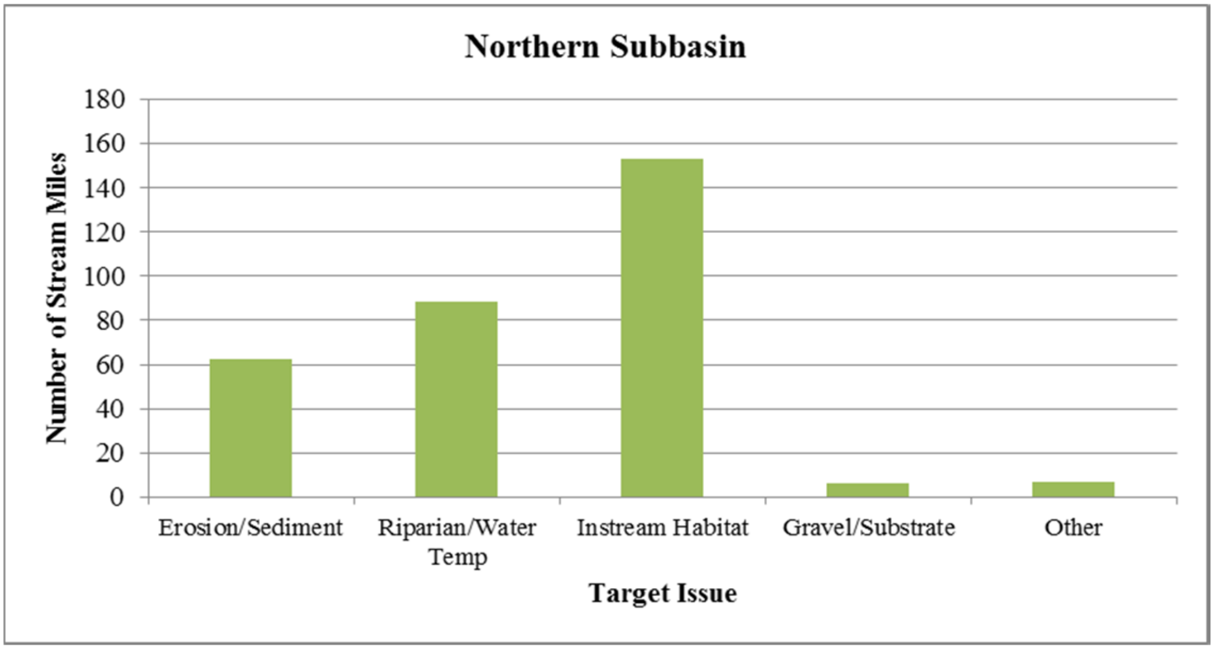



*Figure 52. Recommendation target issues by stream miles for the Northern Subbasin.*

## Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Northern Subbasin using 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 based analysis at the stream reach scale.

Eighteen Northern Subbasin streams were rated as salmonid refugia areas. Refugia categories were defined as:

- **High Quality** – relatively undisturbed habitat, with the range and variability of conditions necessary to support species diversity and natural salmonid production;
- **High Potential** – diminished but good quality habitat with salmonids present, currently managed to protect natural resources with the possibility to become high quality refugia;
- **Medium Potential** – degraded or fragmented instream and riparian habitat, with salmonids present but reduced densities and age class representation. Habitat may improve with modified management practices and restoration efforts;
- **Low Quality** – highly impaired riparian and instream habitat with few salmonids (species, life stages, and year classes). Current management practices and conditions have significantly altered the natural ecosystem and major changes are required to improve habitat.

Salmonid habitat conditions in the Northern Subbasin on streams surveyed by CDFW are generally rated as medium potential refugia, with 11 of 18 streams surveyed in that category (*Figure 53*). Squaw and Bull creeks provide the best salmonid habitat in this subbasin, with Squaw Creek being rated high quality habitat and Bull Creek as high potential habitat.

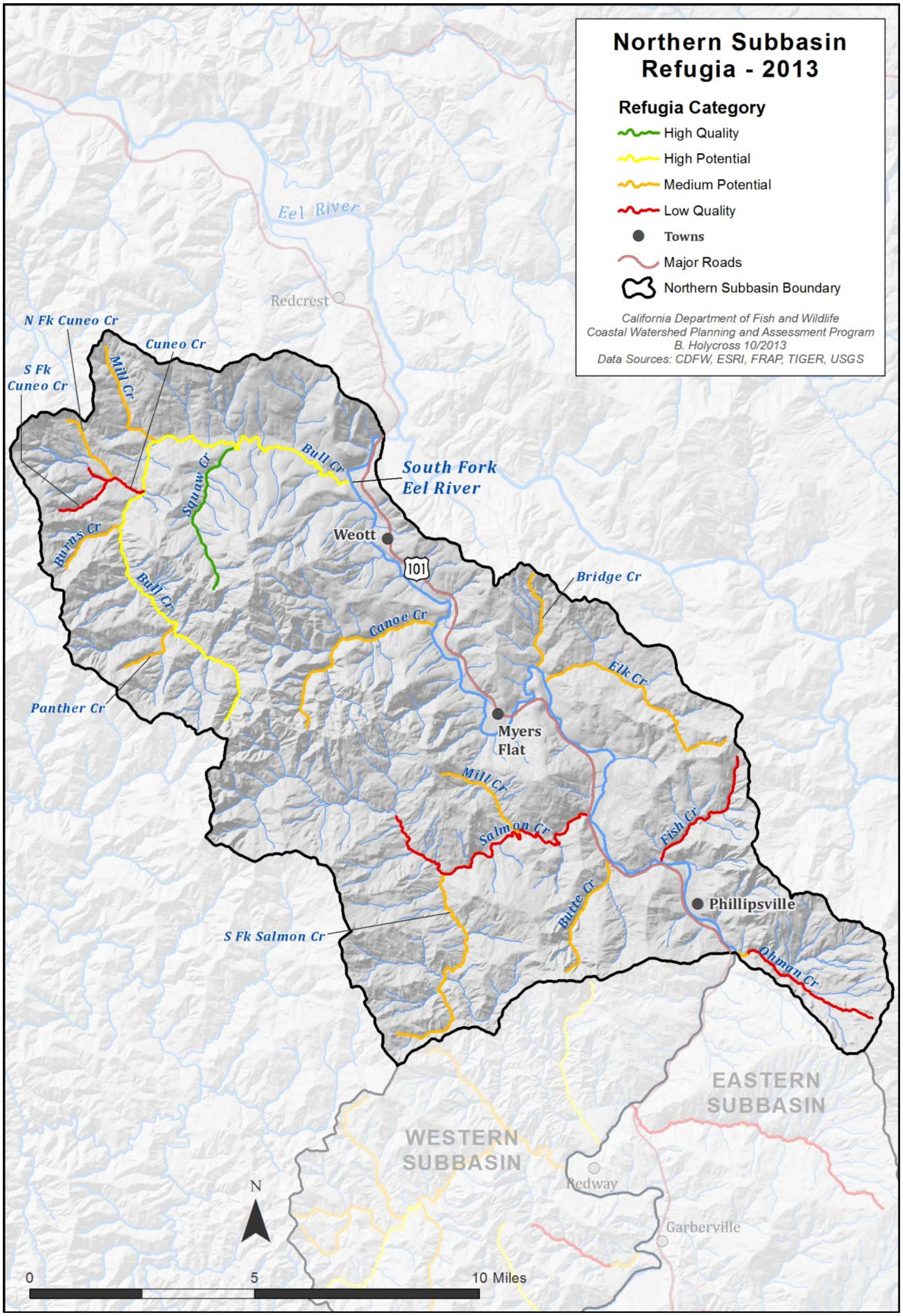



*Figure 53. Refugia categories in SF Eel River Northern Subbasin streams.*

These streams are both within the boundaries of Humboldt Redwoods State Park, and management priorities include tree planting in areas with intensive historic timber harvest, instream restoration projects (installing and improving instream structures), and road decommissioning projects. Squaw Creek is a high quality salmonid stream flowing through areas of old growth coast redwood forest, with excellent riparian condition and low management impacts (disturbed terrain, displaced vegetation, and diversion). Bull Creek was rated as a high potential refugia stream because although the vegetation and riparian conditions in some areas are relatively high quality, overall pool quality and shelter are low due to extensive fine sediment input in upstream areas, unstable geology, and historic practices such as logging and instream wood removal.

Five streams were rated as low quality refugia: Cuneo, South Fork Cuneo, Salmon, Fish, and Ohman creeks for the following reasons:

- Cuneo and South Fork Cuneo Creek receive a great deal of fine sediment input from active landslides and unstable geology on surrounding slopes. Canopy density, pool depth and shelter, and embeddedness values are all low in the upper Bull Creek watershed;
- Salmon Creek is heavily diverted for residential use and marijuana cultivation, and pool quality is low throughout the drainage;
- A culvert on lower Fish Creek has a steep (7.6%) slope and is a partial barrier to adult salmonids and likely a complete barrier to juveniles. This culvert needs to be replaced and modified, and although the project has been proposed in the past, funding has not yet been secured.
- Ohman Creek has a very limited anadromous reach due to a 15’ waterfall approximately 1500’ upstream from the confluence with the SF Eel River. The team split this creek into two sections (at 1800’ upstream from the confluence of the mainstem SF Eel River) because of significant differences in conditions and salmonid use between lower and upper areas. The upper section was rated as low quality refugia habitat and the lower section as medium potential habitat.

## Key Subbasin Issues

- Altered flow regimes from diversion, particularly during low flow periods in late summer;
- Addition of fertilizers, pollutants, and sediment to streams from marijuana cultivation operations;
- Erosion from landslides, roads, construction waste, and ground disturbance;
- Erosion related to timber harvest activities on unstable soils;
- Poor quality pool habitat (depth, shelter, and quality) in most Northern Subbasin streams;
- Low quality refugia in Salmon Creek, which was historically a productive coho and Chinook salmon and steelhead trout stream;
- High instream temperatures in many streams, with above lethal temperatures recorded in the late summer in the mainstem SF Eel River;
- Sacramento pikeminnow documented in mainstem SF Eel River and in some Northern Subbasin tributaries.

## Responses to Assessment Questions

**What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Northern Subbasin?**

*Findings and Conclusions:*

- The Northern Subbasin supports populations of Chinook salmon, coho salmon, and steelhead trout;
- Using data from two long term data sets for salmonid populations in the SF Eel River Basin (Benbow dam counts occurring from 1938-1976, and Van Arsdale counts from 1933 to the present), trend lines for Chinook salmon, coho salmon, and steelhead trout abundance all show significant decreases throughout the sampling duration. These trends are most likely similar for salmonid populations in Northern Subbasin streams;

- Populations of all three salmonids appeared to decline abruptly following the 1955 and 1964 floods;
- Current salmonid populations are not only less abundant, but they are less widely distributed than they were historically:
    - Historical and anecdotal accounts in 33 Northern Subbasin streams dating back to the late 1930s indicate the presence of presence of Chinook salmon in 12 tributaries (36% of streams sampled), coho salmon in 12 tributaries (36% of streams sampled), and steelhead trout in 20 tributaries (61% of streams sampled) in the Northern Subbasin;
    - Current salmonid distribution, based on data collected in 109 streams from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) indicate the presence of Chinook salmon in 14 tributaries (13% of sampled streams), coho salmon in 8 tributaries (7% of sampled streams), and steelhead trout in 23 tributaries (21% of sampled streams) in the Northern Subasin;
- Historically and currently, Steelhead trout have been found in more tributaries and in areas further upstream than both Chinook and coho salmon. This is due to their preference for habitats that are located farther inland, in smaller streams than Chinook and coho salmon (Moyle et al. 2008), and due to their comparatively superior jumping abilities;
- Non-native Sacramento pikeminnow have been documented in most surveys beginning in the late 1990s and are now common in areas of the mainstem SF Eel River and in lower reaches of tributaries. Pikeminnow compete with and prey upon juvenile salmonids, and are adapted to withstand warmer water temperatures than native salmonids.

**What are the current salmonid habitat conditions in the Northern Subbasin? How do these conditions compare to desired conditions?**

*Findings and Conclusions:*

**Flow and Water Quality:**

- Instream flow has been reduced through unpermitted diversion for residential and marijuana cultivation uses. Reduced flow (compared to historical averages) has been documented in Northern Subbasin streams during the late summer and early fall;
- Low summer flows result in dry or intermittent reaches on streams, which may be detrimental or stressful to salmonids;
- Water quality is reduced by marijuana cultivation operations, particularly in areas where land use is primarily residential (e.g. Salmon Creek). Water quality is compromised in these areas by the input of fertilizers, pesticides, rodenticides, diesel fuel from generators, and sediment from improperly constructed roads, and clearing and construction activities at grow sites;
- Water diversion by industrial timber companies for road dust/sediment control has been estimated at 2,000-4,000 gallons/mile/day between May 15th and October 15th. The amount of water used may be substantial at a time when stream flow is already low, particularly in areas with multiple users with high water demand;
- Increased turbidity is stressful to salmonids, especially during the rainy winter months. High levels of turbidity occur during salmon and steelhead spawning season.

**Erosion/Sediment:**

- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing and feeding habitat for salmonids. High sediment input from natural and anthropogenic sources have resulted in low suitability pool habitat and reduced water quality, and are particularly apparent in the Bull Creek drainage, but are thought to occur throughout the subbasin;
- Road density is high (3.3 miles/square mile) in the Northern Subbasin, and is more than twice as high (7 miles/square mile) in the Salmon Creek drainage. Legacy logging roads and new residential road construction are sources of sediment input into streams throughout the subbasin;

- Soils in the Northern Subbasin are prone to erosion, and slides and streambank failures contribute fines to the streams;
- During the historic flood events of 1955 and 1964, very large quantities of sediment entered Northern Subbasin streams, and this sediment is still moving through the system;
- Increased fine-sediment in stream gravel has been linked to decreased fry emergence, decreased juvenile densities, reduced diversity and abundance of invertebrates, loss of winter carrying capacity, and increased predation (Gucinski et al. 2001).

**Riparian Condition/Water Temperature:**

- Canopy density met or exceeded target values in most surveyed streams in the Northern Subbasin, and values increased over time (using habitat typing data collected during two time periods: 1990-1999, and 2000-2010);
- In the 1990s, 55% of the stream length surveyed had canopy densities below 50% and only 19% met target values of 80% or greater. Coniferous canopy cover was relatively low (< 50%) in most streams, especially those creeks that are located outside the boundaries of Humboldt Redwoods State Park. The largest streams in the subbasin, Bull Creek and Salmon Creek, had the lowest coniferous canopy percentages (less than 10%);
- In the early 2000s, there was no stream length with less than 50% canopy density, and 51% of surveyed stream length met target values of 80% or greater;
- Canopy density suitability was in the highest category in most Northern Subbasin streams in the early 2000s. Suitability was in the lowest category on select reaches of Bull and Salmon creeks, and the second lowest suitability category in very limited areas of Butte, Elk, and Canoe creeks;
- The average percent of coniferous vegetation increased and percent open canopy decreased in most streams over time. An exception to this pattern was Elk Creek and its unnamed tributary, which showed significant decreases in coniferous canopy coverage and increases in deciduous cover due to significant timber harvest activity in recent years;
- Water temperature data collected by HCRCD (between 1996-2003), and ERRP (in 2012) indicated poor (≥66ºF) conditions at 16 sites, fair (63-65˚F) conditions at 7 sites, and good conditions (50-62˚F) at 7 locations in Northern Subbasin streams. There was one site where lethal (≥75ºF) conditions were recorded, in the mainstem SF Eel River near Miranda;
- Bouma-Gregson recorded average daily temperatures above lethal levels (≥75˚F) on 27 days between July and August 2013 in the mainstem SF Eel River at Phillipsville.

**Instream Habitat:**

- None of the surveyed streams met target values for pool depth, and the percent of stream length surveyed that was primary pool habitat was less than 10% in all stream order categories during both habitat sampling periods;
- Quality pool structure is lacking in Northern Subbasin streams; the average mean pool shelter rating was 43.0 in the 1990s and 49.4 using habitat data collected between 2000 and 2010. These values are well below the target pool shelter value of 100 for salmonids, although they increased slightly over time;
- Boulders were the dominant shelter type, followed by LWD, in Northern Subbasin streams in all subbasin reaches during both time periods;
- Pool riffle ratios were below optimal ratios (1:1) in any Northern Subbasin streams, but the percentage of pool habitat relative to riffle habitat increased slightly in recent years (2000-2010) compared to percentages recorded on surveys in the 1990s.

**Gravel/Substrate:**

- Cobble embeddedness conditions improved in most Northern Subbasin streams over time, with average embeddedness values of 7.8% for data collected in the 1990s and 33.4% for data collected between 2000 and 2010. Although embeddedness values increased, they were still below target values (>50% category 1) during both time periods;

- The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled between the 1990s and early 2000s. The percent of pool tails in category 2 stayed nearly the same, and the percent of pool tails in embeddedness category 3 was reduced by more than 50% between the two time periods. Only categories 1 and 2 are suitable for salmonid spawning;
- Low substrate embeddedness suitability for salmonids in Northern Subbasin streams is due to extensive sediment input from highly erosive soils, active landslides, roads, and historical flood events.

**Refugia Areas:**

- Salmonid habitat conditions were generally rated as medium potential refugia, meaning that habitat is degraded or fragmented and salmonids are present but reduced in density and age class representation. Habitat may improve with modified management practices and restoration efforts;
- Only Squaw Creek was rated as high quality salmonid habitat in this subbasin. It is the only creek with relatively undisturbed habitat, with conditions necessary to support species diversity and natural production;
- Bull Creek was rated as high potential refugia habitat. This watershed currently has diminished but good quality habitat, and may become high quality refugia habitat with current natural resource management practices;
- Cuneo, South Fork Cuneo, Salmon, Fish, and Ohman Creeks were all rated low quality. These watersheds have few salmonids and highly impaired riparian and instream habitat. Current conditions and management practices have modified the natural environment extensively, and major changes are required to improve habitat conditions.

**Barriers and other concerns:**

- Both natural (landslides, gradient, and LDA) and anthropogenic (partial and total culvert) barriers were mapped using information from stream inventories, field reconnaissance, and the CalFish Passage Assessment Database;
- Most culvert barriers, both total and partial, were located at road crossings along the mainstem SF Eel River, where Highway 101 and smaller roads leading into individual basins cross tributary streams. Two partial culvert barriers were located in the Bull Creek drainage, where the Mattole Road crosses Cow and Harper Creeks;
- Five landslide barriers were identified in upper Bull Creek: one each in Cuneo, NF Cuneo, and SF Cuneo Creeks, and two in the Panther Creek drainage. Habitat restoration and evaluation, assessment, and planning projects have been completed at many of these sites to reduce sediment input and stabilize stream banks;
- Three LDA barriers were identified in the Bull Creek drainage, in Albee, Harper, and Cow Creeks;
- Gradient barriers, mostly waterfalls, were identified in Northern Subbasin streams if they occurred in areas other than natural ends of anadromy in headwater areas. These barriers may be partial (a barrier to certain species or life stages), total, or temporal (only a barrier at certain times of the year), and some form of gradient barrier was identified in most streams in the subbasin.

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

*Findings and Conclusions:*

- Natural erosion rates in the Northern Subbasin are high due to:
  - All rock types in the SF Eel River Basin are considered lithologically soft, prone to erosion, and sensitive to land use. The major rock type underlying the Northern Subbasin is sandstone of the Yager Terrane, which is made up of moderately erodible fine-grained marine sediments;

  - o The relatively unstable geology of the subbasin results in many shallow landslides or debris flows, and streams are affected by sediment deposits from steep slopes in tributaries, mainly in upstream areas such as Cuneo Creek in the Bull Creek drainage;
  - o The Northern Subbasin is located in one of the most seismically active regions in North America, and fault movement can result in uplift or subsidence of the local landscape, increasing the potential for erosion or deposition;
- Floods periodically occur due to high winter precipitation levels and high runoff rates;
- During the rainy season, heavily silted water flows from steep upstream terrain, downstream to lower reaches, increasing turbidity and sediment levels throughout Subbasin streams;
- The predominant vegetation type is mixed conifer and hardwood forest, covering 55% of the Subbasin area. The average percent deciduous canopy was greater than coniferous canopy in surveyed streams, but the percent coniferous canopy increased between the late 1990s (18%) and early 2000s (30%).

**How has land use affected these natural processes?**

*Findings and Conclusions:*

***Changes in basin due to land use:***

- Most (52%) of the land in the Northern Subbasin is owned by the CA State Parks; acquisition occurred between 1920s and 1970s, and the Humboldt Redwoods State Park now includes all of the land in the Bull and Canoe Creek drainages. Historically, timber harvest was the primary land use in these watersheds. Since the Park acquired the property, management actions have prioritized forest habitat preservation and fisheries habitat management;
- In the Salmon Creek drainage, the primary land use is residential, and there has been a substantial increase in the number of marijuana cultivation operations in this watershed. In 2012, there were 567 grows (281 outdoor and 286 indoor) identified in this drainage alone, with an estimated 18 million gallons of water per growing season required to support these operations (Easthouse 2013). Water sources include direct diversion from streams, groundwater wells, and storage tanks, but little is known regarding how much water is supplied by each source;
- Sediment input from land use activities, primarily roads and timber harvest, is particularly problematic in this subbasin due to highly erodible soils and active landslides.

***Possible effects seen in stream conditions:***

<u>Instream habitat conditions for salmonids are thought to be poor:</u>

- Low summer flows are exacerbated by diversions, which result in dry or intermittent reaches on streams, which are stressful to salmonids;
- In addition to low flows, water quality (temperature, pollution, turbidity) decreases in areas with high instream diversion and input of fertilizers, chemicals, sediment, and waste from grow operations, resulting in decreased habitat suitability for salmonids;
- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing, and feeding habitat for salmonids. Sediment input from both natural and anthropogenic sources are high, with correspondingly high turbidity levels which are stressful for salmonids. Substrate embeddedness values were high in most surveyed reaches, but have shown significant improvement over time;
- None of the surveyed streams met target values for pool depth or pool shelter;
- Boulders were the dominant shelter type in pools, followed by LWD. Average percent shelter from LWD was less than 5% for both sampling periods;
- Pool:riffle ratios were well below optimal (1:1) ratios

<u>Erosion related to timber harvest on unstable soils is a concern:</u>

- Industrial timber harvest occurred in most areas in the subbasin prior to the 1960s, when the CA State Park system purchased the last of the land in the northern part of the subbasin (including almost all of the Bull Creek drainage). Landslides are abundant in upper Bull Creek, and large amounts of sediment are constantly entering streams from natural sources. Historically, additional sediment entered the streams from timber harvest and related activities such as road building;
- Timber harvest, while less of an issue than in the past, still occurred in the headwaters of all of the creeks (located outside the State Park boundary) in this subbasin from 1991 to 2013. Erosion related to timber harvest is a concern throughout the subbasin due to highly erosive soils, active tectonics contributing to unstable slopes, and heavy rains received during winter months;
- Timber harvest impacts were magnified by the 1955 and 1964 floods, and sediment pulses from historic land use practices and floods are still moving through Northern Subbasin streams;

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

*Findings and Conclusions:*

Based on available information for this subbasin, it appears that salmonid populations are limited by:

- Low summer flows;
- High summer water temperatures;
- High levels of fine sediments in streams;
- Loss of habitat area and complexity, particularly primary pool habitat and pool shelter;
- Competition with and predation pressure from Sacramento pikeminnow.

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

- Restoration activities that will create additional pool habitat and scour existing shallow pools, while reducing input from surrounding hillsides, are highly recommended throughout this subbasin;
- More than half of all habitat recommendations targeted instream habitat, including pool and cover categories. Most other recommendations targeted riparian habitat/water temperatures (canopy and temperature) and erosion/sediment (related to streambanks and roads);
- Ensure that water diversions used for domestic or irrigation purposes bypass sufficient flows to maintain all needs of fishery resources;
- Identify areas where marijuana cultivation is occurring and quantify environmental effects at sites, including illegal diversions (especially during low flow times), input of pesticides and other pollutants, and sediment loading from these practices. Enforce existing and developing environmental regulations;
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for road dust abatement, and support actions designed to encourage efficient use of water;
- Carefully modify log debris accumulations in tributaries over time, with attention paid to resultant downstream sediment loading;
- Conduct an upslope erosion inventory in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized and improved;
- Stabilize eroding stream banks with appropriately designed structures and vegetation;
- Increase depth, area or shelter complexity in pools, by adding LWD or combinations of boulders and LWD. This must be done where banks are stable, or in conjunction with stream bank armor to prevent erosion;

- Consider replanting of native species, like willow, alder, redwood and Douglas fir in areas with little or no native vegetation, or in areas with non-native vegetation;
- Consider thinning hardwoods to increase growth of conifers where riparian forest is strongly dominated by hardwoods and shade canopy will not be adversely affected;
- Monitor streams near land development activities and existing rural residential areas for turbidity, pollution, and drainage issues;
- Conduct biological sampling to determine salmonid usage and populations, including but not limited to the continuation of current CDFW redd counts and establishment and operation of a life cycle monitoring station within the SF Eel River Basin;
- Consistently collect water quality data, including temperature, dissolved oxygen, and water chemistry throughout the year for several years in order to accurately characterize conditions;
- Regular use of prescribed fire could reduce fuels so that catastrophic fires are less likely to occur. The CA State Parks system already has a prescribed burning program in place in the northern part of the subbasin;
- Support programs and organizations such as SRF and ERRP that develop studies to monitor the flow, temperature, diversion, and water quality of streams throughout the subbasin, particularly in developed areas.

## Subbasin Conclusions

The Northern Subbasin covers an area of 149 square miles, or 22% of the total SF Eel River Basin area. This subbasin includes the drainage area south of the South Fork Eel River from its confluence with the Eel River (RM 0) to the confluence with Ohman Creek (RM 22.9). Streams in this subbasin contain runs of Chinook and coho salmon, and steelhead trout. Current coho salmon populations are considerably smaller and less well distributed compared to their historic range. Maintaining or increasing these remaining populations is critical to the recovery of salmon and steelhead along the entire North Coast.

The fishery resources in the Northern Subbasin have been adversely impacted by land use and resource development. Historically, these streams provided important spawning and juvenile rearing grounds that enabled salmon and steelhead populations to thrive. Currently, 52% of the land is owned by the CA State Parks, and watersheds within the park boundary are relatively undisturbed, with fewer deleterious effects than in areas with other land use practices. Only 24% of the land in this subbasin is used for industrial timber production, which is considerably less than in the Eastern and Western subbasins, and adverse effects to streams and fish that are usually associated with intensive timber harvest are reduced in this subbasin.

Reduced streamflow, particularly during the dry summer months, due to an increase in the number and volume of diversions (for dust abatement on industrial timber company lands, and for residential and agricultural uses), combined with longer dry periods in the winter and early spring, have dramatically affected salmonids in the basin at all life stages. Low flows are particularly apparent in southern areas of the subbasin, especially in Salmon Creek, where most land use is residential and extensive industrial marijuana cultivation operations have been documented. These operations have increased dramatically in both number and magnitude in recent years. In 2012, CDFW biologist Scott Bauer identified 567 grows (281 outdoor and 286 indoor/greenhouse) with a total of 20,000 plants (8,700 in greenhouses and 11,300 outdoors) estimated to be associated with these operations in Salmon Creek alone. These grow operations consumed more than 18 million gallons of water in one growing season, much of which was diverted from nearby tributaries. Many cultivation operations also significantly reduce water quality by discharging pollutants including pesticides, herbicides, rodenticides, and diesel fuel into streams. Fine sediment input has also increased due to illegal or improperly constructed access roads and/or clearing crop locations, and some unpermitted timber harvest has occurred where land has been cleared at grow sites. These impacts have been increasing while enforcement has been challenging due to safety concerns, limited funding, and a lack of laws and regulations related to these activities. Future actions and regulations must address the detrimental environmental impacts of large-scale, illegal marijuana cultivation operations throughout the subbasin.

Sedimentation and in-filling from large historic flood events, natural landsliding and unstable geology, timber harvesting practices, land subdivision activities, and road construction associated with industrial and residential uses have resulted in increased fine sediment and an overall reduction in channel area in Northern Subbasin streams. Large amounts of sediment fills in pool habitat, reduces the depth of existing pools, and increases embeddedness of substrate, resulting in a corresponding decrease in available salmonid spawning and rearing habitat. Natural sediment input from active landslides is especially apparent in the upper Bull Creek drainage, where unstable hillslopes have caused large landslides that are total barriers to salmonid passage. Although streams are designed to move sediment through the system naturally, Northern Subbasin streams often do not have sufficient flow to move the quantities of sediment through, especially with the large volumes of sediment that entered streams during the 1955 and 1964 floods.

CDFW crews collected habitat typing data in 17 Northern Subbasin streams during two time periods (1990-1999 and 2000-2010), and CWPAP staff analyzed data to determine changes in habitat suitability for salmonids over time. Although values for select factors (canopy density, embeddedness, percent primary pool habitat, and pool shelter complexity) appear to be improving with time, overall suitability scores were still low (negative values) during both time periods in most streams. Individual factor scores and corresponding suitability values were low for all variables except canopy density and embeddedness in the early 2000s, when average values for the entire subbasin were positive but still not in the highest suitability category.

Diminishing runs of salmon and to a lesser extent steelhead in SF Eel River Basin streams are susceptible to being reduced to remnant populations. Regulations addressing environmental impacts and their effect on salmonids in the basin have primarily addressed timber harvest practices (and associated impacts from legacy and new roads) and ranching activities, and these rules and guidelines have resulted in decreased riparian impacts, decreased sedimentation from roads, and improved instream conditions in many areas of the basin. However, many regulations that are designed to help protect the basin's salmonid stocks, water resources, and associated stream habitats have not provided sufficient protection since the recent rapid expansion of marijuana cultivation throughout the basin, particularly in areas dominated by residential land use use (e.g. Salmon Creek). While land acquisition by the CA State Parks, and restoration efforts by public and private entities have helped improve certain areas within the subbasin, they have not been on large enough spatial or temporal scales to provide significant improvements to the overall habitat condition and ecosystem function necessary to restore salmonid populations to desirable numbers or ranges. The Northern Subbasin contains critical habitat and runs of salmonids to help in the statewide recovery of salmonids. Concerted efforts are needed to address diversion, stream temperature, and water quality (fine sediment and pollution) issues in order to improve and expand spawning and rearing habitat for salmonids, and to increase overall ecosystem health in streams throughout the Northern Subbasin.

*Cuneo Creek, SF Eel River Northern Subbasin.*

# SF Eel River Western Subbasin

## Table of Contents

## Table of Figures

## List of Tables

# Western Subbasin

## Introduction

The Western Subbasin of the South Fork (SF) Eel River Basin is the second largest of the three subbasins, covering an area of 220 square miles, or 32% of the total basin area (*Table 1*). This subbasin begins at the Northern Subbasin boundary at the confluence of Ohman Creek and the SF Eel River (RM 23) and extends to its headwaters south of Laytonville (RM 105). The subbasin includes 82 miles of the SF Eel River mainstem and 312 miles of tributary streams (172 miles of perennial and 140 miles of intermittent stream habitat) west of the mainstem SF Eel River. The Humboldt/Mendocino County line runs directly across the subbasin at Cooks Valley, just north of Piercy; tributaries to the north are located in Humboldt County, and those to the south are in Mendocino County. Only 13% of the SF Eel River population lives within the boundary of the Western Subbasin; the largest towns are Briceland and Hale's Grove.

The primary land use (75% of total subbasin area) is commercial timber harvest. The rest of the land is mostly private parcels less than 40 acres in size, managed primarily for small-scale timber production, ranching, grazing and small-scale agriculture. The climate is dominated by the coastal marine layer, with mild, foggy summers and wet winters.

This subbasin is characterized by a forested landscape of rugged, steep, sharp-crested ridges and narrow stream valleys. Stream elevations range from approximately 223 feet at the confluence of the SF Eel River with Ohman Creek to approximately 2,560 feet in the headwaters of the tributaries near Elkhorn Ridge (elevation 2975 feet). Streams are generally low gradient in valleys, becoming higher (>10%) in headwaters of tributaries, and are surrounded by predominantly mixed conifer and hardwood forest vegetation with relatively cool summer temperatures (*Figure 1*).

Large tributaries with documented salmonid distribution include Redwood (near Redway), Sproul, Indian, and Hollow Tree Creeks. Chinook and coho salmon, and steelhead trout are more widely distributed in Western Subbasin streams than in Northern or Eastern Subbasin tributaries.

General attributes of the Western Subbasin are listed in *Table 1*. *Figure 2* is a map of the subbasin location in relation to other subbasins within the SF Eel River watershed.

*Table 1. Attributes of the SF Eel River Western Subbasin.*

| | |
|---|---|
| Area (square miles) | 220 |
| Privately Owned (square miles) | 201 |
| Publicly Owned (square miles) | 19 |
| Predominant Land Use | Timber harvest |
| Predominant Vegetation | Mixed conifer and hardwood forest |
| Mainstem Miles | 82 (RM 23-105) |
| Tributary Miles | 312 |
| Total Stream Miles | 394 |
| Low Elevation (feet) | 223 |
| High Elevation (feet) | 2,560 |

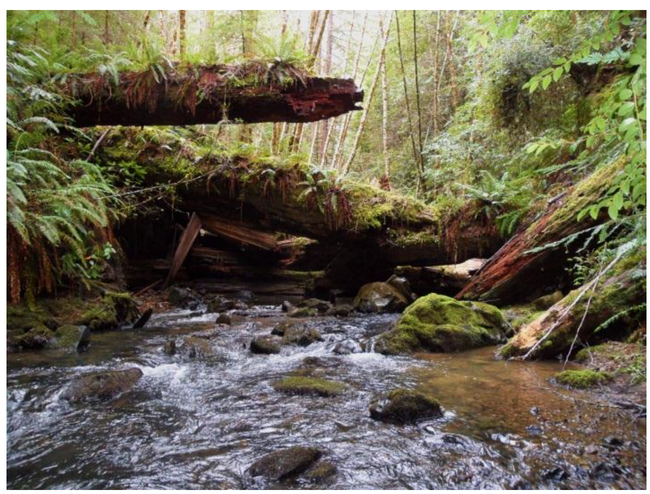


*Figure 1. Anderson Creek in the SF Eel River Western Subbasin.*

*Figure 2. South Fork Eel River Basin and Northern, Eastern, and Western subbasins.*

## Hydrology

The Western Subbasin is made up of 27 CalWater Units (*Figure 4*). There are 73 named and 103 unnamed tributaries with more than 247 perennial and 140 intermittent stream miles in this subbasin (*Figure 5*). The mainstem SF Eel River is a fifth order stream using the Strahler (1964) classification system. The tributaries are first through fourth order streams. Stream drainage areas range from less than one square mile to 42 square miles (*Table 2*). Hollow Tree Creek is the largest tributary to the SF Eel in the Western Subbasin, with a drainage area of approximately 42 square miles and a stream length of 23 miles (*Figure 3*).

Annual precipitation in the Western Subbasin ranges from approximately 60 inches near Hale's Grove in the Hollow Tree Creek drainage to over 80 inches west of Briceland in the Redwood Creek drainage.

During events that cause large amounts of sediment to enter streams, (e.g. 1955, 1964, 1997 floods, seismic activity, sediment accumulation, land use, water diversion, changes in hydrologic connectivity, change in vegetation, climate, drought, changes in land use, etc.) streams that have historically been mapped as perennial may change to intermittent.

There are two USGS stream gauges located in the Western Subbasin; one near Phillipsville (RM 24), and one near Leggett (RM 66) in the mainstem SF Eel River. The Leggett gauge is fed by all streams in the SF Eel River Basin upstream from this point (78% of the total SF Eel River drainage area, or 537.5 square miles). Average annual discharge data were available from 1966-2010, with missing or incomplete data for water years 1995-1999 and 2005-2007 (*Figure 6*). Peak discharge (>1700 cfs) occurred in 1974 and 1983, and minimum discharge (70 cfs) was recorded in 1977. These data were consistent with those recorded at other stations throughout the SF Eel River Basin, including the Phillipsville gauge, which is discussed in the Northern Subbasin section of this report.

*Figure 3. Hollow Tree Creek, tributary to the SF Eel River, located in the Western Subbasin.*


*Figure 4. Calwater planning watersheds in the SF Eel River Western Subbasin.*


*Figure 5. SF Eel Western Subbasin Streams.*

*Table 2. Western Subbasin tributaries and statistics (int. = intermittent stream).*

| Stream | Tributary to: | Length miles | Perennial miles | Intermittent miles | Drainage Area (sq miles) | Stream order |
|---|---|---|---|---|---|---|
| South Fork Eel River | Eel River | 76 | 76 | 0 | 219 | 5 |
| Hooker Creek | S.F. Eel River | 1.9 | 1.3 | 0.6 | 1.8 | 1 |
| Leggett Creek | S.F. Eel River | 4.5 | 3.6 | 0.9 | 5.2 | 2 |
| Redwood Creek (Briceland) | S.F. Eel River | 10.0 | 9.6 | 0.4 | 23.3 | 3 |
| Seeley Creek | Redwood Creek (Briceland) | 3.4 | 2.8 | 0.6 | 5.8 | 2 |
| Frost Creek | Redwood Creek (Briceland) | 1.2 | 0.0 | 1.2 | 0.3 | int. |
| Tank Gulch | Redwood Creek (Briceland) | 0.5 | 0.4 | 0.1 | 0.6 | 1 |
| Somerville Creek | Redwood Creek (Briceland) | 3.0 | 1.9 | 1.1 | 3.1 | 2 |
| Miller Creek | Redwood Creek (Briceland) | 4.3 | 3.3 | 1.0 | 3.7 | 3 |
| Buck Gulch | Miller Creek | 1.1 | 0.7 | 0.4 | 0.9 | 1 |
| China Creek | Redwood Creek (Briceland) | 2.9 | 2.5 | 0.4 | 3.9 | 2 |
| Dinner Creek | China Creek | 2.2 | 1.2 | 1.0 | 1.5 | 1 |
| Connick Creek | S.F. Eel River | 3.3 | 2.3 | 1.0 | 2.7 | 1 |
| Sproul Creek | S.F. Eel River | 8.6 | 8.1 | 0.5 | 24.0 | 3 |
| Little Sproul Creek | Sproul Creek | 3.3 | 2.5 | 0.8 | 1.8 | 1 |
| Warden Creek | Sproul Creek | 2.1 | 1.6 | 0.5 | 1.8 | 1 |
| West Fork Sproul Creek | Sproul Creek | 5.9 | 5.1 | 0.8 | 8.5 | 2 |
| La Doo Creek | West Fork Sproul Creek | 2.5 | 1.9 | 0.6 | 1.5 | 1 |
| Cox Creek | Sproul Creek | 2.1 | 2.1 | 0.0 | 1.5 | 1 |
| Sawmill Creek | S.F. Eel River | 2.5 | 1.0 | 1.5 | 1.9 | 1 |
| Laurel Creek | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| North Creek | S.F. Eel River | 0.7 | 0.0 | 0.7 | 0.2 | int. |
| Durphy Creek | S.F. Eel River | 2.5 | 2.5 | 0.0 | 2.4 | 2 |
| Hartsook Creek | S.F. Eel River | 1.5 | 1.5 | 0.0 | 1.0 | 1 |
| Indian Creek | S.F. Eel River | 14.0 | 13.0 | 1.0 | 27.0 | 2 |
| Jones Creek | Indian Creek | 2.4 | 0.4 | 2.0 | 2.2 | 1 |
| Parker Creek | Indian Creek | 1.7 | 0.0 | 1.7 | 0.9 | int. |
| Moody Creek | Indian Creek | 2.8 | 1.0 | 1.8 | 2.2 | 1 |
| Sebbas Creek | Indian Creek | 3.8 | 3.3 | 0.5 | 2.8 | 1 |
| Coulborn Creek | Indian Creek | 2.6 | 0.7 | 1.9 | 2.5 | 1 |
| Anderson Creek | Indian Creek | 5.5 | 0.0 | 5.5 | 4.3 | int. |
| Piercy Creek | S.F. Eel River | 5.1 | 1.5 | 3.6 | 3.6 | 1 |
| Standley Creek | S.F. Eel River | 5.2 | 4.7 | 0.5 | 7.3 | 1 |
| Bear Pen Creek | S.F. Eel River | 4.0 | 3.4 | 0.6 | 5.0 | 2 |
| Cub Creek | Bear Pen Creek | 0.5 | 0.5 | 0.0 | 0.3 | 1 |
| Wildcat Creek | S.F. Eel River | 4.3 | 1.9 | 2.4 | 6.0 | 1 |
| Mill Creek | S.F. Eel River | 3.0 | 2.1 | 0.9 | 2.4 | 1 |
| Hollow Tree Creek | S.F. Eel River | 23.1 | 22.0 | 1.1 | 42.0 | 4 |
| South Fork Creek | Hollow Tree Creek | 2.5 | 0.9 | 1.6 | 3.3 | 2 |
| Mule Creek | South Fork Creek | 3.4 | 1.9 | 1.5 | 3.3 | 2 |
| Middle Creek | Hollow Tree Creek | 2.4 | 2.0 | 0.4 | 1.7 | 1 |
| Islam John Creek | Hollow Tree Creek | 2.1 | 1.7 | 0.4 | 1.0 | 1 |
| Lost Man Creek | Hollow Tree Creek | 2.0 | 1.3 | 0.7 | 1.1 | 1 |
| Lost Pipe Creek | Hollow Tree Creek | 1.5 | 0.6 | 0.9 | 0.7 | 1 |
| Walter's Creek | Lost Pipe Creek | 1.3 | 1.3 | 0.0 | 1.8 | 1 |
| Bear Creek | Hollow Tree Creek | 1.8 | 1.4 | 0.4 | 1.0 | 1 |
| Redwood Creek | Hollow Tree Creek | 3.1 | 1.1 | 2.0 | 3.4 | 2 |
| S.F. Redwood Creek | Redwood Creek | 1.9 | 1.9 | 0.0 | 1.4 | 2 |
| Bond Creek | Hollow Tree Creek | 4.7 | 3.9 | 0.8 | 6.5 | 2 |
| Michael's Creek | Hollow Tree Creek | 3.3 | 2.8 | 0.5 | 4.7 | 2 |
| Doctor's Creek | Michael's Creek | 1.5 | 1.0 | 0.5 | 1.7 | 2 |
| Lynch Creek | Michael’s Creek | 0.7 | 0.7 | 0.0 | 0.8 | 1 |

| **Stream** | **Tributary to:** | **Length** miles | **Perennial** miles | **Intermittent** miles | **Drainage Area** (sq miles) | **Stream** order |
|---|---|---|---|---|---|---|
| Waldron Creek | Hollow Tree Creek | 2.3 | 0.3 | 2.0 | 3.2 | 1 |
| Bear Pen Creek | Hollow Tree Creek | 0.8 | 0.5 | 0.3 | 1.0 | 1 |
| Huckleberry Creek | Hollow Tree Creek | 1.8 | 1.8 | 0.0 | 2.8 | 1 |
| Bear Wallow | Huckleberry Creek | 2.3 | 1.5 | 0.8 | 1.4 | 1 |
| Little Bear Wallow Creek | Huckleberry Creek | 0.8 | 0.0 | 0.8 | 0.3 | int. |
| Butler Creek | Hollow Tree Creek | 2.8 | 2.8 | 0.0 | 2.6 | 2 |
| Mitchell Creek | Hollow Tree Creek | 0.9 | 0.0 | 0.9 | 0.4 | int. |
| Low Gap Creek (Leggett) | S.F. Eel River | 3.1 | 2.0 | 1.1 | 3.9 | 2 |
| Little Low Gap Creek | Low Gap Creek | 1.0 | 1.0 | 0.0 | 0.6 | 1 |
| Surveyors Canyon | S.F. Eel River | 1.2 | 1.2 | 0.0 | 1.6 | 1 |
| Jack of Hearts Creek | S.F. Eel River | 3.5 | 3.1 | 0.4 | 3.8 | 2 |
| Dark Canyon | Jack of Hearts Creek | 1.1 | 0.8 | 0.3 | 0.7 | 1 |
| Little Charlie Creek | S.F. Eel River | 1.4 | 0.7 | 0.7 | 0.9 | 1 |
| Dutch Charlie Creek | S.F. Eel River | 4.7 | 4.7 | 0.0 | 4.3 | 2 |
| Thompson Creek | Dutch Charlie Creek | 1.1 | 0.5 | 0.6 | 0.6 | 1 |
| Eagle Creek | Dutch Charlie Creek | 1.0 | 0.7 | 0.3 | 0.6 | 1 |
| Redwood Creek (Branscomb) | S.F. Eel River | 3.2 | 0.7 | 2.5 | 4.4 | 2 |
| N.F. Redwood Creek | Redwood Creek (Branscomb) | 1.1 | 1.1 | 0.0 | 0.8 | 1 |
| Haun Creek | S.F. Eel River | 0.9 | 0.0 | 0.9 | 0.7 | int. |
| Section Four Creek | S.F. Eel River | 2.5 | 1.9 | 0.6 | 1.2 | 1 |
| Middleton Creek | S.F. Eel River | 1.1 | 1.1 | 0.0 | 0.8 | 1 |

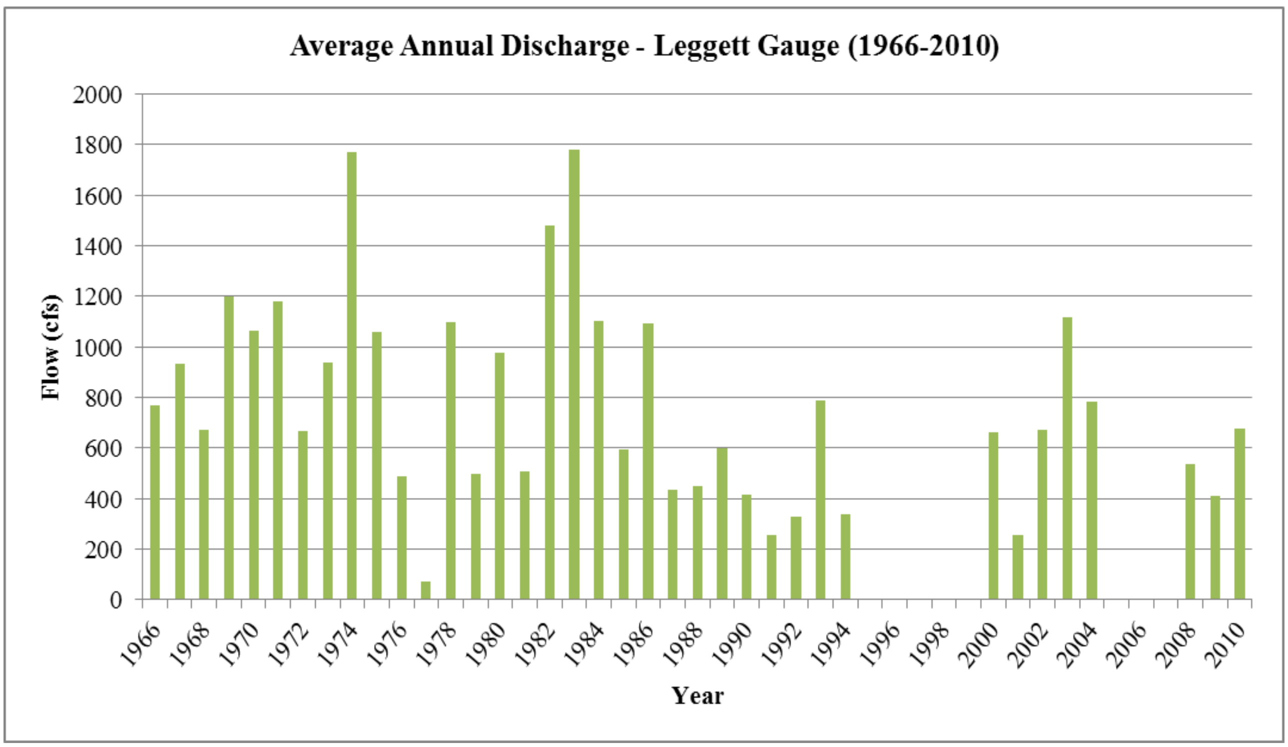



*Figure 6. Average annual discharge at the Leggett gauge, located at RM 66 on the mainstem SF Eel River.*

## Floods

Large floods occur nearly every decade in the SF Eel River drainage. The most devastating floods in recent history occurred in 1955 and 1964. The effects of these floods on the watershed was exacerbated by extensive logging due to the advent of post-WWII tractor technology, changes in local vegetation caused by timber harvest and land use activities, and prior seismic events that further destabilized the hillslopes. The extensive road network also disrupts natural runoff rates and routes. The 1964 flood also involved the melting of a large accumulation of snow in the higher elevations by a warm storm with sustained, heavy rains. Landslides and resulting sedimentation of the streams were unprecedented - these floods washed away entire towns, reset river patterns, and changed stream morphology for decades. In some cases, the lingering effects are still apparent upon the landscape and in streams throughout the basin.

In the SF Eel River Basin the 1955 flood had a peak flow (at Miranda, just north of the subbasin boundary) of 173,000 cubic feet per second (cfs). This flood exceeded 22 million dollars in damages, flooded 43,000 acres, and killed at least one person in the Eel River Basin. The 1964 flood had a peak flow (at Miranda) of 199,000 cfs, exceeded 100 million dollars in damages, and killed at least 19 people in the Mad and Eel River Basins (Dyett and Bhatia 2002).

## Dams, Diversions, and Hydrologic Disturbances

There are presently no functioning, legal, man-made dams on the streams of the Western Subbasin. The Benbow Dam is located on the mainstem of the SF Eel approximately ¼ mile downstream from the confluence with the East Branch SF Eel River (*Figure 7*). This dam has not been in use since 2008 and is presently being considered for removal.

As with most watersheds in Humboldt and Mendocino County, there is a significant number of illegal water diversions associated with covert marijuana cultivation practices that remove water from the streams, especially during the dry times of the year. A number of shallow groundwater wells in this subbasin supply water for rural residential and agricultural uses. The groundwater that these wells draw from is considered "surface water underflow", or water that has permeated through the soil layer into the weathered bedrock layer atop the coherent bedrock. This water is critical to providing dry-season base flow to the streams.

*Figure 7. Aerial view of Benbow Dam in 2012 (Google Earth (8/23/2012) 40˚03'56.98" N 123˚48'03.77" W, elev 366 ft, eye alt 826 ft. Google 2014).*

# Geology

## Bedrock

The Western Subbasin is composed of metamorphic, marine sedimentary, and igneous rock types of the Franciscan Complex and associated overlap assemblage of sediments and sedimentary rock types. The Costal Belt dominates the geology of this subbasin, the majority of which is occupied by the Coastal Terrane, followed by the Yager Terrane. Also present is a minor amount of the Central Belt, juxtaposed along the Coastal Belt Thrust (fault). Descriptions of bedrock composition, depositional history, landscape morphology, strength, and erosional characteristics of each rock type represented on the geology map (*Figure 8*) will be briefly discussed below in order of abundance within the subbasin. *Table 3* contains a brief summary of Western Subbasin geology types and attributes.

### Coastal Terrane

The Coastal Terrane, which occupies approximately 59 percent of this subbasin, is a division of the Coastal Belt of the Franciscan Complex. It consists mainly of slightly metamorphosed, interbedded argillite and sandstone with pebble conglomerate in some places. The Coastal Terrane has been folded, faulted, sheared and shattered in places, sometimes to such an extent that it is considered to be a mélange. Mélange is a highly, penetratively sheared matrix of argillite and sandstone containing blocks of basalt (pillow flows, tuffs, flow breccias, and rare intrusives), limestone (which commonly overlies basalt), and blueschist (McLaughlin et al. 2000).

The sedimentary sequences of sandstone, argillite, and conglomerate are interpreted to be turbidites (sedimentary deposits left from sub-aqueous landslides) and other mass-flow type deposits that punctuated the calm oceanic deposition of mud that accumulated in an east-dipping subduction zone along the western margin of North America between 140 and 28 million years ago. In contrast, the limestone units and exotic blocks are interpreted to be the remnants of rocks and sediment that were carried into the trench and faulted into place within the Coastal Terrane sediments (Aalto 1981).

Sandstone/argillite/conglomerate of the Coastal Terrane tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding especially upon steep stream banks and inner gorge areas.

Mélange of the Coastal Terrane tends to form a rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows as well as secondary debris flows.

### Yager Terrane

The Yager Terrane composes nearly 23 percent of this subbasin. It consists of highly folded and faulted interbedded layers of well consolidated sandstone, argillite, and in some places pebble conglomerate.

This terrane was named by Burdette Ogle in the early 50’s because of its excellent exposure along Yager Creek in the Van Duzen River drainage. It is considered a tectonostratigraphic terrane that has been faulted into its current location by tectonic processes as part of subduction and translation at the margin between the North American and the Farallon plates in the accretionary wedge. This terrane contains a stratigraphic history of deposition, age, and metamorphic grade that sets it apart from neighboring terranes.

Sediments of the Yager Terrane were originally deposited between 65 and 34 million years ago and were transported by ancient river systems from as far away as Idaho (Underwood and Bachman 1986). The sediments accumulated along the continental shelf to the deep ocean floor. The accumulation of sediment composing the Yager Terrane is likely more than 10 thousand feet thick in places (Ogle 1953). The sequence of interbedded argillite and sandstone represents stages of calm, marine deposition of sediments punctuated by large underwater landslide events which deposited sand and gravel, the lithified remnants of which are known as turbidites.

These subaqueous landslides were likely triggered by large seismic events, tsunamis, storm wave loading, and sediment loading (Goldfinger et al. 2003), attesting to the abundance of seismic activity and sediment deposition/erosion in this region.

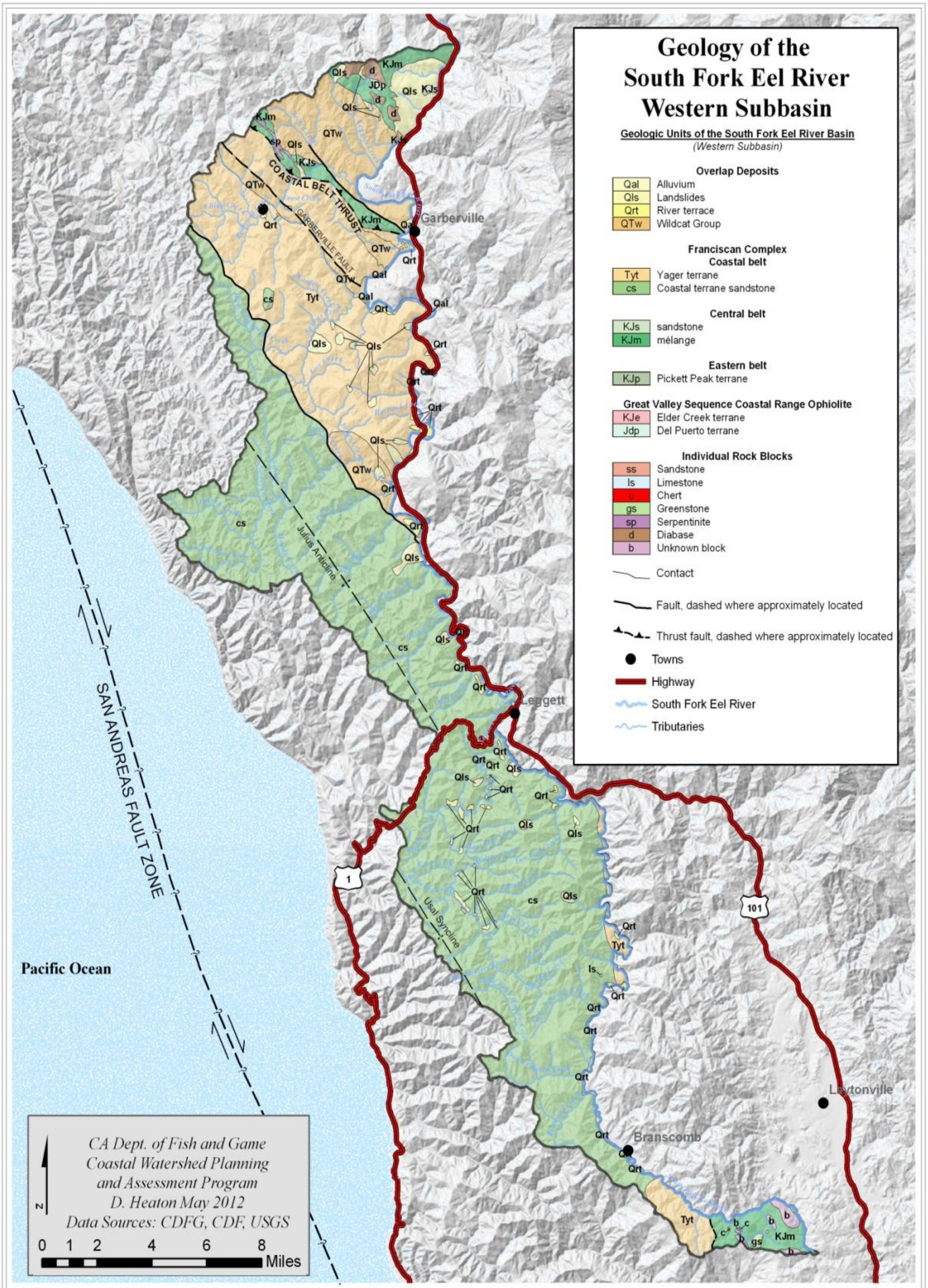



*Figure 8. Geologic Map of the Western Subbasin.*

*Table 3. Western Subbasin bedrock descriptions (ma = millions of years before the present).*

| Unit | Belt/Rock Type | Formation / Terrane | Composition | Morphology/Erosion | Age (ma) | % Sub-basin Area |
|---|---|---|---|---|---|---|
| **Overlap Deposits** | Alluvium | | Unconsolidated river deposits of boulders, gravel, sand, silt, and clay. | Flat to gently sloping, bare river banks, beds, and floodplanes. Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes. | 0-0.01 | 0.3 |
| | Landslide | | Large, disrupted clay to boulder debris and broken rock masses. | Rumpled, disordered hillslopes. Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare. | 0.01-2 | 2.7 |
| | River Terrace | | Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel. | Flat to gently sloping, vegetated, uplifted terrace benches bordering streams. Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes, gullying, debris slides, small earthflows. | 0.01-2 | 1.1 |
| | Wildcat Group | Carlotta Formation | Partially indurated, nonmarine conglomerate, sandstone, and clay. Minor lenses of marine siltstone and clay. | Steep slopes/cliffs and prominent “Flat Irons”. Shallow landslides, debris slides, and block slides along inward dipping bedding planes. Toppling along joints. Some rock-falls and ravel. | 0.78-1.8 | 8.5 |
| | | Scotia Bluffs Sandstone | Shallow marine sandstone and conglomerate. | Steep slopes/cliffs. Friable; typically fails in numerous small debris slides. | 1.8-3.6 | |
| | | Rio Dell Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes/cliffs. The Rio Dell Formation is one of the most susceptible to landsliding. Especially in zones between mudstone and sandstone beds with inward dip during saturation. | 1.8-3.6 | |
| | | Eel River Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes/cliffs. Debris slides/flows, slaking. | 3.6-5.3 | |
| | | Pullen Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes, forested and highly dissected with sharp ridge crests and V-shaped canyons. Debris slides/flows, rotational slides, slumps, slaking. | 5.3-11.6 | |
| **Franciscan Complex** | Coastal Belt | Coastal Terrane | Slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate, limestone lenses, and exotic blocks of rock. | Sandstone/argillite/conglomerate of the Coastal Terrane tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding especially upon steep stream banks. Mélange of the Coastal Terrane tends to form a rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows as well as secondary debris flows. | 1.8-99.6 | 59.3 |
| | | Yager Terrane | Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate. | Steep, straight forested slopes, sharp ridge crests, V-shaped canyons and low drainage density. Prone to debris slides along stream banks. Translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers. | 33.9-65.5 | 23 |
| | Central Belt | Sandstone | Large blocks of metasandstone and metagraywake, interbedded with meta-argillite. | Moderate to steep, straight to convex slopes, sharp ridge crests, V-shaped canyons, and densely forested. Generally stable but prone to debris sliding along steep stream banks and in steep headwater | 65.5-161.2 | 0.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | drainages. | | |
| | | Mélange | Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, and metachert. | Rolling, hummocky terrain. Boulders protrude from surrounding mélange forming knockers. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation. | 1.8-65.5 | 4.0 |
| **Great Valley Sequence** | Coast Range Ophiolite | Del Puerto Terrane | Mudstone, highly sheared locally, containing carbonate concretions and nodules. | Present locally in very limited areas in the northern part of the subbasin. | 161.2 - 145.5 | 0.1 |
| | | | Dismembered Ophiolite: chert, basalt, diabase, serpentinite mélange, and serpentinized peridotite. Diabase intrusions and gabbro below basalt flows. | Correlated with a more extensive ophiolite 300 km to southeast, in the Del Puerto Canyon area near San Jose, California and forms Bear Buttes, approximately 6 miles northwest of Garberville. | 145.5 - 175.6 | |
| Sources: Kilbourne, 1985, Ogle, 1953, McLaughlin, 2000, Kelsey and Allwardt 1975, Kilbourne 1985. | | | | | | |

The Yager Terrane forms steep, sharp-crested ridges and associated valleys that give the landscape a steep and rugged appearance. The relative stability of the Yager Terrane develops soils that typically support lush forest growth.

The Yager Terrane is relatively stable, however, it is faulted and/or sheared in many areas, which typically causes zones of weakness within the bedrock that are prone to large-scale landsliding. Furthermore, the argillaceous interbeds of the Yager Terrane tend to crumble when exposed to repeated cycles of wet and dry (such as in the zone between high water and low water along a stream). This typically leads to undercutting of the stream bank along bedrock reaches, and may cause movement along bedding planes, resulting in translational landslides and rock falls. Excessive crumbling of argillite can also be a source of fine sediments in streams. The beds of the Yager Terrane are tilted by folding and faulting of this region. In areas where the dip of the beds inclines with the hillslope into the stream valley, large translational block landslides are more likely to occur. Yager Terrane is especially prone to debris sliding on steep stream banks (Kelsey and Allwardt 1975).

## Wildcat Group

Overlapping the Franciscan Complex is a relatively soft marine mudstone, siltstone, and sandstone layer grading upwards through the non-marine sandstone and conglomerate. This layer, known as the Wildcat Group, makes up approximately 9 percent of this subbasin.

The sediments of the Wildcat Group were deposited within the last 11 million years in environments ranging from a deep to shallow sea and finally to estuaries and river systems.

The Wildcat Group, located downstream of the confluence of the SF Eel River, was originally divided into the Pullen Formation, Eel River Formation, Rio Dell Formation, Scotia Bluffs Sandstone, and Carlotta Formation by Burdette Ogle in the early 1950s. These divisions of the Wildcat Group did not carry over into the SF Eel River Basin, and are mapped in this basin as either “Wildcat undifferentiated” or “Tertiary marine deposits”.

The bedrock of the Wildcat is loosely cemented and friable, meaning that the sediment crumbles under light pressure. It is highly prone to erosion, especially when disturbed by land use. Erosion of the soft, fine-grained, sedimentary rock types of the Wildcat contribute fine sediments to stream channels. Landsliding is most common in zones between mudstone and sandstone beds with inward dip, especially during episodes of saturation by heavy rain.

Streams within Wildcat bedrock tend to form steep to vertical canyon walls (*Figure 9*), which are prone to undercutting and subsequent rock falls, and translational rock-block sliding.

*Figure 9. Vertical wall in Wildcat Group.*

## Central Belt Mélange

Mélange of the Central Belt is present in four percent of the Western Subbasin. Mélange is a completely sheared matrix of argillite and sandstone containing very small (gravel sized) to very large (city block sized) mappable blocks of sandstone, limestone, blueschist, greenstone, serpentinite, and chert.

The Central Belt mélange formed from 65.5 through 199.6 million years ago within the subduction trench between the Farallon and North American plates, as material from the oceanic crust and its overlying sediments were tectonically mixed with sediments washing off the continent (Aalto 1981). This mixture was then accreted to the western edge of the continent beginning around 88 million years ago (McLaughlin et al. 2000). Mélange has undergone such a degree of internal shearing during its accretionary/tectonic history that is quite weak and tends to behave as an extremely viscous liquid, slowly "flowing" over time and leaving more coherent rock-blocks within its matrix exposed as "Franciscan Knockers".

Central Belt mélange creates a hummocky, rolling landscape with grasslands and prairies existing within the most unstable areas with more resistant exotic rock-block protrusions creating large knobs or buttes.

The Central Belt mélange is considered one of the most unstable rock types in the subbasin and is highly prone to erosion and mass movement, especially when saturated with water and/or disturbed by land use. Mélange is especially prone to earthflows and secondary debris flows.

## Quaternary Landslides

Large landslide features (tens to hundreds of acres) are present in this subbasin, covering roughly three percent of its surface (based on GIS mapping). Landslide deposits are typically a jumble of debris, soil, and underlying bedrock consisting of clay to boulder-size debris and broken rock masses that have moved down slope within the last 2 million years.

Landslide deposits produce rumpled, jumbled hillslopes and may develop debris slides and rotational slumps on steep slopes or eroding toes. Where vegetation has been stripped, surface erosion and gullying typically occur (McLaughlin et al. 2000).

Landslides have the potential for continued sliding and are sensitive to land use because the coherency of the slide material has been disrupted. The toes of these landslides are typically eroded by stream channels causing subsequent, prevalent small-scale sliding and bleeding of fine sediments into the river system. If the toes erode enough, become saturated by heavy seasonal rain, or if there is a large, local seismic event, the landslide may reactivate.

Earthflows usually form in mélange due to its very low shear strength, and they are capable of contributing large amounts of sediment. Large scale GIS mapping shows only a small percent of the probable extent of landslides within this subbasin. It is estimated based upon topographic diversity that much more material has likely moved over time (Ellen et al. 2007).

## River Terrace Deposits

River terrace deposits blanket about one percent of this subbasin. They consist of unconsolidated through poorly consolidated cobbles, gravels and fine sediments.

These terraces were once river-channel and flood-plain deposits, which were subsequently raised during the last 2 million years by regional tectonic uplift above the hundred-year-flood level.

### Alluvium

Alluvium covers less than one percent of this subbasin. Alluvium includes any active stream channel sediments as well as unconsolidated bank deposits and floodplain deposits. Alluvium forms flat to gently sloping river beds, banks, flood-plains, and fan-plains.

## Faults and Shear Zones

The Western Subbasin is located to the east of the north-northwest trending boundary between the Pacific Plate and North American Plate. At present, most movement consists of the plates grinding past one another at a rate of approximately 5 centimeters per year. The plate boundary also has a component of compression that causes uplift, which forms mountain ranges. The plate boundary is not a single or narrow seam but is a region of crustal deformation approximately 65 miles wide. The Western Subbasin lies within this region of deformation and is located between two of the most active fault rupture zones in north coastal California: the San Andreas that lies just off the coast to the west and the Maacama fault zone at the southern end of this subbasin. Both of these faults are right-lateral strike slip faults and are considered active by the State of California (they exhibit evidence of displacement within the past 11,000 years). Estimations of the recurrence interval between large seismic events for the northern segment of the San Andreas fault range from about 250–100 years. The Western Subbasin is underlain by major, mapped, active faults including the Garberville fault and the Briceland fault. Ground displacement is therefore possible within the basin. Strong seismic shaking should be anticipated to occur if these faults rupture.

A brief description of faults within the Western Subbasin follows, with summary information included in *Table 4*.

### San Andreas Fault (Northern Segment)

The San Andreas is an active, right-lateral fault that runs just off shore to the west of this subbasin. It is capable of large (magnitude (M) 7 and greater) earthquakes that can significantly affect the basin with seismic shaking and widespread landsliding. The earthquake of 1906 (the San Francisco earthquake) caused significant damage to the surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments.

### Maacama Fault

The Maacama is an active right-lateral fault zone that runs north by northwest through the southern portion of this subbasin. It is related to translational plate boundary tectonics between the Pacific and North American plates. The Maacama fault is capable of producing earthquakes of up to approximately M 7.1 and has an estimated reoccurrence interval of about 220 years (Hart and Bryant 2001). Over half an inch of right-lateral movement is taken up by the Maacama fault per year on average, more than half of which is accommodated by aseismic creep, meaning that the fault slowly and steadily moves without producing perceptible earthquakes. Approximately 0.26 inches of creep per year were measured in the town of Willits spanning a 10-year period (Galehouse and Lienkaemper 2003).

### Garberville Fault

The Garberville fault zone consists of several widely spaced, steeply dipping reverse faults with components of dextral slip that bound elongated northwest-oriented slivers of marine and nonmarine overlap assemblage strata. Earthquakes along the Garberville fault have deep epicenters (greater than 10-12 km) and may be generated from the underlying Gorda plate (McLaughlin et al. 2000).

### Briceland Fault

The Briceland fault is thought to be an extension of the Garberville fault, and is a series of steeply dipping reverse faults with components of dextral slip that bound elongate northwest-oriented slivers of marine and nonmarine overlap assemblage strata.

### Coastal Belt Thrust

The Coastal Belt Thrust fault cuts through the northern end and the tip of the southern end of this subbasin, juxtaposing the Coastal Belt and the Central belt of the Franciscan Complex.

The Coastal Belt thrust is most likely the zone which accommodated movement between the subducting Farallon plate and the North American plate before accretion of the Coastal Belt when the active subduction moved west to its present location along the Cascadia Megathrust.

*Table 4. Western Subbasin fault descriptions. M = magnitude; R. Int. = recurrence interval.*

| FAULTS WITHIN AND WITH INFLUENCE TO THE SOUTH FORK EEL RIVER BASIN | | | | | |
|---|---|---|---|---|---|
| | **Active Faults:** | **Fault Type** | **M** | **R. Int.** | **Description** |
| **SAN ANDREAS FAULT ZONE** | San Andreas Fault (Northern Segment) | Dextral | 7.3-8.3 | 200-300 | The San Andreas Fault (Northern Segment) is and active dextral fault that runs just off shore, southwest of the Van Duzen River Basin. It is capable of large earthquakes (~M 7) that can significantly affect the basin by seismic shaking, deformation, and associated mass wasting/erosion effects. Although not well documented within the Van Duzen River Basin, the 1906 northern San Andreas Fault seismic event (the San Francisco earthquake) caused significant damage to the surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments. |
| **SAN ANDREAS FAULT ZONE** | Maacama Fault (Northern Segment) | Dextral | 7.1 | 370-500 | Creep rate 7.3mm/year (Galehouse 1995). Slip rate 9mm/year (WGNCEP 1996). Mapped from Laytonville southward into Sonoma County. Interpreted as a right-stepping, northern extension of the Roger's Creek Fault. Most recent event is estimated to have occurred between 1520 and 1650 A.D. |
| **SAN ANDREAS FAULT ZONE** | Brush Mountain Shear Zone | Dextral | | | Inferred extension of the Maacama Fault. |
| **SAN ANDREAS FAULT ZONE** | Garberville Fault | Dextral | 6.9 | 220 | Inferred extension of the Maacama Fault. |
| **SAN ANDREAS FAULT ZONE** | Briceland Fault | Dextral | 6.9 | 220 | Inferred extension of the Maacama Fault. |
| **Faults:** | | | | | |
| | Coastal Belt Thrust (Freshwater Fault) | Thrust | | | The Coastal Belt Thrust fault is the major fault that juxtaposes the Coastal Belt and the Central Belt. It trends north by northwest through the Van Duzen River Basin. It is most likely the zone which accommodated movement between the subducting Farallon Plate and the North American Plate before accretion of the Coastal Belt when the active subduction moved west to its present location along the Cascadia Megathrust. |
| | Piercy Fault | | | | |
| Sources: USGS website – Quaternary fault and fold database of the US, accessed 2011; McLauglin et al. 2000 | | | | | |

### Julius Anticline

The Julius Anticline is a major structure where the bedrock bows upward. This upward fold runs through the Western Subbasin and is caused by localized compression throughout the region (*Figure 10*).

### Usal Syncline

The Usal Syncline is a major structure where the bedrock is bowed downward. This downward fold runs through the Western Subbasin and is caused by compression (*Figure 10*). Rock layers that have become tilted towards stream channels or road cuts by syncline or anticline features may increase the likelihood of landsliding.

Ground shaking generated by earthquakes can trigger rock falls and landslides that deliver large amounts of sediment to the streams. Where fault rupture reaches the ground surface it can weaken bedrock, offset streams, and truncate and over-steepen certain topographic landforms, enhancing the erosion and transport of sediment to the streams.

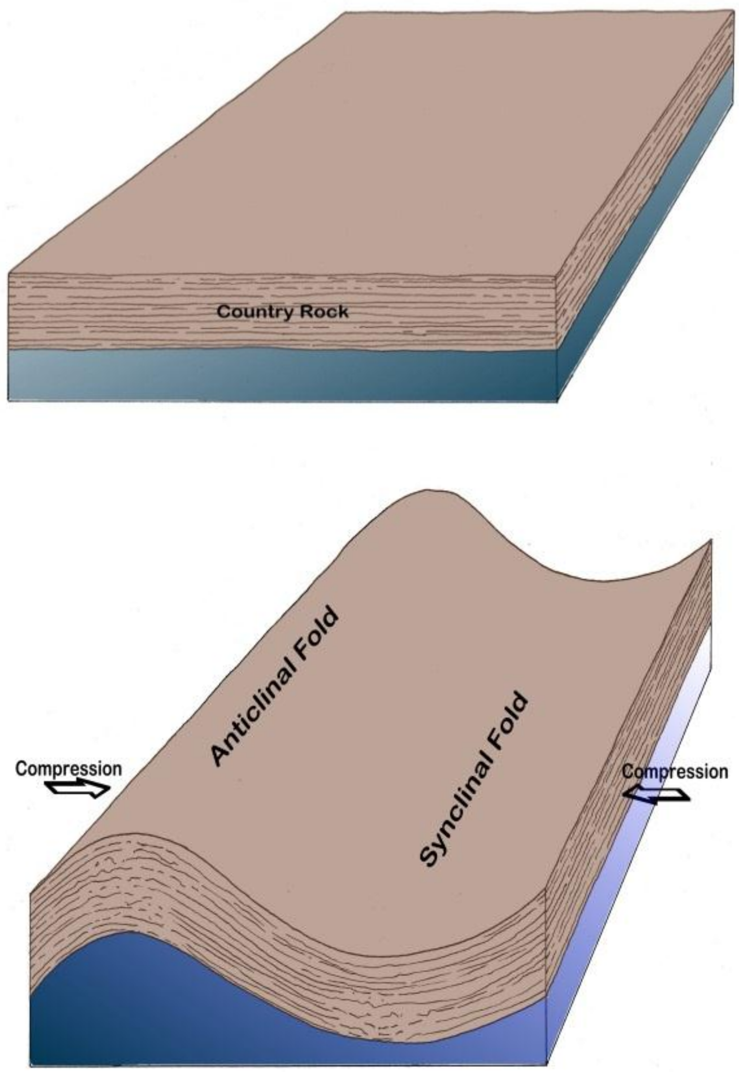



*Figure 10. Typical anticline/syncline formation caused by compression.*

## Landslides and Erosion

The Western Subbasin is predominantly underlain by soft, weak and erodible rock types of the Coastal Belt of the Franciscan Complex, with some areas of Central Belt rock types.

Most of the subbasin is Coastal Terrane. Although the sandstone, argillite, and conglomerate of the Coastal Terrane is relatively more competent than other rock types in the subbasin, it is susceptible to debris sliding, especially on steep stream banks. Mélange of the Coastal Terrane is prone to earthflows as well as secondary debris flows, and contributes sediment at high rates.

The Yager Terrane is prone to debris slides and translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers. Argillite within the Yager Terrane becomes very friable when repeatedly exposed to cycles of wetting and drying and can perpetuate these rock slides as well as contribute fine sediments to the streams. Areas where faults have disrupted the coherency of the bedrock are prone to rockslides, debris flows, and enhanced surface erosion.

The majority of natural sediment entering the streams is produced by landslides. The term “landslide” is used in this report to refer to the various processes of mass wasting of soil, unconsolidated sediment, or bedrock.

There are both positive and negative effects of natural landsliding on fish. On the positive side, landslides typically contribute large woody debris, large boulders, and spawning gravels from the hillsides that increase stream channel diversity by forming plunge-pools, riffles, meanders, and side channels. On the negative side, landslides can contribute an abundance of fine sediments, clear riparian vegetation, decrease channel depth, and fill in pools. Salmonids have evolved over time to thrive in the delicately balanced, highly unstable, natural landscape of this area, but anthropogenic activities may exacerbate the negative effects of natural landsliding throughout the subbasin.

The major factors that tend to increase the likelihood of landsliding include: steep hillslopes, high pore pressure between grains (water saturated ground), bedding planes and/or planes of weakness within the soil or bedrock, undercutting of slopes, poor vegetation cover, seismic shaking, and weak hillslope material. Weak rocks in conjunction with high amounts of rainfall and the dynamic tectonics of Northwestern California create a landscape naturally prone to landsliding. In the past, anthropogenic processes have enhanced the susceptibility of the landscape to landsliding.

Central Belt mélange occurs in the northern most portion of the subbasin. While not widespread, mélange is more susceptible to erosion than other terranes. The amount of internal shearing within mélange has weakened the rock-strength to such an extent that it has become an incoherent matrix of its parent rock types, in this case completely sheared argillite, sandstone, and conglomerate. This sheared matrix, which comprises most of the volume of mélange, has very little internal strength and flows downhill over time via small through very large, deep-seated earthflows. Studies have estimated that while only about 7 to 8 percent of mélange terrain might be active at a given time, approximately 70 to 80 percent of the landscape moves over geologic time (Mackey and Roering 2011). Large, active, deep-seated earthflows are capable of delivering tens of thousands of tons of sediment per square mile of surface area each year (Kelsey 1977). Even when dormant, the toes of these earthflows typically erode, providing a constant source of fine sediments into the streams. If erosion of the toe progrades far enough, if heavy rainfall saturates the earthflow, or if there is local seismic shaking, dormant earthflows may reactivate.

Surface erosion affects recent earthflows by developing rills and gullies, as well as secondary slumps and small debris flows on top of them, which wash additional sediments into the streams.

Three percent of this subbasin has been mapped with large Quaternary landslide features. These landslides reflect only what has been mapped on a large scale without detailed field investigation. Many smaller and/or less obvious landslides most likely exist that have not been mapped or have been mapped as part of landslide inventories at a much more detailed scale.

The largest mapped Quaternary landslide in the Western Subbasin occurs on the flank of Bear Buttes, located north of Redway on the bank of the SF Eel River (*Figure 11*). This landslide occurs in the Central Belt mélange and is drained by Hooker Creek and a few smaller, unnamed tributaries.


*Figure 11. Pseudo-aerial-oblique of Bear Buttes earthflow.*

## Fluvial Geomorphology

The overall fluvial geomorphology of the Western Subbasin may be described by moderately steep tributaries with steeply incised valleys draining into a low gradient mainstem. The relatively resistant geology of this landscape is subject to high rates of tectonic uplift, and the streams incise at similar rates, creating geologically young ridge/valley morphology.

Coastal Belt geology of the Coastal Terrane and Yager Terrane (sandstone, argillite, and conglomerate) dominate this subbasin and typically produce a rugged landscape with steep, sharp ridges and valleys. The trend of these features (~N25°W) is mainly controlled by regional folding and faulting induced by Mendocino triple Junction and San Andreas tectonics.

Mélange geology in the northernmost and southernmost portions of this subbasin typically produces a hummocky topography with rolling hills of oak woodlands and grasslands. Ridge-valley sets of mélange units are more rounded and have lower relief than sandstone units. Exotic rock blocks within mélange protrude from the landscape, forming knockers jutting out from the terrain.

Mélange typically moves via large earthflows. Where active earthflows terminate at a stream, toe erosion delivers large amounts of fine sediment and large boulders of exotic rock types into streams. This creates chronic turbidity as well as boulder-runs and cascade reaches, both of which may become possible barriers to fish passage.

## Sediment Transport

Processes of stream sedimentation are controlled by sediment supply and stream power, which is a combination of the stream's discharge and the slope over which it runs (velocity). Streams are typically divided into a source reach (channel gradient of >20%), a transport reach (channel gradient 4-20%), and a depositional reach (channel gradient <4%) in terms of sedimentation based on channel steepness. Sediment is eroded from steep headwater reaches and steepened knick-zones, transported along moderately steep reaches, and deposited within gentle gradient reaches. Although streams are broadly divided into three regions, forms of erosion, transport, and deposition occur on all reaches of a given stream at any given time. Seasonal variations in stream flow and local bedrock morphology alter where and when such processes occur.

The recruitment and transport of most sediment through the system occurs during large storm events. Heavy, long duration rainstorms may completely saturate hillslope soil and trigger landslides and surface erosion. Sediment pulses from large storms migrate slowly downstream and tend to affect the stream for tens of years. Land use can greatly increase the natural rate of erosion and sediment input to streams. Very large storm/flood events mobilize so much sediment that it may take up to a century for the stream to flush out the sediment pulse naturally.

Large flood events can trigger widespread bank erosion and landsliding, recruiting excess sediment into the stream and redepositing it. This can cause aggradation of the stream valleys in decades following the flood event. In time, the channel typically incises through these sedimentary deposits back to its former level, leaving terrace deposits along its banks. Large landslides may block the stream from time to time causing a landslide dam. Water backing up behind the dam typically triggers many smaller streamside landslides, contributing large amounts of sediment which is impounded behind the dam. Eventually the dam is breached and worn away and the stream responds by incising into the impounded deposit, leaving behind terraces along the stream banks.

During high stands of sea-level, base-levels of streams also become raised. Streams usually respond to a raised base-level by depositing sediment and decreasing their slope. Eventually as the seas recede, streams will readjust and incise, leaving behind extensive terrace deposits.

Stream terrace deposits are present at several places along the mainstem of the SF Eel River and some of its tributaries. These deposits have been developed due to their flat morphology, which is easy to build on, as well as the sediment itself, which usually supports good crop growth and forest cover. Portions of the towns of Redway, Garberville, Benbow, Leggett, and Branscomb in the Western Subbasin are built on these terrace deposits.

The tributaries of the Western Subbasin are predominantly bedrock controlled. Bedrock controlled streams create their fluvial-geomorphology from the gradual wearing away of the containing bedrock. As opposed to creating channel morphology from a strict interaction of sediment supply and the transport power of stream-flow, local geology will dictate the creation of these forms. Regional uplift, folding and faulting, and the mechanical strength and behavior of bedrock control the overall morphology of the streams in the Western Subbasin.

Although controlled by bedrock, Western Subbasin streams are also influenced by localized sediment input, typically from landsliding and surface erosion. These processes are often intensified by land use and management activities.

The 1955 and 1964 floods recruited massive amounts of sediment into the streams, aggrading the channels and completely burying bedrock within them. Filling channels with sediment effectively forces the water up and out of the channel, causing extensive bank erosion and channel widening to accommodate increased flow volumes.

### Spawning Gravel

Cobble and gravel sized sediment required by salmonids for redd construction, egg emplacement, and rearing, is typically introduced into the stream through landslides, rock-falls, and bank erosion.

In Western Subbasin streams, dominant spawining gravel substrate types are sandstone of the Coastal Belt Coastal and Yager terranes, sandstone of the Central Belt, and resistant rock types found within mélange matrix.

## Knickzones

Knickzones are areas of locally steepened stream channel. Major knickzones in the Western Subbasin are formed by regional uplift causing stream incision.

Knickpoints form in series throughout the knickzone and tend to congregate or "bunch up" in areas with limited stream power (Foster 2010). Knickzones provide a record of regional uplift or base-level lowering within the subbasin, and may create gradients steep enough to become obstacles or barriers to fish passage.

The major knickzone in the Western Subbasin is located on the mainstem SF Eel River just upstream from Low Gap Creek and extends upstream approximately eight miles. This knickzone may be the result of cumulative past base-level lowering events stalling near Rattlesnake Creek, which includes about 22% of the upstream drainage area. Studies of stream channel steepness in this area also indicate local uplift (Foster 2010).

CDFW field crews identified the probable end of anadromy on habitat surveys. In 12 Western Subbasin streams, the end of anadromy was associated with a knickzone, usually located near its downstream end.

Bedrock waterfalls marked the end of anadromy for seven mainstem tributaries. All of the waterfall-bearing tributaries were grouped between RM 55 – 65, just downstream of the major knickzone on the mainstem. Five of these waterfalls were easily associated with local stream knickzones and all of them correlate with the major knickzone on the mainstem.

## Channel Type

The fluvial geomorphology of individual streams within a system can be used to understand current as well as past fluvial regime changes. Rosgen (1996) defined basic morphologic stream patterns based on entrenchment, sinuosity, and slope of streams (*Figure 12*). The most recent (1983 to 2010) stream surveys of 51 tributaries of the SF Eel River within the Western Subbasin documented A, B, C, E, F, and G Rosgen channel types (*Table 5*).

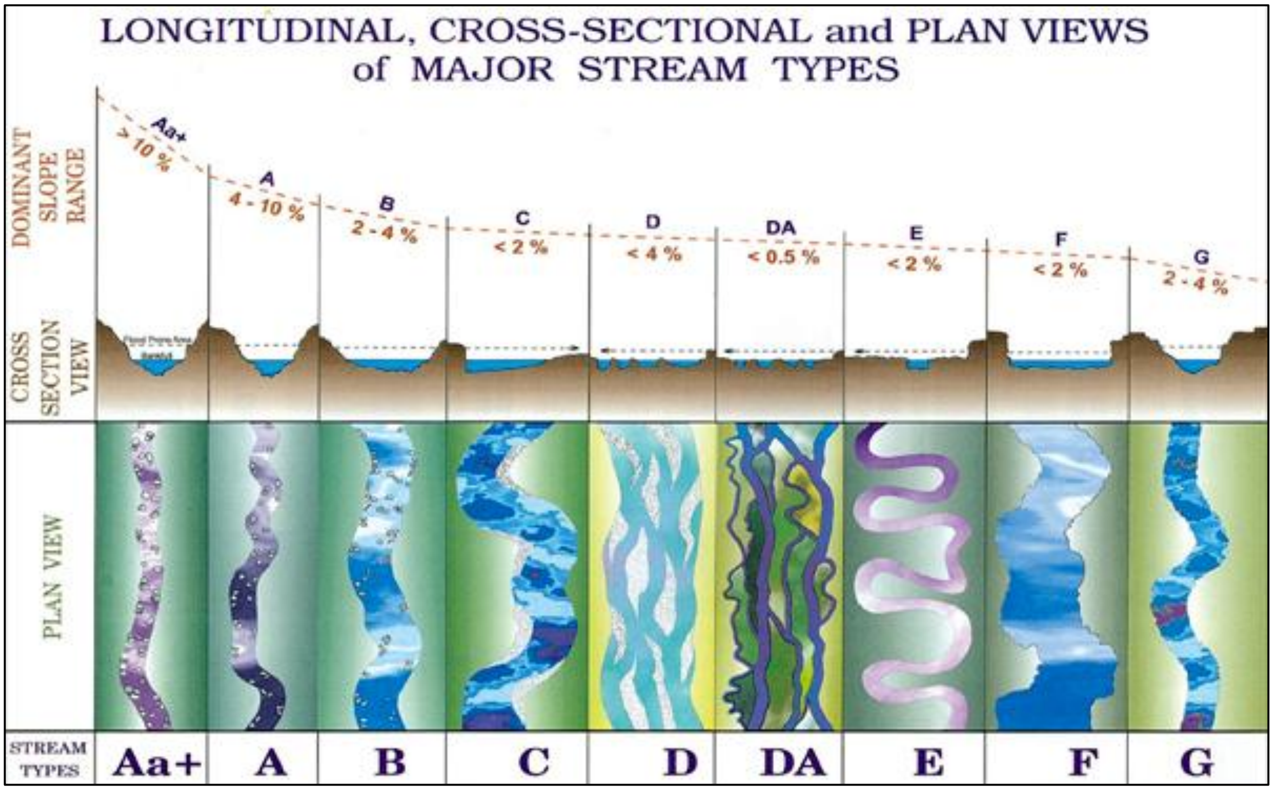



*Figure 12. Illustration of channel types A-G (Rosgen 1996, courtesy of Wildland Hydrology).*

*Table 5. Surveyed channel types by percent of subbasin.*

| Western Subbasin General Channel Types | | |
|---|---|---|
| **Type** | **%** | **Description** |
| **A** | 2.4% | Type A reaches have a moderate to steep slope (4-10%), flow through steep V- shaped valleys, do not have well-developed floodplains, and have few meanders. |
| **B** | 22% | Type B stream reaches are wide, shallow, single thread channels. They are moderately entrenched, moderate gradient (2-4%) reaches, which are riffle-dominated with step/pool sequences. Type B reaches flow through broader valleys than type A reaches, do not have well-developed floodplains, and have few meanders. |
| **C** | 4.3% | Type C stream reaches are wide, shallow, single thread channels. They are moderately entrenched, low gradient (<2%) reaches with riffle/pool sequences. Type C reaches have well-developed floodplains, meanders, and point bars. |
| **E** | 0.2% | Type E channels are low gradient (<2%), meandering, riffle/pool streams with a gravel, sand, or silt substrate. |
| **F** | 59% | Type F stream reaches are wide, shallow, single thread channels. They are deeply entrenched, low gradient (<2%) reaches and often have high rates of bank erosion. Type F reaches flow through low-relief valleys and gorges, are typically working to create new floodplains, and have frequent meanders. |
| **G** | 5.5% | Type G, or gully stream reaches, are similar to F types but are narrow and deep and have a steeper gradient (2-4%). With few exceptions, type G reach types possess high rates of bank erosion as they try to widen into a type F channel. They can be found in a variety of landforms, including meadows, developed areas, and newly established channels within relic channels (Flosi, et al. 1998). |

Type F stream reaches (*Figure 13*) were the most common type of channel in surveyed Western Subbasin tributaries, accounting for 59% of the total stream length surveyed.

Type B streams were the second most common channel type in Western Subbasin tributaries (22% of the total surveyed habitat length), followd by G (5.5%), C (4.3%), A (2.4%), and E (0.2%) channel types.In addition to channel type, Rosgen's system includes a "level II" classification, which describes the size of channel material or D50 (median particle size).

Material size classes include:

- 1 - Bedrock (>2048 mm);
- 2 - Boulder (256-2048 mm);
- 3 - Cobble (64-256 mm);
- 4 - Gravel (2-64 mm);
- 5 - Sand (0.062-2 mm); and
- 6 - Silt/clay (<0.062 mm).

The total distance surveyed by CDFW habitat typing crews in Western Subbasin streams was 565,400 feet. The most common channel types using the level II classification system were F4 (216.519 ft., or 38% of all surveyed habitat) and F3 (96,498 ft., or 17% of surveyed habitat) (*Table 6*).

*Figure 13. Type F stream reach in Hollow Tree Creek, in the Western Subbasin.*

*Table 6. Surveyed channel types of the Western Subbasin by stream reach.*

| Creek | Length (ft) | Channel Type |
|---|---|---|
| Leggett Creek | 17,137 | F4 |
| Redwood Creek (N) | 39,901 | F4 |
| Miller Creek | 22,411 | F3 |
| China Creek | 11,635 | F4 |
| Twin Creek | 2,846 | F4 |
| Dinner Creek | 751 | B1 |
| | 693 | B3 |
| | 8,504 | C3 |
| Connick Creek | 11,866 | C1 |
| Sproul creek | 2,887 | B2 |
| | 31,231 | F3 |
| Little Sproul Creek | 3,055 | A2 |
| | 10,018 | B3 |
| Warden Creek | 609 | B2 |
| | 1,382 | B3 |
| West fork Sproul Creek | 4,335 | B1 |
| | 5,919 | B4 |
| | 16,350 | F4 |
| La Doo Creek | 963 | B4 |
| Cox Creek | 6,799 | F3 |
| Durphy Creek | 2,065 | A2 |
| | 7,229 | B3 |
| Hartsook Creek | 3,316 | A2 |
| | 3,739 | B4 |
| Indian Creek | 2,553 | F1 |
| | 5,616 | F2 |
| | 43,307 | F4 |
| Jones Creek | 3,930 | B1 |
| Moody Creek | 8,707 | B1 |
| Sebbas Creek | 4,384 | B1 |
| | 15,899 | F3 |
| Coulborn Creek | 5,892 | B1 |
| | 1,638 | C3 |
| Anderson Creek | 978 | E4 |
| | 11,191 | F3 |
| Piercy Creek | 6,479 | B3 |
| | 5,166 | F2 |
| Standley Creek | 10,090 | G4 |
| Bear Pen Creek | 12,631 | B4 |
| | 2,233 | F2 |
| Wildcat Creek | 12,207 | B3 |
| Mill Creek | 1,765 | A3 |
| Hollow Tree Creek | 18,849 | F4 |
| SF Hollow Tree Creek. | 1,317 | B1 |
| Mule Creek | 1,317 | B1 |

| Creek | Length (ft) | Channel Type |
|---|---|---|
| Middle Creek | 715 | B1 |
| Islam John Creek | 2,428 | B1 |
| Lost Man Creek | 99 | B1 |
| Walter's Creek | 4,333 | B1 |
| Bear Creek | 2,042 | C2 |
| Redwood Creek | 1,654 | B4 |
| | 4,700 | F3 |
| | 909 | G4 |
| | 3,263 | G5 |
| SF Redwood Creek | 1,316 | B4 |
| | 8,528 | G5 |
| Bond Creek | 811 | A2 |
| | 1,181 | A3 |
| | 2,347 | B4 |
| | 9,558 | F4 |
| Michael's Creek | 5,890 | B4 |
| | 7,859 | F4 |
| Doctor's Creek | 1,603 | F3 |
| Lynch Creek | 996 | F4 |
| Waldron Creek | 550 | F3 |
| | 6,399 | F4 |
| | 672 | G1 |
| Bear Pen Creek | 12,631 | B4 |
| | 2,233 | F2 |
| Huckleberry Creek | 1,042 | F1 |
| | 4,141 | F4 |
| | 2,161 | G4 |
| | 747 | G6 |
| Bear Wallow Creek | 630 | F3 |
| | 5,718 | F4 |
| | 4,951 | G4 |
| Butler Creek | 7,531 | F4 |
| Low Gap Creek | 13,256 | B3 |
| Little Low Gap Creek | 1,085 | A3 |
| Jack of Hearts Creek | 16,258 | B3 |
| Dutch Charlie Creek | 689 | B2 |
| | 1,484 | F3 |
| | 13,027 | F4 |
| Redwood Creek (S) | 11,285 | F4 |
| | 1,569 | F6 |
| Middleton Creek | 5,540 | B4 |

# Stream Channel Geometry

## Longitudinal Stream Profiles

Over time, in ideal conditions, a stream will carve into the landscape and form a channel slope in relative balance to its erosive stream power, sediment availability, and strength of bedrock, eventually reaching a steady state. A stream in a topographically steady state of slope (at equilibrium) tends to form a topographically smooth, concave slope that gets exponentially steeper towards the headwaters. A stream that is out of equilibrium deviates from this basic pattern along various portions of its length. In Western Subbasin streams, typical divergence from this pattern is caused by changes in underlying geology, regional uplift, movement along stream-crossing faults, large landslides, and large amounts of sediment (aggradation) within the stream channel.

These processes cause the longitudinal profile of a particular stream to become progressively convex (*Figure 14*), or form prominent knickzones that migrate upstream over time due to headwater erosion. Changes in the natural resistance of the bedrock to erosion may also cause variations in the longitudinal profile. Sections of the stream channel that are significantly out of equilibrium may become too steep (>10% channel slope) to allow passage of fish and will decrease the length of anadromy. In the Western Subbasin, only three out of 20 (15%) of the surveyed tributaries of the SF Eel River with identified ends of anadromy have profiles that are consistent with the basic pattern of equilibrium. Uplift or basal lowering has created multiple knickzones that are apparent on longitudinal stream profiles and are out of equilibrium. Knickzones are sensitive to disturbance and may limit fish passage over time. Land use and management practices should be studied closely when planning activities that may alter the fluvial morphology or regime of each stream.

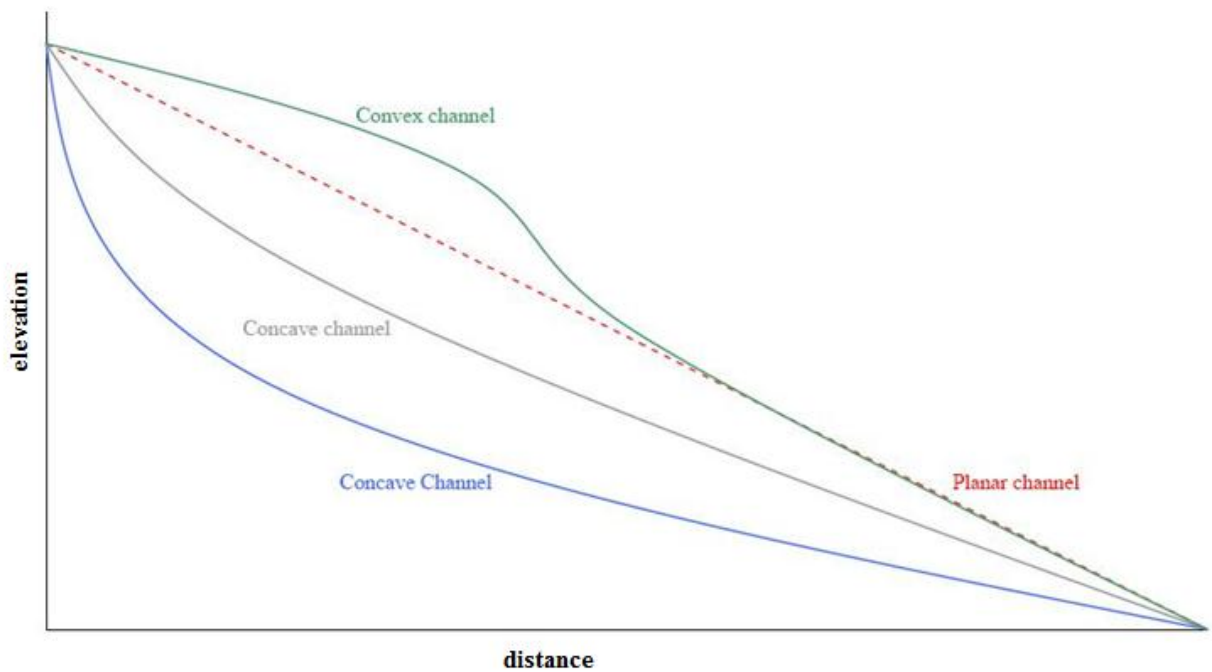



*Figure 14. Basic channel profile shapes.*

### *Profiles of Western Subbasin Streams*

Stream profiles were completed for 26 Western Subbasin streams (*Figure 15*). Six streams had profiles that were near equilibrium and 24 had profiles that were clearly out of equilibrium. Knickzones and ends of anadromy (EOA) were included on profiles where applicable. Twenty of the 26 streams had EOAs identified on habitat typing reports. Of these 20, 75% had EOAs associated with knickzones, and 55% of EOAs were located at the downstream end of a knickzone.

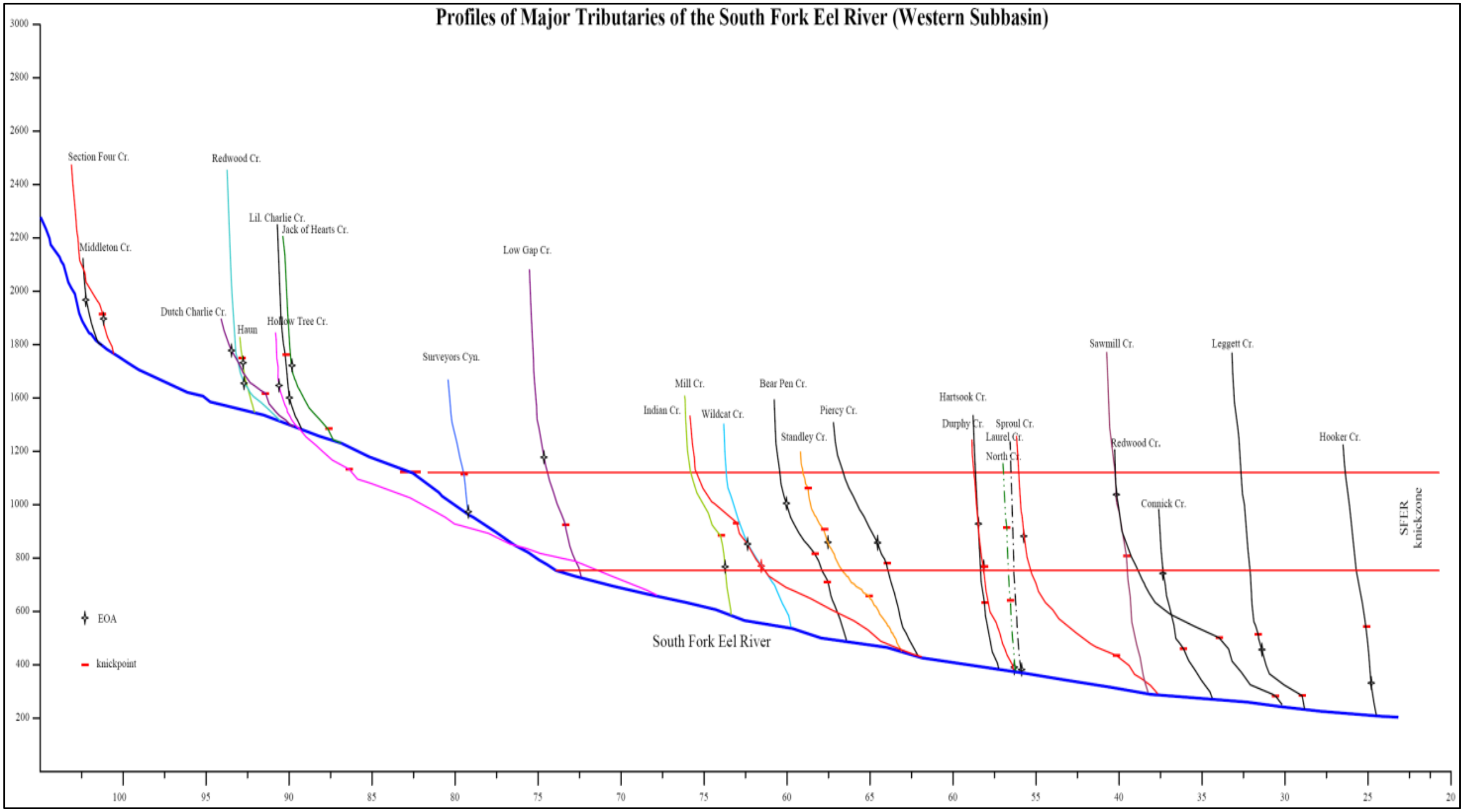



*Figure 15. Longitudinal stream profiles of SF Eel River Western Subbasin streams.*

## Soils

In this assessment, the term "soil" refers to any loose material derived from the weathering of bedrock and mixed upward by biogenic and/or mechanical processes. Like the other SF Eel River subbasins, bedrock of the Western Subbasin is mantled with unstable soils.

The majority of bedrock in the subbasin is composed of sedimentary rock types of the Coastal Belt – Coastal Terrane, which produce soil types (loam to extremely gravely sandy loam) that are prone to mass wasting, hillslope erosion, and transport by fluvial processes. The dominate soil series in the Western Subbasin is Wohly-Holohan-Casabonne which covers approximately 52% of the subbasin area (*Figure 16*). The Wohly-Holohan-Casabonne soil series predominantly mantles steep, rugged ridges and valleys of Central Belt sandstone and the Coastal and Yager Terrane bedrock (sandstone, shale, and conglomerate) of the Coastal Belt (*Table 7*).

The Western Subbasin receives high levels of rainfall between October and May. Rainfall-initiated soil movement varies with storm intensity. As soil becomes saturated, pore pressure between grains increases, which lowers its ability to resist downslope movement. Gradual downslope movement of soil caused by gravity, weathering, saturation, rain-splash, and biogenic activity (soil creep) is evident throughout this subbasin, and delivers large amounts of sediment to Western Subbasin streams (Stillwater Sciences 1999).

A healthy cover of forest vegetation helps stabilize and reinforce the strength and stability of hillslope soils. Roots mechanically reinforce the soil by transfer of shear stress in the soil to tensile resistance in the roots (Menashe 2001). A mesh of intertwining roots also increases cohesion of the soil. Roots decrease the likelihood of saturation-related slope failure by drawing water out of the soil, which can prevent or at least delay soil saturation. Tree cover on hillslopes can increase the soil shear-strength by more than 50% (O'Loughlin and Ziemer 1982), sometimes as much as 100% (Waldron 1977). The soils in this subbasin support a lush growth of Redwood and Douglas-fir, and Tan-oak in second-growth forests (Stillwater Sciences 1999).

A significant portion (nearly 75% of the total area) of the Western Subbasin is managed for industrial timber production. When trees are removed from a slope, the roots tend to decay and lose their stabilizing influence, predisposing soils to failure (O'Loughlin and Ziemer 1982). Soil compaction associated with logging access roads, landings, and skid-trails, and the removal of vegetative cover through timber harvest affect soil hydrology and erosion within this subbasin.

Roads are listed as the most significant source of anthropogenic sediment within the South Fork Eel River Basin (USEPA 1999). Input of soil from roads in Western Subbasin streams will be discussed in detail in the Roads and Railroads section of this report.

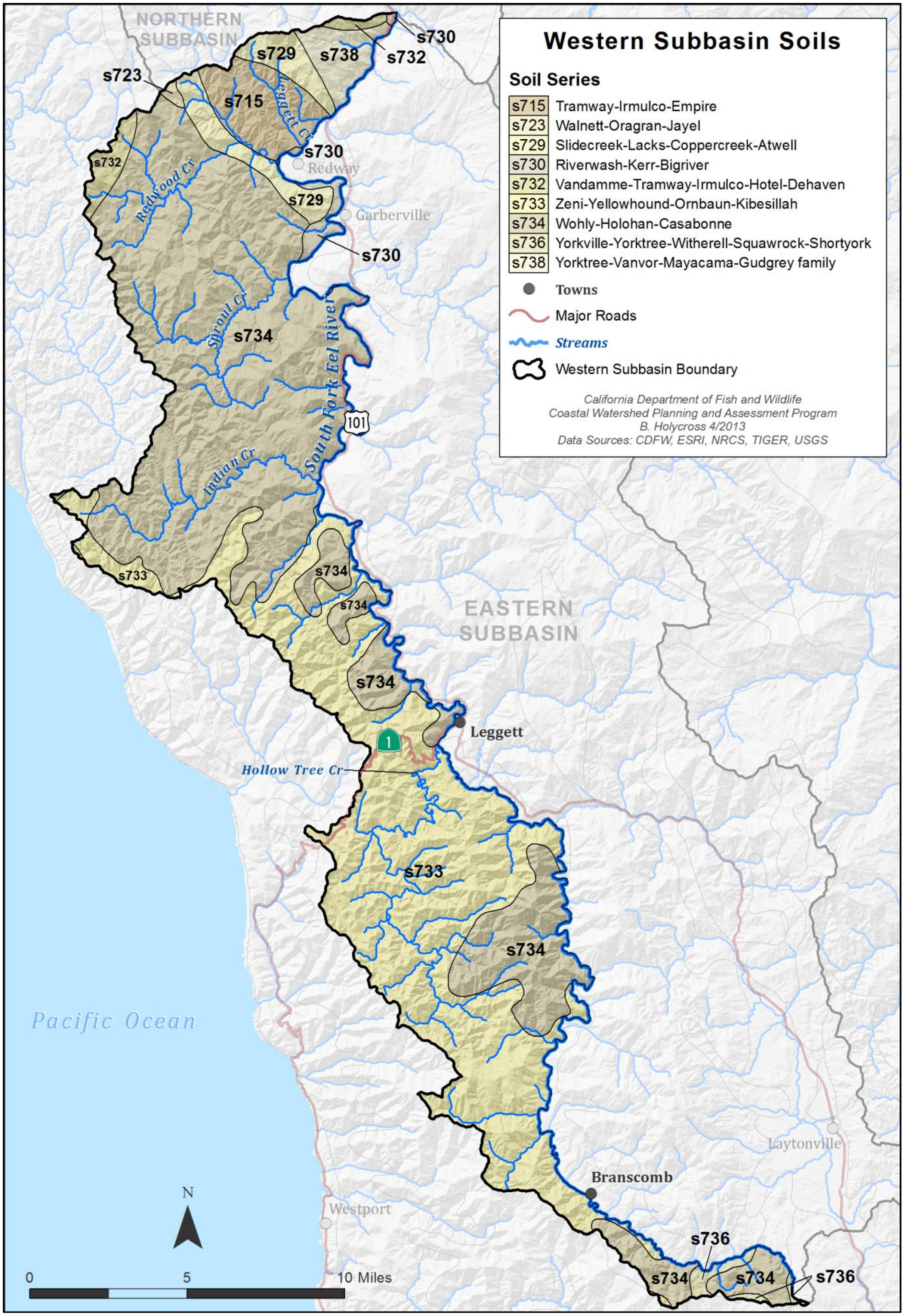



*Figure 16. Soils map of the Western Subbasin.*

*Table 7. Western Subbasin soil descriptions.*

| Soil series | Texture | Description | Parent Bedrock | Slope % |
|---|---|---|---|---|
| **Wohly-Holohan-Casabonne (52%)** | | | | |
| WOHLY | loam | Very deep, well drained soils that formed in residuum weathered from sandstone and shale. | Central Belt mélange and sandstone. Coastal Belt Coastal and Yager Terrane. | 9 - 75 |
| HOLOHAN | extremely gravelly sandy loam | Very deep, well drained soils formed in colluvium weathered from sandstone. | | 9 - 75 |
| CASABONNE | gravelly loam | Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale. | | 9 - 75 |
| **Zeni-Yellowhound-Ornbaun-Kibesillah (37%)** | | | | |
| ZENI | loam | Moderately deep, well drained soils formed in material weathered from sandstone or mudstone. | Coastal Belt Coastal Terrane | 9 - 75 |
| YELLOWHOUND | gravelly loam | Deep, well drained soils formed in material weathered from sandstone or conglomerate. | | 9 - 99 |
| ORNBAUN | loam | Deep, well drained soils formed in material weathered from sandstone and mudstone. | | 9 - 75 |
| KIBESILLAH | very gravelly loam | Deep, well drained soils formed in material weathered from sandstone. | | 9 - 99 |
| **Tramway-Irmulco-Empire (4%)** | | | | |
| TRAMWAY | loam | Deep, well drained soils formed in material weathered from sandstone. | Wildcat group. | 9 - 75 |
| IRMULCO | loam | Deep or very deep well drained soils formed in material weathered from sandstone. | | 9 - 75 |
| EMPIRE | loam | Moderately deep, well to moderately drained soils formed in material derived from soft sedimentary rocks. | | 10-40 |
| **Slidecreek-Lacks-Coppercreek-Atwell (3%)** | | | | |
| SLIDECREEK | gravelly loam | Very deep, well drained soils that formed in colluvium and residuum weathered from sandstone and mudstone. | Central Belt mélange. | 9 - 75 |
| COPPERCREEK | loam | Very deep, well drained soils that formed in colluvium and residuum from schist, sandstone, and mudstone. | | 9 - 75 |
| ATWELL | silt loam | Very deep, moderately well drained soils formed in material from sheared sedimentary rocks | | 15 - 50 |
| **Yorktree-Vanvor-Mayacama-Gudgrey family (2%)** | | | | |
| YORKTREE | loam | Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone. | Central Belt sandstone. | 15 - 75 |
| VANVOR | very gravelly sandy clay loam | Moderately deep, well drained soils on mountains. These soils formed in colluvium from metavolcanic rock. | | 30 - 75 |
| MAYACAMA | very gravelly sandy loam | Moderately deep, somewhat excessively drained soils formed in material derived from sedimentary and metasedimentary rocks. | | 9 - 75 |
| GUDGREY | gravelly sandy clay loam | Deep, well drained soils formed in material weathered from sandstone, schist or shale. | | 8 - 75 |
| **Vandamme-Tramway-Irmulco-Hotel-Dehaven (1%)** | | | | |
| VANDAMME | loam | Deep, well drained soils formed in material weathered from sandstone or mudstone. | Coastal Belt Yager | 2 - 75 |

| | | | | |
|---|---|---|---|---|
| TRAMWAY | loam | Moderately deep, well drained soils formed in material weathered from sandstone. | Terrane. | 9 - 75 |
| IRMULCO | loam | Deep or very deep well drained soils formed in material weathered from sandstone. | | 9 - 75 |
| HOTEL | very gravelly loam | Moderately deep, well drained soils that formed in material weathered from sandstone. | | 30 - 100 |
| DEHAVEN | gravelly loam | Deep, well drained soils formed in material weathered from sandstone. | | 30 - 99 |
| **Riverwash-Kerr-Bigriver (1%)** | | | | |
| RIVERWASH | N/A | Barren alluvial areas of unstablilized sand silt, clay or gravel reworked by frequently by stream activity. | Alluvium and river terrace deposits. | 0 - 5 |
| KERR | loam | Dark olive gray recent moderately well drained alluvial soils without profile development that are formed in material derived mainly from micaceous schists. | | 0 - 5 |
| BIGRIVER | loamy sand | Very deep, well drained soils formed from alluvium derived from mixed sources. | | 0 - 5 |
| **Yorkville-Yorktree-Witherell-Squawrock-Shortyork (1%)** | | | | |
| YORKVILLE | loam | Very deep, well drained soils that formed in material weathered from chloritic schist and other sedimentary and metamorphic rocks. | Central Belt Sandstone and Mélange. | 5 - 75 |
| YORKTREE | loam | Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone. | | 15 - 75 |
| WITHERELL | loam | Very deep, somewhat excessively drained soils formed in material weathered from sandstone. | | 5 - 75 |
| SQUAWROCK | cobbly loam | Moderately deep, well drained soils formed in material weathered from sandstone or graywacke. | | 15 - 75 |
| SHORTYORK | gravelly loam | Very deep, well drained soils formed in material weathered from sandstone, schist, shale and graywacke. | | 8 - 75 |
| **Walnett-Oragran-Jayel (<1%)** | | | | |
| WALNETT | stony loam | Very deep, well drained soils formed in material weathered from serpentinized peridotite. | Central Belt Mélange – peridotite block | 5 - 75 |
| ORAGRAN | very stony loam | Shallow, well drained soils formed in material weathered from peridotite or serpentinite. | | 5 - 75 |
| JAYEL | stony clay loam | Moderately deep, well drained soils formed in material weathered from serpentinized peridotite. | | 5 - 75 |

## Vegetation

Two of the main factors for the decline of salmonids throughout the South Fork Eel River Basin over the past century have been an overabundance of fine sediments entering streams and an increase in stream temperatures. Vegetation on the landscape directly influences both of these conditions. Hillslope vegetation intercepts and slows the velocity of rainwater and provides leaf-litter and duff layers to the surface of soils, which intercepts and disperses rainwater and increases resistance to surface erosion. Leaf and duff layers also provide an intricate irregular, permeable interface that allows surface water to pond and be absorbed rather than flow downhill as runoff. Vegetation also increases transpiration, decreasing pore pressure between soil grains during heavy rains and thereby reducing slope failure. Root systems increase the tensile slope strength of unstable soils, reducing landslides, erosion and sedimentation.

Riparian vegetation shades streams and reduces solar radiation, both of which lower stream temperatures. Stream bank roots and low hanging branches provide cover for fish. Large woody debris generated by riparian vegetation and recruited by streams provides habitat and increases stream channel diversity. Stream bank root systems increase the tensile slope strength of unstable soils, reducing bank failure and subsequent sedimentation.

In the Western Subbasin, the predominant vegetation cover type as described by the USFS CALVEG data is mixed conifer and hardwood forest, covering approximately 73 percent of the subbasin area (*Figure 17*, *Table 8*). This vegetation type consists of forests and woodlands where conifers are the primary vegetation and hardwoods are present secondarily. Conifers are prevalent throughout this subbasin and are found in nearly all areas except river floodplains, and some river terrace low lands and hillside meadows where the underlying geology is too unstable to support forest growth.

Conifer forest is the next most abundant vegetation in this subbasin, covering approximately 11 percent of the subbasin. Similarly, hardwood forest vegetation cover classification composes just less than 11 percent of the subbasin area.

Grassland/prairie (herbaceous) vegetation is the fourth most abundant vegetative cover type, making up three percent of the total area. This vegetation type is found in small, interspersed hillside prairies in the northern and extreme southern part of the subbasin, overlying earthflows and unstable soils within geology of the Central Belt mélange. Herbaceous vegetation is also found along some of the low-lying areas on the mainstem SF Eel River.

Historically, grasslands were composed of native prairie bunch grasses with relatively deep root systems. In the late 1800's ranchers began seeding European short-rooted annual grasses for grazing that soon replaced the native bunch grasses. Replacement of the more deeply rooted grasses with the shallower rooted annual grasses is believed to have increased surface erosion and hillslope soil stability (Kelsey 1980).

GIS data indicate that less than one percent of this subbasin is covered by agriculture, however this may be an under-representation because pastures used for livestock grazing may not be included in this vegetation designation since land use is often difficult to determine remotely. For this reason, it can be assumed that areas mapped as grassland/prairies may also be agricultural in nature and the overall percentage of agricultural lands is likely to be greater than depicted. Agricultural lands in this subbasin are primarily located on the low-lying river terraces near Garberville and Redway.

Undocumented marijuana cultivation is also not represented in these figures but can have a significant impact on the subbasin's natural resources. Both legal and illegal marijuana cultivation are becoming large scale problems when considering water diversion and water contamination in subbasin streams. Illegal grow sites are established in remote residential areas and on privately owned timber company land.

To supply a constant, reliable source of water to their plants, growers will typically divert water from a nearby stream or spring through plastic pipes to their cultivation sites. The warm, dry season is when plants require the most water, both natural vegetation and cultivated plants. This is the same time period when stream base flows are at their lowest. When low base-flow conditions exist, suitable stream habitat diminishes, and stressors on

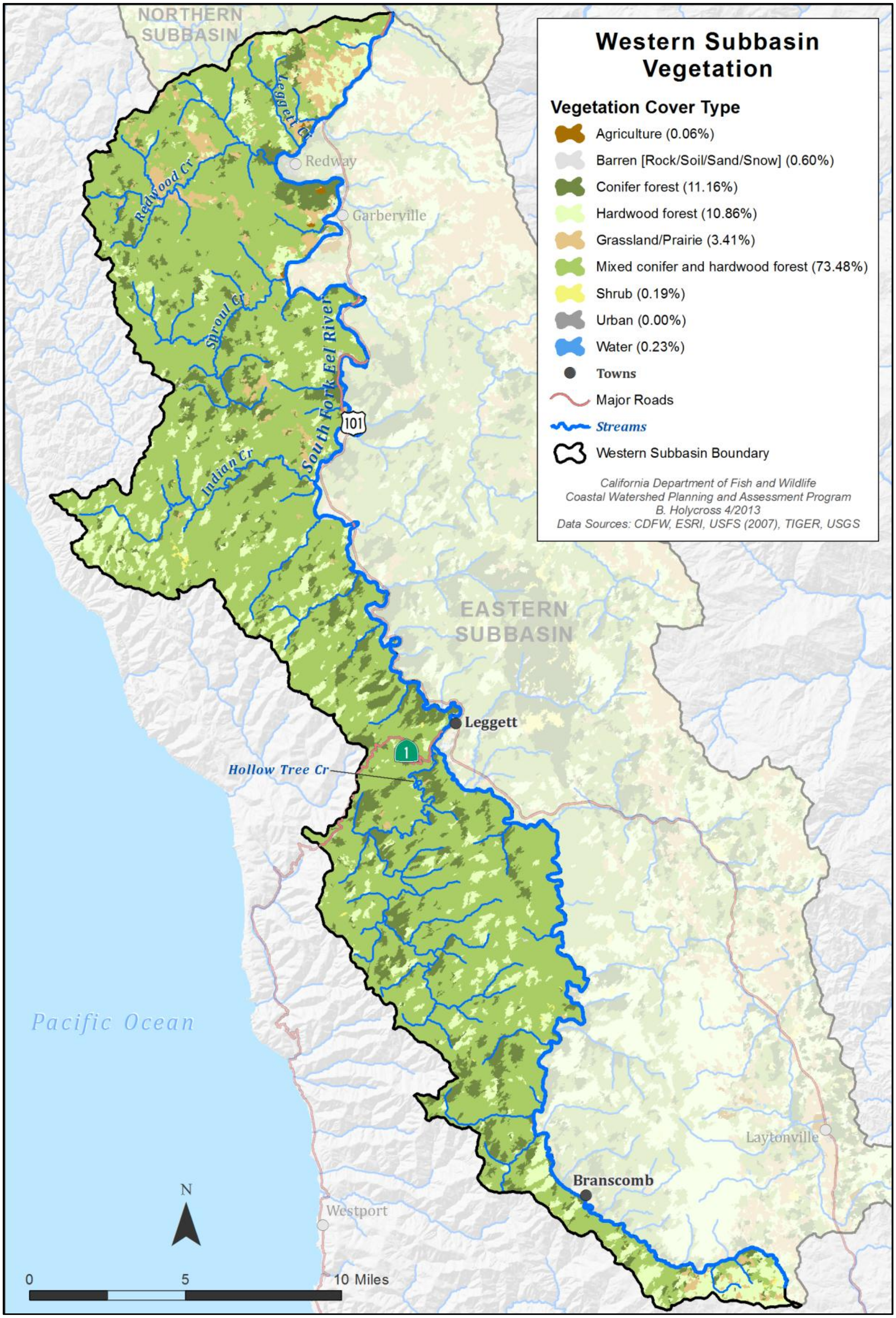



*Figure 17. Vegetation map of the Western Subbasin.*

*Table 8. Vegetation of the Western Subbasin (USFS CALVEG).*

| Vegetation Cover Type | % of Basin | Primary Vegetation Type | % of Type |
|---|---|---|---|
| Mixed conifer and hardwood forest/woodland | 73.48 | Pacific Douglas-Fir | 58.83 |
| | | Redwood - Douglas-Fir | 41.05 |
| | | Redwood | 0.05 |
| | | Douglas-Fir Ponderosa Pine | 0.01 |
| Conifer forest/woodland | 11.16 | Redwood - Douglas-Fir | 47.01 |
| | | Pacific Douglas-Fir | 46.00 |
| | | Redwood | 6.78 |
| | | Jeffrey Pine | 0.21 |
| Hardwood forest/woodland | 10.86 | Tanoak (Madrone) | 78.92 |
| | | Oregon White Oak | 14.12 |
| | | California Bay | 4.48 |
| | | Canyon Live Oak | 1.89 |
| | | Madrone | 0.39 |
| | | Black Oak | 0.15 |
| | | Riparian Mixed Hardwood | 0.03 |
| | | Willow | 0.02 |
| Grassland/Prairie | 3.41 | Annual Grasses and Forbs | 99.99 |
| | | Perennial Grasses and Forbs | 0.01 |
| Barren | 0.60 | Barren | 74.33 |
| | | Urban-related Bare Soil | 25.36 |
| | | Dune | 0.32 |
| Shrub | 0.19 | Blueblossom Ceanothus | 75.80 |
| | | Manzanita Chaparral | 12.12 |
| | | Scrub Oak | 11.92 |
| | | Willow (Shrub) | 0.12 |
| Agriculture | 0.06 | Agriculture (General) | 100.00 |
| Statistics exclude classification of water | | | |

salmonids increase. During these times when water flow is minimal (usually in the late summer through early fall), even a single diversion can significantly reduce stream flow. Because these diversions are purposefully concealed, especially when grows are located on public lands or industrial timberland, they cannot be managed. Sedimentation and pollution associated with grow operations are also increasing and becoming a greater concern. Illegal marijuana cultivation will be discussed further in the Industrial Marijuana Agriculture section of this report.

## Fire

Historically, fire has shaped ecosystems throughout California, and there are three periods where human influences have managed both fire and fire environments differently: 1) prior to European settlement (before 1700); 2) the settlement period (1700 to 1920); and 3) the suppression era (1920 to present). Fire patterns in pre-European times resulted in many millions of acres burning in California each year, with fire acting as a major cause of ecosystem change (CalFire 2003). Fires renewed mature vegetation communities that required fire to restore vegetation life cycles.

Habitat structure and composition, climate, weather, prior fire history, land management activities, and physical properties such as elevation and aspect influence the frequency, size, and severity of fires (Flannigan et al. 2000, Pilliod et al. 2003). Most fires are effectively suppressed using advanced technology and increased early efforts to protect resources, commodities, and people. To reduce the potential for severe, widespread fires, fuel treatments are considered the only practical means of altering potential wildfire behavior (CalFire 2003). In some areas where cutting and removal of fuel is controversial, infeasible, or prohibitively expensive, fire has been used as a tool to reduce fuel loads. These prescribed burns may limit the extent, effects, and severity of subsequent fires (Collins et al. 2008).

Fire is one of the primary natural disturbance factors influencing vegetation structure in the Western Subbasin. Natural post-fire stands are usually a mosaic of burn severities, from unburned to stand-replacing, within a watershed. Historically, Native Americans and settlers used fire to manage grasslands and prairies, and to maintain the ratio of conifers to oaks in tanoak stands (USBLM et al. 1996).

Modern land use practices have influenced the likelihood and effects of wildfire throughout the subbasin. Logging on highly erodible hillslopes has altered the natural hydrology, and construction of roads and stream crossings causes additional erosion and sediment runoff at greater levels than would have occurred naturally. This is a particular concern in Western Subbasin streams, where industrial timber harvest is the predominant land use, (occurring on nearly 75% of the subbasin area) and road density is extremely high (4.8 miles/square mile).

Human settlement has also affected wildland fire patterns and occurrences. Areas where residential communities border parklands or industrial timberlands are known as the wildland-urban interface. In this interface, a combination of fuel, weather, and topographical conditions may create an environment of increased wildland fire risk.

Twenty two percent (48 square miles) of the Western Subbasin has burned since the early 1900s (*Figure 18*). The largest area burned prior to 1950 (38 square miles, or 17% of the total subbasin area), with most fires burning near the town of Leggett (RM 66). The most recent fires (encompassing 4 square miles, or less than 2% of the subbasin area) occurred between 1990 and 2012 in the upper Hollow Tree Creek watershed. The Western Subbasin had fewer fires (16) than either the Northern (19) or Eastern (35) subbasins, but the percentage of subbasin area burned was similar to the two other subbasins (23% of Northern and 20% of Eastern subbasin area burned).

Fire behavior is strongly influenced by vegetation type and fuel moisture content. Large fires in the Western Subbasin burned in the Hollow Tree Creek, Mill Creek (Leggett), and Low Gap Creek drainages (*Figure 18*) where vegetation types are a mix of conifer, mixed conifer and hardwood forest, and hardwood forest.

Fire-fighting practices may directly affect the landscape and streams within the subbasin. Actions and their effects include the following:

- Construction of fire roads and fire breaks, which may increase erosion and sediment input to streams;
- Aerial application of fire retardant in upslope and riparian areas (and directly in streams when mis-applied), which may result in the input of toxic chemicals to stream habitats;
- Prescribed burning, which may affect LWD recruitment, soils, and stream habitat (Pilliod et al. 2003).

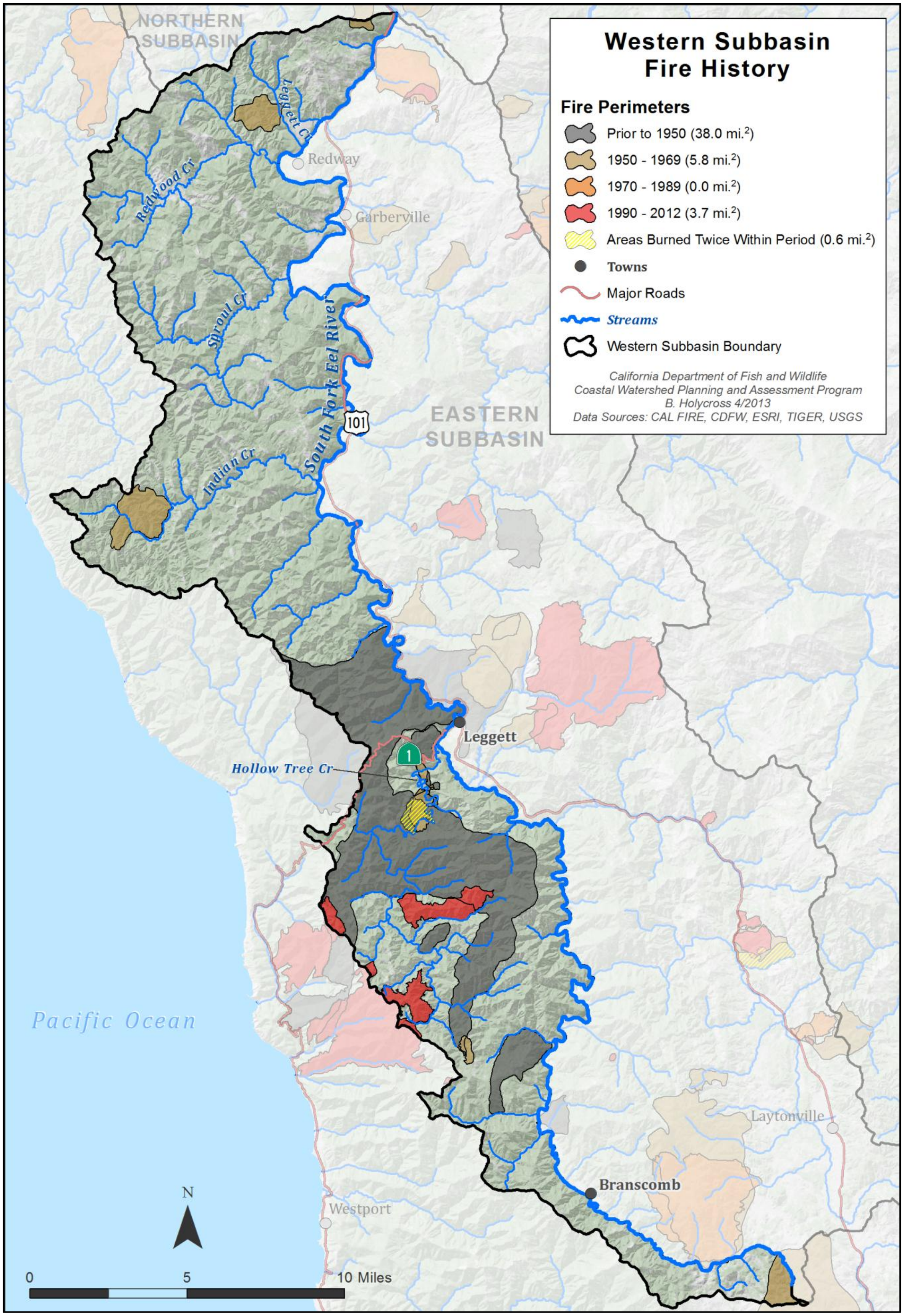



*Figure 18. SF Eel River Western Subbasin fire history, with total square mileage burned within each time period.*

Climate change has the potential to affect fire behavior, fuels, ignition, season duration, and management strategies. Global climate change models predict drier conditions for northwestern California, which will result in an increased probability of large fires (Westerling and Bryant 2008). Drier conditions, including warmer temperatures and reduced precipitation, will lead to decreased fuel moisture and increased flammability, both of which increase wildfire spread rate, intensity, and duration. Increased fuel flammability may also result in greater fire frequency in wetter, forested areas like the Western Subbasin, and higher temperatures will extend fire seasons, resulting in larger total burn areas from fires occurring both earlier and later than expected (Fried et al. 2004, McKenzie et al. 2004). Fire behavior will also be less predictable due to changes in temperatures, precipitation, fire frequency and fire severity (Tetra Tech 2013). Resource management strategies such as the modification of vegetation structure and fuels can help mitigate the effects of climate change throughout the subbasin.

Reduced rainfall and drier conditions resulting from climate change may also affect the natural fire regime (Flannigan et al. 2000, Fry and Stephens 2006). The fire season in Humboldt County generally begins in June, peaks in August, and ends in October, but this may vary with local geography. According to the County of Humboldt (2012), the western half of the county has a fire season that is generally shorter than the eastern half due to:

- The western half of the county receives more rainfall;
- The west has spring seasons that are wetter and cooler than the east;
- Temperatures in the eastern portion of the county are much higher in the summer months; and
- Much of the precipitation received in the east is snow that falls during winter.

Despite the generally damp climate prevailing in the county's forests, studies have suggested a fire return interval of 50 to 100 years in the northern part of the county, and 12 to 50 years in the south (CalFire 2005).

The effects of wildfire in watersheds may include:

- Loss of vegetative cover;
- Increased runoff;
- Hydrophobic (water repellent) soils;
- Severe erosion; and
- Increased sediment production.

Post-fire erosion may increase sediment loads in both streams and riparian areas. In some areas where large-scale forest fires have occurred, accelerated sediment production has been documented (Humboldt County 2012). Increased erosion and sediment production following fires are of particular concern in the Western Subbasin due to very high natural and anthropogenic sediment input that already exists.

Depleted vegetation in riparian areas following wildfires reduces instream shading, resulting in increased water temperatures that threaten fish and other aquatic life (Pilliod and Corn, 2003). Increased water temperatures during low flow times are already a major concern for salmonids in many areas of the Western Subbasin. Low flows occur during late summer and early fall, which correspond to the times of highest fire danger. Post fire monitoring and the development of management strategies are essential for areas where the loss of riparian vegetation and associated shade results in elevated instream temperatures. Active fuels management in riparian zones, including hazardous fuels reduction and habitat restoration, is increasingly common among land managers (Dwire et al. 2011).

The most recent large fires in the Western Subbasin occurred in areas of moderate to very high fire threat (*Figure 19*). Approximately 66% of the land in the subbasin is classified as either as very high or high fire threat. In a high fire threat area, all fine dead fuels ignite readily and fires start easily from most causes; fires spread rapidly and high intensity burning may develop on slopes or in concentrations of fine fuels; and fires may become severe and their control difficult unless they are attacked successfully while small (National Wildfire Coordinating Group 2002). Thirty three percent of the subbasin area is classified as moderate fire threat, and one percent as low threat (agricultural regions). Threat rankings address wildfire related impacts on ecosystem health, with ecosystems defined as unique vegetation types by tree seed zones (http://www.fire.ca.gov/index.php).

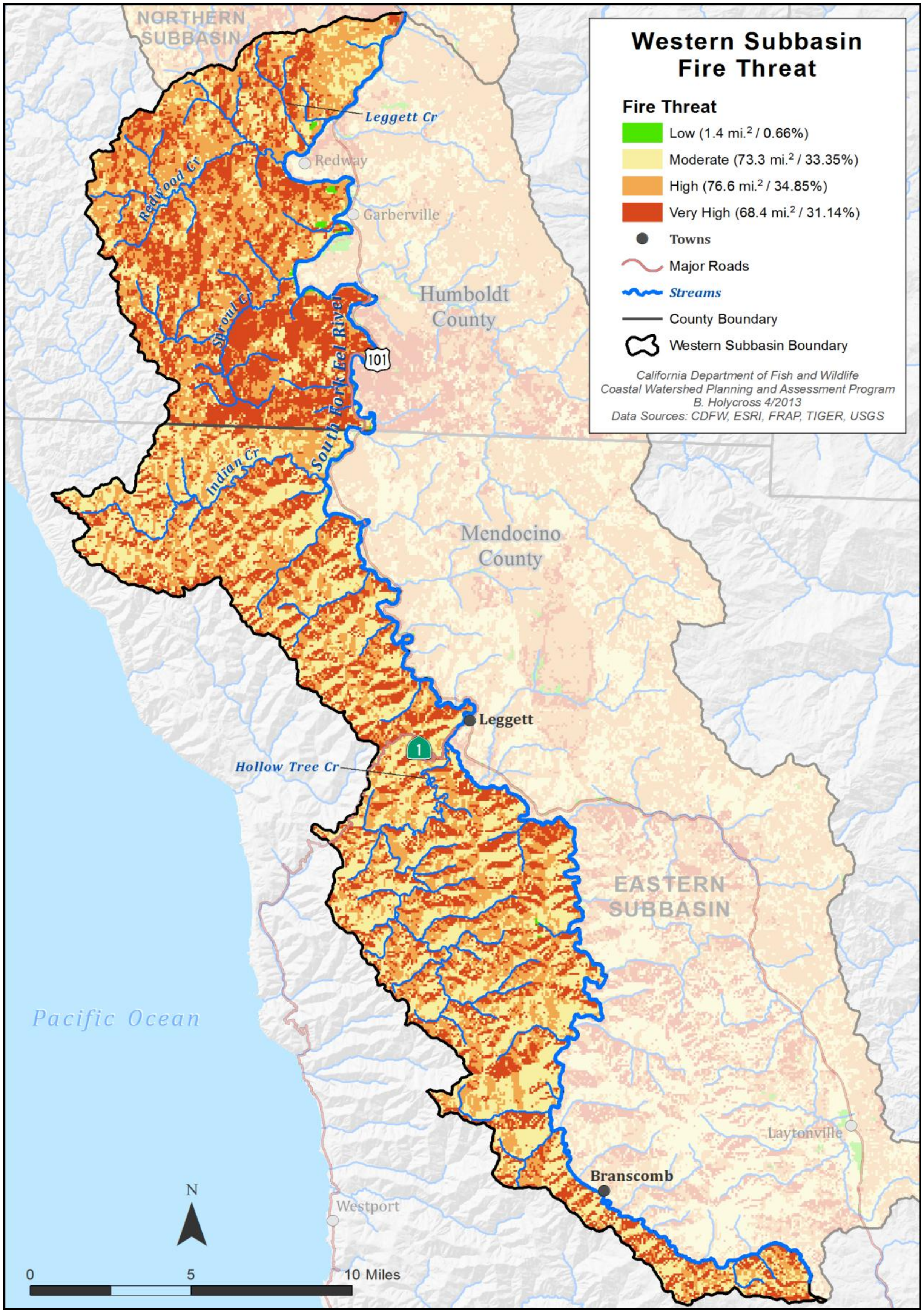



*Figure 19. SF Eel River Western Subbasin fire threat, with percentage of total Basin area in each threat category.*

CalFire's Fire and Resource Assessment Program (FRAP) data used to produce fire threat maps are related to:

- stand-level data: estimated fire frequency and fire behavior characteristics at a fine scale, and
- landscape-level data: the risk of widespread landscape-level damage to an entire ecosystem, based on the percentage of an ecosystem at risk of losing key ecosystem components or functions.

Sudden oak death (SOD) has spread throughout southern Humboldt, and cases have been confirmed in the SF Eel River Basin. In one SOD hot spot north of Garberville, the rate of expansion of diseased areas was approximately1,500 acres per year from 2004 through 2010 (Valachovic 2011). The OakMapper website (Kelly et al. 2004; http://www.oakmapper.org/oaks/index/4132) shows two clusters within the SF Eel River hot spot area (*Figure 20*). The southernmost cluster near Garberville is within the boundary of the Western Subbasin. Affected stands can detrimentally affect fuel loading and fire behavior because SOD causes 100% mortality in tanoak, and infected areas have higher fuel loads and trees that are prone to rapid failure during fires (CalFire 2012). The duration of infection in stands is also important when considering fire behavior; late-phase (>8 years) diseased forests may show increased rates of fire spreading, flame length, and fireline intensity, which reduces the effectiveness of firefighting strategies and techniques (Valachovic et al. 2011).

In summary, fire is a natural and important part of the disturbance regime of the Western Subbasin. Direct effects to salmonids, particularly increased sedimentation and reduced riparian canopy resulting in increased stream temperatures, may be compounded in areas where human activities have resulted in increased sedimentation and higher instream temperatures, and where sediment input from roads, land use practices, and unstable geology are already concerns.

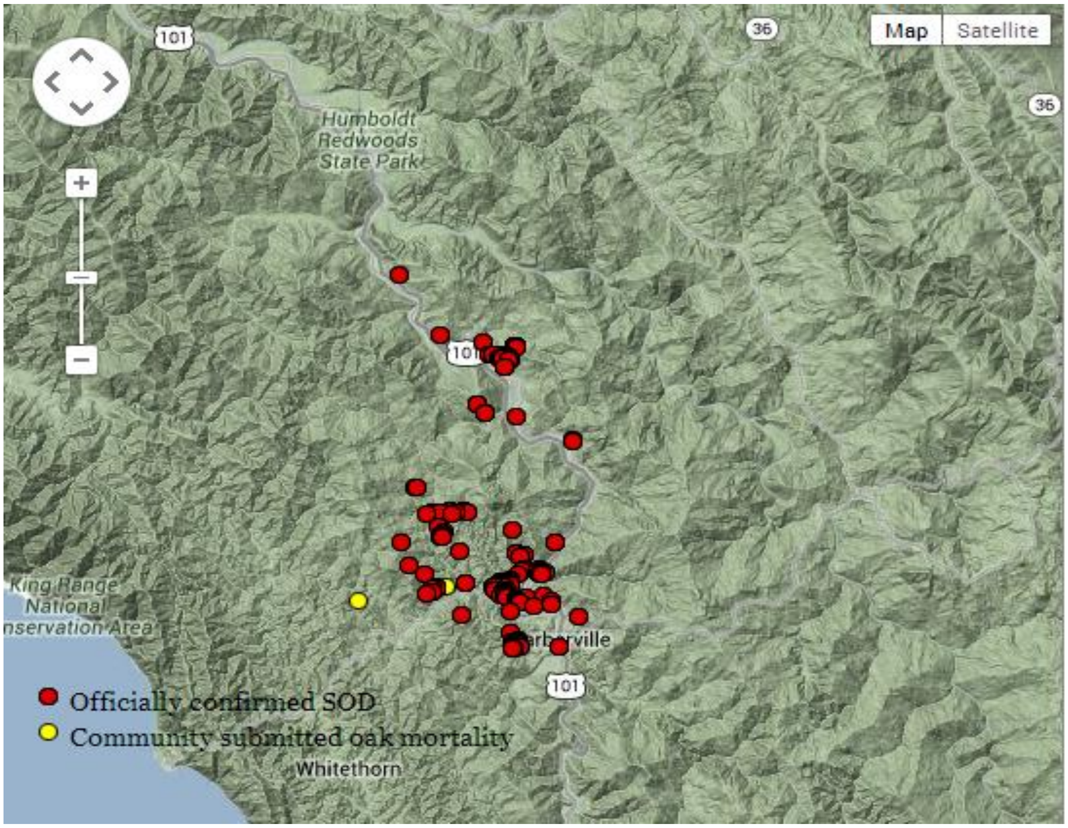



*Figure 20. Confirmed (red) and reported (yellow) cases of Sudden Oak Death (SOD) in the SF Eel River Basin, from Oak Mapper website (accessed 2/27/2014).Confirmed locations west of the SF Eel River are located within Western Subbasin boundaries.*

# Land and Resource Use

## Historic Land Use

The first Native Americans inhabiting the Western Subbasin of the SF Eel River Basin were the Sinkyone and Cahto, two subgroups of the Coastal Southern Athabaskans (USBLM et al. 1996). They subsisted primarily on anadromous fish, with secondary resources including upland game and acorns. The Sinkiyone occupied the northern part of the Western Subbasin and the Cahto were found in the southern portions, northwest of Laytonville (USBLM et al. 1996). Native American land use practices such as hunting, gathering, use of fire, and establishment of villages had some influence on the ecosystem, however, the cumulative impact on the environment and natural resources of the Western Subbasin was relatively minor (Yoshiyama and Moyle 2010). Native Americans occupied the North Coast Ranges for at least 4,000 years, possibly as many as 10-15,000 years, prior to the arrival of the first European settlers in the early 1850s (Jack Monschke Watershed Management (JMWM) 2000). Most of these early settlers were trappers, encouraged by the Homestead Act of 1862 which allowed them to purchase affordable land. By the late 1860s, most Native Americans had disappeared from the basin due to violence, disease, and relocation (JMWM 2000). Homesteaders trapped, farmed, harvested timber, and grazed livestock throughout the Western Subbasin.

Historically, logging was most intense in the Northern and Western Subbasins of the SF Eel River Basin, where old growth redwood was relatively abundant. Early logging efforts resulted in the removal of nearly all accessible old growth redwoods along the creek mouths. Prior to WW II, Douglas-fir was considered unmerchantable timber, but after the war, nearly all of the Douglas-fir was harvested in an effort to keep up with the post-war building boom (USBLM et al. 1996). The development of new technologies and additional transportation options made access to remote areas with steep terrain possible, and resulted in an increase in the number and magnitude of logging operations throughout the subbasin. In the 1950s, many small mills were set up throughout the basin, including “brush mills”, small temporary mills set up close to stands so that trees could be cut and skidded to the mills easily. Brush mills were dismantled and moved to new locations when stands were depleted (JMWM 2000). Roads, skid trails, and landings were often located in creeks so logs could be skidded downhill easily. During this time, extensive damage to streams and poor road building techniques combined with unstable geology led to increased sedimentation in streams throughout the subbasin (JMWM 2000).

In addition to improvements in timber harvest techniques and equipment, the Humboldt County Board of Supervisors levied a tax on standing timber in 1956, which led to an increase in the amount of timber harvested in the county because many landowners were forced to harvest timber rather than leave it standing for financial reasons (O’Hara and Stockton 2012). Peak timber production years were 1956 in Mendocino County and 1959 in Humboldt County, and although timber harvest levels have declined recently, the timber industry is still an important component of the economy in both counties (Downie 1995).

The major flood events of 1955 and 1964 exacerbated the impacts of intensive timber harvest and poor road building practices in a naturally fragile landscape, resulting in large-scale soil erosion and sedimentation throughout the SF Eel River Basin (Yoshiyama and Moyle 2010). Major aggradation during the floods also buried or destroyed natural armoring of stream banks, allowing high flows to scour banks, causing an increase in bank failures and slides (JMWM 2000). During the 1955 flood, peak flow at Miranda was 173 thousand cubic feet per second, and during the 1964 flood, peak flow was 199 thousand cubic feet per second, (Humboldt County Sheriff’s Office 2012). These flows, combined with the unstable geology, steep terrain, high road density, and extensive timber harvest resulted in substantial sediment input during these flood events in streams throughout the Western Subbasin.

Nearly all merchantable timber had been removed from the Western Subbasin by the late 1960s, and land developers bought up large tracts of land, subdivided the smaller parcels (40-80 acres), and sold them to “back-to-the-landers”, also known as “new settlers”. Significant changes to the watershed from these activities included the development of roads or the increased use of existing seasonal roads to access every parcel, an increase in the number of diversions, and an increase in the total amount of water diverted from streams in the basin to supply additional residences. Many of these "back-to-the-landers" also started cultivating marijuana, and these operations have expanded in both size and number; development of this underground industry in the 1970s provided a boost to the economy throughout the SF Eel River Basin (JMWM 2000). These activities and their impact on the ecosystem and economy are discussed in greater detail in the Industrial Marijuana Agriculture section of this subbasin report.

## Current Land and Resource Use

The four principal land uses as of June, 2012 in the SF Eel River Western Subbasin were commercial timber production, residential, open space/parks, and grazing/timber (*Table 9*).

*Table 9. Four principal land uses in the Western Subbasin.*

| Land Use | square miles | acres | % of total area |
|---|---|---|---|
| Timber production | 165 | 105,600 | 75 |
| Residential | 24 | 15,360 | 11 |
| Open space/parks | 20 | 12,800 | 9 |
| Grazing/Timber | 10 | 6400 | 5 |

Timber production occurs throughout the subbasin, open space/park land is concentrated in the Southern portion of the subbasin (and at points along the mainstem SF Eel River) between Leggett and Branscomb, and residential development is located primarily in the northern part of the subbasin near Garberville and Redway (*Figure 21*).

### Timber Production

Commercial timber production is the primary land use in the Western Subbasin, occurring in 75% of the total subbasin area (*Table 9*). Based on CalFire data collected between 1995 and 2012, timber harvest occurred throughout the subbasin, with the most recent activity occurring along the western edge of the subbasin, southwest of Piercy, west of Leggett, and south of Branscomb in Mendocino County (*Figure 22*). More than half of the land in the Western Subbasin is in Mendocino County, which was ranked fifth among California counties in 2006 in timber harvest, after Humboldt, Siskiyou, Shasta, and Plumas counties; however, it ranked second in total timber value, due to the high value of redwood. The most productive timber forests in Mendocino County are Douglas-fir and redwood forests, with high growth rates resulting from local soil and climate conditions (Mendocino County 2009; Chapter 4).

Timber harvest activities require the development of plans detailing the amount and method of planned harvest. There are different plans based on the area of timberland owned and whether or not the landowner is an individual/family or a corporation. Non-industrial timber management plans (NTMPs) were established in 1989 to allow non-commercial landowners with less than 2,500 acres of timberland to develop harvest plans that were not as expensive and time-consuming as THPs (CalFire 2003). Once an NTMP has been approved, the actual harvest is reported in a notice of timber operations (NTO). Commercial harvest by timber companies and private landowners with more than 2,500 acres of timberland requires the development of a timber harvest plan (THP). Based on CalFire data collected between 1995 and 2012, most timber harvest in the Western Subbasin is commercial (THPs), as opposed to non-commercial (NTOs) (*Figure 22*).

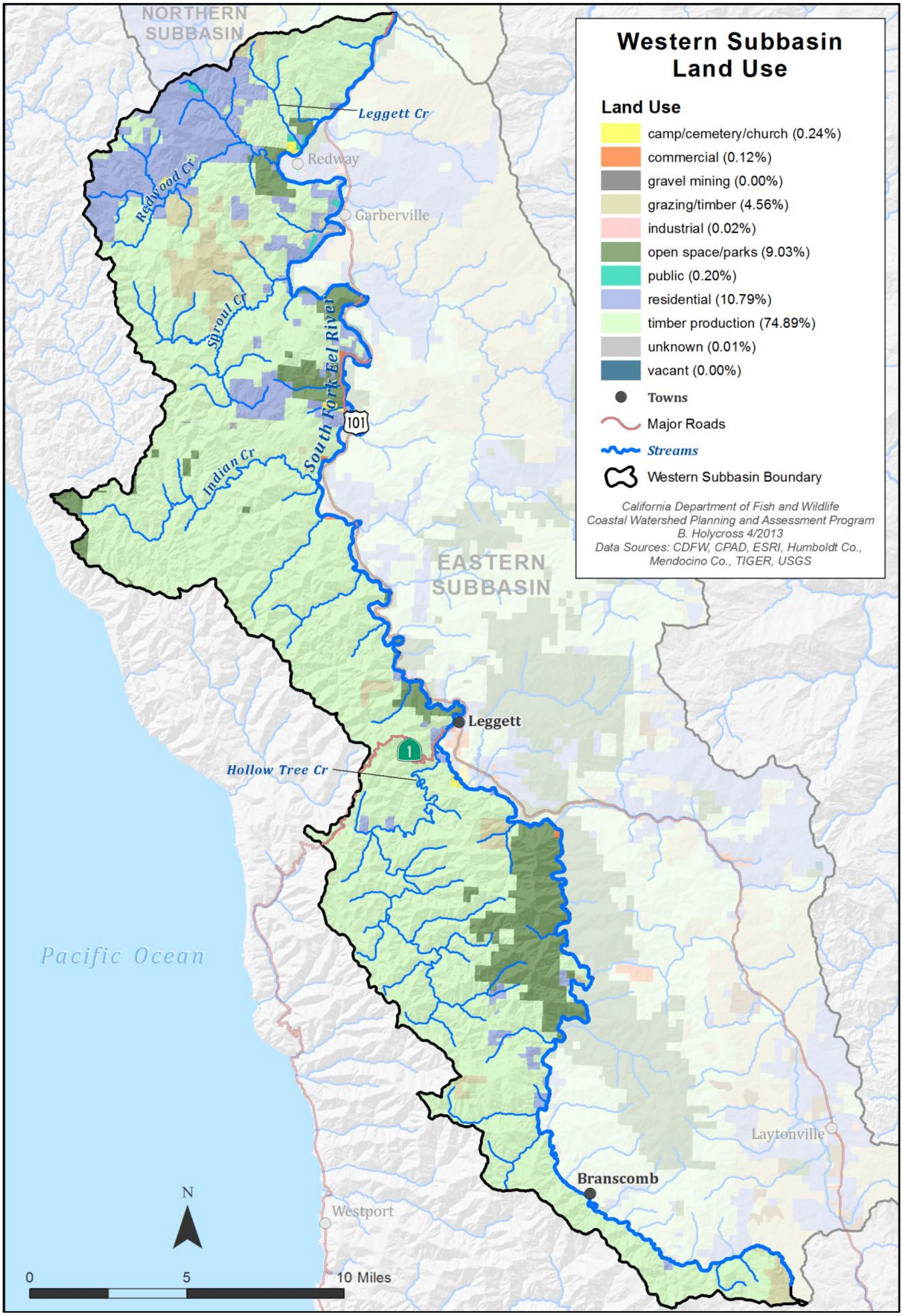



*Figure 21. Land use in the Western Subbasin of the SF Eel River Basin.*

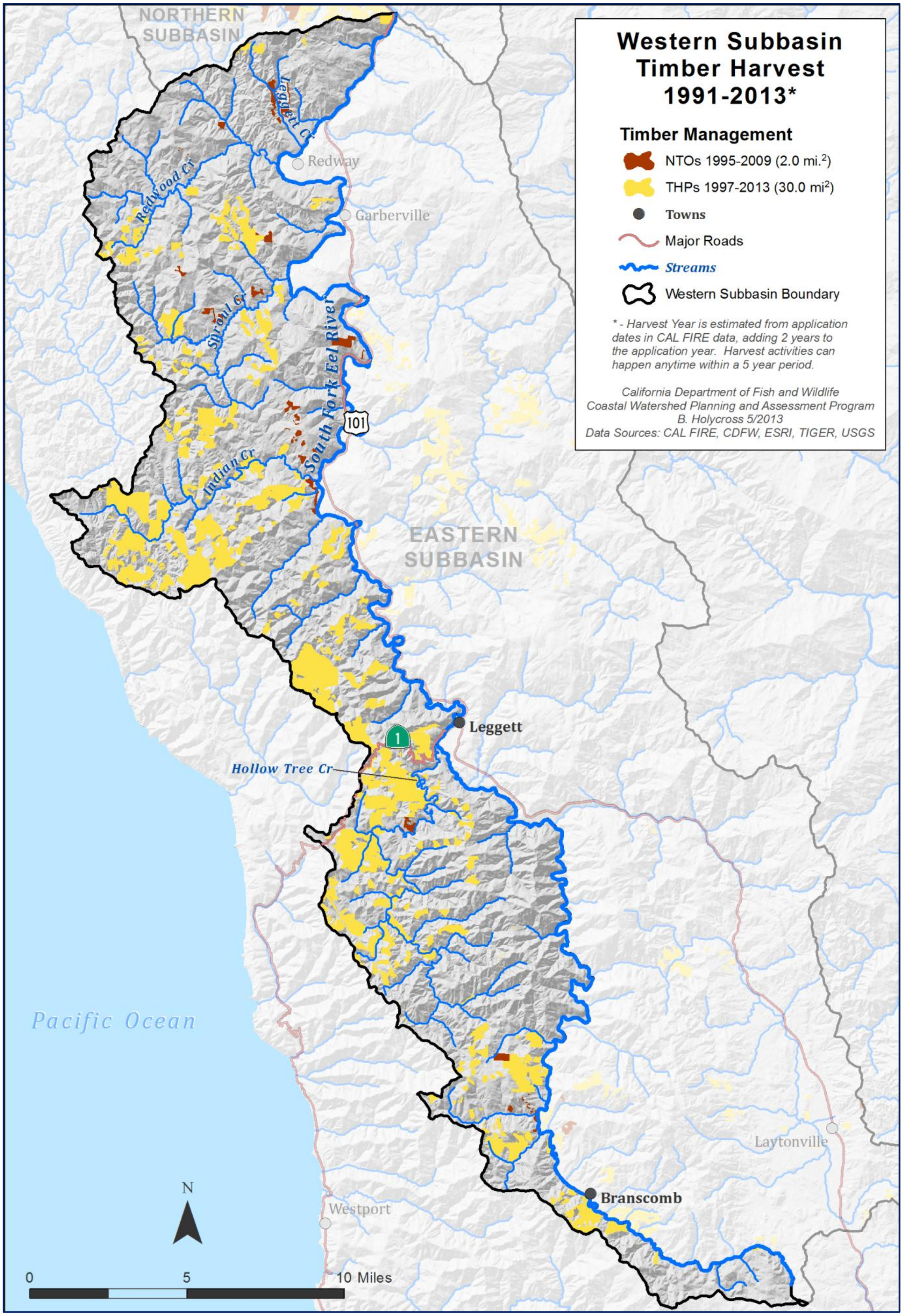



*Figure 22. Timber Harvest (NTOs and THPs) between 1995 and 2012 in the SF Eel River Western Subbasin.*

The Western Subbasin had the largest number of acres harvested compared to the other subbasins, with almost twice as much as the Northern Subbasin and more than three times as much as the Eastern Subbasin. The total area of timber harvested in the Western Subasin was 21,111 acres: 4,343 acres in Humboldt County and 16,768 acres in Mendocino County (*Table 10*). The total acreage harvested under THPs was 19,937 acres (3,544 acres in Humboldt County and 16,393 acres in Mendocino County) and individual operations ranged in size from 807 acres to less than one acre. Major landowners and harvesters include Barnum Timber Company, Hawthorne Timber Company, Mendocino Redwood Company, and Usal Redwood Forest Company. NTO harvest area in the basin totaled 1,174 acres (799 acres in Humboldt County and 375 acres in Mendocino County) and harvest areas ranged in size from 97 acres to less than one acre.

*Table 10. Timber harvest by plan type (THP or NTO) for the SF Eel Western Subbasin (data from CalFire 2012).*

| Western Subbasin | Plan Type | Acres | County |
|---|---|---|---|
| | THP | 3544 | Humboldt |
| | THP | 16393 | Mendocino |
| | **Total THPs** | **19937** | |
| | NTO | 799 | Humboldt |
| | NTO | 375 | Mendocino |
| | **Total NTOs** | **1174** | |
| | **Subbasin Total** | **21111** | |

The primary silviculture methods used in the subbasin from 1991-2011 were: seed tree removal cut (33% of harvested area); alternative prescription (14% of harvested area); and clearcut (13% of harvested area) (*Figure 23*). Seed tree removal cuts are defined as the cutting of widely dispersed seed trees after regeneration is established (Adams et al. 1994). Alternative prescriptions are modifications of a recommended practice when an alternative could provide better results for forest resource stewardship; harvest techniques differ on a case-by-case basis. Each alternative prescription requires a written analysis of pre- and post-harvest timber stand conditions, and a description of silvicultural practices and systems to be used in lieu of standard methods (CalFire 2012). Clearcutting is defined as the removal of all trees in one operation, producing a fully exposed microclimate for the development of a new age class/even-aged stand (Adams et al. 1994). Following a clearcut, the remaining slash and ground vegetation is usually burned to prepare the site for artificial regeneration.

Each type of silvicultural and yarding technique results in different levels of landscape disturbance and modified stream flows (Harr et al. 1979, USFS 1985, Keppeler and Ziemer 1990). In general, clear-cutting has the highest level of disturbance of any silviculture method (USFS 1985). This includes both a terrestrial disturbance component (soil exposure and instability due to tree removal), and an aquatic disturbance component (removal of shade and reduced contribution of large woody debris). The least disturbing method of timber harvest is commercial thinning (USFS 1985), where trees are felled and cut into segments (bucked), either manually or, where the terrain is not too steep, by machine.

Water drafting as a road dust/sediment control measure is an important consideration due to the amount of water diverted and the possible direct and indirect effects of this practice on salmonids. This will be discussed further in the Water Use: Diversions, Dams, and Hydrologic Disturbances section of this report.

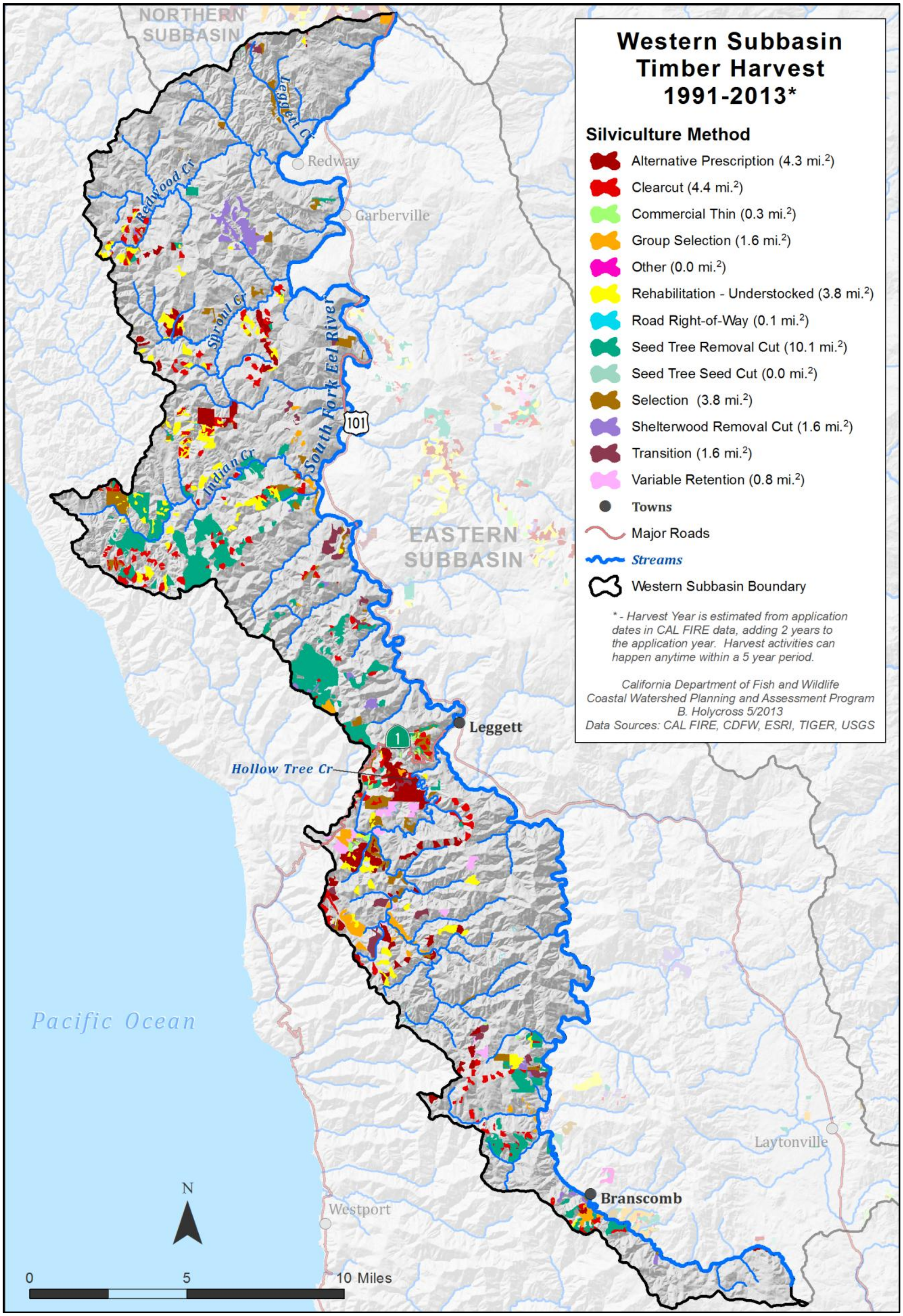



*Figure 23. Timber harvest activity by silvicultural method in the SF Eel River Western Subbasin.*

## Residential

Approximately 13% of the population in the SF Eel River Basin lives in the Western Subbasin, and the population density is the lowest of all three subbasins (5.37 people/square mile). This population estimate was obtained by looking at all of the census blocks within the Western Subbasin boundary, adding the population in those blocks that were fully contained within the boundary, then identifying any blocks with areas outside the subbasin boundaries ("straddling blocks"). The population in these straddling blocks was estimated proportionally based on the amount of each block area that was within the subbasin boundary, and was added to the total population estimate.

Population density in this subbasin is low because there are very few towns, and most of the land (68% of the subbasin area) is owned by industrial timber companies. Of the 23% of the Western Subbasin that is privately owned, 18% are parcels >40 acres, and 5% are ≤40 acres in size. Most residential development is located in the northern area of the subbasin, in the Redwood Creek drainage (*Figure 21*).

Compared to other parts of California, major development of water resources has not occurred in either Humboldt or Mendocino County. No major surface water storage exists; existing water projects include surface water diversions, some small dams and reservoirs, and many small stock watering ponds (Mendocino County 2009; Chapter 3). In both counties, marijuana cultivation operations are rapidly increasing in both number and magnitude. These operations often occur in residential areas, and they require extensive amounts of water. Growers rely on illegal diversion from streams and groundwater reserves to support these operations. Marijuana cultivation and its impacts on the environment in the SF Eel River Basin will be discussed further in the Industrial Marijuana Agriculture section of this report.

The Western Subbasin normally receives substantial wintertime precipitation, but relies on a combination of groundwater and surface water to supply residences outside of the larger communities during the hot summer months. There are four water service providers in the Western Subbasin (*Table 11*). The Garberville Sanitation District and the Redway Community Services District provide both water and wastewater services.

*Table 11. Water and wastewater service providers in the SF Eel River Western Subbasin (Humboldt County General Plan Update Draft EIR 2012 and Mendocino County General Plan 2009).*

| Water Provider | Connections | | Capacity | | | Usage | |
|---|---|---|---|---|---|---|---|
| | Existing | Available | Supply (mgd) | Treatment (mgd) | Storage (mg) | Peak Day (mgd) | Connection (gpd) |
| Briceland Community Services District | 26 | 0 | 0.010 | Unknown, but not limiting | 0.042 | 0.040 | 1,538 |
| Redway Community Services District | 600 | 180 | 0.838 | 0.460 | 0.375 | 0.475 | 792 |
| Benbow Water Company | 113 | 0 | 0.327 | 0.200 | 0.150 | 0.382 | 3,381 |
| Garberville Sanitation District | 396 | 25 | 0.461 | 0.330 | 0.270 | 0.310 | 787 |
| **Wastewater Service Provider** | **Subbasin Served** | **Connections** | | **Permitted Capacity (mgd)** | | **Flows (mgd)** | |
| | | **Existing** | **Available** | **Dry Weather** | **Wet Weather** | **Existing Dry Weather** | **Peak Wet Weather** |
| Garberville Sanitation District | Eastern, Western | 420 | 180 | 0.162 | 0.235 | 0.140 | 0.55 |
| Redway Community Services District | Eastern, Western | 524 | 175 | 0.186 | 0.64 | 0.140 | 0.43 |
| From Humboldt County General Plan Draft EIR (2012) and Mendocino County General Plan (2009) | | | | | | | |

The Garberville water system supplies approximately 396 active connections (*Table 11*), and consists of a treatment plant, four water tanks, three booster stations, and two sources: surface water from the SF Eel River (Eel River Infiltration Gallery) and a shallow well located in downtown Garberville (Humboldt Lafco and GSD 2011). The water treatment plant holds a current water diversion permit from the SWRCB, which allows them to divert a maximum of 430 acre feet/year from the SF

Eel River, and the Tobin Well has a limited capacity of 40-70 gallons per minute. Service areas outside the district boundary include: Leino Road and Sproul Creek Road (8 connections), Southern Humboldt Community Park/Buck Mountain Ranch/River Ranch Homes (4 connections), Connick Creek Subdivision (8 connections), and Kimtu (20 connections). The total storage capacity for the system is approximately 300,000 gallons and is adequate to meet the maximum daily demand of 262,398 gallons per day recorded in July 2009 (Humboldt Lafco and GSD 2011). A CEQA initial study was completed in 2013 for a GSD upgrade to replace the existing 30,000 gallon storage tank with a 200,000 gallon tank (LACO Associates 2013).

The Garberville Sanitation District (GSD) also provides wastewater services to some areas in the Western Subbasin, and the wastewater treatment plant (WWTP) is located on the west bank of the SF Eel River (*Figure 24*). The treatment plant was upgraded in 2011 to include three oxidation ponds, four wetland treatment ponds, an onsite chlorination system, improved percolation ponds, and an on-site operations and maintenance building. The district uses naturally occurring processes in created lagoons and wetlands, providing habitat for wildlife while processing the community's wastewater (Humboldt Lafco and GSD 2011).

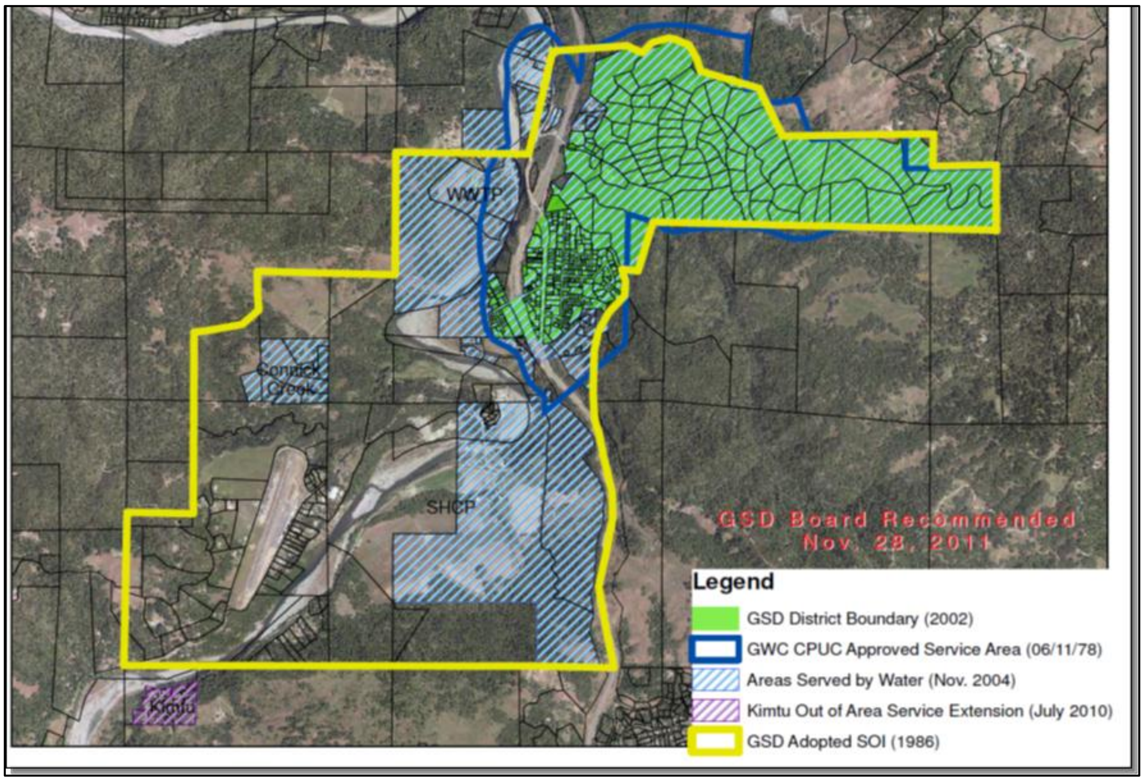



*Figure 24. Garberville Sanitation District service area district boundary and sphere of influence (from Humboldt Lafco and GSD 2011).*

Other water service providers in the Western Subbasin that draw water directly from the SF Eel River include the Redway Community Services District and the Benbow Water Company. The Benbow Water Company is permitted to divert up to 30 acre feet/year, and also claims a riparian right to divert directly from the East Branch SF Eel River. The State Water Resources Control Board recently (Nov. 26, 2013) ordered the company to stop the sale of bulk water outside the service area, citing possible negative impacts to fish and wildlife.

## Open Space/Parks

Nine percent of the land (20 square miles; 12,655 acres) in the Western Subbasin is open space/parkland (*Figure 21*). The largest area is part of the Elkhorn Ridge Wilderness (11,271 acres), managed by the USBLM and located in the southern part of the subbasin between Leggett and Laytonville. This wilderness area is located in both the Eastern and Western subbasins, with approximately half of the acreage in each subbasin. Other open space/parkland is located mainly along the mainstem SF Eel River and includes: Humboldt

Redwoods, Benbow Lake, Richardson Grove, and Standish Hickey State Parks. Other small areas of public land include the Angelo Coast Range Reserve, part of the University of California Natural Reserve System, near Branscomb, and a small area in the headwaters of the Indian Creek drainage that is within the boundaries of Sinkiyone Wilderness State Park.

### Grazing/Timber

Approximately 5% of the land in the Western Subbasin is utilized for livestock grazing and small timber operations. These differ from the commercial timber production operations because they are small, usually family-owned ranches that manage their lands using a variety of techniques and schedules. Most of these small grazing/timber operations are located in the northern part of the subbasin, south and east of Garberville, with some isolated operations in the central and southern parts of the subbasin near Leggett and in the headwaters south of Laytonville. The small percentage of land dedicated to grazing and small timber operations in this subbasin is due to a lack of grassland habitat (3.41% of the total area), and a relatively small amount of land owned by private landowners.

## Roads

There are approximately 1,048 miles of road within the Western Subbasin (road density = 4.76 miles/square mile). This subbasin has the highest road density of the three subbasins in the SF Eel River drainage. Cal Fire categorizes roads based on capacity, surface material, and frequency of use. Permanent roads include primary (4+ lanes) and secondary (2-3 lanes) paved roads and rocked (improved) roads; seasonal and temporary roads are considered unimproved. Eighty one percent (852 miles) of the roads in the Western Subbasin are seasonal roads, followed by 8% (90 miles) permanent roads and 4% (44 miles) proposed seasonal roads (*Figure 25*).

Most of the roads in the Western Subbasin are seasonal roads used for hauling timber, but many are also used to access residential and agricultural areas, particularly in areas such as Redwood Creek, where marijuana cultivation operations are abundant in areas of residential land use. Road density and type are a reflection of the primary land use in the subbasin (*Table 9*). The Western Subbasin has the highest overall road density, the highest percentage of seasonal roads, and the highest percentage of land allocated for commercial timber harvest (75% of the subbasin) of the three subbasins.

Highway 101, the only primary road in the basin, follows the SF Eel River from north of Weott to south of Leggett, then up the Rattlesnake Creek drainage and south to Laytonville (*Figure 25*). The highway was built from 1909 to 1923 and crosses the SF Eel and many of its tributaries throughout the Basin. The highway follows the river mainly along the eastern side (within the Eastern Subbasin boundary), so the amount of primary road located within the Western Subbasin boundary is relatively small (4.8 miles).

Many of the smaller roads and railroads built in the subbasin either cross streams or run alongside them. Both of these types of roads can affect stream condition and site condition; therefore, road location and road design should be considered when constructing roads to reduce sediment input (Amaranthus et al. 1985, Cafferata and Spittler 1998). Stream crossings may create fish passage barriers or sediment sources (Cafferata et al. 2004), and roads that run along streams can also act as sediment sources and limit the migration of stream channels across floodplains. In addition to these legacy effects, many roads added large amounts of sediment to streams as they were built.

Logging roads contribute more sediment to streams than any other land management activity (Gibbons and Salo 1973, Meehan 1991). Throughout the SF Eel River Basin, major anthropogenic sediment sources were found to be road-related, including roads associated with timber harvest. Specific issues identified as concerns for sediment loading in the Western Subbasin include the following: road surface erosion, road crossing failures and gullies, skid trails, and landslides from roads and harvest (Dyett and Bhatia 2002, MRC 2004).

In the sediment source analysis for the SF Eel River TMDL (Stillwater Sciences 1999), average sediment delivery in the basin was approximately 700 $t/km^2/yr$, with 46% of the total loading contributed by anthropogenic sources. Road-related landslides, road crossings, and gully erosion were the largest anthropogenic sources of sediment.

Stillwater Sciences' (1999) study area was located southeast of Leggett and included the Hollow Tree Creek Basin and adjacent tributary basins (Low Gap

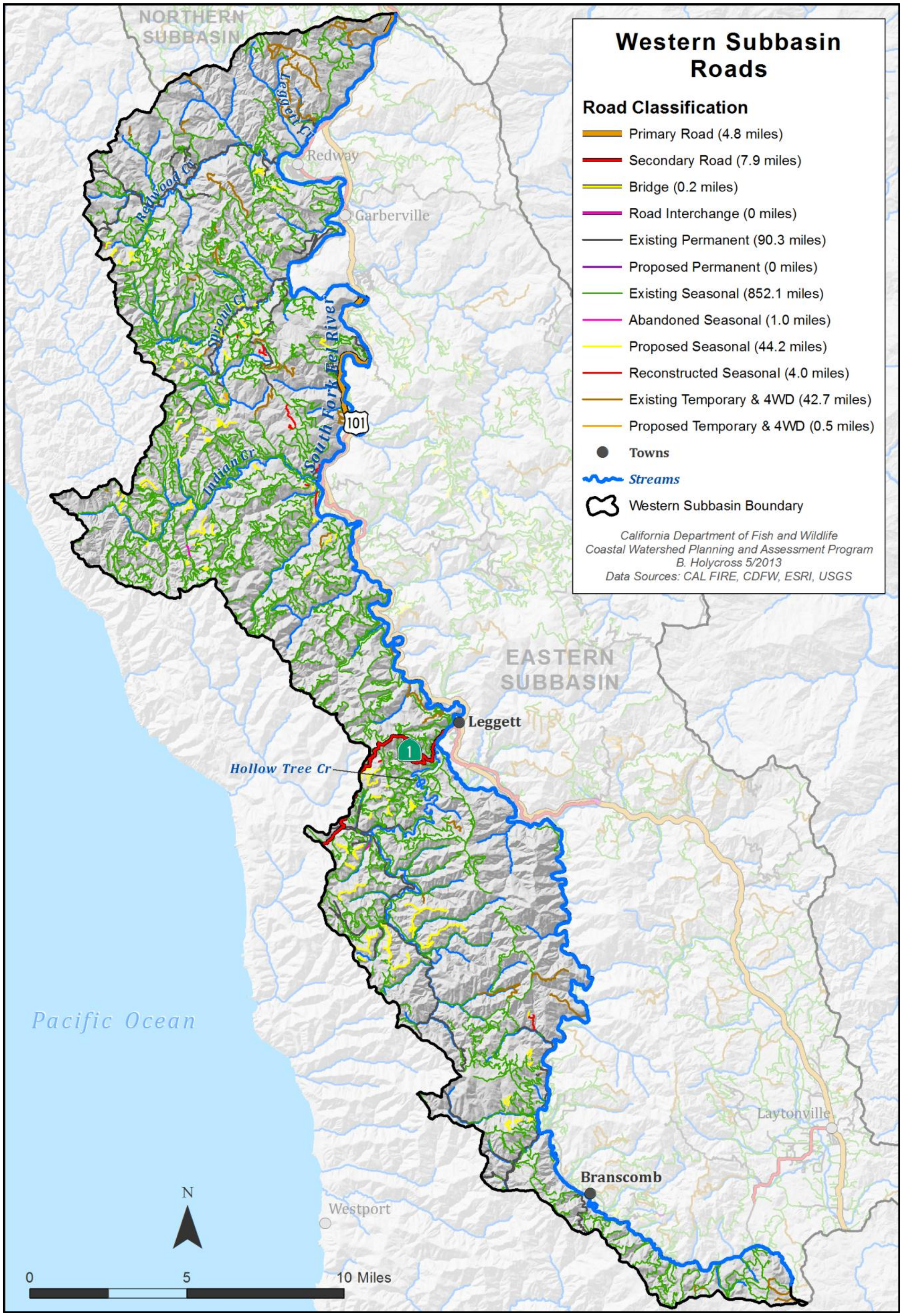



*Figure 25. Roads in the SF Eel River Western Subbasin.*

and Mill Creek), with a total area of 61 square miles. More than half of the Hollow Tree Creek study area is owned by MRC, and was logged intensively in the 1970s, with decreased levels of timber harvest in the 1980s and 1990s (Stillwater Sciences 1999). MRC mapped 177 landslides between 1966 and 1978 and 206 landslides between 1978 and 1996. Stillwater Sciences analyzed their sediment input data and determined that approximately half of the sediment delivered to Hollow Tree, Low Gap, and Mill Creek was road-related, with 239 tons/square kilometer/year delivered between 1966 and 1978, and 131 tons/square kilimeter/year delivered between 1978 and 1996. MRC also completed a skid trail assessment in the study area and concluded that there is very little sediment (16 tons/square kilometer/year on MRC land) delivered to streams from skid trails under current conditions. However, between 1966 and 1978, there were high rates of sediment delivery to streams (107 tons/square kilometer/year) due to intensive tractor logging and construction of skid trails near streams (Stillwater Sciences 1999). Current logging practices require fewer new skid trails and most sediment input is attributed to legacy effects of old skid trails adjacent to streams in the study area (Stillwater Sciences 1999). As a result, many current restoration and management projects focus on legacy road rehabilitation.

Stillwater Sciences (1999) also studied the Sproul Creek basin during two time periods: 1966-1981 and 1981-1994, as part of their sediment source analysis. This study area is located west of Garberville and is 24 square miles in size. Barnum Timber owns 65% of the basin, and Wagner Timber Company owns most of the remaining. Average sediment loading was higher in the 1966-1981 time period (866 tons/square kilometer/yr) than in the 1981-1994 time period (552 tons/square kilometer/yr), but the ratio of anthropogenic to total inputs was greater for the recent period (0.76) than for the earlier period (0.51). This may be due to an increase in timber harvest, and to drier climatic conditions and reduced natural sediment production in recent years (Stillwater Sciences 1999). The Sproul Creek Basin had the lowest sediment input volume of all studied basins, primarily due to the absence of active earthflows; most of the sediment in this basin is produced by road crossings and gully erosion.

Erosion from rural and logging roads includes two components: chronic erosion of fine sediments and catastrophic failure of roads prisms during winter storms. The geologic setting – steep slopes, rapid uplift, and unstable soils – in which logging occurs in the Western Subbasin creates more erosion from acceptable logging practices and from legacy and new logging roads relative to those in more stable geologic locations (*Figure 26*).

*Figure 26. Example of legacy road failure in the SF Eel River Basin.*

In 2004, MRC completed a watershed assessment report for Hollow Tree Creek watershed assessment unit (WAU). The WAU included 6 planning watersheds (32.9 square miles total), with Lower, Middle, and Upper Hollow Tree Creek watersheds comprising nearly 90% (29.5 square miles) of the total WAU area. MRC determined that between 1969 and 2000, the average estimated sediment input for the WAU was 1260 tons/square mile/year. Fifty seven percent of all sediment input in the watershed was road related, and when skid trails were included in the analysis, the proportion of sediment input increased to 63% (MRC 2004). MRC collaborated with CDFW, USFWS, and Trout Unlimited on a collaborative restoration program beginning in 2003 that included road improvement, road decommissioning, and instream habitat improvement. Monitoring is ongoing in the Hollow Tree WAU, and is designed to determine if management created mass wasting has been reduced and to determine the effectiveness of erosion control measures on roads and landings.

Surfleet (2007) completed a sediment source analysis for MRC lands in coastal Mendocino (including the Hollow Tree Creek watershed) and Sonoma Counties and determined that 73% of the total sediment input in the last 30-40 years was related to road and skid trail erosion. Thirty percent of the total input was associated with road and skid trail mass wasting, 32% with surface and point source erosion from roads, and 11% with surface and point source erosion from skid trails. At the time this study was completed, MRC had decommissioned approximately 10 miles of streamside logging roads, and was committed to upgrading its entire road network, a process that was expected to take approximately 30 years (Surfleet 2007).

MRC also developed a comprehensive monitoring program to determine whether aquatic habitat and resource conditions are improving as a result of their policies and restoration efforts. From 1998-2012, MRC reported that 993,216 cubic yards of sediment have been prevented from entering streams, and more than 20 million dollars has been contributed by MRC and their funding partners to complete road improvement, road decommissioning, and culvert upgrade or removal projects (http://www.mrc.com/monitoring/forest-and-road-restoration/).

When developing restoration initiatives, NMFS (1996) classified basins with road densities of <2 $mi/mi^2$ with no valley bottom roads as "properly functioning", those with densities of 2-3 $mi/mi^2$ with some valley bottom roads as "at risk", and those with densities of >3 $mi/mi^2$ with many valley bottom roads as "not properly functioning". According to this classification system, the Western Subbasin is "not properly functioning", and road rehabilitation projects for both legacy and current roads should be a high priority for managers. Specific road rehabilitation projects will be discussed in the Restoration Projects section of this report.

## Gravel Mining

Gravel mining operations are permitted by the US Army Corps of Engineers (USACE), and SF Eel River operations listed in *Table 12* are authorized under LOP (letter of permission) 2004-1 (USACE 2004). In 1992, the Humboldt County Board of Supervisors appointed the County of Humboldt Extraction Review Team (CHERT) to provide scientific oversight and recommendations on extraction designs for sites on the Mad River, and their role was expanded to include the review of operations on most Humboldt County rivers in 1996. CHERT's recommendations are based on the need to minimize potentially cumulative effects by ensuring that sustainable volumes are harvested, and that site-specific extraction methods protect local habitat (Klein et al. 2011). Annual cross section surveys are used to monitor and evaluate river conditions, and individual operations are reviewed to reduce or eliminate impacts and develop protection/mitigation strategies. Surface Mining and Reclamation Act documents related to gravel mining in the SF Eel River, including CHERT's post extraction reports from 1998-2013 are available at: http://co.humboldt.ca.us/planning/smara/default.asp?inc=slm.

Gravel mining occurs in two relatively isolated locations on four bars in the SF Eel River Basin between Cooks Valley (± RM 50) and Garberville (RM 33.5) (*Table 12*). Sites are located on the banks of the mainstem SF Eel River, which is the dividing line between the Eastern and Western Subbasins.

*Table 12. SF Eel River gravel extraction sites, locations, and lengths. RM = river mile.*

| Gravel Bar Site Name | Location (RM) | Length (ft) |
|---|---|---|
| Cook's Valley | Humboldt/Mendocino County line (49.5) | 809 |
| Home Bar | Garberville (34.0) | 1218 |
| Tooby Park Bar | Garberville (34.0) | 2097 |
| Wallan and Johnson Bar | Between Redway and Garberville (33.5) | 1854 |

Two of these sites are located southwest of Garberville at Tooby Park (*Figure 27*). The total extracted volume at all SF Eel River sites from 1997 to 2010 averaged 49,578 cy per year, and ranged from a high of 75,900 cy in 1999 to a low of 24,833 cy in 2008 (*Table 13*). Extracted totals averaged 71% of the annual percent approved, ranging from 110% in 1997 to 38% in (Klein et al. 2011). The average extracted volume for the SF Eel River is relatively low compared to other north coast streams (*Table 14*). The Lower Eel River had the highest average extracted volume per year (198,923 cy), followed by the Mad River (149,300 cy) and Van Duzen River (107,580 cy). The percent extracted versus percent approved each year ranged from a high of 91% for the Mad River to a low of 64% on the Lower Eel River. The average volume extracted from the Lower Eel River is more than four times the volume extracted from the South Fork, and the amount extracted would have been more than six times greater if the approved volume had been removed from the Lower Eel River sites.

*Figure 27. Two gravel mining operations at Tooby Park, near Garberville, in the SF Eel River Western Subbasin.*

*Table 13. SF Eel River Annual Extraction (1997-2010) (Klein et al. 2011).*

| Year | Recommended Volume (cy) | Extracted Volume (cy) | Percent of recommended volume extracted |
|---|---|---|---|
| 1997 | 67,700 | 74,700 | 110% |
| 1998 | 75,400 | 70,100 | 93% |
| 1999 | 85,400 | 75,900 | 89% |
| 2000 | 75,700 | 53,700 | 71% |
| 2001 | 66,000 | 43,100 | 65% |
| 2002 | 58,163 | 48,122 | 83% |
| 2003 | 87,060 | 54,660 | 63% |
| 2004 | 80,730 | 50,745 | 63% |
| 2005 | 82,770 | 36,480 | 44% |
| 2006 | 92,000 | 35,075 | 38% |
| 2007 | 90,737 | 73,956 | 82% |
| 2008 | 32,358 | 24,833 | 77% |
| 2009 | 40,170 | 24,986 | 62% |
| 2010 | 42,864 | 27,732 | 65% |
| Totals | 894,018 | 641,371 | 72% |
| **Average** | **69,789** | **49,578** | **71%** |

Gravel mining can have serious impacts on stream channels, with possible effects including:

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

These effects on stream channels can also influence 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 et al. 2000). 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 migration, and creating the potential for fish entrapment (Packer et al. 2005).

Additional impacts to salmonids can occur due to destruction of riparian zones, decreased food (macroinvertebrates) in stream channels, and toxic chemical spills that could occur during mining activities (Packer et al. 2005). Increased stream temperatures due to gravel mining activities that result in shallowing or reduced pool habitat and decreased riparian cover may also adversely affect adult and juvenile salmonids (Spence et al. 1996). The USACE (2004) recognized that the SF Eel River sites provided habitat for Chinook, coho salmon, and steelhead (particularly spawning habitat for Chinook), and recommended the use of alternative extraction techniques such as horseshoe extractions, wetland pits, trenches, and dry trenches, as opposed to traditional skimming techniques. Extraction methods currently used at SF Eel River sites include wide offset and shoreline skim, and wet trench (Klein et al. 2011).

*Table 14. Historical extraction volume summaries for selected rivers in Humboldt County from 1992 - 2010. Mad River data from 1992-2010; all other river data from 1997-2010 (Klein et al. 2011). cy = cubic yards.*

| River | | Approved volume (cy) | Extracted volume (cy) | Percent extracted vs approved |
|---|---|---|---|---|
| South Fork Eel River | Total (all years) | 894,018 | 641,371 | 72% |
| | Average (annual) | 69,789 | 49,578 | 71% |
| Lower Eel River | Total | 3,923,757 | 2,489,719 | 63% |
| | Average | 311,531 | 198,923 | 64% |
| Middle Eel River | Total | 1,013,087 | 744,292 | 73% |
| | Average | 72,363 | 53,164 | 73% |
| Van Duzen River | Total | 1,968,094 | 1,362,964 | 69% |
| | Average | 165,162 | 107,580 | 65% |
| Mad River | Total | 3,037,319 | 2,751,126 | 91% |
| | Average | 164,814 | 149,311 | 91% |
| Trinity River | Total | 570,437 | 397,368 | 70% |
| | Average | 42,936 | 28,504 | 66% |

## Water Use: Diversions and Hydrologic Disturbances

### Diversions

Water sources in the Western Subbasin include both groundwater and surface water. Groundwater is part of a dynamic flow system that moves into and through aquifers from areas of high water-level elevation to areas of low water-level elevation (NC DWR, available at: http://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/Interaction/). Surface water and streamflow is influenced by precipitation, and by the interaction between surface water and groundwater. The interaction of groundwater and surface water is affected by the interchange of local and regional ground-water flow systems with the rivers and by flooding and evapotranspiration (Winter et al. 1998). Groundwater-level fluctuations due to aquifer storage changes involve either the addition or extraction of water from the aquifer, both through natural means and human involvement.

Water rights are defined as “the legal entitlement authorizing water to be diverted from a specified source and put to beneficial, nonwasteful use” (SWRCB 2013). There are many types of water rights in CA, including: appropriative (for commercial use), registered (for small domestic or livestock use), and riparian (for use on land adjacent to the water body). Appropriative rights require an application, environmental review, public notification, permit issuance, and finally licensing, providing “beneficial use” of the requested amount has been demonstrated. Registered users divert water from streams for use in non-riparian areas, and are permitted to use a specific amount of water. Riparian rights have a higher priority than appropriative rights, and there are no required permits, licenses, or government approvals. Riparian rights apply to water that would naturally flow in the stream, and users are not entitled to divert water for storage, for use during the dry season, or to use on land outside the watershed (SWRCB 2013). Beginning in 2010, riparian users were required to file a statement of use with the SWRCB, but few have complied and the magnitude of the diversions and the impact on fish and wildlife in the Western Subbasin remains unknown. For more information on water rights and diversions, go to: http://www.calsalmon.org/srf-projects/water-rights-education.

Most water rights in the Western Subbasin are for direct diversions, and diverted water is used for municipal and domestic purposes, irrigation, fire protection, recreation, and stock watering. The Western Subbasin contains the fewest permitted diversions and the smallest amount of diverted water of the three SF Eel River subbasins. There are only 3 licensed, permitted, or pending water rights within the Western Subbasin, with a maximum total diversion of 47 acre feet/year (afy) (*Table 15*). In addition to these diversions, there are 11 diversions, with a maximum total diversion of 1,404 afy, located along the mainstem SF Eel River, which is the dividing line between the Eastern and Western subbasins. *Table 15* does not include riparian users

*Table 15. Water rights in the SF Eel River Western Subbasin.*

| Creek | Application Number | Direct Diversion | Maximum Application Direct Diversion | Diversion Storage | Purpose |
|---|---|---|---|---|---|
| UNST, Redwood Creek | A010198 | 12,000 gpd | 13.4 afy | | Domestic and irrigation |
| Durphy Creek | A014652 | 0.046 cfs | 33.3 afy | | Standby emergency domestic and fire protection |
| Connick Creek | A025864 | 1600 gpd | 0.1 afy | | Domestic |
| **TOTAL (n = 3)** | | | **46.8 afy** | | |
| **On boundary line between Eastern and Western subbasins (Mainstem SF Eel)** | | | | | |
| SF Eel River | A005317 | 0.15 cfs | 41.4 afy | | Domestic and irrigation |
| SF Eel River | A009686 | 0.155 cfs | 112.2 afy | | Municipal |
| SF Eel River | A011876 | 0.223 cfs | 161.5 afy | | Domestic |
| SF Eel River | A016088 | 0.14 cfs | 34.2 afy | | Irrigation (2 sites) |
| SF Eel River | A023691 | 0.337 cfs | 81 afy | | Irrigation, domestic, stock watering |
| SF Eel River | A023017 | 1.05 cfs | 441 afy | | Municipal and domestic (use by 12/1995) |
| UNSP, SF Eel River | A023018 | 0.123 cfs | 52 afy | | Municipal and domestic (use by 12/1989) |
| UNST (AKA Marshall Creek) | A025436 | 0.04 cfs | 13.5 afy | | Domestic |
| UNSP, Rancheria Creek | A025693B | 420 gpd | 0.1 afy | | Domestic |
| SF Eel River | A029329 | | 37.5 afy | | Industrial and mining (use by 12/1997) |
| SF Eel River | A029981 | | 430 afy | | Municipal (use by 12/1999. 2 sites) |
| **TOTAL (n = 11)** | | | **1404.4 afy** | | |

and other diversions that are not registered with the State Division of Water Rights, including illegal diversions for domestic use and industrial marijuana grow operations.

## Water Drafting for Dust Abatement

The following section is based on information provided by the North Coast Regional Water Quality Control Board (NCRWQCB) in June of 2014 (J. Burke, Senior Engineering Geologist, Southern Timber Unit, NCRWQCB, personal communication 2014).

Water is used for dust abatement/sediment control on timber company roads throughout Humboldt and Mendocino counties between May 15th and October 15th. Timber companies draw water from streams near active harvest operations and apply it to unpaved roads to maintain safety and visibility, minimize input of fine sediment to adjacent streams, and to maintain infrastructure. The amount of water used may be substantial at a time when stream flow is already low. Estimates for the amount of water used each harvest season range from 2,000 to 4,000 gallons/mile/day (treating two times each day). Quantities vary depending on the volume of traffic, road surface, exposure/aspect (east side roads tend to be drier and require more treatment than west side roads), and the use of additional treatments such as magnesium chloride, which may reduce the amount of water required by approximately 50%. It is difficult to make generalizations about the amount of water used, but one timber company with approximately 400,000 acres located in Northwestern California estimated an annual use of two million gallons for dust abatement.

Regulations and limitations currently exist for surface water drafting, including the following:

- Lake and Streambed Alteration Agreements – any landowner that is drafting water must notify CDFW and develop a Streambed Alteration Agreement. These agreements generally contain requirements pertaining to water depth, bypass stream flow, and stream velocity. However, there are no consistent region- or state-wide standards regarding the specific conditions of these agreements;

- Anadromous Salmonid Protection (ASP) Rules – these stipulate the following conditions:
    - Bypass flows during drafting shall be at least 2 cubic feet per second;
    - Diversion rates are limited to 10 percent of surface flow; and
    - Pool volume reduction shall not exceed 10 percent.
- Board of Forestry Emergency rules for water drafting – these require users to comply with CDFW Streambed Alteration Agreements, but do not include specific recommendations for bypass flows;
- Statement of Water Diversion and Use – these are required by the State Water Board for all individuals or organizations that divert surface water or pump groundwater. Beginning January 1, 2012, users are required to measure and report the amount of water diverted each month.

Until recently, the amount of water used and the timing and location of withdrawals has not been carefully documented by industrial timber companies. Drought conditions in California, which are expected to persist through the 2014 logging season, will result in reduced water availability in areas throughout the SF Eel River watershed. In February 2014, staff from timber harvest review agencies including CDFW, CalFire, State and Regional Water Quality Control Boards, and the California Geologic Survey met to discuss water drafting on industrial timber harvest lands, limitations associated with these activities that further reduce instream flows, and the impacts of these activities in relation to current drought conditions. The interagency group developed a list of actions that could be developed to ensure the efficient use of water for dust control, including the following:

- Investigate current scope of use by requesting information from large landowners in an effort to quantify amounts used and specific data available on withdrawal locations and applications. This information will be used to determine if current use is significant to warrant changes in practices;
- Education and outreach to address efficient water use and alternatives to current drafting methods;
- Establish a list of best management practices (BMPs) to present in timber review correspondence;
- Develop regulatory solutions and recommendations; and
- Evaluate prudent use of alternatives to water for dust abatement, especially in areas with existing high industrial or agricultural runoff rates.

Existing ASP rules and regulations specifying minimum bypass flows and diversion rates may be adequate to minimize the impacts to water supplies solely from water drafting for industrial timber harvest operations in most situations. However, additional regulations/actions may be required in watersheds throughout the SF Eel River Basin where significant volumes are already diverted in response to high water demands from industrial marijuana cultivation and residential use.

### Industrial Marijuana Agriculture

The permitted water diversions discussed above do not include illegal diversions from the recent proliferation of industrial marijuana agricultural operations in the SF Eel River Basin. During the late 1960s and early 1970s, a large influx of "back to the landers" came to the SF Eel River Basin in search of an independent, peaceful, and rural lifestyle (USBLM et al. 1996). With the decline of the timber and fisheries industries, also in the 1970s, the local economy began to dwindle. With favorable climate conditions and available land, back to the landers, displaced forest workers, and successive generations of homesteaders turned their ingenuity and agricultural talents to cultivating marijuana to accommodate the rising demand both locally and throughout the state. Mendocino and Humboldt Counties are home to the largest marijuana growing operations in the state, and these operations are increasing in both size and number, with a corresponding increase in local revenue currently accounting for nearly two-thirds of Mendocino County's economy (Evers 2010).

Since the passage of Proposition 215 in 1996 and SB420 in 2003 in California, CDFW field staff, local law enforcement agencies, and other state and federal agency representatives have discovered increasing numbers of large marijuana grows on private lands, presumably for medical purposes.

During an August 29th, 2012 flight over several watersheds in the SF Eel River Basin, Third District Supervisor Mark Lovelace and CDFW staff observed many growing operations that showed evidence of illegal and unpermitted clearcutting, road building, and water diversion (S. Bauer, CDFW, personal communication 2013, www.arcataeye.com). In the Salmon Creek and Redwood Creek watersheds (*Figure 28*, *Figure 29*), two coho salmon strongholds in the SF Eel River Basin, CDFW Environmental Scientist Scott Bauer used satellite photography to assess the number of indoor and outdoor grows, then estimated the number of plants grown in greenhouses, and the total amount of water necessary to supply these operations during each growing season (Easthouse 2013).

Bauer identified 567 grows (281 outdoor and 286 indoor/greenhouse) in the Salmon Creek drainage and 549 grows (226 outdoor and 323 indoor) in the Redwood Creek watershed (*Figure 28*, *Figure 29*). The total number of plants estimated to be associated with these grow operations was: 20,000 (8,700 in greenhouses and 11,300 outdoors) in Salmon Creek; and 18,500 (8,100 in greenhouses and 10,400 outdoors) in Redwood Creek. Bauer estimated that grow operations in Salmon Creek are consuming more than 18 million gallons of water per growing season and more than 16.5 million gallons per season in Redwood Creek. This usage during the growing season is nearly 30% of the total streamflow in these basins (Easthouse 2013). Although Salmon Creek is located within the boundaries of the Northern Subbasin, information on grows in this watershed was included in this section because it demonstrates how marijuana cultivation impacts local watersheds throughout the SF Eel River Basin, particularly in those with high percentages of residential land use.

CWPAP staff documented extremely low flow conditions in Redwood Creek (Redway) in August and September, 2013, as part of a study designed to compare conditions in SF Eel River streams that were heavily diverted with those that were not heavily diverted. Low flow conditions resulted from limited rainfall in the winter and spring of 2012-2013 and an increase in the number of diversions due to extensive marijuana cultivation operations (*Figure 29*). Other Western Subbasin streams that were affected extensively by diversion were Twin, Sproul, Little Sproul, Jack of Hearts, and Little Charlie (*Figure 30*) creeks. Flows decreased dramatically during the study, due primarily to active diversions supplying water to grow operations throughout the watershed. For a full description of the CDFW study and other low flow projects and results, see the Flow section of this subbasin report.

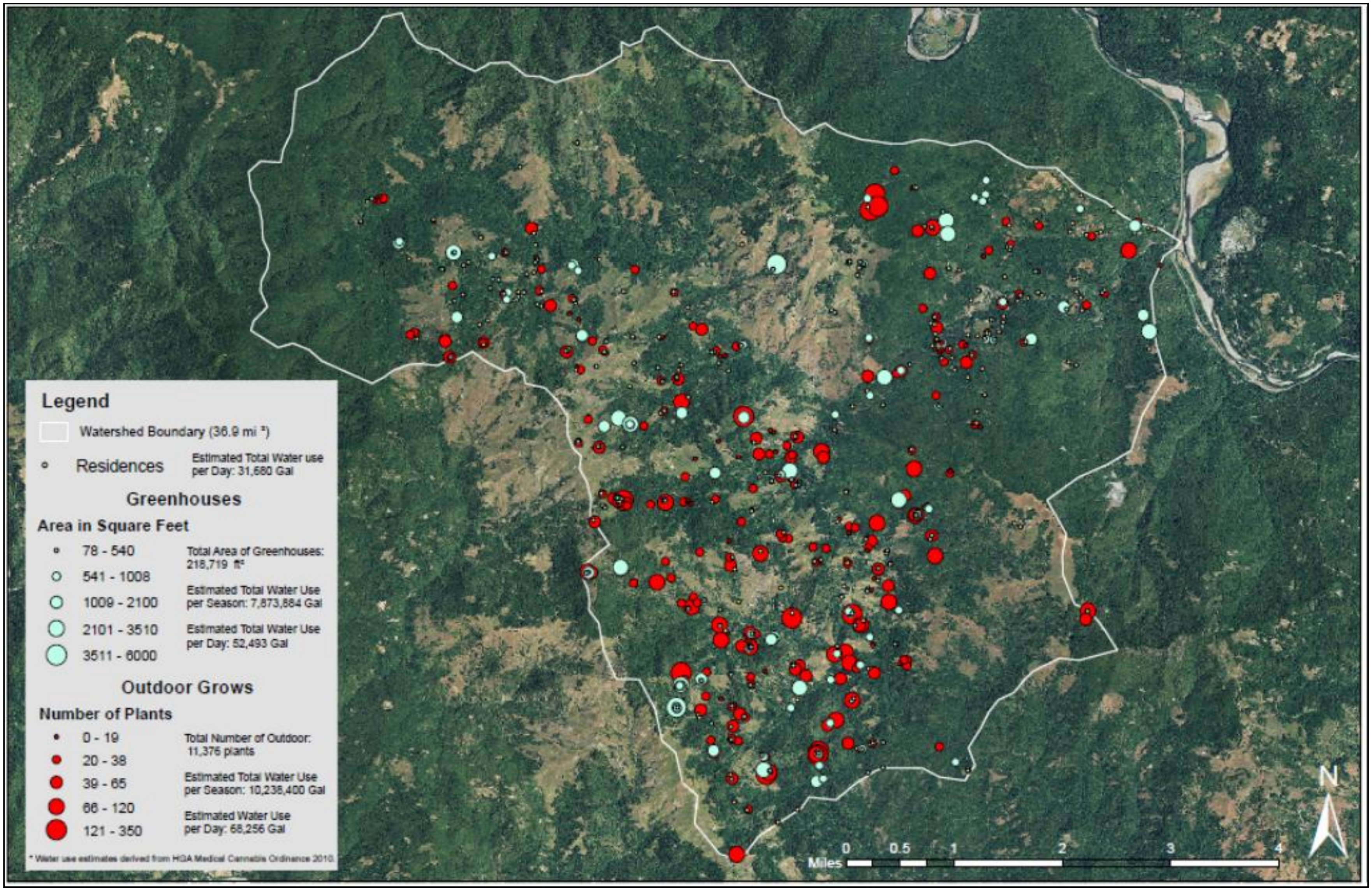



*Figure 28. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Salmon Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW, 2013).*

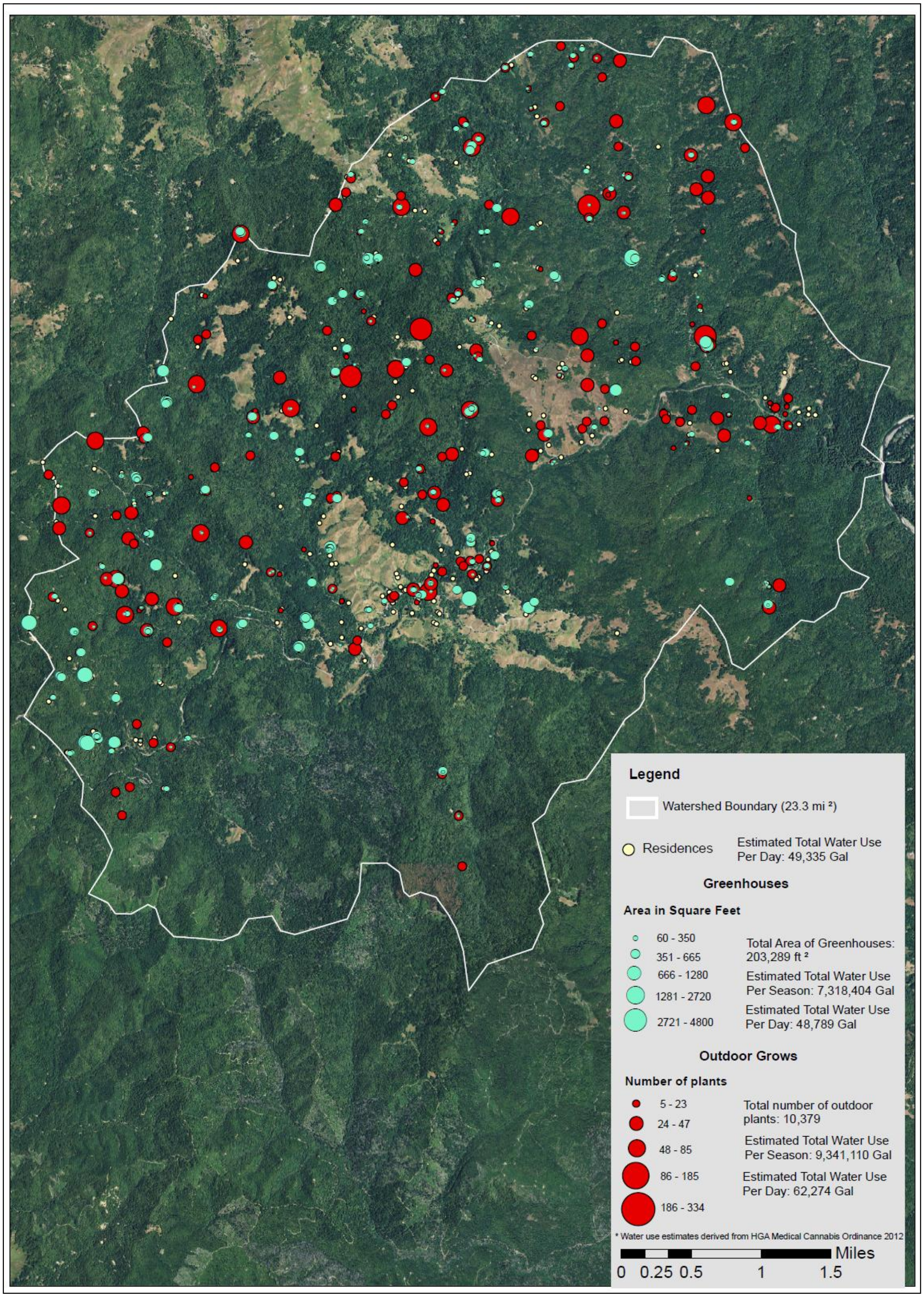



*Figure 29. Marijuana cultivation operations from satellite images, with estimated total water use by cultivation type in Redwood Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW, 2013).*

*Figure 30. Dry streambed in Little Charlie Creek, September 2013.*

While numerous factors may be relevant (wet spring vs dry spring, overall summer temperatures, etc.), a 10,000 square foot outdoor marijuana grow operation uses approximately 250,000 gallons of water in a five-month growing season (T. LaBanca, CDFW, personal communication 2012). Considering the number of outdoor and indoor operations within the watershed, this industry is having a significant effect on water flows in the SF Eel River and its tributaries. A recent trend has emerged that shows atypical low flows occurring during the late summer to early fall even during wet weather years (T. LaBanca, personal communication 2012). *Figure 31*, *Figure 32*, and *Figure 33* illustrate this potential trend using flow data from the USGS SF Eel River gauging stations near Miranda (RM 17), Leggett (RM 66, located in the Western Subbasin), and Bull Creek (4 miles up Bull Creek from the confluence of the mainstem SF Eel River). Daily mean discharge (in cfs) for the 2011-2014 water years was plotted along with the median daily statistic (73-year flow average for the Miranda gauge, 40-year flow average for the Leggett gauge, and 52-year flow average for the Bull Creek gauge). 2011 was considered a wet weather year, with above average rainfall throughout Northern California, and 2012 and 2013 were considered a dry years, with less than normal rainfall received. *Figure 31* shows a slight decrease in low flows in September and October 2011 at Miranda compared to the 73 year average, and significantly lower discharge from July through November 2012 and July through December 2013, continuing into January 2014, when compared to the 73 year average.

*Figure 32* shows slightly lower flows in September and October 2011 and considerably lower flows in August, September, and October 2012 and 2013 compared to the 40-year average at Leggett. *Figure 33* shows much lower flows in September and October 2011 and 2012, and for nearly all of 2013, compared to the 52-year average flows recorded at the Bull Creek gauge. These atypical low flows (especially during normal water years) support the contention that water diversions by the marijuana industry are affecting streams and tributaries throughout the SF Eel River Basin, by contributing to higher water temperatures, reduced stream flow at critical times for fish rearing and migration, and altering water chemistry in the entire basin.

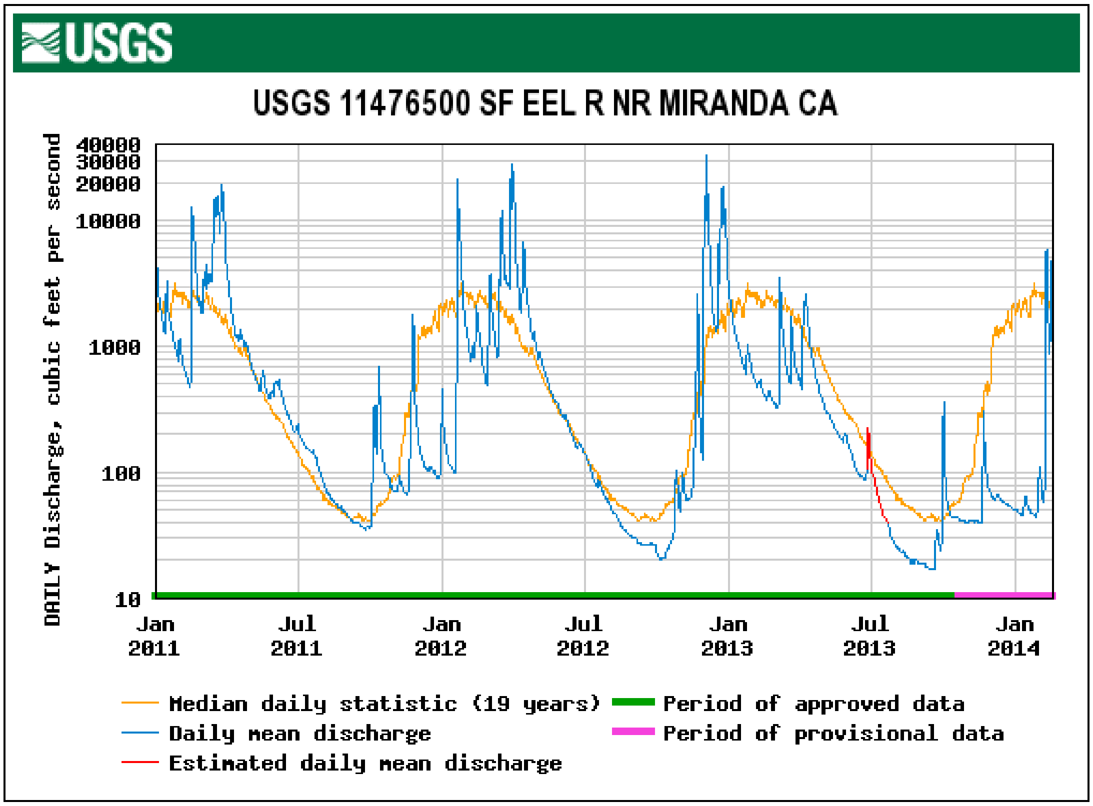



*Figure 31. USGS gauging station near Miranda showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (73-year average in cfs).*

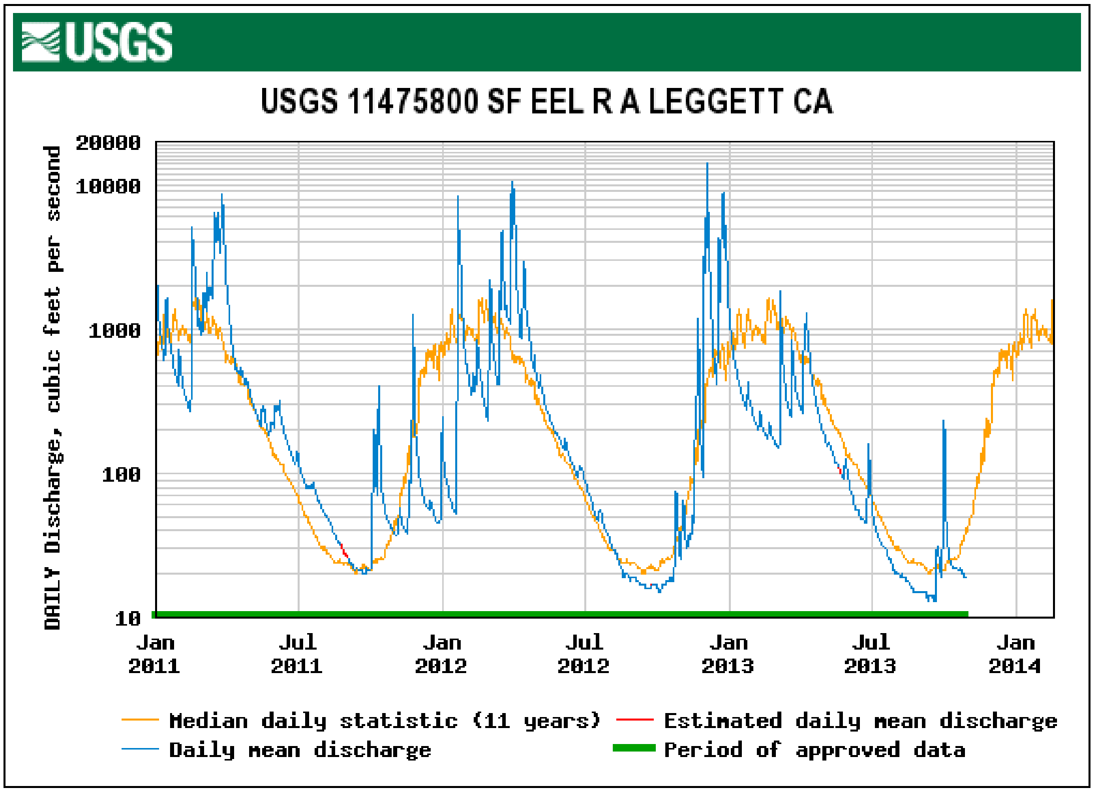



*Figure 32. USGS gauging station near Legett showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (40-year average in cfs).*

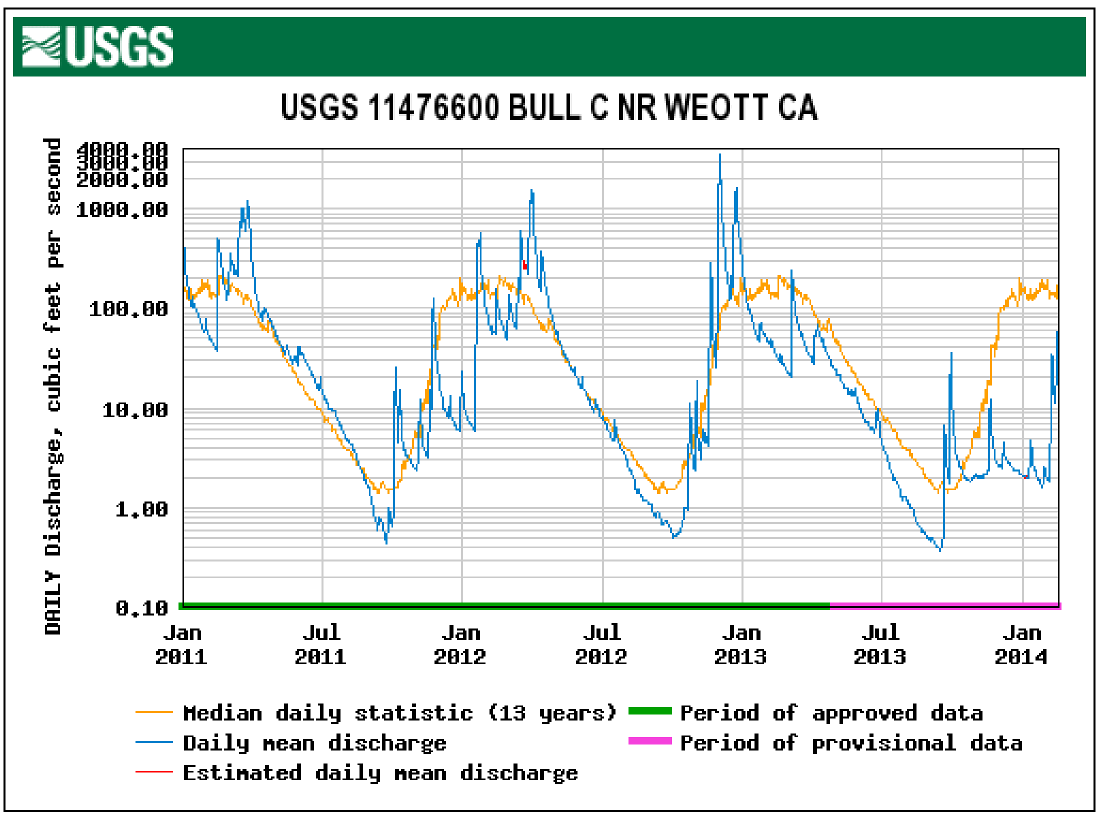



*Figure 33. USGS gauging station at Bull Creek showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (52-year average in cfs).*

Unlike permitted/licensed water diversions and other regulated land use activities such as legal timber harvesting and/or mining operations, there are no established "best management practices" or any review by agencies like CDFW and the state Water Quality Control Board on industrial marijuana grow sites. Therefore, a wide range of impacts to watercourses and their aquatic resources can be associated with these industrial marijuana agricultural operations. These impacts may include the following (CDFW 2012; T. LaBanca, personal communication 2012):

- Illegal water diversions that draw directly from the streams without screens or bypass, so juvenile fish and amphibian can be pulled from their habitat and die;
- Decreased stream flows due to illegal water diversions, leading to reduced stream depths and diminished pool habitat, possible subsurface flow in streams with excessive sediment recruitment, elevated water temperatures, and concentrated pollutants;
- A wide range of pollutants may be used (*Table 16*), including fuel, fertilizers, herbicides, pesticides, rodenticides, and construction debris. These chemicals and debris may go directly into watercourses or could leach into the soil, eventually being released into the water throughout the year;
- Human waste from camps that could also directly enter or leach into watercourses;
- Sediment from improperly constructed roads and construction around grow sites that enters watercourses throughout the rainy season;
- “Grow trash” such as plastic hose, construction supplies, and gardening waste left on site;
- Conversion and fragmentation of natural wildlife habitat and native ecosystems. Riparian and aquatic habitat may be disturbed or removed, grasslands and hillside habitats cleared and leveled; and
- Unpermitted timber harvests that may occur when an area is cleared for an agricultural grow operation.

In addition, there are many pollutants in fertilizers and pesticides that may enter the stream system from grow operations, but one which poses a particular danger to salmonids is copper. Sorenson (1991, in Woody 2007) determined that copper levels below lethal concentrations have the following potential effects on salmonids:

- Interfere with normal migration;
- Impair salmonids’ sense of smell;
- Impair their ability to fight disease;
- Make breathing difficult;
- Impair their ability to sense vibrations through their lateral line canals, which interferes with their ability to avoid predators;
- Impair brain function;
- Change their blood chemistry and metabolism; and
- Modify natural hatch rates.

Additional research is necessary to determine the concentrations of copper entering the SF Eel River system, and to determine the impacts of other pollutants from pesticides and herbicides on salmonids within this system.

There are some exceptions to the poor land-use practices associated with marijuana cultivation listed above. Local residents with small scale cultivation operations seem to employ more care than larger growers who do not live on site, and may not even own the land. A more comprehensive understanding of the magnitude of the impacts of industrial operations, their effects on fish and wildlife, and consumer and grower education leading to regulation is necessary to address these problems (Weiser 2012).

Although there are no established best management practices for marijuana growing, the Northern California Farmers Guide is a community-based collaborative project that outlines concerns and solutions for many of the issues listed above. This guide is an evolving project that is designed to increase awareness of environmental issues and help cannabis growers protect the environment while growing a high quality, sustainably produced crop. For more information, go to: http://www.norcalfarmersguide.org/.

*Table 16. Pollutants associated with marijuana grows and their effects on fish and wildlife (adapted from Greacen 2012).*

| Pollutant | Application | Result |
|---|---|---|
| Rodenticide | Poison is applied to garden and/or perimeter to keep rodents from harming crop. | Wild animal populations are impacted as poison travels up the food chain. Contamination of fresh stream water. |
| Insecticide | Poison is applied to garden and/or perimeter to keep insects from harming crop. | Toxic to native insects as well as fish. |
| Fungicide | Fungicide is applied to plants to keep fungus from harming crop. | Can be toxic to fish and beneficial soil invertebrates. May contain mercury. |
| Fertilizer | Fertilizer and soil amended with potent nutrients are brought to the grow and used liberally for the growing season then discarded. | Nutrients get into the streams causing problematic algal blooms. Used soil/fertilizer is washed into the streams during the rainy season which adds to the sediment load. Typically leads to a reduction of dissolved oxygen in streams. |
| Sediment | Tractor/dozer work on larger grows is implemented, often with little or no regard for good road/landscape practices in regard to site stability and erosion. | Sediment from dozer work (roads, landings, gardens) gets into streams. |
| Reduced flow | Water is taken from a nearby stream by diversion pipe or water truck and used to water crop (individual plants take 3-5 gallons/day). | Evapotranspiration releases most of the water into the atmosphere resulting in a loss of water available to the stream during the driest, hottest part of the year producing extremely low flows downstream of diversion. |

# Fish Habitat Relationship

## Fishery Resources

### Historical Distribution

Fish presence has been documented in the Western Subbasin by anecdotal accounts and observations made during stream surveys since 1938. However, stream survey efforts were neither specific nor standardized until 1991 when the *California Salmonid Stream Habitat Restoration Manual (*Flosi et al. 2010) was published. Most observations in stream surveys are not quantitative and have limited use.

Historical salmonid documentation is available for 50 Western Subbasin streams. Information sources include CDFW carcass surveys, stream survey and inventory reports, electrofishing and general field notes, downstream migrant trapping data, fyke net records, and spawning stock and escapement reports (*Table 17*). Coho salmon were found in 28 of the 50 surveyed streams, mostly in those with low gradient and favorable instream and riparian habitat conditions. Large tributaries to the mainstem SF Eel River with documented historical coho salmon presence included: Hollow Tree, Indian, and Redwood (Redway), and Sproul Creeks. Chinook salmon were documented in 17 Western Subbasin streams, and steelhead in 41 of the 50 tributaries. Nine creeks surveyed had no record of Chinook, coho salmon, or steelhead presence, but unidentified salmonids were observed in five of these streams (Butler, Eagle, Hartsook, Hooker, and Sebbas creeks) (*Table 17*).

*Table 17. Documented fish presence in surveys from 1938 to 2001 in the Western Subbasin.*

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Anderson Creek (tributary to Indian) | 6/19/1968 | Stream Survey (CDFG 1968) | | | X | |
| | April/May 1979 | Stream Survey (CDFG 1979) | X | | X | |
| Bear Pen Creek | 7/11/1968 | Stream Survey (CDFG 1968) | | | X | |
| Bear Wallow Creek | 9/26/1962 | Stream Survey (CDFG 1962) | | | X | |
| Bond Creek | 7/25/1968 | Stream Survey (CDFG 1968) | | | X | |
| | 9/23 - 9/24/1980 | Stream Survey (CDFG 1980) | | | X | |
| | 10/19/1983, 7/16/1987, 7/27/1988 | Electroshocking Survey Summary (CDFG 1988) | | X | X | |
| | 12/12/1988 | Carcass Survey: Field Note (CDFG 1988) | | | | |
| | 10/17/1991 | Stream Inventory Report (CDFG 1991) | | | X | |
| | July, Sept, Oct 1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| Butler Creek | 5/10/1979 | Stream Survey (CDFG 1979) | | | | X |
| | 1/11/1983 | Spawning Stock Survey (CDFG 1983) | | | | |
| China Creek | 6/27/1962 | Field Note (CDFG 1962) | | | | X |
| | 9/5/1966 | Stream Survey (CDFG 1966) | | X | X | |
| | 5/24 - | Stream Survey (CDFG | | | | X |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | 5/26/1982 | 1982) | | | | |
| China Creek (con.) | 11/28, 12/21/1994 | Field Note (CDFG 1994) | | | | |
| | 12/2, 12/11/1997 | Spawner Surveys (CDFG 1997) | X | | | |
| | 2000-2001 | Spawner Surveys (CDFG 1997) | X | X | | X |
| Cox Creek | 1/5/1994 | Field Note (CDFG 1994) | | | | |
| Dinner Creek | 9/1/1966 | Stream Survey (CDFG 1966) | | | X | |
| | 3/20/1985 | Field Note (CDFG 1985) | | | X | |
| | 10/25/1985 | Stream Survey (CDFG 1985) | | | | X |
| | 10/5/1990 | Biological Inventory Field Form (CDFG 1990) | | | X | |
| | 1/5/1993 | Field Note (CDFG 1993) | | | X | X |
| | 2/16/1995 | Field Note (CDFG 1995) | | | | |
| Durphy Creek | 6/25/1938 | Stream Survey (CDFG 1938) | X | X | X | |
| | 1/6/1958 | Stream Survey (CDFG 1958) | X | X | | |
| | 6/8/1961 | Stream Survey (CDFG 1961) | | | | X |
| | 4/1/1968 | Field Note (CDFG 1968) | | | X | |
| | 4/30/1969 | Field Note (CDFG 1969) | | X | X | |
| | 12/28/1987 | Field Note (CDFG 1987) | X | | | X |
| Dutch Charlie Creek | 7/30/1969 | Stream Survey (BLM 1969) | | X | X | |
| | 12/9/1982 - 1/17/1983 | Spawner Survey (CDFG 1983) | X | | | |
| | 9/21-25/1992 | Stream Inventory Report (CDFG 1992) | | X | X | |
| | 9/30/1992 | Stream Inventory Report (CDFG 1992) | | X | X | |
| Eagle Creek | 2/11/1972 | Stream Survey (CDFG 1979) | | | | X |
| Hartsook Creek | 6/13/1961 | Stream Survey (CDFG 1961) | | | | X |
| | 4/8/1981 | Stream Survey (CDFG 1981) | | | | X |
| Haun Creek | 8/22/1969 | Stream Survey (CDFG 1969) | | X | X | |
| Hollow Tree Creek | 5/22/1940 | Stream Survey (CDFG 1940) | X | X | X | |
| | 7/31 and 8/6/1968 | Stream Survey (CDFG 1968) | | X | X | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | 12/12 - 12/13/1979 | Carcass Survey: Field Note (CDFG 1979) | X | X | | |
| Hollow Tree Creek (con.) | 1983, 1986-1989 | Electroshocking Survey Summary (CDFG 1989) | | X | X | X |
| | 1/11/1983 | Salmon Spawning Stock Survey (CDFG 1983) | X | | | X |
| | 1/2 - 1/3/1986 | Carcass Survey: Memorandum (CDFG 1986) | X | X | | X |
| | 1/13 - 1/14/1987 | Salmon Carcass Survey (CDFG 1987) | X | | | X |
| | 2/2 - 2/9/1993 | Carcass Suvey: Field Notes (CDFG 1993) | X | X | | X |
| | 6/28/1993 | Spawning Stock Survey (CDFG 1983) | X | | | X |
| | 1/12 - 1/13/1994 | Carcass Suvey: Field Notes (CDFG 1994) | X | X | | X |
| | 12/30/1994 | Carcass Suvey: Field Note (CDFG 1995) | X | X | | X |
| Hooker Creek | 7/4/1962 | Stream Survey (CDFG 1962) | | | | X |
| Huckleberry Creek | 10/29/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 7/15/1981 | Stream Survey (CDFG 1981) | | | X | |
| | 1/12/1994 | Carcass Survey: Field Note (CDFG 1994) | | | | |
| Indian Creek | 6/18 and 6/25/1938 | Stream Survey (CDFG 1938) | | X | X | X |
| | 8/11/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 1968 | Stream Survey (CDFG 1968) | | | X | |
| | 11/27/1979 | Bid for Andersonia Land (Indian Creek Rehabilitation Project) | X | | | |
| | 12/14/1988 | Salmonid Survey: Field Note (CDFG 1989) | X | | | |
| | 12/14 and 12/22/1988, 1/5, 1/19, 1/24/1989 | Salmonid Survey: Field Note (CDFG 1989) | X | X | | X |
| Jack of Hearts Creek | 7/29/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 2/11/1979 | Stream Survey (CDFG 1979) | | | | X |
| | 10/6/1992 | Stream Inventory Report (CDFG 1992) | | X | X | |
| | 10/6/1992 | Stream Inventory Report (CDFG 1992) | | X | X | |
| | 2001 | MRC Sampling (CDFG email 2002) | | X | | |
| La Doo Creek | 7/6/1961 | Stream Survey (CDFG 1961) | | | | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | 10/15/1992 | Stream Inventory Report (CDFG 1992) | | | | |
| Leggett Creek | 8/11/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 6/20/1962 | Stream Survey (CDFG 1962) | | | | X |
| | 6/21/1973 | Electrofishing Field Note (CDFG 1973) | | | X | |
| | 7/5/1974 | Field Note (CDFG 1974) | | | X | |
| | 8/12/1980 | Stream Survey (CDFG 1980) | | | | X |
| | 7/19/1984 | Stream Survey (CDFG 1984) | | | | X |
| | 6/16/1989 | Electrofishing Field Note (CDFG 1989) | | | X | |
| | 9/29/1992 | Stream Inventory Report (CDFG 1992) | | X | X | |
| | 1994, 1995 | Spawning Survey Summary (CDFG 1995) | | | X | |
| | 7/27/2000 | Electrofishing Field Note (CDFG 2000) | | X | X | |
| Little Charlie Creek | 8/4/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 3/19/1979 | Stream Survey (CDFG 1979) | | | | |
| Little Sproul Creek | 5/22/1940 | Stream Survey (CDFG 1940) | | | X | |
| | 12/1/1981 | Stream Survey (CDFG 1981) | | | | |
| | 3/12/1985 | Stream Survey (CDFG 1985) | | | X | |
| | 6/16/1989 | Electrofishing Field Note (CDFG 1989) | | X | X | |
| | 3/15/1990 | Field Note (CDFG 1990) | | | X | |
| | 2/11/1991 | Field Note (CDFG 1991) | | | X | |
| | 12/23/1992 | Field Note (CDFG 1992) | | X | | |
| | 2/23/1993 | Field Note (CDFG 1993) | | | | |
| | 1/5/1994 | Field Note (CDFG 1994) | | X | X | X |
| | 12/20/1994 - 2/9/1995 | Spawner Survey Summary (CDFG 1995) | X | | X | |
| | 3/30/1995 | Field Note (CDFG 1995) | | | | |
| Little Waldron Creek | 7/30/1968 | Stream Survey (CDFG 1968) | | X | X | |
| Lost Pipe Creek | 7/23/1968 | Stream Survey (CDFG 1968) | | | X | |
| Low Gap | 8/11/1938 | Stream Survey (CDFG | | | X | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Creek | | 1938) | | | | |
| | 7/4/1962 | Field Note (CDFG 1962) | | | X | X |
| | 6/13/1968 | Stream Survey (CDFG 1968) | | | | X |
| | 8/14/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 3/26/1979 | Stream Survey (CDFG 1979) | | | | X |
| | 1/31/1980 | Stream Survey (CDFG 1980) | | | | X |
| | 12/6/1988 | Carcass Survey: Field Note (CDFG 1989) | | | | |
| | 1/4/1989 | Carcass Survey: Field Note (CDFG 1989) | X | | | |
| | 7/20/1995 | Stream Inventory Report (CDFG 1995) | | | X | |
| Lynch Creek | 10/30/1968 | Stream Survey (CDFG 1968) | | | X | |
| Michael's Creek | 7/24/1968 | Stream Survey (CDFG 1968) | | | X | |
| | 7/3/1981 | Stream Survey (CDFG 1981) | | X | X | |
| Middleton Creek | 9/2/1969 | Stream Survey (CDFG 1969) | | | | |
| | 3/11/1979 | Stream Survey (CDFG 1979) | | | | |
| Mill Creek (tributary to SF Eel River) | 7/12/1968 | Stream Survey (CDFG 1968) | | | X | |
| Moody Creek | 6/18/1968 | Stream Survey (CDFG 1968) | | | X | |
| | 4/20/1979 | Stream Survey (CDFG 1979) | | | X | |
| Mule Creek | July 1968 | Stream Survey (CDFG 1969) | | X | X | |
| Parker Creek | 6/17/1968 | Stream Survey (CDFG 1968) | | | X | |
| Piercy Creek | 6/25/1938 | Stream Survey (CDFG 1938) | | X | X | |
| | 6/24/1968 | Stream Survey (CDFG 1968) | | | X | |
| | 9/27 and 9/28/1977 | Stream Survey (CDFG 1977) | | | X | |
| Pollock Creek (Upper Redwood Creek) | 1988-1989 | Spawner Survey Summary (CDFG 1989) | X | X | | |
| | 7/8, 7/9/1998 | Memorandum (CDFG 1998) | | | X | |
| | 9/29/1999 | Field Sampling Report (CDFG 1999) | | X | X | |
| Redwood Creek (Branscomb) | 7/31/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 1/3/1979 | Stream Survey (CDFG | | | | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | | 1979) | | | | |
| Redwood Creek (Branscomb) (con.) | 1/12/1983 | Spawning Stock Survey (CDFG 1983) | X | | | |
| | 12/15/1988 | Carcass Survey: Field Note (CDFG 1989) | X | X | | X |
| Redwood Creek (Hollow Tree) | 7/24/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 12/12/1988 | Carcass Survey Summary (CDFG 1989) | X | X | | |
| | 1/12/1994 | Carcass Survey (CDFG 1994) | | X | | X |
| Redwood Creek (Redway) | 6/12/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 1966 | Fyke Net Record (CDFG 1966) | X | X | X | |
| | 9/7/1966 | Stream Survey (CDFG 1966) | | X | X | |
| | 1/7/1969 | Spawner Survey Field Note (CDFG 1969) | X | | | |
| | 1/5 - 1/6/1971 | Field Note (CDFG 1971) | X | X | | |
| | 7/20 - 7/31/1984 | Stream Survey (CDFG 1984) | | X | X | |
| | 1983-1990 | Trap Summary (CDFG 1990) | X | X | X | |
| | 1984-1985 | Spawner Survey Summary (CDFG 1985) | X | X | | X |
| | 1985-1986 | Spawner Survey Summary (CDFG 1986) | X | | | |
| | 1986-1987 | Spawner Survey Summary (CDFG 1987) | X | X | | |
| | 1987-1988 | Spawner Survey Summary (CDFG 1988) | X | X | | |
| | 1988 | Downstream Migrant Trapping Notes (PCFFA 1988) | X | X | X | |
| | 9/11/1989 | Electrofishing Field Note (CDFG 1989) | | X | X | |
| | 1989-1990 | Field Note (CDFG 1990) | X | X | X | |
| | 1990-1991 | Spawner Survey Summary (CDFG 1991) | X | | | |
| | 1/17/1991 | Streamwalk Information (CDFG 1991) | | | | |
| | 8/24/1993 | Population Estimate Field Note (CDFG 1993) | | X | X | |
| | 9/1/1993 | Stream Inventory Report (CDFG 1993) | | X | X | |
| | 1994-1995 | Field Notes (CDFG 1994-95) | | | | |
| | 8/12/1994 | Electrofishing Field Note (CDFG 1994) | | X | X | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | 8/23/1995 | Electrofishing Field Note (CDFG 1995) | | X | X | |
| Redwood Creek (Redway) (con.) | 7/3/1996 | Field Note (CDFG 1996) | | X | X | |
| | 1999-2000 | Spawner Survey Summary (CDFG 2000) | X | X | | X |
| Sawmill Creek | 3/30/1939 | Stream Survey (CDFG 1938) | X | | X | |
| | 7/5/1961 | Stream Survey (CDFG 1961) | | | | X |
| | 4/21/1981 | Stream Survey (CDFG 1981) | | | | X |
| Sebbas Creek | 3/23/1979 | Stream Survey (CDFG 1979) | | | | X |
| Section Four Creek | 9/2/1969 | Stream Survey (CDFG 1969) | | | X | |
| | 1/30/1979 | Stream Survey (CDFG 1979) | | | | |
| Seely Creek | 6/11/1961 | Stream Survey (CDFG 1961) | | | | X |
| | 9/22/1966 | Stream Survey (CDFG 1966) | | X | X | |
| | 1/19/1967 | Field Note (CDFG 1967) | X | | | |
| | 1/25/1968 | Field Note (CDFG 1968) | X | | | |
| | 1/7/1969 | Field Note (CDFG 1969) | X | | | |
| | 1/31/1969 | Field Note (CDFG 1969) | X | | | |
| | 1/6/1971 | Field Note (CDFG 1971) | X | | | |
| | 1989 | Downstream Migrant Trapping Summary (PCFFA 1989) | X | X | X | |
| Sommerville Creek | 8/1/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 9/25/1966 | Stream Survey (CDFG 1966) | | | X | |
| Sproul Creek | 1963-2001 | Spawning Stock Summary Tables, Electrofishing Suumaries (CDFG) | X | X | | X |
| Standley Creek | 6/27 - 7/1/1968 | Stream Survey (CDFG 1968) | | | X | X (possibly coho salmon) |
| | 5/10 - 5/11/1976 | Stream Survey, Electrofishing (CDFG 1976) | | X | X | |
| | 7/27 - 7/28/1977 | Electroshocking Memorandum (CDFG 1977) | | | X | |
| | 1/11/1983 | Spawning Stock Survey (CDFG 1983) | | | | X |
| Surveyors | 1975 | Stream Survey (BLM | | | | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Canyon | | 1975) | | | | |
| Thompson Creek | 3/11/1979 | Stream Survey (CDFG 1979) | | | | |
| Waldron Creek | 9/27/1988, 9/15/1989 | Electroshocking Survey Summary (CDFG 1989) | | X | X | |
| | 1/12/1994 | Carcass Survey (CDFG 1994) | | | | |
| Warden Creek | 7/5/1961 | Stream Survey (CDFG 1961) | | | X | |
| | 12/23/1992 | Field Note (CDFG 1992) | | X | | |
| | 10/7/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| West Fork Sproul Creek | 1987-1996 | Electrofishing Field Notes (CDFG 1987-1996) | | X | X | |
| | 9/13/1999, 4/7/2000, 8/30/2001 | Field Notes (CDFG 1999, 2000, 2001) | X | X | X | |
| Wildcat Creek | 7/15/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 1/5/1983 | Spawning Stock Survey (CDFG 1983) | X | | | |

There is one long-term salmon and steelhead data set for the Western Subbasin, with data collected at the CDFW fish ladder at Benbow Dam, located at approximately RM 40 on the mainstem SF Eel River near Garberville. Counts were conducted between 1938 and 1975, and they show more than an 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the span of the last century (*Figure 34*). Linear regression lines for all three species show significant declines in abundance, and it is likely that salmonid populations throughout the SF Eel River Basin declined similarly during this time period.

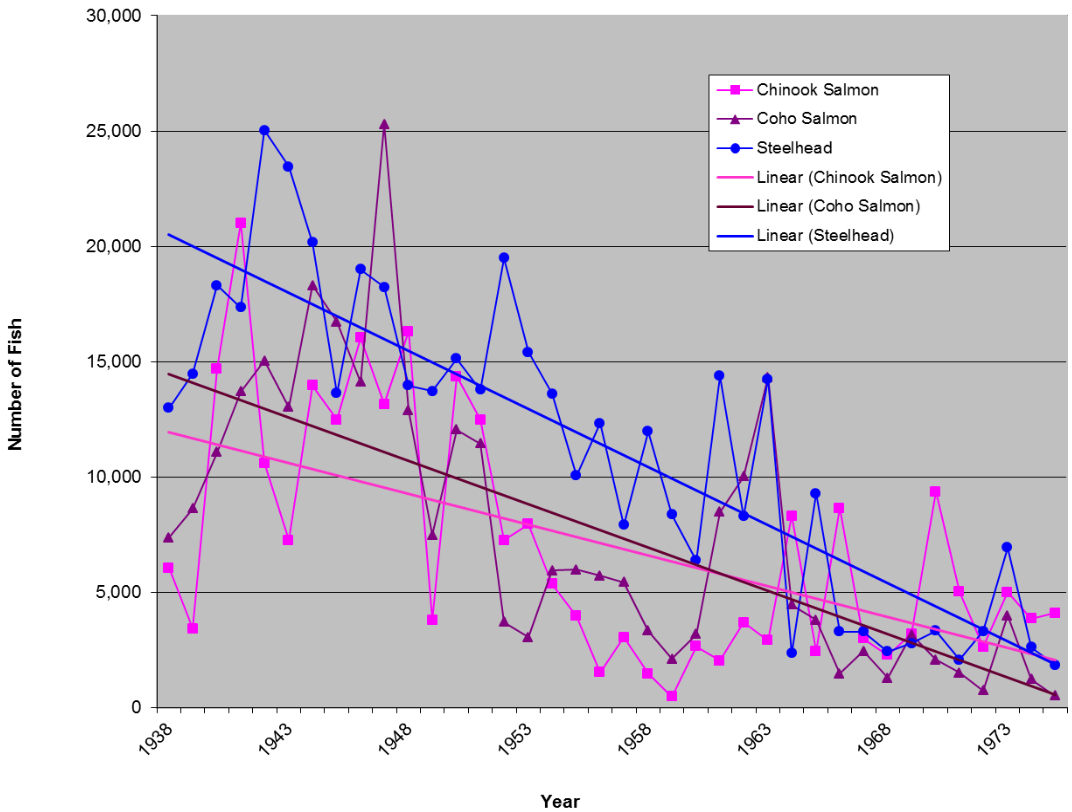



*Figure 34. Counts of migrating Chinook salmon, coho salmon, and steelhead at the Benbow Dam fish ladder between 1938 and 1975. Regression lines for all three species show declines over time.*

## Current Distribution

Current estimated Chinook salmon, coho salmon, and steelhead distributions were based on data collected from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) and compiled by the Pacific States Marine Fisheries Commission (PSMFC). Data are available on the CalFish website at: [http://www.calfish.org/Programs/ProgramIndex/AnadromousFishDistribution/tabid/184/Default.aspx](http://www.calfish.org/Programs/ProgramIndex/AnadromousFishDistribution/tabid/184/Default.aspx).

CalFish data is observation-based, meaning that any recorded observation is collected, verified, evaluated, and applied to standard hydrography to develop a linear GIS layer. These layers are overlaid onto local watershed polygons (Calwater Planning Watersheds) to determine distribution ranges, assuming that target species can be found anywhere downstream from the observation point. Distribution layers differ slightly by species:

- Chinook distribution was developed using CDFW reports and the NOAA National Marine Fisheries Service GIS layer, which uses CDFW and PSMFC stream based routed hydrography. This layer was updated in June 2005;
- Coho salmon distribution was developed using CDFW reports and the CalFish observation-based distribution, and was updated in June 2012;
- Steelhead distribution was developed using CDFW reports and the CalFish steelhead distribution layer, and was last updated in June 2012.

Final maps were reviewed by CDFW fishery biologists and distribution lines were added or removed where known distribution was different than gradient and observation-based information. Salmonids in the SF Eel River Basin may be present in areas where they have not been documented due to a lack of data, landowner access issues, or inadequate sampling techniques.

Proportionally, in terms of total number of streams and stream miles, the Western Subbasin contains more documented fish presence than Northern or

Eastern Subbasin streams (*Table 18*), due in part to favorable instream conditions. The Western Subbasin is strongly influenced by the coastal marine layer and defined by morning fog and overcast conditions, which supports coniferous and hardwood forest vegetation. These moderated air temperatures and shady conditions result in cooler summer water temperatures and lush riparian vegetation in Western Subbasin streams, in contrast to the inland Eastern Subbasin where the climate is very hot and dry, and stream temperatures are often unsuitable for Chinook and coho salmon.

*Table 18. Number of tributary streams and approximate number of stream miles currently occupied by anadromous salmonids in SF Eel River Basin and subbasins.*

| **Subbasin** | **Number of Tributaries** | **Total mainstem miles/tributary miles** | **SFER mainstem miles currently used by anadromous salmonids*** | | | **Number of SFER tributaries/miles currently used by anadromous salmonids** | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Chinook** | **Coho** | **Steelhead** | **Chinook** | **Coho** | **Steelhead** |
| **Northern** | 109 | 23 / 190 | 23 | 23 | 23 | 14 / 27 | 8 / 13 | 23 / 50 |
| **Eastern** | 167 | 82 / 360 | 80 | 79 | 80 | 27 / 82 | 17 / 25 | 44 / 130 |
| **Western** | 175 | 82 / 312 | 80 | 79 | 80 | 44 / 86 | 34 / 99 | 53 / 128 |
| ***** Mainstem SFER is dividing line between Western and Eastern subbasins; mainstem mileage is counted in both Eastern and Western Subbasin totals. | | | | | | | | |

In the SF Eel River Basin coho salmon have the most limited distribution of all three salmonid species. However, in the Western Subbasin, coho salmon have been documented in 34 tributaries (more than Northern and Eastern subbasins combined) and with generally lower gradients allowing for easier access, they are also found further upstream in Western Subbasin streams than in Northern and Eastern Subbasin tributaries. Western Subbasin tributaries with extensive coho salmon distribution included Redwood (Redway), Sproul, Indian, and Hollow Tree creeks; many tributaries to these larger creeks also had documented coho presence (*Figure 35*).

Chinook salmon have been documented in 44 Western Subbasin streams. Many of these also have coho salmon present, but Chinook are also found in some tributaries to the mainstem SF Eel River with little or no coho salmon presence (e.g. Sawmill, Bear Pen, and Wildcat Creeks).

Steelhead trout are the most widely distributed of the three species, documented in 53 Western Subbasin streams, and are generally found further upstream and in more tributaries than either Chinook or coho salmon (*Table 18*). Steelhead and Chinook have been documented in a similar number of miles of tributary streams in the Eastern and Western subbasins, but they are found in a greater number of tributaries throughout the Western Subbasin.

Both SF Eel River coho salmon and steelhead were selected as “salmon strongholds”, which represent the healthiest wild Pacific salmon populations remaining, and recognize the high value of the habitats occupied by these populations (Wild Salmon Center 2012). Identification of these strong populations is part of a larger conservation effort to complement recovery efforts for salmonids throughout the state. Hollow Tree Creek is particularly important for both coho salmon and steelhead due to high quality habitat and healthy, well-established populations. Land use in this drainage is primarily industrial timber harvest, and most of the land in the Hollow Tree Creek watershed is owned by Mendocino Redwood Company (MRC). Lower Hollow Tree Creek, from the confluence with the SF Eel River upstream to RM 6.3, is used primarily as a migration corridor and is located on Hawthorne Timber Company land. MRC’s (2004) potential salmonid distribution is consistent with CWPAP current salmonid distribution in this watershed.

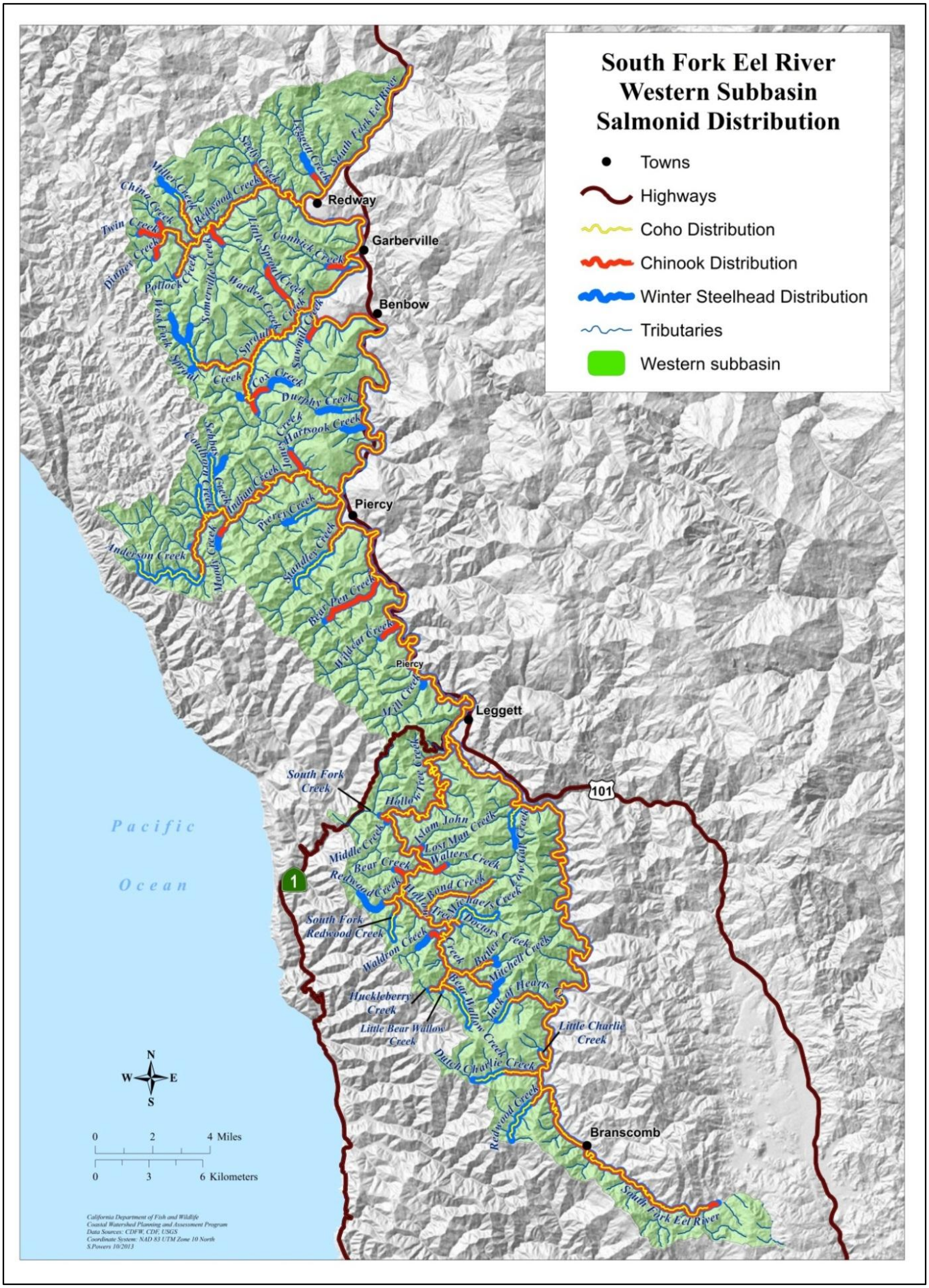



*Figure 35. Coho salmon, Chinook salmon, and steelhead trout distribution in SF Eel River Western Subbasin streams.*

In addition to salmonids, other native freshwater fish that have been observed in the Western Subbasin include rainbow trout, pacific lamprey, coastrange sculpin (Brown and Moyle 1997, Stillwater Sciences 2010), Sacramento sucker, California roach, and three-spine stickleback (MRC 2004). Invasive species present include Sacramento pikeminnow (*Figure 36*), which have been detected in the mainstem SF Eel River and many of its tributaries (Nakamoto and Harvey 2003). Pikeminnow abundance is increasing and their distribution is expanding due to the species' high tolerance for warm water and low flow conditions, which have become more prevalent throughout the mainstem SF Eel River Basin in recent years. However, Western Subbasin streams are generally cooler than those in the Eastern Subbasin, so pikeminnow are most likely less abundant and present in fewer streams throughout this subbasin.

*Figure 36. Juvenile pikeminnow in the mainstem SF Eel River.*

## CDFW Spawning Ground Surveys

Data on the number of spawning Chinook salmon, coho salmon, and steelhead trout have been collected in SF Eel River streams using two different approaches: index reach sampling (2002 to present) and California Coastal Salmonid Population Monitoring (CMP) program techniques (2010 to present). These methods differ in sampling frequency and intensity, and in the applicability of their conclusions, however, both provide valuable information that can be used to assess the status of salmonid populations in the basin.

### Index Reach Sampling

CDFW survey crews have collected data on the number of redds, live Chinook and coho salmon, and salmonid carcasses in 10 SF Eel River stream reaches, six of which were located in the Western Subbasin (the remaining four were located in the Northern Subbasin and are discussed in the Fishery Resources section in that part of the assessment report). Three hundred twenty five surveys were conducted in three Western Subbasin streams (*Table 19*). Sproul Creek sampling reaches included upper, lower, and West Fork locations. Survey sites were not randomly selected; CDFW biologists selected index reaches based on known salmonid (primarily coho salmon) presence in areas with relatively good quality instream and riparian habitat. Annual surveys also differed in sampling duration and effort, and redds were not assigned to species; however, these data provide a continuous record of spawner survey information in select Western Subbasin streams.

*Table 19. Index reach sampling streams and survey information for Western Subbasin streams sampled between 2002and 2012.*

| Stream | Years Surveyed | # of Surveys |
|---|---|---|
| Lower Sproul Creek | 2002-2012 | 74 |
| Upper Sproul Creek | 2002-2012 | 74 |
| West Fork Sproul Creek | 2002-2012 | 74 |
| Redwood Creek (Redway) | 2002-2010 | 34 |
| Upper Redwood (Pollock) Creek | 2002-2010 | 35 |
| China Creek | 2002-2010 | 34 |

Data collected between 2002 and 2012 show relatively large numbers of Chinook (up to 108 live fish and 34 carcasses per season) spawning in Upper, Lower, and West Fork Sproul Creek compared to other streams surveyed. The total number of redds (not identified to individual species) observed was also greatest in the Sproul Creek watershed, with as many as 128 redds counted annually in WF Sproul Creek.

Coho salmon (live fish and carcasses) were present in all of the reaches sampled in the Western Subbasin. West Fork Sproul Creek contained the most live coho salmon (81), coho salmon carcasses (64), and total salmonid redds (128) observed during the 2011-12 sampling season.

Very few steelhead were documented during index reach sampling due to the timing of surveys, which were conducted between November and early March. The peak of steelhead spawning in the SF Eel River usually occurs in late February, but spawning continues through May.

## California Coastal Salmonid Monitoring Program (CMP)

Chinook salmon, coho salmon, and steelhead trout spawning ground surveys have been have been completed annually since 2010 in SF Eel River streams, as part of the CMP program. This program is designed to describe the regional status of SONCC coho salmon in coastal watersheds, including the SF Eel River (Adams et al. 2011). The CMP uses the Viable Salmonid Population (McElhaney et al. 2000) concept, with key population characteristics including: abundance, productivity, spatial structure, and diversity, to assess viability. Repeated periodic surveys were conducted on a spatially balanced random sample of stream reaches with possible coho spawning. A total of 818 surveys were completed on 151 stream reaches throughout the SF Eel River drainage between 2010 and 2014 (*Figure 37*). The number of reaches sampled varied slightly by year, and sampling occurred between mid-November and late March.

CMP data were analyzed for the entire SF Eel River Basin, and numbers of live fish, carcasses, redds, and redd estimates were not developed for individual subbasins.

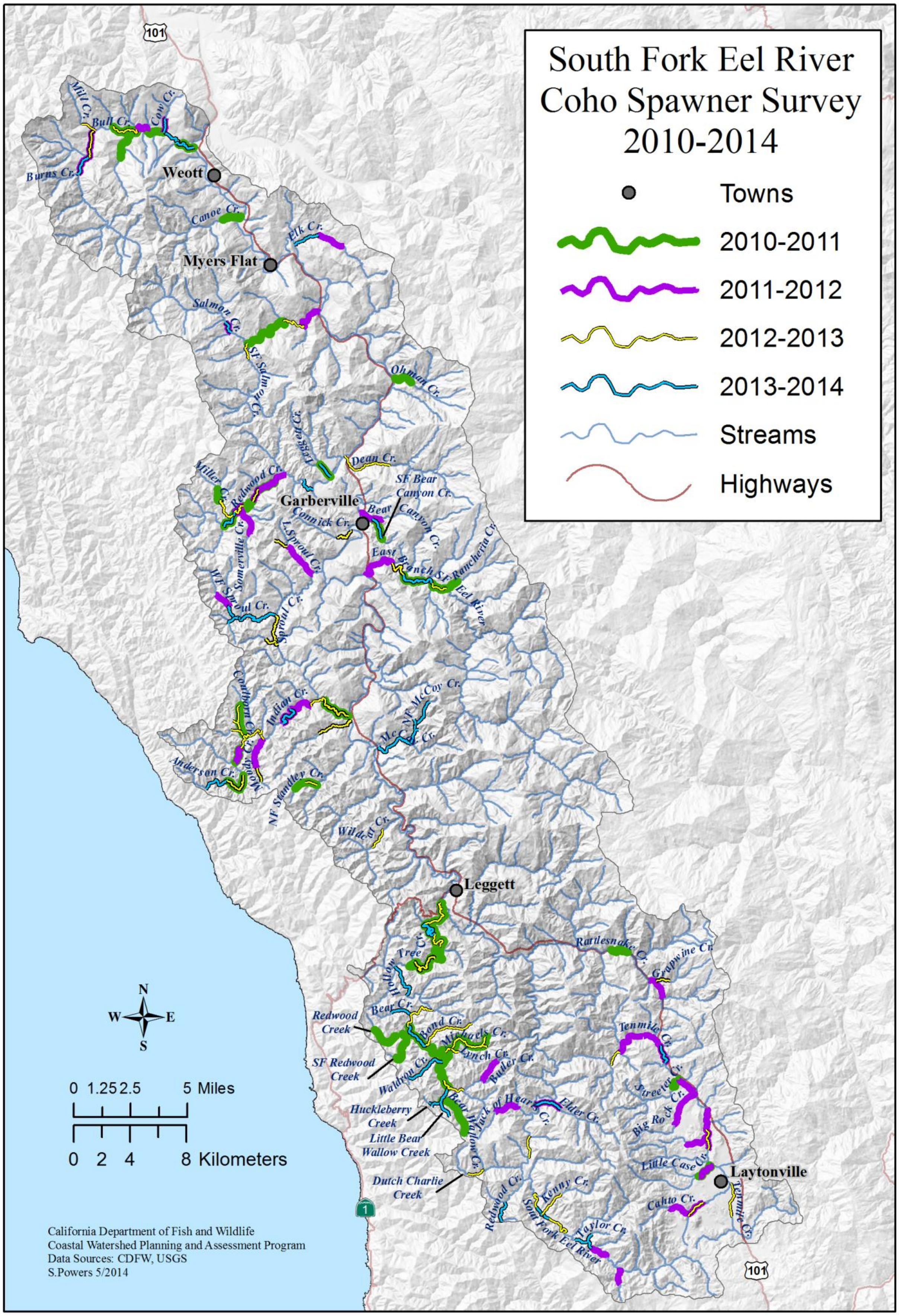



*Figure 37. Location of 2010-2014 CMP spawning reaches in the SF Eel River Basin.*

Field crews recorded the number of spawning fish, carcasses, and redds observed in each reach, including identifying the salmonid species that constructed each redd where possible (*Table 20*). CDFW biologists then predicted unidentified redds to species using the K-nearest neighbor algorithm (Ricker et al. in review) and estimated the total number of redds constructed across all reaches in the sample frame. Sampling methods and calculations are described in detail in Ricker et al. 2014a - 2014d.

*Table 20. Summary of CMP regional spawning ground surveys and estimates of total salmonid redd construction in the SF Eel River (data from Ricker et al. 2014a - 2014d). UI = unidentified salmonids.*

| | **Report Year** | | | |
|---|---|---|---|---|
| | **2010** | **2011** | **2012** | **2013** |
| # of surveys | 150 | 198 | 224 | 246 |
| # of stream reaches | 31 | 42 | 39 | 39 |
| survey dates | 11/17/2010 - 3/9/2011 | 11/14/2011 - 3/12/2012 | 11/26/2012 - 2/28/2013 | 11/14/2013 - 3/25/2014 |
| # live fish | | | | |
| Chinook salmon | 93 | 63 | 106 | 17 |
| coho salmon | 39 | 293 | 33 | 178 |
| steelhead | 6 | 41 | 29 | 107 |
| UI salmonids | 44 | 142 | 41 | 24 |
| # carcasses | | | | |
| Chinook salmon | 0 | 21 | 53 | 4 |
| coho salmon | 0 | 51 | 25 | 22 |
| UI salmonids | 2 | 2 | 0 | 7 |
| # redds observed | 463 | 495 | 524 | 349 |
| # redds assigned to species | 38 | 65 | 33 | 51 |
| estimate of redds in sampling area | | | | |
| Chinook salmon* | 1316 | 569 | 1045 | 126 |
| coho salmon | 1705 | 1323 | 1346 | 905 |
| steelhead* | 160 | 431 | 148 | 736 |
| * Chinook salmon and steelhead redd estimates represent only the time period and area encompassed by the study (Ricker et al. 2014a - 2014d). | | | | |

Chinook salmon and steelhead spawning is extended both spatially and temporally compared to coho salmon. The range of Chinook and steelhead extends further upstream and in more tributaries than coho salmon, and spawning occurs during different peak times and intervals than coho salmon spawning. Therefore, redd abundance estimates for Chinook salmon and steelhead apply only to the time period and physical sampling area used in the study. Redd estimates for Chinook salmon were also not particularly accurate for the first three years (A. Renger, CDFW, personal communication 2012) due to the following limitations:

- Year 1 (2010-2011) – restricted access from landowners in selected reaches resulted in limited sampling;
- Year 2 (2011-2012) – low flow in tributaries resulted in extensive mainstem and limited tributary spawning;
- Year 3(2012-2013) – heavy rainfall in December, when most spawning occurs, limited spawning surveys (high flow and low visibility in streams).

Population estimates have not yet been developed from redd estimates because there are no redd-to-adult corrections available. These corrections are developed using life cycle monitoring stations, which are established in streams with known coho salmon presence. Essential components of a life cycle monitoring station include:

- A counting station for adults (e.g. a weir);

- Adult escapement surveys in areas above the counting station; and
- Outmigrant juvenile trapping using a fyke net, inclined plane, or rotary screw trap (*Figure 38*).

Counts of adults and outmigrating smolts are recorded, and these counts are used to calibrate spawning ground escapement estimates and freshwater and ocean survival. CDFW submitted a funding request in 2014 to establish a life cycle monitoring station in Sproul Creek in 2015, and information collected at this station will be used to assess the status of SONCC coho salmon in the ESU.

Data will be collected annually as part of the CMP in SF Eel River streams and at the life cycle monitoring station in order to generate more accurate salmonid population estimates, and results will be available in annual CDFW summary reports.

For additional information on the CMP, see Adams et al. (2011) or go to: [http://www.calfish.org/Programs/CaliforniaCoastalMonitoring/tabid/186/Default.aspx/](http://www.calfish.org/Programs/CaliforniaCoastalMonitoring/tabid/186/Default.aspx/).

*Figure 38. Rotary screw trap used to sample outmigrant juvenile fish.*

# Habitat Overview

## Historic Conditions

Stream surveys were conducted as early 1938 in SF Eel River Western Subbasin streams; 112 surveys were completed in 41 creeks between 1938 and 1990. Beginning in the 1950s, CDFG (now CDFW) used a standard stream survey form to record data, but it was not until the early 1990s that a standard habitat inventory protocol was developed by Flosi et al. (first published in 1991) and is outlined in the *California Salmonid Stream Habitat Restoration Manual*. The protocol described specific data parameters, methods of data collection, and training procedures that were designed to reduce potential bias and error while collecting field data at a relatively rapid rate (Albin and Law 2006). The manual has been revised three times since 1991, and the current ($4^{th}$) edition, published in 2010, is available at: http://www.dfg.ca.gov/fish/resources/habitatmanual.asp.

Two major flood events occurred in the SF Eel River Basin: December of 1955 and December of 1964. The flood crest in 1955 was 43 feet (at Weott) and in 1964, it was 46 feet (at Miranda) (CA State Parks 2012). These historic flood events, combined with land use activities (particularly timber harvest and rural residential development) have modified natural stream channels and conditions throughout the subbasin. The most notable changes have been in stream temperatures, flow regimes, and sediment input rates and volumes. These changes from historic stream conditions have resulted in reduced salmonid habitat quality and quantity.

Stream surveys were completed by CDFW on 44 streams in the Western Subbasin (including six reaches on the mainstem SF Eel River), with 120 site visits documented between 1938 and 1990 (*Table 21*). Stream survey efforts were neither specific nor standardized until 1990. Most observations in historic stream surveys are not quantitative and have limited use in comparative analysis with current habitat inventories. However, data from these stream surveys provide a snapshot of conditions, including barriers limiting fish passage at the time of survey. Streams with relatively consistent good habitat ratings were: Anderson (lower reach), Dutch Charlie, Hollow Tree, Little Sproul, Low Gap, Redwood (tributary to Hollow Tree) creeks, and the headwaters of the SF Eel River near Branscomb.

Historic habitat surveys included comments on possible barriers to fish passage; log jams were abundant due the input of material from watershed slopes to streams. Intensive logging practices, road building, and the naturally fragile landscape resulted in large amounts of sediment and logging debris in Western Subbasin streams, particularly after the major flood events of 1955 and 1964. These land use practices and related input of sediment and woody debris resulted in many log jams inventoried as partial barriers and recommended for modification or removal in the “barrier comments” sections of historic stream surveys. Barrier removal can be problematic in these streams due to the large amount of sediment behind barriers that will move downstream after removal. Historically, this has been an issue in streams with limited spawning habitat; barrier removal upstream increases fine sediment loads, which then further diminish spawning habitat quality and quantity of downstream gravels.

*Table 21. Habitat observations made in the SF Eel River Western Subbasin from 1938-1990 (ND = no data recorded).*

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Anderson Creek | 6/19/1968 | Stream Survey (CDFG 1968) | Good to excellent spawning gravel in lower areas; good shelter; with creek cleaned of logging debris, some very good spawning water for migratory fish. | Ongoing logging - continual mess of logging debris. Lower 1-2 miles is usable but not above. |
| | 8/5 - 8/7/1978 | Stream Survey (CDFG 1978) | Average stream flow conditions; medium shade canopy; invertebrates common. | Three sinks and many log jams. Not total barriers at high water. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Anderson Creek (con.) | Apr, May 1979 | Stream Survey (CDFG 1979) | Excellent shelter from alders except in areas of middle reach; good pools and cover (3' depth); spawning gravels in lower reaches best; abundant invertebrates. Lowest three miles would be accessible and good salmonid habitat with barrier modification and erosion control. | Eight log and debris barriers holding sediment - removal or modification recommended for first (largest) barrier. |
| | 8/2/1979 | Gravel Sample (CDFG 1979) | ND | |
| Bear Pen Creek | 7/11/1968 | Stream Survey (CDFG 1968) | Good spawning areas; pools increased as gradient increased; mainly log shelter in pools. | One log jam should be removed 3 miles upstream from the mouth. |
| Butler Creek | 10/29/1968 | Stream Survey (CDFG 1968) | Good shade entire length (alder, tan oaks); generally good spawning areas; average pool depth 1.5'. | Recommend removal of 8 debris jams; jam 0.25 miles up North Fork is complete barrier. |
| | 4/9/1979 | Stream Survey (CDFG 1979) | Abundant shelter; average pool depth 1-2' (from upper to lower areas); recommend clearing log jams in lower reach. | |
| | 5/10/1979 | Stream Survey (CDFG 1979) | Removal of blockages would open 4 miles of good gravel to spawners; riparian vegetation sparse in some areas; silt is not a problem. | 12 log jams. |
| | 4/15/1980 | Sediment Analysis (CDFG 1980) | ND | |
| China Creek | 6/27/1962 | Stream Survey (CDFG 1962) | 70-80% of lower reaches good for spawning; adequate shelter in pools from undercut bedrock and brush. | 18 log jams; no total barriers. |
| | 9/5/1966 | Stream Survey (CDFG 1966) | Fair to good pools and shelter; scattered areas good for Chinook spawning; more area good for steelhead spawning; low summer flows. | |
| | 5/24 - 5/26/1982 | Stream Survey (CDFG 1982) | Pool riffle ratio 1:8 - 1:5; average pool depth 2'; 50% embeddedness; 1-2 invertebrates/square ft; canopy 70-90%. | |
| Dinner Creek | 9/1/1966 | Stream Survey (CDFG 1966) | Fair spawning and nursery habitat; limited/intermittent summer flows; pools and cover fair; canopy good; limited aquatic insects. | Several log jams may be partial barriers at low flows. |
| | 5/22/1982 | Stream Survey (CDFG 1982) | Pool riffle ratios were 1:3 at beginning, 1:2 in middle, and 1:1 at end of survey; poor bank stability; 60% canopy; abundant aquatic insects. | |
| Durphy Creek | 6/25/1938 | Stream Survey (CDFG 1938) | ND | |
| | 6/8/1961 | Field Note (CDFG 1961) | Excellent spawning areas below barrier; nursery area lacking - shallow pools and no shelter; canopy cover sparse. | Total barrier 400 yards below first tributary. |
| | 1/6/1968 | Survey Notes (CDFG 1958 | Erosion evident at logging points above Richardson Grove water supply; mouth of creek spreads out into three different channels, making spawner access difficult; bulldozer scheduled to clean out mouth and make single channel. | |
| | 1/29/1980 | Stream Survey (CDFG 1980) | Limited spawning habitat; canopy 80%; riparian vegetation sparse; continuous riffle in lower area, with pool riffle ratio 2:3 above; aquatic insects abundant; slide stabilization necessary. | 17 barriers documented; 2 total log jam barriers near end of survey. |
| Dutch Charlie Creek | 6/26/1938 | Stream Survey (CDFG 1938) | Excellent spawning areas, pools and shelter, and arboreal shade. Abundant coho salmon and steelhead YOY. | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Dutch Charlie Creek (con.) | 6/30/1969 | Stream Survey (CDFG 1969) | Good spawning areas in lower 1.5 miles; fair to poor in upper areas due to siltation; small (1') pools. | Logging debris and small jams; no total barriers. 7' bedrock falls near upper forks is end of anadromy. |
| | 1/24/1979 | Stream Survey (CDFG 1979) | Good spawning areas in middle section; good shelter from logs and boulders; shallow (1') pools in lower section, deep (3') resting pools in middle section, sparse pool habitat in upper section. | 4 log jams; 2 are total barriers under some flow conditions. |
| Hartsook Creek | 6/13/1961 | Field Note (CDFG 1961) | Good spawning gravel available in 800 lineal yards of riffle habitat; good nursery habitat; good shelter and cover. | |
| | 4/8/1981 | Stream Survey (CDFG 1981) | Adequate spawning and nursery habitat; 50-70% canopy; pool riffle ratio 1:15 near mouth, 1:3 in middle of survey, and 1:1 at end; 10-30% silt substrate, highest in upper areas. | 6 barriers observed; 4 possible low water barriers and one possible complete barrier. |
| Hollow Tree Creek | 5/22/1940 | Stream Survey (CDFG 1940) | Excellent pools and shelter. Steelhead, Chinook, and coho salmon present. | |
| | 7/31 and 8/6/1968 | Stream Survey (CDFG 1968) | Excellent spawning areas; deep pools (2-10'); poor shelter downstream; good flow; excellent nursery habitat. | |
| | 1/27/1982; 2/1984 | Fish Habitat Improvement Completion Form (CDFG 1982, 1984) | | Emergency removal of log debris jam that was possible threat to egg collection station. |
| Hooker Creek | 7/4/1962 | Field Note (CDFG 1962) | Small area of spawning habitat but good quality; excellent shelter and nursery areas; pool riffle ratio 4:1; flow 1 cfs. | 25' waterfall 650' above mouth is complete barrier. |
| Indian Creek | 6/18/1938 | Stream Survey and DFG Improvements (CDFG 1938) | Clear passage at old mill pond dam; 2 side channels at mouth improved by diverting them into main channel; excellent shelter; steelhead abundant. | Very large log jam several hundred yards below Moody Creek confluence. |
| | 6/25/1938 | Stream Survey (CDFG 1938) | ND | |
| | 8/11/1938 | Stream Survey (CDFG 1938) | Good pools and shelter; excellent spawning areas; abundant fish food; school of 250 steelhead, 75 of which were "sick" (fungus). | Removal of debris at old Anderson sawmill site would avert possible waste and barrier to fish passage. |
| | 8/27/1982 | Fish Habitat Improvement Completion (CDFG 1982) | | Two logs in a waterfall removed with explosives and hand labor on Georgia Pacific land. |
| Indian Creek and tributaries (Jones, Moody, Coulbourn, and Anderson Creeks) | 6/17 - 6/21/1968 | Stream Survey (CDFG 1968) | Good spawning and nursery conditions; logging active on slopes; many good pools (up to 6' deep); good shelter in tributaries and upper Indian Creek (above Moody Creek). | 15 debris jams in 10-12 mile survey; possibly passable in winter; many jams on tributaries. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Jack of Hearts Creek | 3/6/1957 | Field Note (CDFG 1957) | | Log jam inventory and removal cost estimates. Jam #2, located 0.3 miles upstream, is complete barrier. |
| | 7/29/1969 | Stream Survey (CDFG 1969) | Good spawning areas; pools long, narrow, and shallow (1.5'deep); heavy canopy; boulder shelter in lower section; steelhead and coho salmon present. | 23 log jams, 3 large in lower region; recommend removal of barriers and brush. |
| | 2/11/1979 | Stream Survey (CDFG 1979) | 5% of stream area has suitable spawning area; pool riffle ratio 40:60; average pool depth 1.5 feet. | 6 log jams; no total barriers but may be deterrents under most water conditions; recommend removal. |
| La Doo Creek | 7/6/1961 | Field Note (CDFG 1961) | 20' fall at mouth makes creek unavailable to anadromous fish; excessive erosion upstream has increased siltation and decreased spawning and shelter area to a bare minimum. | |
| Leggett Creek | 8/1/1938 | Stream Survey (CDFG 1938) | Excellent spawning habitat; scant pools and shelter; extensive juvenile steelhead use. | |
| | 6/20/1962 | Field Note (CDFG 1962) | 75% of stream area is suitable spawning habitat; pool riffle ratio 1:3; 25% of stream area provides good shelter and nursery area; abundant fish food; flow 3 cfs. | 35 log jams observed; jams in gorge area are probable barriers. |
| | 6/21/1973 | Field Note (CDFG 1973) | Pool riffle ratio 1:3; logging on slopes on both sides of creek. | |
| | 5/11/1977 | Field Note (CDFG 1977) | Considerable logging in this area has resulted in accumulated material (logs and slash) in streambed, and increased siltation; removal of barriers would open up spawning potential but stream bed is heavily silted and not very suitable for spawning. | Log jams are impassable during low flows but probably passable at high flows. |
| | 6/8/1979 | Memorandum (CDFG 1979) | Adequate spawning gravel; available gravel slightly to moderately silted. | |
| | 8/12/1980 | Stream Survey (CDFG 1980) | Infrequent spawning and rearing habitat; pool riffle ratio 1:3; 50% canopy; high percentage of sand and silt in substrate. | 8 barriers observed; one total obstruction at site #7. |
| | 7/19/1984 | Stream Survey (CDFG 1984) | Stream flows through narrow gorge 6-12' wide, making log jams a persistent problem; gravels loose and moderately silted; pool riffle ratio 1:4; rearing habitat lacking; canopy 40% in lower, 70% in middle, and 20% in upper sections; abundant instream invertebrates. | 12 barriers observed; three were total barriers. |
| Little Low Gap Creek | 8/14/1968 | Stream Survey (CDFG 1968) | Steep gradient and debris in creek; poor conditions, low flow; not usable for salmonids. | |
| Little Sproul Creek | 5/22/1940 | Stream Survey (CDFG 1940) | Water temperature 62 degrees F. Steelhead and coho common. | |
| | 6/23/1961 | Field Note (CDFG 1961) | Good spawning and nursery areas below forks; pool riffle ratio 50:50; adequate shelter and cover; hillsides have been logged so active erosion is occurring but does not seem to be detrimental to the stream. | 15 log jams; no complete barriers. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Little Sproul Creek (con.) | 12/1/1981 | Stream Survey (CDFG 1981) | Good usable habitat for steelhead and possibly salmon; good spawning gravel; pool riffle ratio 1:2; 5% shade canopy; sufficient escape cover. | North Fork: log jam 6' high 20' above confluence is probable barrier to salmonids; South Fork: bedrock chute at confluence with no pools. |
| | 3/12/1985 | Field Note (CDFG 1985) | Spawning and rearing habitat declined 200' above each fork confluence. | Log jam 300' downstream from forks (10'H x 50'W x 200-300'L); not a complete barrier. |
| | 7/21 and 9/1/1988 | Stream Enhancement Work Plan (CCC 1988) | Long spawning channels could be enhanced by creating pools for resting and escape areas; gravel retention needed to increase spawning material; unstable banks and lack of canopy throughout. | |
| Low Gap Creek | 8/11/1938 | Stream Survey (CDFG 1938) | Good spawning areas; good pools and shelter; scant aquatic vegetation; abundant fish food; steelhead YOY abundant. | |
| | 7/4/1962 | Stream Survey (CDFG 1962) | Pool riffle ratio 1:9; abundant good spawning gravel; large amounts of fish food; very little shelter (few trees); little existing nursery area is poor quality. | Extensive log jams and debris should be cleared. |
| | 6/13/1968 | Stream Survey (CDFG 1968) | Good spawning areas; few pools, most small; poor shelter. | 7 log and debris barriers; 40' falls 3.5 miles upstream from mouth is end of anadromy. Numerous log jams in 3 tributaries. |
| | 8/14/1968 | Stream Survey (CDFG 1968) | Spawning habitat it lower reaches good, but limited above forks; excellent shelter due to narrow canyon slopes above forks; few large pools (2' deep), limited by gradient. | |
| | 3/26/1979 | Stream Survey (CDFG 1979) | Average pool depth 4'; abundant pool shelter; steep walled, sparsely foliated, narrow canyon habitat. | 6 log jams; recommend removal of major jams blocking passage. |
| | 1/31/1980 | Stream Survey (CDFG 1980) | North and South Forks: shade canopy 60% (alders); good spawning areas; pool riffle ratio 1:2 except at mouth (continuous riffle); invertebrates plentiful; juveniles in side pools and adult steelhead present. | 6 log jams; 2 are possible barriers to fish passage. |
| Lynch Creek | 7/24/1968 | Stream Survey (CDFG 1968) | Good spawning areas but low summer flow present nursery problems; loose log debris and jams along entire length; removal of litter recommended. | Three barriers between mouth and forks. |
| | 8/24/1972 | Aerial Stream Inventory (BLM 1972) | | 8-10' falls at mouth; deep pool. |
| Michaels Creek | 7/24/1968 | Stream Survey (CDFG 1968) | Poor spawning habitat at mouth, becoming good above lower 0.25 mile and excellent upstream; few 3' deep and numerous 1' deep pools; good shelter; lack of water in summer offers poor nursery conditions. | 10 log jams in lower 1.5 miles of stream; no total barriers but recommend removal. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Michaels Creek (con.) | 7/3/1981 | Stream Survey (CDFG 1981) | Good summer flow; large amounts of spawning gravel above Lynch Creek; good canopy; feral pig streambank damage in upper drainage. | Numerous barriers recommended for removal to open 2 miles of anadromous habitat. |
| Piercy Creek | 6/25/1938 | Stream Survey (CDFG 1938) | Subsurface flow annually in summer from mouth upstream 250 yards; fish rescue work would be difficult due to snags and rough bottom. | Large log jam 250 yards upstream from mouth causes flow to go subsurface. |
| | 6/24/1968 | Stream Survey (CDFG 1968) | Spawning areas good in upper and lower reaches but poor to fair in middle; numerous pools 1.5' deep, better in upstream areas; good shade/canopy in upper reaches; good nursery areas throughout survey area. | Numerous jams, 4 intense and recommended for removal. |
| | 9/27 - 9/28/1977 | Stream Survey (CDFG 1977) | 40% of lower section, 25% of middle section, and 20% of upper section was good spawning habitat; pools numerous but averaged 6/8" deep; pool riffle ratio 1:4; good nursery habitat; productivity limited by logging (wood input, bedload buildup, and increased siltation resulting in reduced flows). | Numerous log jams are partial barriers. |
| Redwood Creek (Branscomb) | 6/26/1938 | Stream Survey (CDFG 1938) | Excellent spawning areas, pools, and shelter. | |
| | 7/31/1969 | Stream Survey (CDFG 1969) | Excellent spawning areas in lower reaches decreasing in quality in upstream areas due to low velocity and siltation; average pool depth 1.5', above NF depth 1'; excellent shelter. | 27 barriers recommended for removal; heavy jams in firs 1.5 miles of survey. |
| | 1/3/1979 | Stream Survey (CDFG 1979) | No spawning areas; average pool depth 1.5'; pool riffle ratio 50:50. | One total barrier (log jam #8); 10 jam areas recommended for removal - none total barriers at time of survey. |
| | 1/4/1979 | Stream Survey (CDFG 1979) | Very few spawning areas; hard clay substrate in second half of stream; pool riffle ratio 50:50; average pool depth 2'; some large pools off main stream; water muddy and silty | 6 log jams recommended for removal but no total barriers. |
| Redwood Creek (Hollow Tree) | 7/24/1968 | Stream Survey (CDFG 1968) | Good spawning area at mouth but diminishing as bottom becomes more clayish where SF enters mainstem; very abundant pools (1.5' depth); heavy undergrowth of alder and tank oak; SF littered with debris and alders but has good flow. | 4 intensive jams in first 0.75 miles - all are passable but recommend removal; SF littered with small jams every 100'; main creek above fork is littered entire way. |
| | 11/14/1980 | Memorandum (CDFG 1980) | | Log jams observed but 50' natural falls found 400' above mouth, so recommended no effort expended to remove log jams. |
| Redwood Creek (Redway) | 6/12/1938 | Stream Survey (CDFG 1938) | Good spawning areas, pools, and shelter. | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Redwood Creek (Redway) (con.) | circa 1962 | Field Note (CDFG no date). | Pool riffle ratio 1:9; spawning areas in 7.6 miles of riffle; shelter not abundant in lower area but improves in upstream areas. | 16 log jams recommended for removal - no total barriers. |
| | 7/26/1968 | Field Note (CDFG 1968) | Low flow and lots of algae; water barely trickling at mouth - may be cut off from SF Eel River in future. | |
| | 7/20/1977 | Field Note (CDFG 1977) | Mouth closed, stream intermittent. | |
| | 1/18/1984 | Field Note (CDFG 1984) | Redwood and Dinner Creeks have abundant spawning gravels but large amounts of sediment; some areas lacking in adult holding and juvenile rearing habitat. | |
| | 7/20 and 7/30-31/1984 | Stream Survey (CDFG 1984) | Pool riffle ratio 1:3; average pool depth 3'; 70% canopy; stream banks unstable and in poor condition in lower areas, but good in middle and upper areas; medium compaction of gravel. | Probable total barrier (log jam) 4500' above China Creek. |
| Redwood Creek (Redway) - 1000' below Frost creek to mouth. | 9/6/1966 | Stream Survey (CDFG 1966) | Spawning areas adequate and pools and shelter present but not abundant; limiting factors are low summer flow and associated limited food supply. | |
| | 9/7/1966 | Stream Survey (CDFG 1966) | Low flow (0.3 cfs); good pool development with moderate to poor shelter; | |
| Redwood Creek (Redway) - confluence of China Creek to 1.7 miles upstream. | 9/24/1966 | Stream Survey (CDFG 1966) | Abundant spawning areas; good pool shelter (undercut banks, logs, and debris); adequate pools. | Numerous log jams from logging operations; no total barriers. |
| Redwood Creek (Redway) - headwaters. | 9/21/1966 | Stream Survey (CDFG 1966) | Low flows but good water temperatures; poor food supply. | |
| Redwood Creek (Redway) UT | 9/21/1966 | Stream Survey (CDFG 1966) | Intermittent flows at mouth; scarce shelter; limited spawning areas. | |
| Sawmill Creek | 3/30/1939 | Stream Survey (CDFG 1939) | Good pools, shelter, and invertebrate food; abundant juvenile Chinook and steelhead. | |
| | 7/5/1961 | Stream Survey (CDFG 1961) | Gradual gradient; pool riffle ratio 1:1; several hundred yards upstream from forks, gradient steepens; light siltation; abundant shelter and nursery areas. | 20,135 cubic ft of logs and debris recommended for removal; cascading waterfall 2-3 yards upstream from forks. |
| | 4/21/1981 | Stream Survey (CDFG 1981) | Suitable spawning gravel; good bank stability; gradient 4-8% at beginning of survey and 23% at end; shade canopy 50% at mouth and 80% upstream; pool riffle ratio 1:3 near mouth and 1:1 in upper half; average pool depth 1.5'. | |
| | 2/5/1983 | Field Note (CDFG 1983) | Barnum Timber Co concluded hardwood harvesting - end of commercial timber harvesting in the watershed; reduced turbidity and bedload shift; lack of meander and pools limiting for upstream migrants | Log jam 100' above bridge should be removed for upstream migrants. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Section Four Creek | 9/2/1969 | Stream Survey (CDFG 1969) | Below forks, spawning areas fair to good; above forks, good; few, small pools (0.5' deep); poor shelter and cover for entire survey length; poor nursery conditions; in summer, no water above forks and slight flow below; poor summer stream. | Below forks, streambed cluttered with logs and litter; short section of steep gradient 1/8 mile upstream may be partial barrier. |
| | 2/18/1979 | Stream Survey (CDFG 1979) | Good quality spawning areas below forks; pools average 10" deep; abundant shelter (logs and boulders). | Boulder 1/8 mile from mouth - total drop 30', no pools; 6 log jams between mouth and forks; final barrier is 50' vertical boulder run for 100' of stream. |
| Seeley Creek | 6/11/1961 | Field Note (CDFG 1961) | Good spawning areas; good canopy in lower reaches but logging in upper results in decreased canopy cover; pool riffle ratio 1:1. | 29 log jams (ongoing restoration projects); temporary culvert will be removed; no natural barriers. |
| | 9/22/1966 | Stream Survey (CDFG 1966) | Spawning habitat suitable (available in 13% of stream); riparian vegetation limited; aquatic insects scarce. | |
| | 1/7/1969 | Field Note (CDFG 1969) | Fish observed between mouth and 1 mile upstream. | Potential log jam barrier 1.3 miles from mouth. |
| SF Eel River | 6/8, 8/15-8/17, 8/25-8/26, 9/2-9/3, 10/21/1959 | Stream Surveys (CDFG 1959) | Multiple survey locations from confluence to headwaters; high water temperatures may be limiting factor; salmonids seeking cooler water throughout survey locations (water temps 70-77 degrees F in many areas); very few fish in large pools; fish present only in pools with thermal stratification; steelhead and coho production greatest near Branscomb (good cover and cooler water). | |
| SF Eel River - near Branscomb | 12/15/1988; 1/18/1989 | Field note - carcass surveys (CDFG 1988, 1989) | Typically good; abundant spawning gravels, pools, and canopy. Woody materials lacking. Chinook and coho salmon. | |
| SF Eel River (100' above Cedar Creek) | 9/4/1941 | Stream Survey (CDFG 1941) | Good spawning areas, good pools and shelter. | |
| SF Eel River (Hollow Tree Creek bridge) | 5/22/1940 | Stream Survey (CDFG 1940) | Good spawning areas, excellent pools and shelter. | |
| SF Eel River - rock shop to Mud Creek | 1/7/1988 | Field note - carcass survey (CDFG 1988) | Abundant canopy; pool riffle ratio typically good, but long riffle stretches. Woody materials lacking. Spawning gravel fair to good - lots of fine sediment. | Several debris piles should be re-evaluated. |
| SF Eel River (mouth of Piercy Creek) | 6/25/1938 | Stream Survey (CDFG 1938) | Water temperatures too high for stocking steelhead. | Concrete dam at Reynolds Redwoods between McCoy and Red Mountain Creeks not a barrier. |
| SF Eel River UT (near Benbow) | 2/19/1963 | Field Note (CDFG 1963) | Virtually no spawning area; slopes logged extensively and much silt deposited; upper portions dry in summer months. | 200 yards above mouth is 250-300 foot cascading waterfall - total barrier. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Sommerville Creek | 8/1/1938 | Stream Survey (CDFG 1938) | 10 gpm flow; 69 degrees F. | |
| | 9/25/1966 | Stream Survey (CDFG 1966) | Spawning gravel scarce; fair pool development; adequate cover and shade except where active logging is occurring; logging practices damaging stream and hillslopes; severe siltation from logging; recommend removal of road crossings, logs, and debris. | Three log jams may be complete barriers. |
| Sproul Creek | 6/20/1939 | Stream Survey (CDFG 1939) | Water temp 60 degrees F; murky; medium to low stream condition. | |
| | 5/23/1940 | Velocity Measurement (CDFG 1940) | Good (5%) flow. | |
| | 7/5-7/6/1961 | Field Note (CDFG 1961) | Logging in upper regions results in erosion of hillsides and siltation of stream; spawning areas in lower areas plentiful; pool riffle ratio 1:1; nursery and shelter ample; little overhanging vegetation. Logging operations have pushed logs and debris into streams to use as roadbeds. | 59 log jams on mainstem and 32 in West Fork. Two natural falls above West Fork are not complete barriers. |
| | 7/26/1968 | Field Note (CDFG 1968) | Low flow (1.42 cfs) at time of survey; three dams (probably to provide swimming holes) with bypasses allowing fish passage. | |
| | 6/11 and 6/13-6/14/1984 | Stream Survey (CDFG 1984) | 47 sites described and considered for restoration; spawning gravel limited and habitat diversity low. | |
| | 6/18-6/20/1984 | Stream Survey (CDFG 1984) | Mainstem and tributaries surveyed. Mainstem, Cox, and tributary D contain excellent spawning and rearing habitat; revegetating slides and undercut banks would improve riparian habitat; landslide toe stabilization necessary; summer low flows are a limiting factor. | |
| Sproul Creek (West Fork) | 2/3/1983 | Stream Survey (CDFG 1983) | Relatively stable streambanks; canopy 50-80%; pool riffle ratio 1:1; average pool depth 3'; stream clearance recommended. East Branch West Fork: pool riffle ratio 1:1; average pool depth 3'; 0.25 miles upstream is bedrock canyon; 50-80% canopy. | |
| Standley Creek | 6/27 and 7/1/1968 | Stream Survey (CDFG 1968) | Good spawning areas; abundant pools 2-6' deep; good shelter from overhanging vegetation, undercut banks, and logs; excellent nursery habitat; frequent landslides from logging roads. | 28 log jams on mainstem and tributaries; recommended removal of one jam (#16) and litter clearing on tributary #2. |
| | 5/10-5/11/1976 | Stream Survey (CDFG 1976) | Suitable spawning areas in 10% of stream; extensive steelhead spawning activity; large amounts of siltation from logging activities; numerous pools (in 30% of stream, averaging 3' deep); abundant pool shelter; canopy good except at mouth; recommend controlling road building and logging to minimize erosion. | No total barriers but some log jams may be barriers at certain flows. Active slides causing trees to fall into creek and may become barriers. |
| Surveyors Canyon Creek | 9/10/1975 | Stream Survey (BLM 1975) | Stream erosion caused by logging in and near stream basin has led to siltation of all gravel beds. | Numerous rock and log falls prohibit steelhead use and make stream uninhabitable for resident trout. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Waldron Creek | 7/25/1968 | Stream Survey (CDFG 1968) | | Log jam at mouth - temporary dam created to collect water for filling tank trucks. |
| | 7/30/1968 | Stream Survey (CDFG 1968) | Few deep pools (1.5'); few, fair spawning areas; steelhead and coho YOY. | No total barriers; intensive jam 0.5 miles above mouth recommended for removal. |
| Warden Creek | 7/5/1961 | Stream Survey (CDFG 1961) | Spawning areas limited to lower 300 yards of stream; pool riffle ratio 50:50; shelter and nursery area fair. | 300 yards upstream from mouth, natural gradient is barrier to migration. 11 log jams recommended for removal. |
| | 6/27/1987 | Field Note (BLM 1987) | 20% pools; 80% canopy; active logging on side slopes; not adequate salmonid habitat due to lack of spawning areas, pools, and flow. | Falls at mouth prevent fish migration. |
| Wildcat Creek | 7/15/1968 | Stream Survey (CDFG 1968) | Spawning conditions fair at mouth and improving to good upstream; numerous pools (2' deep); good pool shelter. | Debris plentiful but no total barriers; jams more numerous and intense in upper areas due to new logging operations. |

## Current Conditions

A total of 110 habitat inventories were conducted by CDFW in the Western Subbasin between 1990 and 2010 (*Table 22*). Most streams were surveyed twice within that time frame, and survey lengths ranged from 14.82 miles (Hollow Tree Creek 1992) to 0.19 miles (SF Redwood Creek 2003). Survey data were divided into two sampling periods (1990-1999, and 2000-2010) in order to assess changes in habitat factors and suitability of habitat for salmonids over time.

The number of reaches and the total stream length surveyed varied by stream. Habitat typing surveys describe specific stream reaches by Rosgen channel type (see Channel Types section of this report) and sequence. Reaches show characteristics of certain channel types for a minimum distance of 20 bankfull channel widths (Flosi et al. 2010), but are highly variable in overall length.

Some streams were surveyed in multiple years within each sampling period, and if the surveys covered the same area of stream, only the most recent survey information (from 44 streams) was used in the EMDS-based analysis. Only habitat typing surveys completed on perennial streams were used in the analyses. However, some perennial streams contain dry reaches during certain times of the year (usually in late summer) due to variation in annual precipitation, natural aquifer levels, and magnitude of diversion. These dry reaches were categorized as Type 7 (Flosi et al. 2010) in habitat typing reports.

Streams that were surveyed during both time periods were often completed at different times of the year (e.g. Bear Wallow Creek was surveyed in June in 1990 but in September-October in 2002). For a complete list of the month each survey was completed, see *Table 35* in the SF Eel River Basin Overview. Environmental conditions vary by month and year, and may influence habitat suitability values. For example, flow is reduced between mid-July and early- to mid-September in streams throughout the Western Subbasin (due to limited rainfall, evapotranspiration by plants, groundwater levels, and the number and magnitude of diversions), so primary pool values and corresponding scores would most likely be lower in creeks where sampling was completed during this time interval. Variability in rainfall received during wet and dry years may also influence flow, and therefore habitat factors and suitability values. According to records from the USGS gauge at Leggett (RM 66), which is located within the Western Subbasin boundary, annual flow was very high in 1998 and 2006, and very low in 1991 and 2001 (*Figure 6*).

CWPAP staff evaluated habitat typing data using an analysis based on the Ecological Management Decision Support (EMDS) model used in previous CWPAP Watershed Assessments. Rating scores were developed from habitat typing data summarized in *Table 22* and were used in the analysis to evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. Additional analysis details can be found in the Analysis Appendix and in the NCWAP Methods Manual, available at: http://coastalwatersheds.ca.gov/. Calculations and conclusions in the analysis are pertinent to surveyed streams and are based on conditions existing at the time of each survey.

Surveys completed on the same stream during both time periods may also show differences in habitat values because of changing land use practices. For example, in Redwood Creek, there has been a dramatic increase in the number and magnitude of marijuana cultivation operations in the past few decades (see the Industrial Marijuana Agriculture section of this report). Increased diversions from these operations have resulted in lower flows and reduced pool depth suitability in this watershed.

Observer variability and error during habitat typing surveys may also account for changes in habitat variables over time but error and bias can be minimized through use of standards and training. Well-designed sampling schemes, comprehensive observer training, and the use of established operating protocols (e.g. the *California Salmonid Stream Habitat Restoration Manual)* will result in monitoring that effectively detects changing stream conditions (Roper et al. 2002). Because of observer and other error sources, habitat typing is best suited to detecting fundamental changes in Level I or II habitat types (Gerstein 2005), and to identify potential limiting factors for salmonids in specific watersheds for assessment purposes.

Summary values of each factor and the associated target values for these attributes are listed in *Table 22*. Average embeddedness, length of primary pools, and pool shelter ratings for all streams in the subbasin were below target values during each time period. Average canopy density for all Western Subbasin streams was below the target value of 80% in the 1990s, but increased to 88.5% in the 2000-2010 sampling period, which exceeded the target value established by Flosi et al. (2010). The importance of each habitat factor to salmonids, and their effect on habitat suitability will be discussed in detail in the individual factor sections of this subbasin report.

*Table 22. Summary of CDFW habitat inventories used in analysis for streams in the SF Eel River Western Subbasin, and associated target values. Averages are weighted by stream length surveyed.*

| Stream | Survey Year | Survey length (miles) | Mean Canopy Density (%) | Category 1 Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|---|
| **TARGET VALUES** | | | **>80** | **>50** | **>40** | **>100** |
| Anderson Creek | 2008 | 2.29 | 97.1 | 64.7 | ND | 22.4 |
| Bear Pen Creek | 1992 | 3.38 | 66.5 | 2.0 | 5.0 | 33.2 |
| | 2007 | 2.82 | 79.4 | 26.7 | 6.1 | 41.6 |
| Bear Wallow Creek | 1990 | 1.41 | 86.7 | 78.0 | 4.76 | 105.9 |
| | 2002 | 2.14 | 96.1 | 29.7 | 8.7 | 48.6 |
| Bond Creek | 1991 | 1.83 | 49.8 | 9.8 | 1.9 | 54.6 |
| Bond Creek (con.) | 2003 | 2.63 | 92.4 | 23.8 | 10.0 | 62.8 |
| Butler Creek | 1990 | 1.22 | 76.0 | 75.6 | 7.3 | 112.7 |
| | 2002 | 1.43 | 96.2 | 52.0 | 4.5 | 34.8 |
| Butler Creek (unnamed left bank tributary) | 2002 | 0.29 | 97.9 | 73.0 | 3.8 | 43.0 |
| China Creek | 1998 | 2.87 | 87.9 | 0.8 | 12.1 | 32.6 |
| | 2009 | 2.20 | 92.9 | 35.0 | 18.1 | 29.7 |
| Cox Creek (SF Eel River) | 1993 | 1.22 | 72.6 | 8.0 | 1.1 | 44.6 |
| | 2004 | 1.29 | 96.7 | 0.0 | 0.9 | 27.7 |

| Stream | Survey Year | Survey length (miles) | Mean Canopy Density (%) | Category 1 Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|---|
| Doctors Creek | 1991 | 0.16 | 66.5 | 0.0 | 0.5 | 68.5 |
| | 2003 | 0.30 | 96.8 | 80.0 | 3.1 | 56.3 |
| Durphy Creek | 2006 | 1.76 | 74.2 | 13.6 | 0.9 | 9.1 |
| Durphy Creek (unnamed left bank tributary) | 1993 | 0.43 | 60.2 | 5.0 | 0.0 | 39.5 |
| | 2006 | 0.49 | 79.3 | 38.0 | 0.1 | 10.9 |
| Dutch Charlie Creek | 1992 | 3.55 | 84.7 | 0.0 | 18.8 | 24.9 |
| | 2007 | 2.88 | 98.1 | 22.6 | 20.6 | 59.1 |
| Hartsook Creek | 1999 | 1.25 | 88.8 | 17.0 | 0.4 | 5.7 |
| | 2009 | 1.32 | 89.0 | 36.8 | 0.5 | 24.0 |
| Hollow Tree Creek | 1992 | 14.82 | 32.5 | 13.0 | 22.8 | 38.2 |
| | 2002 | 1.89 | 88.8 | 16.9 | 10.2 | 31.9 |
| | 2003 | 3.44 | 91.9 | 26.0 | 13.6 | 38.3 |
| Huckleberry Creek | 1990 | 1.18 | 80.9 | 21.0 | 17.4 | 87.7 |
| | 2002 | 1.48 | 98.5 | 28.0 | 14.6 | 36.4 |
| Indian Creek | 1993 | 11.15 | 53.7 | 34.3 | 23.7 | 46.6 |
| | 2008 | 9.75 | 82.0 | 78.5 | 34.0 | 11.5 |
| Jack of Hearts Creek | 1992 | 2.88 | 84.2 | 14.0 | 6.7 | 49.2 |
| | 2005 | 3.07 | 93.7 | 53.0 | 10.7 | 37.2 |
| Leggett Creek | 1995 | 2.31 | 75.8 | 3.0 | 7.6 | 20.6 |
| | 2007 | 3.25 | 87.6 | 21.0 | 5.3 | 23.1 |
| Little Sproul Creek | 1995 | 1.66 | 85.9 | 0.0 | 8.1 | 44.8 |
| Little Sproul Creek (unnamed tributary) | 2004 | 0.92 | 94.2 | 0.0 | ND | 41.8 |
| Low Gap Creek | 1990 | 2.71 | 19.4 | 10.4 | 1.7 | 77.8 |
| | 2007 | 2.51 | 79.6 | 31.0 | 3.4 | 49.5 |
| Lynch Creek | 1991 | 0.31 | 67.3 | 0.0 | 0.0 | 42.0 |
| | 2003 | 0.19 | 94.1 | 10.0 | 3.5 | 62.0 |
| Michaels Creek | 1991 | 1.75 | 40.1 | 5.0 | 4.0 | 28.4 |
| | 2003 | 2.60 | 93.2 | 75.4 | 8.3 | 56.8 |
| Mill Creek | 2010 | 0.33 | 92.4 | 29.0 | 10.6 | 21.2 |
| Moody Creek | 1993 | 1.65 | 88.5 | 5.0 | 2.6 | 69.3 |
| | 2008 | 1.74 | 92.6 | 51.0 | 11.6 | 18.2 |
| Piercy Creek | 2007 | 2.21 | 92.0 | 14.2 | 3.2 | 57.1 |
| Pollock Creek (Upper Redwood Creek) | 1998 | 2.04 | 90.5 | 0.0 | 17.1 | 28.5 |
| | 2009 | 2.68 | 95.1 | 23.5 | 12.1 | 35.3 |
| Redwood Creek (Hollow Tree Creek) | 2003 | 1.99 | 90.8 | 2.0 | 41.8 | 31.5 |
| Redwood Creek (Branscomb) | 1993 | 2.43 | 81.9 | 5.6 | 29.6 | 36.4 |
| | 2007 | 2.43 | 96.9 | 1.9 | 23.4 | 75.2 |
| Redwood (Redway) | 2009 | 7.43 | 66.1 | 71.8 | 27.3 | 20.1 |
| SF Eel headwaters | 1996 | 9.06 | 82.5 | 1.0 | 11.9 | 42.2 |
| | 2007 | 5.38 | 94.6 | 11.0 | 29.2 | 47.4 |
| SF Redwood | 1991 | 1.68 | 87.5 | 0.0 | 15.7 | 69.2 |
| | 2003 | 1.86 | 92.0 | 0.0 | 20.2 | 24.4 |
| SF Redwood (unnamed tributary) | 2003 | 0.19 | 90.6 | 0.0 | 0.5 | 5.0 |
| Sproul | 2004 | 6.15 | 83.3 | 10.8 | 18.1 | 33.7 |
| Sproul (tributary 5) | 2004 | 0.48 | 99.4 | 5.0 | 0.2 | 16.8 |
| Standley Creek | 1992 | 3.10 | 61.4 | 13.0 | 17.6 | 46.4 |

| Stream | Survey Year | Survey length (miles) | Mean Canopy Density (%) | Category 1 Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|---|
| | 2007 | 3.04 | 82.3 | 5.5 | 19.0 | 20.1 |
| | 2009 | 1.91 | 94.0 | 56.0 | 7.3 | 21.2 |
| Twin (unnamed tributary to China) | 2009 | 0.54 | 97.4 | 55.0 | 0.9 | 30.3 |
| Waldron | 1991 | 1.38 | 74.8 | 1.0 | 4.7 | 35.9 |
| | 2002 | 1.44 | 83.4 | 40.6 | 17.8 | 46.1 |
| Warden | 1992 | 0.38 | 78.6 | 0.0 | 0.2 | 37.0 |
| | 2004 | 0.38 | 97.2 | 18.2 | 5.1 | 56.4 |
| WF Sproul | 1992 | 5.52 | 80.6 | 0.0 | 14.4 | 28.4 |
| | 2004 | 5.04 | 95.4 | 12.1 | 17.2 | 62.5 |
| WF Sproul (tributary 8) | 2004 | 0.55 | 98.5 | 0.0 | 0.7 | 63.1 |
| WF Sproul (tributary 9) | 2004 | 1.54 | 98.4 | 7.0 | 6.9 | 75.4 |
| Wildcat | 1992 | 2.37 | 64.0 | 28.2 | 8.7 | 44.5 |
| | 2007 | 2.31 | 93.8 | 73.0 | 16.5 | 53.7 |
| Wood | 2002 | 0.99 | 84.6 | 30.5 | 3.5 | 14.3 |
| **AVERAGES** | 1990-1999 | | 64.7 | 12.7 | 12.5 | 43.5 |
| | 2000-2010 | | 88.5 | 34.4 | 14.5 | 36.4 |

## Overall Habitat Suitability

Four factors (canopy density, pool depth, pool shelter complexity, and substrate embeddedness) were used in the EMDS-based analysis to determine overall habitat suitability using habitat typing data collected from two separate time periods: 1990 to 1999, and 2000 to 2010. Suitability scores were calculated by assessing how measured values compared to target values for each factor. Overall habitat suitability and suitability of each factor used in the analysis were calculated based on a weighted (by reach or stream length surveyed) average for Western Subbasin streams in each time period, and the change in suitability between time periods was compared for streams and for individual reaches.

Suitability scores ranged between +1 and -1, and were divided into four categories:

- 1.00 - 0.50 (high suitability);
- 0.49 - 0;
- -0.01 - -0.49; and
- -0.50 - -1.00 (low suitability).

Scores were weighted by survey length to facilitate comparison of habitats between different tributaries based on sampling effort. For a detailed discussion of the analysis framework and calculation of suitability scores, see the Analysis Appendix.

Overall habitat suitability increased in Western Subbasin streams between the 1990s and early 2000s, but scores were still low (negative values) during both sampling periods (*Table 23*). Overall suitability increased over time mainly due to an increase in embeddedness scores, but also due to a small increase in pool depth scores between the two sampling periods.

*Table 23. Overall suitability and suitability by factor in SF Eel River Western Subbasin streams during two sampling periods: 1990-1999 and 2000-2010 (suitability scors range between 1 and -1).*

| Sampling period | Stream miles surveyed | Overall habitat suitability score | Canopy density suitability score | Pool depth suitability score | Pool shelter suitability score | Pool quality score | Embeddedness suitability score |
|---|---|---|---|---|---|---|---|
| 1990-1999 | 85.70 | -0.75 | 0.06 | -0.71 | -0.60 | -0.62 | -0.44 |
| 2000-2010 | 101.55 | -0.39 | 0.87 | -0.61 | -0.69 | -0.64 | 0.15 |

Canopy density scores were higher than any other factor scores used in the EMDS-based analysis. In the model, canopy density (riparian vegetation score) was evaluated with an "in channel score" (a combination of pool depth, pool complexity, and substrate embeddedness factors, all weighted equally), at the final decision node where the lower of the two scores was used to indicate the potential of the stream reach to sustain salmonid populations. In Western Subbasin streams, in channel scores were almost always lower than canopy density scores, therefore, canopy density scores were often not used as the final indicator of a stream's potential to support salmonids. Canopy density scores were lower for data collected in the 1990s than in the 2000s, but were only lower than in channel scores 5 times for data collected during the 1990s and only once using data collected between 2000 and 2010.

Most Western Subbasin streams and reaches showed improvement in overall suitability between the two sampling periods (*Figure 39*). Different stream reaches were sampled in Redwood, Sproul, and Hollow Tree creeks during each time period, but overall suitability scores still increased in these watersheds.

In the Indian Creek drainage, overall suitability increased from the lowest level (-0.79) to the second highest level (0.47) of suitability because of an increase in the percentage of habitat with category 1 embeddedness, and also due to very low canopy scores in the 1990-1999 sampling period. Canopy densities recorded on habitat surveys in Indian Creek in 1993 were very low (53.7%), which resulted in a lower riparian score than in-channel score, and a very low overall suitability score. In 2008, pool depth, cobble embeddedness, and canopy density were excellent in Indian Creek, and only pool shelter was low, resulting in relatively high overall suitability.

Overall suitability in 3 tributaries in the upper Hollow Tree Creek drainage increased in suitability between the two sampling periods (Waldron, Bond, and Michaels), however, overall suitability decreased in Bear Wallow Creek and Butler Creek due to decreases in pool shelter scores. Habitat in the upper mainstem of Hollow Tree Creek (from Redwood Creek upstream to the headwaters) is some of the best salmonid habitat in the Western Subbasin, and coho salmon have been found in more tributaries in this watershed than in any other SF Eel River catchment. Management activities and restoration projects should address the need for increased pool shelter in streams throughout this watershed.

Although overall suitability scores improved over time, most reaches had negative suitability scores, as indicated by red and orange segments, during both time periods (*Figure 39*). In the 1990-1999 sampling period, only Butler and Bear Wallow creeks had positive overall suitability scores.

Although unstable geology, high road density, and active timber harvesting in the Western Subbasin negatively affects pool depth pool and pool shelter (and therefore pool quality), increases in overall suitability may be due to changes in land use and restoration efforts in areas throughout the subbasin. Most of this subbasin was heavily logged in the last century. However, since 1973 with the passage of the Z'Berg-Nejedly Forest Practice Act, environmental regulations have increased and environmental disturbance and the amount of timber harvested have been reduced. Road decommissioning and improvement, instream habitat, and upslope restoration projects are ongoing, especially in Redwood Creek (near Redway) and Hollow Tree Creek watersheds. Reduced disturbance is reflected in increasing habitat suitability, and with time, management practices and restoration projects that improve salmonid habitat may be expressed by factor values approaching target values, with associated increases in suitability scores. Individual factors scores and how they may influence overall scores are discussed in more detail in the following sections.

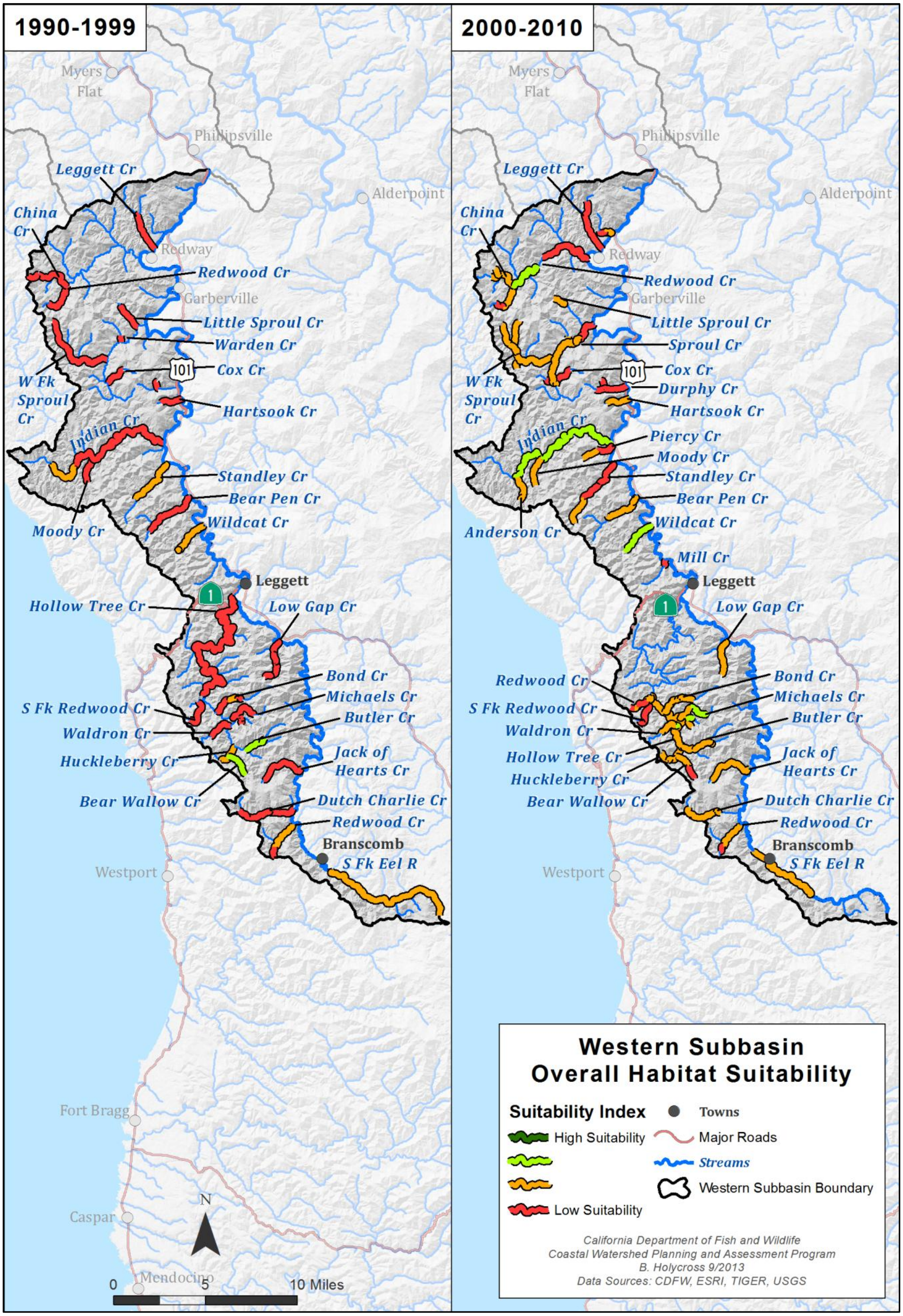
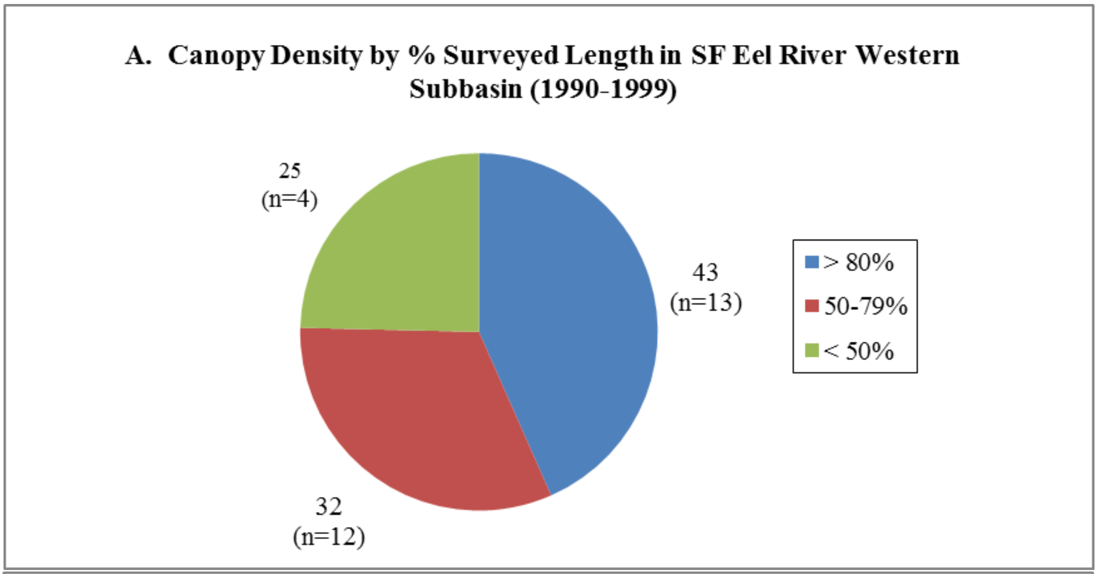



*Figure 39. Overall habitat suitability in SF Eel River Western Subbasin streams in two sampling periods: 1990-1999 and 2000-2010.*

## Canopy Density

Canopy density is one of the measurements estimated during CDFW habitat surveys. These measurements, which are defined as a percentage of shade canopy over the stream, provide an indication of potential recruitment of organic debris to the stream channel, and are a measure of the insulating capacity of the stream and riparian areas during the 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 established a target of 80% for shade canopy along coastal streams (Flosi et al. 2010). The CDFW recommends areas with less than 80% shade canopy as candidates for riparian improvement efforts.

Canopy density is generally good in Western Subbasin streams, and average values increased in streams between the two sampling periods. Using data collected between 1990 and 1999, 16 streams did not meet the target value of 80%, and four of those were below 50% canopy cover (*Figure 40A*). Habitat typing reports from 2000-2010 showed only 5 streams with canopy densities below target values, and none of these were in the <50% category (*Figure 40B*).



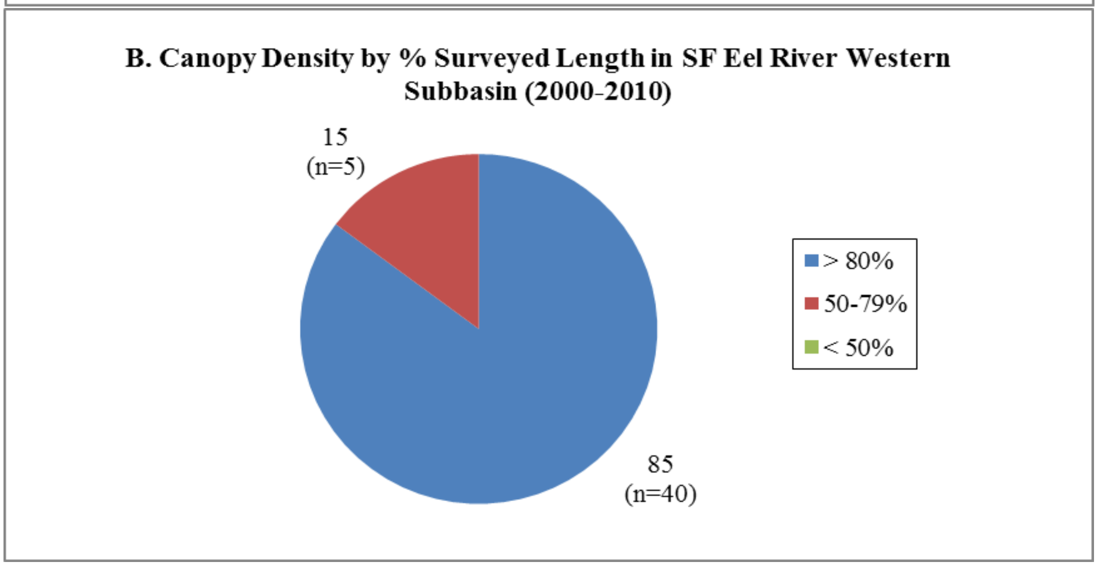




*Figure 40A, B. Canopy Density by percent habitat typing survey length in Western Subbasin streams, using data collected from 1990-1999 (A) and 2000-2010 (B); n = number of streams surveyed.*

Canopy density suitability scores increased in most Western Subbasin streams between the two sampling periods (*Figure 42*). From surveys completed between 1990 and 1999, the average canopy score for all Western Subbasin streams was 0.06 (*Table 23*). During this sampling period, canopy density was in the lowest suitability category in Indian, mainstem Hollow Tree (below Redwood Creek), Michaels, and Low Gap Creek, and two reaches in Bond Creek.

From surveys completed between 2000 and 2010, the average canopy score for all streams was 0.87. Most streams were in the highest suitability category, and only two reaches in the entire subbasin had riparian vegetation scores that were negative (unsuitable). The lower reach of Redwood Creek (near Redway) had a canopy density score in the lowest suitability category when sampled in 2009, and one reach in lower Sproul Creek had a score in the second to lowest suitability category when sampled in 2008. These reaches were not sampled in the previous decade so there is no quantitative information available to determine how canopy density changed over time.

In Hollow Tree Creek, canopy density was much lower in the earlier sampling period, but surveys in the 1990s were conducted in the mainstem, from the confluence with the SF Eel River upstream to Redwood Creek (*Figure 42*). The stream channel in this lower area of Hollow Tree Creek is relatively wide and lower canopy densities are expected. The lower mainstem is also not used much for spawning; most fish travel upstream to tributaries in the headwaters above Redwood Creek, using the lower reaches of Hollow Tree Creek primarily as a migratory corridor (A. Renger, CDFW, personal communication 2013). Canopy density in upper Hollow Tree Creek, including in Michaels Creek (*Figure 41*) has improved over time due to timber harvest policies promoting streamside canopy and riparian management (MRC 2004) and to the relatively large number of upslope restoration projects completed in tributaries above Redwood Creek.

Canopy density improved over time in Indian Creek, and the same reaches were sampled during both time periods. Most of the land in this watershed is owned by industrial timber companies, and was intensively harvested in the 1990s. Riparian habitat may have grown back by the time habitat crews collected data in 2008.

*Figure 41. Example of good canopy density in Michaels Creek.*

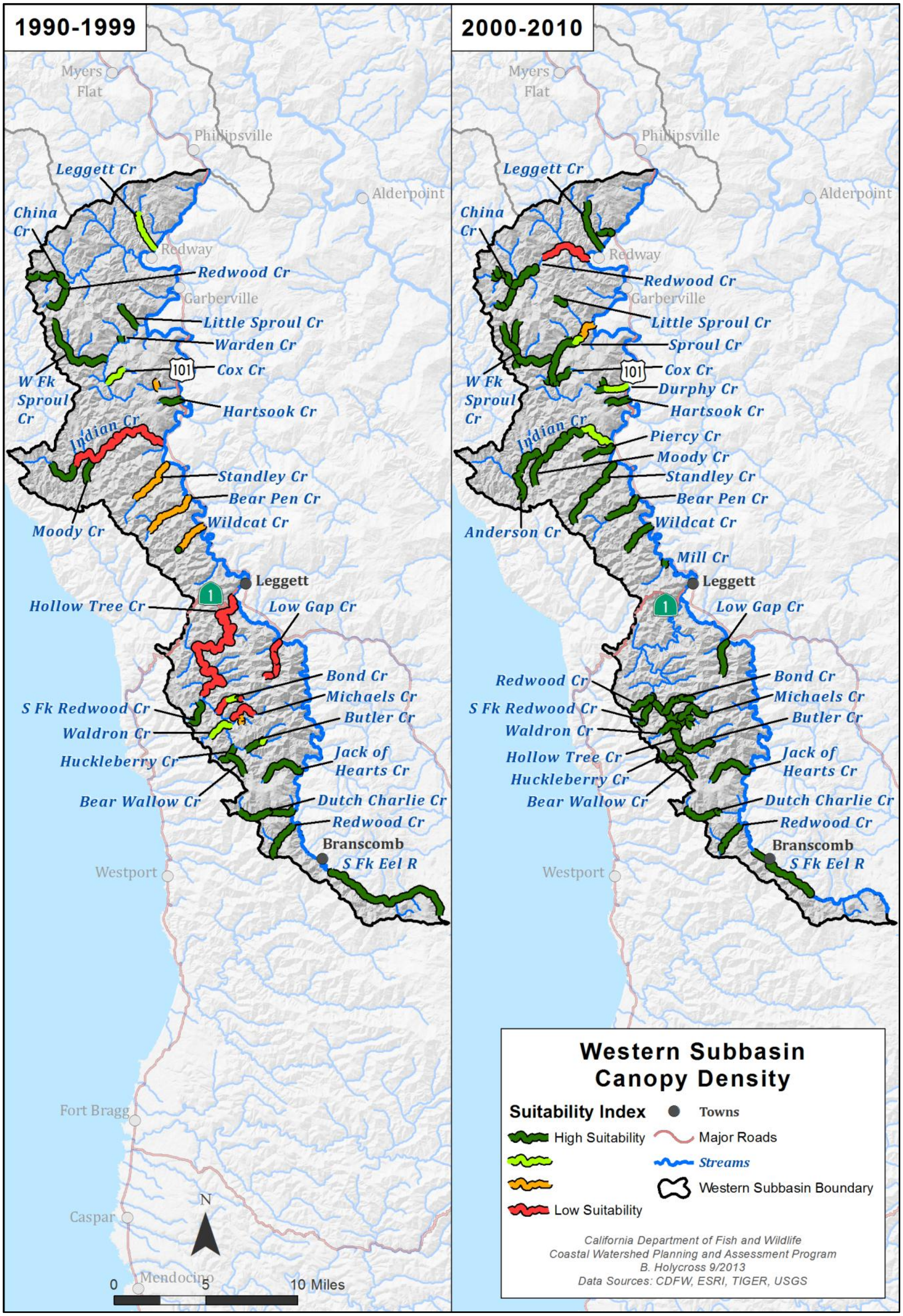



*Figure 42. Canopy density suitability for Western Subbasin streams during two sampling decades: 1990-1999 and 2000-2010.*

In addition to overall canopy density, it is important to consider the contribution of coniferous and deciduous components in the canopy. Dense deciduous riparian vegetation such as alder and maple trees provide excellent canopy closure and habitat/food for macroinvertebrate production, but do not provide the LWD recruitment potential of larger, more persistent coniferous trees (Everest and Reeves 2006). In Western Subbasin streams, the percent contribution of canopy density from coniferous and deciduous trees was estimated visually during habitat typing surveys.

Coniferous canopy cover was relatively low (< 50%) in most streams in the Western Subbasin. Very low (< 10%) coniferous canopy densities were recorded in Bond (1991), Doctor's (2003), unnamed tributary to Durphy (1993 and 2006), Hollow Tree (1992 and 2003), Michaels (1991), Mill (2010), and Sproul (2004) Creeks (*Table 24*).

For streams with survey data available during both time periods, the average percent of open canopy decreased in all streams over time and the percent coniferous vegetation increased in 50% of streams (*Table 24*). The average percent of deciduous canopy increased in nearly all streams, but decreased slightly in SF Redwood Creek and decreased considerably in Jack of Hearts Creek. Most of the land in this subbasin is used for industrial timber harvest, and although management plans are designed to promote streamside canopy and riparian habitat, reductions in coniferous habitat are expected.

*Table 24. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Western Subbasin.*

| STREAM | AVG%CONIFEROUS | AVG%DECIDUOUS | AVG%OPEN |
|---|---|---|---|
| Anderson Creek 08 | 45.5 | 51.6 | 2.9 |
| Bear Pen Creek 92 | 23.3 | 43.2 | 33.5 |
| Bear Pen Creek 07 | 17.6 | 61.8 | 20.6 |
| Bear Wallow Creek 02 | 32.6 | 63.5 | 3.9 |
| Bond Creek 91 | 7.5 | 42.3 | 50.2 |
| Bond Creek 03 | 35.7 | 56.7 | 7.6 |
| Butler Creek 02 | 22.2 | 74.0 | 3.8 |
| Butler Crk LB Trib 3 02 | 17.0 | 80.9 | 2.1 |
| China Creek 98 | 12.8 | 75.1 | 12.1 |
| China Creek 09 | 10.2 | 82.7 | 7.1 |
| Cox Creek 93 | 11.6 | 61.0 | 27.4 |
| Cox Creek 04 | 20.9 | 75.8 | 3.3 |
| Doctors Creek 91 | 21.6 | 44.9 | 33.5 |
| Doctors Creek 03 | 6.1 | 90.7 | 3.2 |
| Durphy Creek 06 | 18.4 | 55.8 | 25.8 |
| Durphy Creek UT 93 | 6.7 | 53.5 | 39.8 |
| Durphy Creek UT 06 | 7.6 | 71.7 | 20.7 |
| Dutch Charlie Creek 92 | 13.6 | 71.1 | 15.3 |
| Dutch Charlie Creek 07 | 25.1 | 72.9 | 1.9 |
| Hartsook Creek 99 | 27.4 | 61.4 | 11.2 |
| Hartsook Creek 09 | 16.9 | 72.1 | 11.0 |
| Hollow Tree Creek 92 | 1.6 | 30.9 | 67.5 |
| Hollow Tree Creek 02 | 16.0 | 72.8 | 11.2 |
| Hollow Tree Creek 03 | 6.4 | 85.5 | 8.1 |
| Huckleberry Creek 02 | 24.7 | 73.4 | 1.9 |
| Indian Creek 93 | 16.4 | 37.3 | 46.3 |
| Indian Creek 08 | 16.1 | 65.9 | 18.0 |
| Jack of Hearts Creek 92 | 38.9 | 45.3 | 15.8 |
| Jack of Hearts Creek 05 | 66.3 | 27.5 | 6.3 |
| Leggett Creek 95 | 31.5 | 44.3 | 24.2 |

| STREAM | AVG%CONIFEROUS | AVG%DECIDUOUS | AVG%OPEN |
|---|---|---|---|
| Leggett Creek 07 | 27.9 | 59.7 | 12.4 |
| Little Sproul Creek 95 | 41.8 | 44.1 | 14.1 |
| Little Sproul Creek UT 04 | 15.4 | 78.9 | 5.8 |
| Low Gap Creek 07 | 22.3 | 57.3 | 20.4 |
| Lynch Creek 91 | 22.7 | 44.6 | 32.7 |
| Lynch Creek 03 | 35.5 | 58.6 | 5.9 |
| Michaels Creek 91 | 7.6 | 32.5 | 59.9 |
| Michaels Creek 03 | 18.5 | 74.7 | 6.8 |
| Mill Creek 10 | 3.9 | 88.5 | 7.6 |
| Moody Creek 93 | 19.5 | 69.0 | 11.5 |
| Moody Creek 08 | 15.7 | 76.9 | 7.4 |
| Piercy Creek 07 | 18.0 | 74.1 | 8.0 |
| Pollock Creek (aka Upper Redwood) 98 | 18.0 | 72.5 | 9.5 |
| Pollock Creek (aka Upper Redwood) 09 | 19.5 | 75.6 | 4.9 |
| Redwood Creek (Hollow Tree) 03 | 34.2 | 56.5 | 9.2 |
| Redwood Creek (Branscomb) 93 | 53.1 | 28.7 | 18.2 |
| Redwood Creek (Branscomb) 07 | 39.2 | 57.8 | 3.1 |
| Redwood Creek (Redway) 09 | 14.4 | 51.7 | 33.9 |
| South Fork Eel River 96 | 16.0 | 66.5 | 17.5 |
| South Fork Eel River 07 | 17.8 | 76.8 | 5.4 |
| South Fork Redwood Creek 91 | 34.0 | 53.5 | 12.5 |
| South Fork Redwood Creek 03 | 40.0 | 52.0 | 8.0 |
| South Fork Redwood Creek UT 03 | 58.9 | 31.7 | 9.4 |
| Sproul Creek 04 | 7.1 | 76.3 | 16.7 |
| Sproul Creek Trib 5 04 | 14.3 | 85.1 | 0.6 |
| Standley Creek 92 | 21.2 | 40.2 | 38.6 |
| Standley Creek 07 | 33.8 | 48.5 | 17.7 |
| Standley Creek 09 | 41.7 | 52.3 | 6.0 |
| Twin Creek UT to China Creek 09 | 25.5 | 71.9 | 2.6 |
| Waldron Creek 91 | 27.2 | 47.6 | 25.2 |
| Waldron Creek 02 | 27.1 | 56.2 | 16.6 |
| Warden Creek 92 | 31.4 | 47.2 | 21.4 |
| Warden Creek 04 | 17.5 | 79.6 | 2.8 |
| West Fork Sproul Creek 92 | 15.1 | 65.5 | 19.4 |
| West Fork Sproul Creek 04 | 12.6 | 82.8 | 4.6 |
| West Fork Sproul Creek Trib 8 04 | 21.7 | 76.8 | 1.5 |
| West Fork Sproul Creek Trib 9 04 | 23.9 | 74.5 | 1.6 |
| Wildcat Creek 92 | 11.1 | 52.9 | 36.0 |
| Wildcat Creek 07 | 10.6 | 83.2 | 6.2 |
| Wood Creek 02 | 45.7 | 38.9 | 15.4 |

## Pool Depth

Primary pools provide salmonids with 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 to 55% of its length in primary pools to be suitable for salmonids. Good coho salmon streams have >40% of total length in primary pool habitat. According to Flosi et al. (2010), in first and second order streams, a primary pool is described as being at least 2.5 feet deep; in third and fourth order streams, primary pool depths are 3 feet and 4 feet, respectively. Because pools are important salmonid habitat even if they are slightly shallower than the established primary pool guidelines, CWPAP staff adjusted primary pool length data for use in the analysis. This adjustment allowed 25% of the length of pool habitat in the depth category below the minimum for each stream order class to be represented in the analyses. For example, in first and second order streams, where pools ≥ 2.5 feet deep are considered primary, 25% of the length of pool habitat between 2 and 2.5 feet deep was added to the total primary pool length to obtain an adjusted percent of primary pool habitat. For third and fourth order streams, 25% of pool habitat between 2.5 and 3 feet, and 3.5 and 4 feet, respectively, was added to the primary pool length. For a complete description of pool depth categories and details of pool depth calculations, see the Analysis Appendix.

*Table 22* lists the percent length of primary pool habitat by stream. Percentages ranged from zero (in Lynch Creek and in an unnamed tributary to Durphy Creek) to 41.8% (in Redwood Creek, tributary to Hollow Tree Creek). Redwood Creek (2003) was the only location sampled where the percent of primary pool habitat met the target value of 40%. Overall percent primary pool habitat (weighted by surveyed length) was 12.5% for habitat surveys completed in the 1990s, and increased slightly to 14.5% for surveys in the early 2000s. These averages are well below target values of >40%.

The percent of primary pool habitat in first through third order streams was very low (10% or less) in both the 1990s and the early 2000s (*Figure 43*). Although the percent of primary pool habitat is low, it increased slightly over time in first and second order streams, and nearly doubled in third order streams.

Lower Hollow Tree Creek was the only 4th order stream habitat sampled in the 1990s, and the percent of primary pool habitat was 22.8% (of 14.8 miles of stream surveyed). This reach was not sampled between 2000 and 2010.

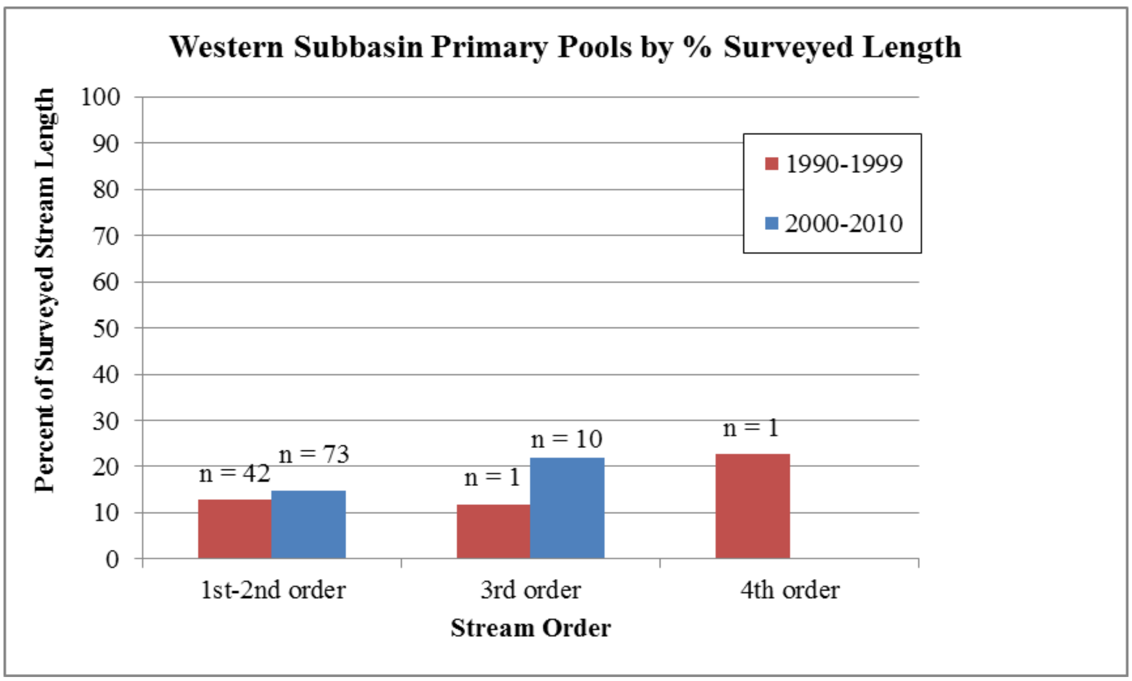



*Figure 43. Percent of surveyed habitat in primary pools in the Western Subbasin, using data collected from 1990-1999 and 2000-2010.*

Pool depth suitability in Western Subbasin streams was in the lowest category for most streams during both sampling periods (*Figure 44*). Indian Creek and the mainstem SF Eel River headwaters near Branscomb showed considerable improvement between the 1990s and early 2000s. Pool habitat suitability improved in some areas of WF Sproul, Standley, Redwood (tributary to Hollow Tree Creek), and Dutch Charlie creeks between the sampling periods, and deteriorated over time in Redwood Creek (near Branscomb). Tributaries in upper Hollow Tree Creek are important coho spawning and rearing habitats, and most streams had pool depth suitability levels in the lowest category, during both the 1990s and early 2000s. Western Subbasin streams receive a tremendous amount of sediment from both anthropogenic (mainly timber harvest and roads) and natural sources. Heavy

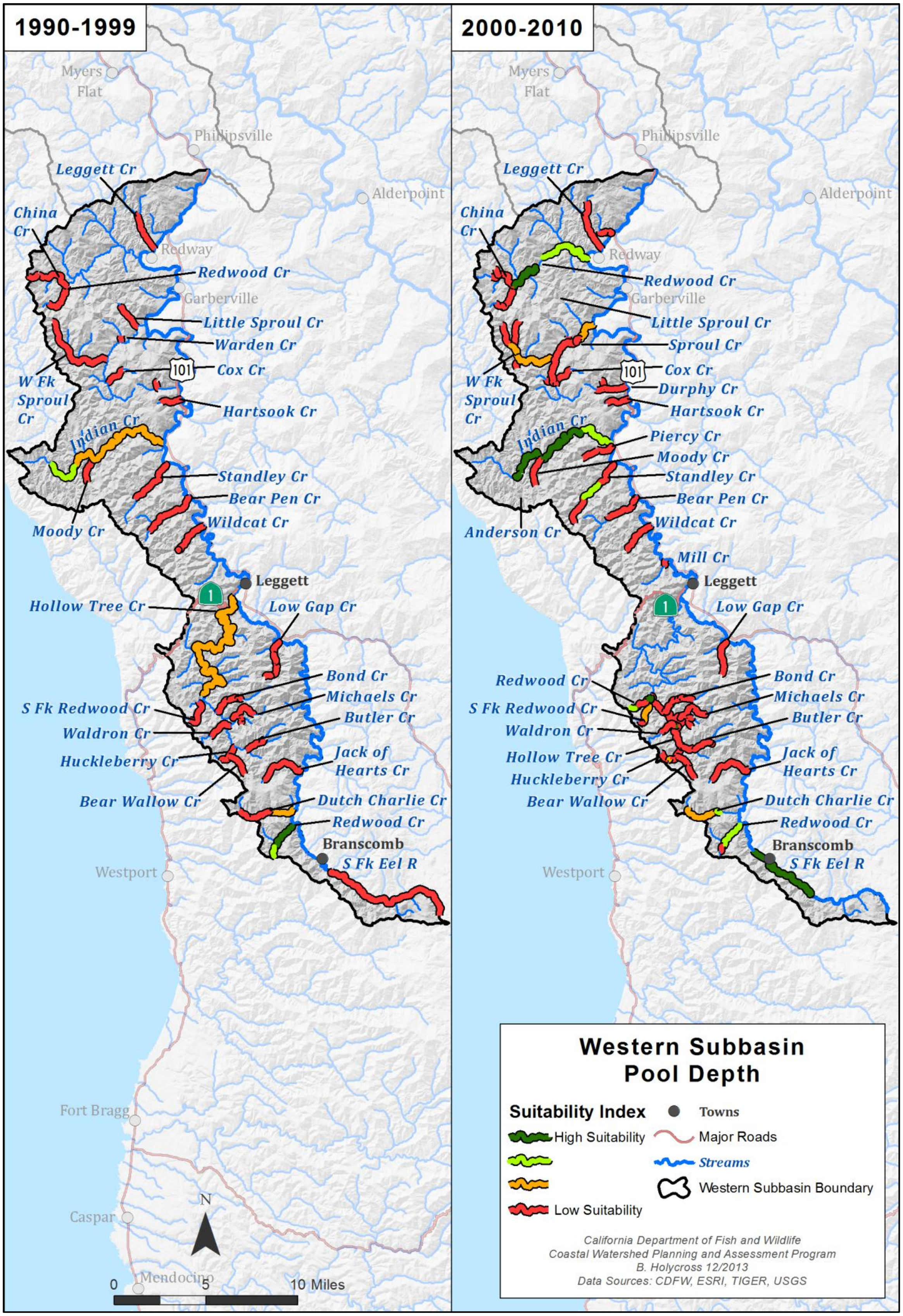



*Figure 44. Pool depth suitability in SF Eel River Western Subbasin streams, using data collected between 1990 and 1999, and 2000 and 2010.*

sedimentation rates, especially during large flood events such as the 1955 and 1964 floods, have modified stream channels from deep, cool and relatively stable, to shallow and relatively unstable by filling in pool habitat and depositing sediment throughout the channel bed. In their sediment source analysis, Stillwater Sciences (1999) found that earthflow toes and associated gullies were the primary source of sediment input in the Hollow Tree Creek Basin, followed by road related mass wasting, road crossing and gully erosion, and skid trail erosion. In Sproul Creek, the primary source of sediment input was road crossing and gully erosion, followed by inner gorge and upland mass wasting. Overall sediment loads were less in these areas of Coastal Belt geomorphic terrain, compared to mélange terrain in the Northern Subbasin. However, the Western Subbasin has the highest road density (4.76 mi/sq mi) of the three SF Eel River subbasins, and industrial timber harvest is the primary land use, resulting in high anthropogenic sediment loads filling in existing pool habitat. Restoration activities that create additional pool habitat and scour existing shallow pools while reducing sediment input from surrounding hillsides and roads are highly recommended throughout this subbasin.

## Pool Shelter

Pool shelter provides protection from predation and rest areas from high velocity flows for juvenile and adult salmonids. The pool shelter rating is a relative measure of the quantity and percent composition of small and large woody debris, root masses, undercut banks, bubble curtains, and submerged or overhanging vegetation in pool habitats. A standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) is assigned according to the complexity of the shelter. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent of pool habitat covered. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream. Shelter ratings of 100 or less indicate that pool shelter/cover enhancement should be considered.

The average mean pool shelter rating for all Western Subbasin streams was 43.5 in the 1990s and 36.4 using habitat data collected between 2000 and 2010 (*Table 22*). Values ranged from a low of 5.0 (unnamed tributary to SF Redwood Creek) to a high of 112.7 (Butler Creek). Only two streams had pool shelter ratings above target values: Butler Creek (1990) and Bear Wallow Creek (1990). Both of these streams had substantially lower pool shelter ratings when sampled in the 2000-2010 period: 34.8 in Butler Creek in 2002, and 48.6 in Bear Wallow Creek in 2002. Pool shelter type in both creeks in the 1990s was mostly LWD and boulders, but in the 2000s, shelter was mainly boulders, with only a small amount of LWD in Butler Creek, and mainly SWD in Bear Wallow Creek. Reductions in LWD and corresponding decreases in shelter values are most likely due to the lack of LWD recruitment in these streams.

Most streams in the subbasin had pool shelter scores in the lowest suitability category (*Figure 45*). A few streams showed some improvement between the two sampling periods, including West Fork Sproul Creek, Wildcat Creek, Redwood Creek (near Branscomb), and some of the tributaries in upper Hollow Tree Creek.

Restoration projects targeting streams with particularly low pool shelter values and potential salmonid presence should be a high priority throughout the Western Subbasin. Because most of the land is owned by timber companies, wood recruitment is low and projects that add LWD to streams are recommended. These projects could be combined with pool habitat creation/enhancement projects, since both primary pool habitat and pool shelter are limiting factors for salmonids in this subbasin.

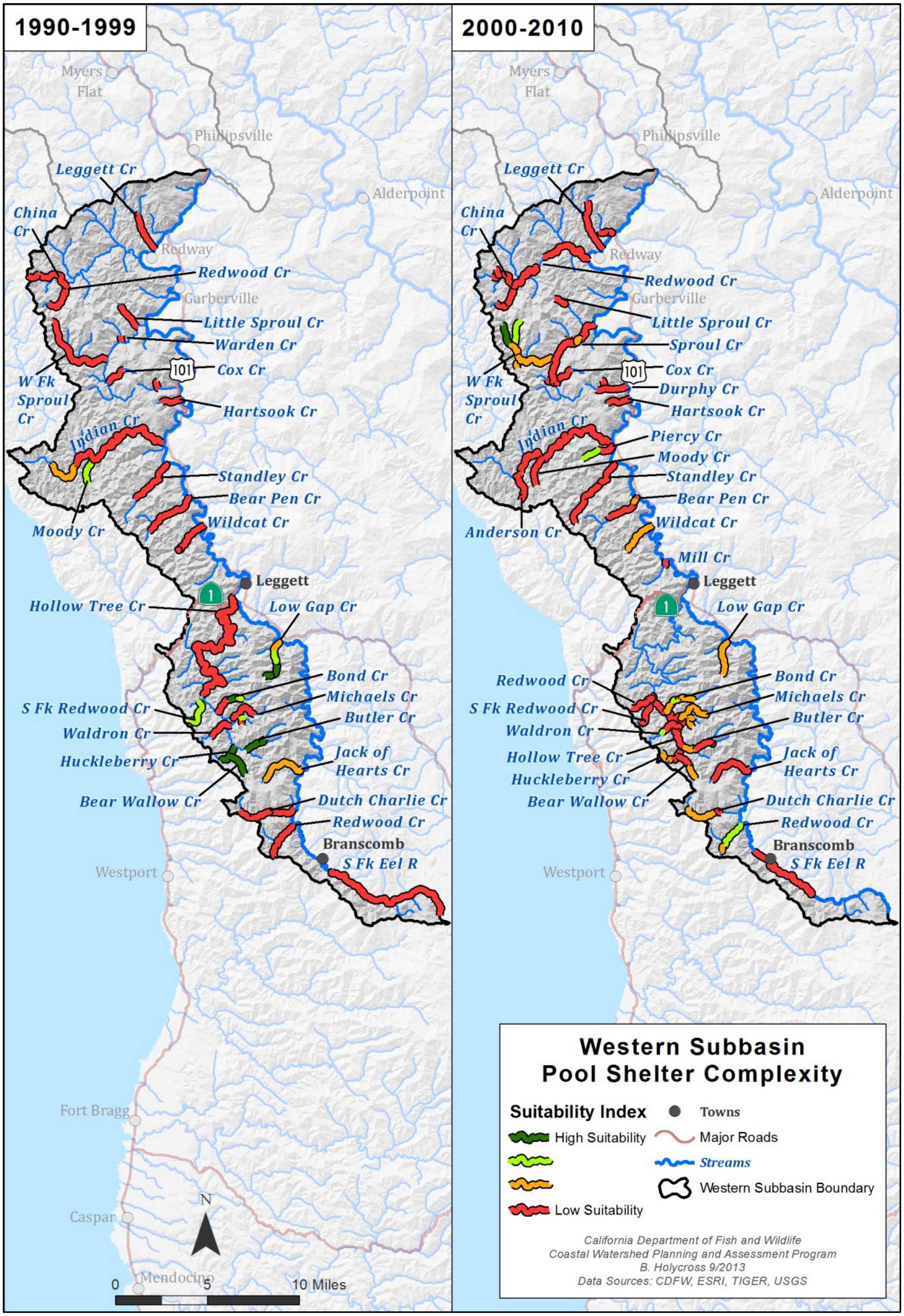



*Figure 45. Pool shelter complexity suitability for Western Subbasin streams during two sampling decades: 1990-1999 and 2000-2010.*

## Substrate Embeddedness

Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments in gravels reduce spawning and incubation success. Substrate embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 cobbles are 0-25% embedded, category 2 are 26-50% embedded, category 3 are 51-75% embedded, and category 4 are 76-100% embedded. Embeddedness categories 3 and 4 are not within the fully suitable range for successful use by salmonids. Category 5 embeddedness, represented by the bars furthest to the right in *Figure 46* represent tail-outs deemed unsuitable for spawning due to inappropriate substrate like sand, bedrock, log sills, or boulders, and were not included in the suitability analysis.

Cobble embeddedness condition improved in most Western Subbasin streams over time, with average percent category 1 embeddedness values of 12.7% for data collected in the 1990s and 34.4% for data collected between 2000 and 2010 (*Table 22*).

While subbasin averages are a good overall indicator of embeddedness, it is valuable to consider the changes in each category type over time, since only categories 1 and 2 are suitable for salmonid spawning. The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled between the 1990s and early 2000s (*Figure 46*). Although nearly 35% of surveyed pool tails were in category 1 in the early 2000s, this is still less than the target value of 50% in category 1 embeddedness established by Flosi et al. (2010).

The percentage of pool tails in category 2 was nearly the same (31-36%), and the percentage of pool habitat in categories 3 and 4 was substantially lower when comparing the two time periods. The percentage of pool habitat in category 5 (unsuitable for spawning) doubled between the two time periods, due to sediment input from both natural and anthropogenic sources.

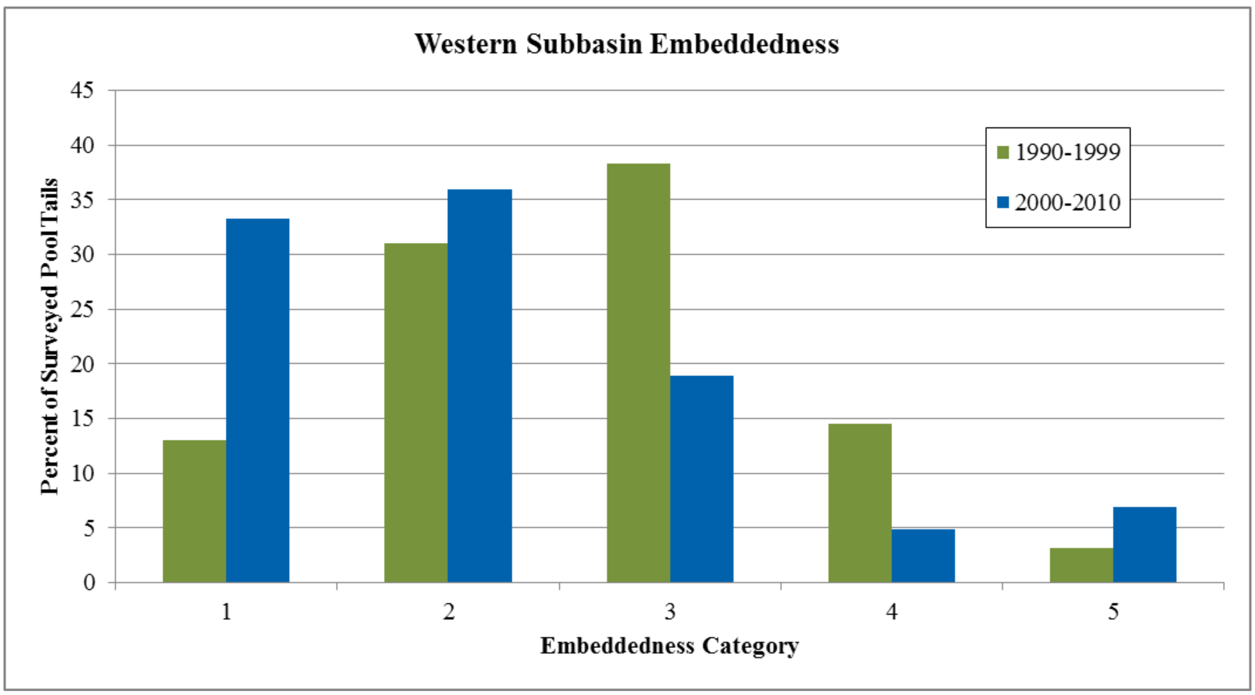



*Figure 46. Cobble Embeddedness in the Western Subbasin using data collected from 1990-1999 and 2000-2010.*

The EMDS-based model used a weighted sum of embeddedness category scores to evaluate the pool tail substrate suitability for survival of eggs to emergence of fry. The percent embeddedness categories were weighted by assigning a coefficient to each category. Embeddedness category 1 was rated as fully suitable for egg survival and fry emergence and a coefficient of +1 was assigned to the percent of embeddedness scores in category 1. Embeddedness category 2 was considered uncertain and given a coefficient of 0. Embeddedness categories 3 and 4 were considered unsuitable and were assigned a coefficient of -1. Category 5 values were omitted because they are composed of impervious substrate. The values for each category were summed and evaluated in the analysis.

Embeddedness suitability increased in streams throughout the Western Subbasin between the 1990s and early 2000s (*Figure 47*). Most streams were in the lowest suitability category in the 1990s, but by the early 2000s, most streams were in either the highest or second highest suitability category. Indian Creek, Redwood Creek (near Redway), and tributaries in the upper Hollow Tree Creek are some of the more important coho streams with improved embeddedness scores. These improvements are most likely due to sediment from historical floods moving through the system, and due to bank stabilization and upslope watershed restoration projects that have been completed or are in progress throughout the subbasin.

Upslope watershed restoration, including road decommissioning and upgrading projects, are designed to decrease fine sediment input and therefore decrease embeddedness are particularly important in this subbasin because of the high road density (4.76 miles/square mile) and intensive historic and current timber harvest activities, in addition to increased road usage for residential and agricultural purposes. Many road related restoration projects have been completed in Hollow Tree Creek and Standley Creek watersheds, and will be discussed in the Restoration Projects section of this subbasin report.

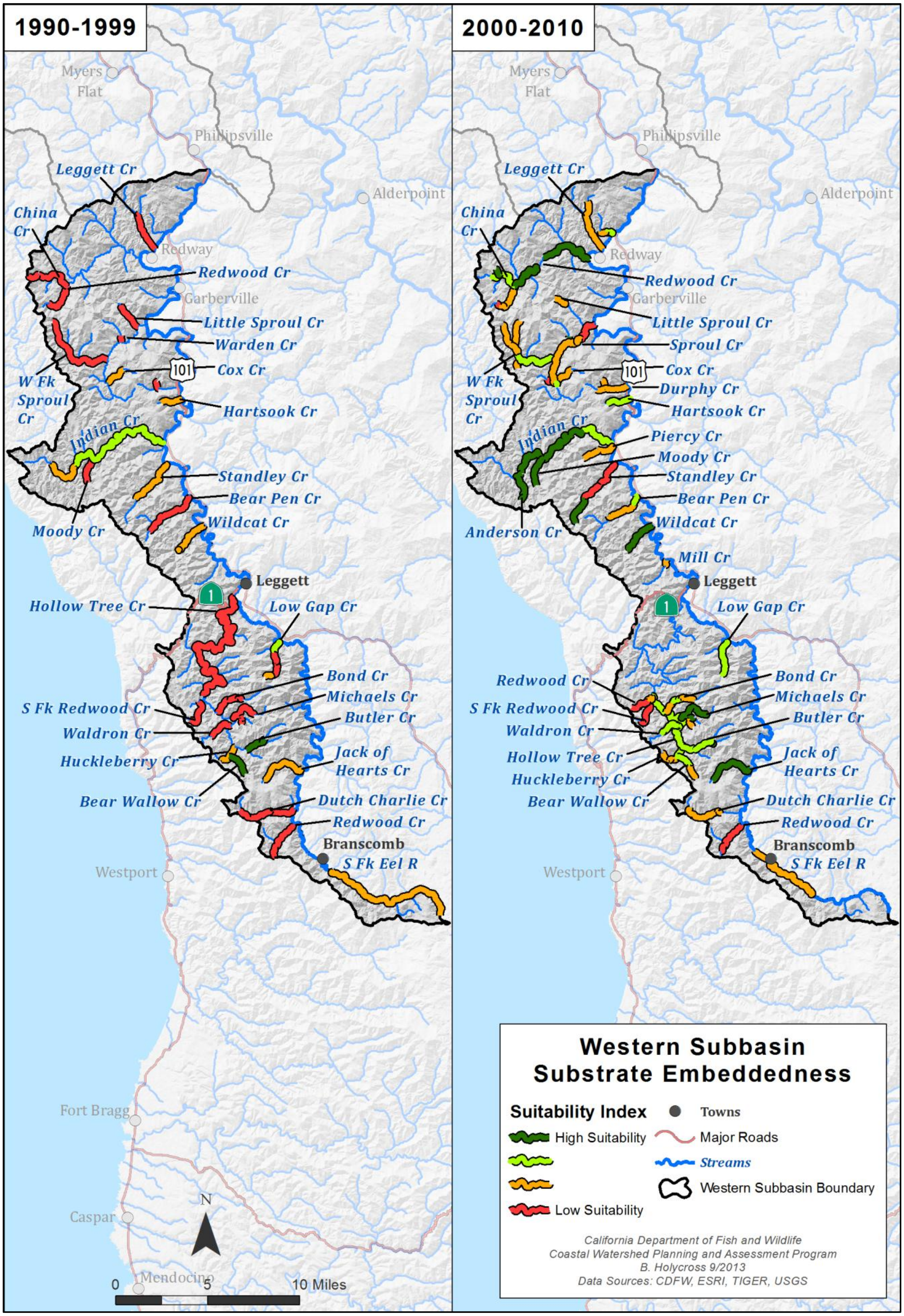



*Figure 47. Embeddedness suitability in Western Subbasin streams using data collected during between 1990 and 1999, and 2000 and 2010.*

## LWD

Wood recruitment processes vary spatially across landscapes due to differences in forest composition and age, climate, stream size, topography, natural disturbances, and land use history (Benda and Bigelow 2011). Large wood shapes channel morphology, helps streams retain organic matter and nutrients, and provides essential cover for salmonids. It also modifies streamflow, adds habitat complexity and structure, and increases pool formation and available habitat for Chinook and coho salmon and steelhead trout at all life stages during both low and high flow times (Snohomish County Public Works 2002). Natural LWD recruitment is lower in areas where industrial timber harvest occurs (Murphy and Koski 1989, Beechie et al. 2000).

CWPAP staff did not develop reference values for frequency and volume of LWD in the EMDS-type analysis. Other models have used values derived from Bilby and Ward (1989), which are dependent on channel size. Most watersheds in the Western Subbasin did not have sufficient LWD surveys and channel size measurements for use in the analysis, but existing data were summarized to determine the frequency of LWD as the dominant shelter type and the percent shelter from LWD in pools.

Boulders were the dominant shelter type recorded in Western Subbasin streams in all subbasin reaches during both time periods (*Table 25*). Large and small woody debris were the next most common shelter types, and the occurrence of both of these types as dominant sources of shelter increased from the 1990s to the early 2000s. This was expected due to the predominance of coniferous and hardwood forest vegetation types (which supply LWD to streams), timber harvest policies promoting streamside canopy and riparian management, and restoration efforts and management strategies designed to encourage natural LWD recruitment and placement in Western Subbasin streams.

*Table 25. Dominant pool shelter type by number of reaches surveyed in Western Subbasin streams.*

| Dominant Shelter Type | 1990-1999 | 2000-2010 |
|---|---|---|
| Boulders | 32 | 39 |
| Root masses | 0 | 1 |
| Terrestrial vegetation | 2 | 3 |
| LWD | 3 | 20 |
| SWD | 4 | 14 |
| Aquatic vegetation | 0 | 0 |
| Undercut banks | 3 | 8 |
| Whitewater | 0 | 1 |
| **Total number of reaches surveyed** | **44** | **86** |

The average percent shelter from LWD in pools in Western Subbasin streams was very low during both sampling periods, but increased slightly over time (*Table 26*). These low values may be due to past management practices and land uses. Most of the land in this subbasin has been used for industrial timber harvest historically and currently, and rates of natural LWD recruitment are low. In the 1960s and 1970s, management strategies included aggressive removal of large wood (from landslides, flood events, and logging debris) from channels; these accumulations were thought to be barriers to fish passage. Recent restoration activities have emphasized adding large wood back into streams (Opperman et al. 2006), especially in areas where wood is readily available in close proximity to the stream. Although the average percent shelter from LWD values increased over time, these values were very low (<5%), indicating the need for additional large wood as vital rearing and holding habitat components in streams throughout the Western Subbasin.

*Table 26. Total length of pool habitat and average percent shelter from LWD in Western Subbasin streams using data collected during two time periods: 1990-1999 and 2000-2010.*

| Western Subbasin | Total length of pool habitat (mi) | Avg % shelter from LWD |
|---|---|---|
| 1990-1999 | 27.08 | 3.52 |
| 2000-2010 | 34.35 | 4.00 |

## Pool-Riffle Ratio

Pool-riffle ratio is a measure of the amount of habitat available to salmonids in a stream, specifically the amount of pool habitat for resting and feeding, and the amount of riffle habitat for food production and spawning. Pool-riffle sequences, ratios, and lengths are dependent on channel gradient, resistance of channel boundaries (bedrock walls and bed material), and discharge (Wohl et al. 1993). A 50:50 (1:1) ratio is usually considered optimal, but streams with a slightly lower percentage of pool habitat compared to riffle habitat (0.4:1 ratio) have also been found to support a high biomass of salmonids (Platts et al. 1983). Flosi et al. (2010) recommended that approximately 40% of anadromous salmonid stream length should be pool habitat. Streams with a high percentage of riffles and few pools are generally low in fish biomass and species diversity (Snohomish County Public Works 2002).

Although pool depth, as measured by the percentage of primary pool habitat in Western Subbasin streams, was below optimal levels during both sampling periods, the ratio of pool to riffle habitat exceeded the recommended 50:50 ratio during both time periods (*Table 27*). A pool-riffle ratio of 60:40 is generally considered to provide suitable holding area and habitat diversity for both juvenile salmonids and benthic invertebrates, which are utilized as prey items by salmonids (Johnson 1985). Aggradation from numerous active landslides and unstable geology, and sediment input from roads may have contributed to a decrease in channel complexity and less than optimal pool depths in this subbasin, and projects designed to enhance pool depths are recommended.

*Table 27. Percent pool and riffle habitat, and pool riffle ratios for Western Subbasin streams (from habitat typing data collected between 1990 and 1999, and 2000 and 2010).*

| DATE | % POOL HABITAT | % RIFFLE HABITAT | POOL:RIFFLE RATIO |
|---|---|---|---|
| 1990-1999 | 32 | 23 | 58 : 42 |
| 2000-2010 | 34 | 23 | 60 : 40 |

The ratio of pool to riffle habitat improved slightly in recent years (2000-2010) compared to conditions in the 1990s. This improvement may be due to restoration projects completed in the basin, especially instream and riparian habitat improvement, upslope watershed restoration, and bank stabilization projects, and to large sediment deposits from historic floods moving through the system.

Most pools sampled during both time periods were shallow, resulting in primary pool lengths below target values and corresponding low pool depth suitability scores. This was expected because habitat typing surveys are conducted during summer (relatively low flow) months, and are not a reflection of winter habitat conditions, when flows and pool depths increase. Additional information on pool depths and pool-riffle ratios collected during the winter would be beneficial for future assessments.

# Water Quality

## Water Temperature

Water temperature is one of the most important environmental influences on salmonids at all life stages, affecting physiological processes and timing of life history events (Spence et al. 1996, Carter 2005). Stressful conditions from high temperatures are cumulative and are positively correlated with both the severity and duration of exposure (Carter 2005). Elevated instream temperatures result from an increase in direct solar radiation due to the removal of riparian vegetation, channels widening and becoming shallower due to increased sedimentation, and the transport of excess heat downstream (USEPA 1999).

The Humboldt County Resource Conservation District (HCRCD), with the cooperation of 21 supporting agencies, individuals, and landowners, completed temperature monitoring and biological sampling in the Eel River Watershed, collecting data during eight field seasons from 1996-2003 (Friedrichsen 2003). They collected maximum weekly average temperature (MWAT) in streams throughout the SF Eel River Basin, including 64 sampling locations (53 in tributaries and 11 in the mainstem SF Eel River) in the Western Subbasin (*Figure 48*). Data loggers were generally deployed from June through October, and not all sites were sampled every year. Some large streams (Redwood and Sproul Creeks) were sampled at more than one location, and site locations are listed for each data point. Friedrichsen (2003) provided X,Y coordinates for most gauge locations, and others were digitized using HCRCD map data where available. Although not all sampling locations are included on the map, most missing data points were located in mainstem areas of larger tributaries (S. Downie, CDFW, personal communication 2013).

The CWPAP staff created suitability ranges for stream temperature based on MWATs, considering the effect of temperature on salmonid viability, growth, and habitat fitness (*Table 28*). This metric was calculated from a seven-day moving average of daily average temperatures. The maximum daily average was used to illustrate possible stressful conditions for salmonids. The instantaneous maximum temperature that may lead to salmonid mortality is ≥75°F; this temperature is potentially lethal for salmonids if cooler refuge is not available.

*Table 28. CWPAP-defined salmonid habitat quality ratings for MWATs.*

| MWAT Range | Description |
|---|---|
| 50-62°F | Good stream temperature |
| 63-65°F | Fair stream temperature |
| ≥66°F | Poor stream temperature |

Using Friedrichsen's data and these temperature ranges, 40 sites (on 26 creeks) in Western Subbasin tributaries and one site on the mainstem SF Eel River had good salmonid temperatures (*Table 29*). Eight tributary sites (on seven creeks) and one mainstem site had fair temperatures, and five tributary sites (on four creeks) and nine mainstem sites had poor stream temperatures (*Figure 49*). There were more Western Subbasin streams with good stream temperatures recorded compared to Northern and Eastern Subbasin streams in the SF Eel River Basin, primarily because of good canopy cover, narrow stream valleys, and the location of this subbasin in the coastal fog belt and corresponding cool air temperatures.

Many of the sampling sites with poor stream temperatures were located in the mainstem SF Eel River, and in the lower reaches of large tributary streams (e.g. Hollow Tree, Redwood (Redway), and Sproul creeks). In these areas, increased direct solar radiation from reduced riparian cover and wide channels results in warmer water temperatures than in nearby tributaries. Researchers obtained a maximum daily average reading of 75˚F or greater in two sites in the mainstem SF Eel River (near Piercy at RM 54, and near Sylvandale at RM 25), both of which exceeded the lethal temperature for salmonids if cooler refuge areas (springs and seeps) are not available nearby. Although we expect higher temperatures in mainstem SF Eel River than in tributaries, it is important to capture the duration that salmonids are exposed to these stressful or lethal temperatures, and to document the location and availability of cool water refugia areas near sites where lethal MWAT values have been recorded.

In addition to the HCRCD studies, Higgins (2013) and the Eel River Recovery Project (ERRP) employed a citizen monitoring effort in 2012 to collect water temperature data as an indicator of flow depletion in streams throughout the Eel River Basin. Higgins compared 2012 stream temperatures with data collected at similar locations by HCRCD between

1996 and 2003, and his conclusions were similar to Friedrichsen's: mainstem SF Eel River temperatures in the upper areas near Branscomb were some of the coolest mainstem conditions in the entire Eel River system, and temperatures became progressively warmer downstream. Higgins and ERRP also found temperatures in the mainstem SF Eel River near Piercy were above optimal for salmonids. Fish in these areas may seek refuge in thermally stratified pools or in localized refugia provided by surface and groundwater interactions when mainstem and tributary temperatures reach stressful or even lethal temperatures (Nielsen et al. 1994). These cool water refugia are particularly important in areas where high temperatures result in increased primary productivity (algal blooms), low dissolved oxygen concentrations, and conditions favoring invasive species such as Sacramento pikeminnow. Both spatial and temporal changes in stream temperatures are concerns in some Western Subbasin tributaries. Stressful temperature conditions caused by drawing more water out of streams both during dry years and during dry seasons each year have exposed salmonids to extremes that they would not normally encounter. These extremes are particularly problematic for fragmented populations, which are less resilient to variations in stream temperature and other habitat conditions (Poole et al. 2001).

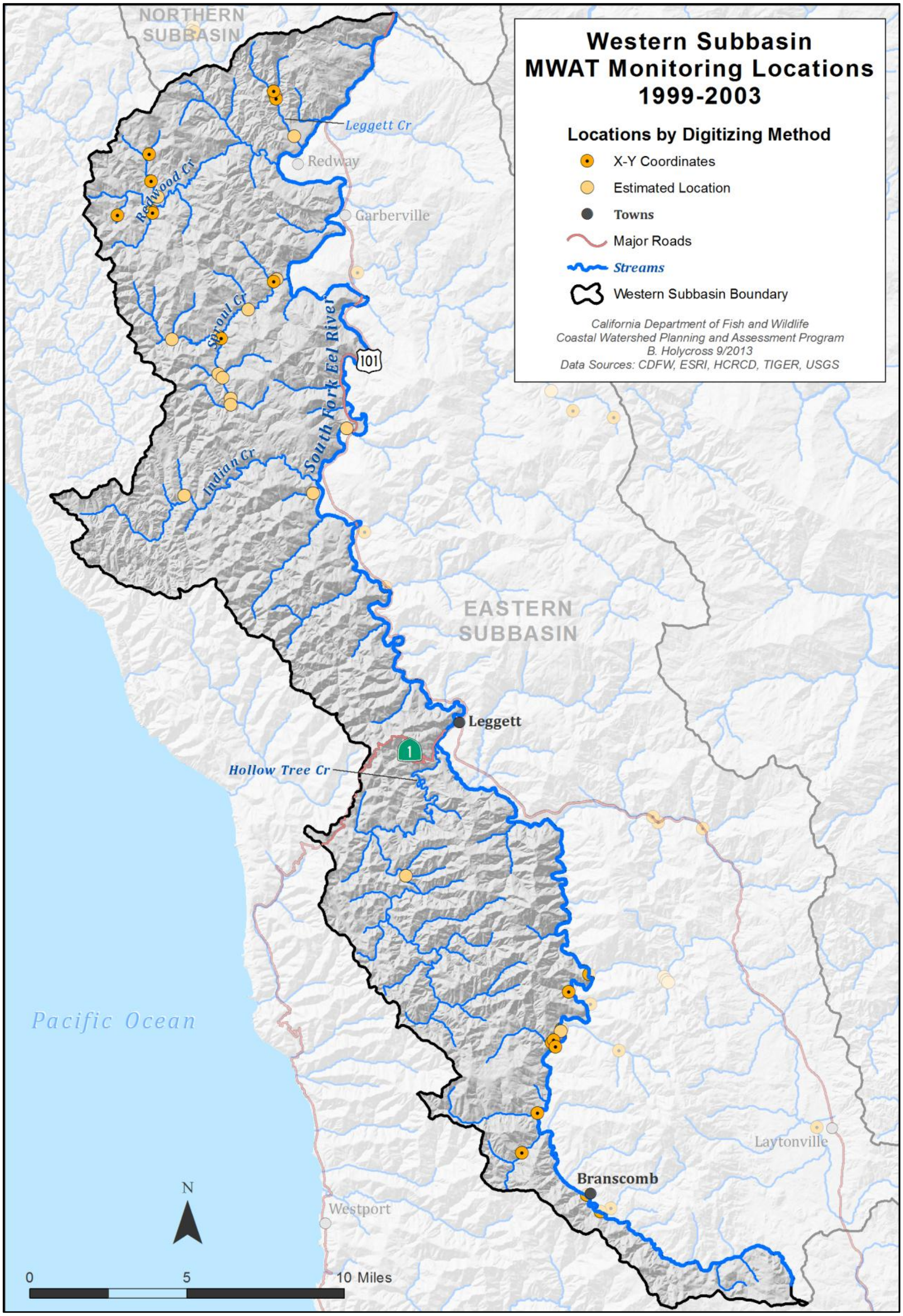



*Figure 48. Locations of temperature monitoring sites in the Western Subbasin.*

*Table 29. Maximum weekly average temperatures (MWATs) and ranges collected in SF Eel River Western Subbasin tributaries from 1999-2003 (data from Friedrichsen 2003).*

| Creek | Site | MWAT Range (°F) | Average MWAT (°F) | Years of Data |
|---|---|---|---|---|
| **Good Stream Temperature (50-62 °F)** | | | | |
| Bear Creek | 1839 | 57 | 57 | 1 |
| Barnwell Creek | 8046 | 61 | 61 | 1 |
| Bear Pen Creek | 1776 | 62 | 62 | 1 |
| Bond Creek | 2150 | 59 | 59 | 1 |
| Buck Gulch | 8001 | 60-63 | 61 | 5 |
| China Creek | 1525 | 59-61 | 60 | 3 |
| Dinner Creek | 8002 | 60 | 60 | 2 |
| Dinner Creek | 8003 | 59-62 | 60 | 5 |
| Dutch Charlie Creek | 1534 | 62 | 62 | 4 |
| Dutch Charlie Creek | 1780 | 56 | 56 | 1 |
| Hollow Tree Creek (Middle) | 2142 | 62 | 62 | 1 |
| Hollow Tree Creek (Upper) | 2036 | 55 | 55 | 1 |
| Huckleberry Creek | 2037 | 55 | 55 | 1 |
| Indian Creek | 1770 | 59 | 59 | 1 |
| Indian Creek | 1786 | 62 | 62 | 1 |
| Jack Of Hearts Creek | 1566 | 61-64 | 62 | 5 |
| Ladoo Creek | 1106 | 58-60 | 59 | 3 |
| Legget Creek | 8034 | 61 | 61 | 1 |
| Legget Creek | 8035 | 62 | 62 | 1 |
| Lost Man Creek | 8038 | 60 | 60 | 1 |
| Michael's Creek | 2152 | 60 | 60 | 1 |
| Miller Creek | 8012 | 57-60 | 59 | 4 |
| Miller Creek | 8014 | 60 | 60 | 1 |
| Miller Creek | 8032 | 58-64 | 61 | 2 |
| Piercy Creek | 1772 | 61 | 61 | 1 |
| Piercy Creek | 1606 | 61-63 | 62 | 2 |
| Pollock Creek | 1412 | 58-62 | 60 | 3 |
| Redwood Creek | 1779 | 55 | 55 | 1 |
| Redwood Creek (Hollow Tree) | 2151 | 58 | 58 | 1 |
| Redwood Creek @ Branscomb.Dump | 1612 | 57-61 | 59 | 5 |
| Sebbas Creek | 1117 | 60-62 | 61 | 2 |
| South Fork Eel River @ Mud Creek (RM 97) | 8045 | 62 | 62 | 1 |
| Sproul Creek | 1102 | 58 | 58 | 2 |
| Sproul Creek | 1103 | 57-62 | 59 | 3 |
| Sproul Creek | 1105 | 61 | 61 | 2 |
| Sproul Creek | 1136 | 61 | 61 | 1 |
| Sproul Creek | 1104 | 61-62 | 62 | 2 |
| West Fork Sproul Creek | 1107 | 58 | 58 | 1 |
| West Fork Sproul Creek | 1108 | 59 | 59 | 1 |
| West Fork Sproul Creek | 1109 | 59 | 59 | 1 |
| Wildcat Creek | 1773 | 62 | 62 | 1 |
| **Fair Stream Temperature (63-65 °F)** | | | | |
| Jack Of Hearts Creek | 8060 | 63 | 63 | 1 |
| Hollow Tree Creek | 8063 | 65 | 65 | 1 |
| Leggett Creek (Upper) | 1572 | 62-67 | 64 | 4 |

| Creek | Site | MWAT Range (°F) | Average MWAT (°F) | Years of Data |
|---|---|---|---|---|
| **Fair Stream Temperature (63-65 °F) (con.)** | | | | |
| Little Sproul Creek | 1477 | 62-64 | 63 | 2 |
| Seely Creek | 8061 | 65 | 65 | 1 |
| South Fork Eel River @ Branscomb (RM 95) | 1658 | 63-66 | 64 | 5 |
| Sproul Creek | 1407 | 62-64 | 63 | 4 |
| Sproul Creek | 1408 | 57-67 | 64 | 4 |
| Sproul Creek (West Fork) | 1409 | 63 | 63 | 2 |
| **Poor Stream Temperature (≥66 °F)** | | | | |
| Hollow Tree Creek | 1778 | 69 | 69 | 1 |
| Hollow Tree Creek (Lower) | 2029 | 66 | 66 | 1 |
| Leggett Creek 2 | 8021 | 65-67 | 66 | 4 |
| Redwood Creek (Redway) (Walley's Repair; 0.5 mi upstream from Seeley Creek) | 1614 | 73 | 73 | 1 |
| South Fork Eel River (RM 51) | 241 | 73 | 73 | 1 |
| South Fork Eel River (RM 54) | 249 | 74 | 74 | 1 |
| South Fork Eel River (RM 84) | 9636 | 73 | 73 | 1 |
| South Fork Eel River (RM 86) | 9637 | 72 | 72 | 1 |
| South Fork Eel River @ Angelo Reserve (RM 88) | 8059 | 69 | 69 | 1 |
| South Fork Eel River @ Piercy Creek (RM 54) | 1416 | 75 | 75 | 1 |
| South Fork Eel River @ Sylvandale (RM 25) | 1634 | 74-78 | 76 | 4 |
| South Fork Eel River above Elder Creek (RM 90) | 1657 | 68-71 | 70 | 3 |
| South Fork Eel River above Rattlesnake Creek (RM 76) | 1638 | 74 | 74 | 1 |
| Sproul Creek | 1137 | 69-70 | 69 | 2 |

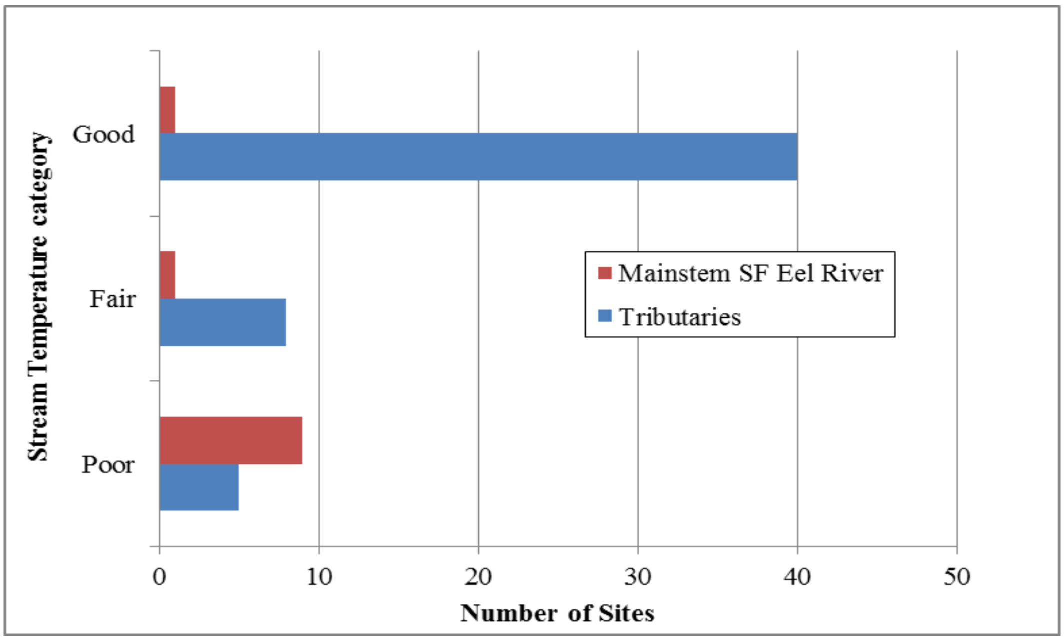



*Figure 49. Number of sites in each CWPAP suitability rating category for MWATs collected from 1999-2003 (n=64; 53 tributary and 11 mianstem sites) in the SF Eel River Western Subbasin (data from Friedrichsen 2003).*

Temperature data were also collected during the summer of 2013 by UC Berkeley graduate student Keith Bouma-Gregson. Bouma-Gregson sampled cyanotoxins, nutrients (nitrogen and phosphorous), and temperature at seven Eel River Basin sites, including 4 in the mainstem SF Eel River: Phillipsville (RM 22), Richardson Grove (RM 49), Standish-Hickey State Recreation Area (SRA) (RM 66), and Angelo Reserve (RM 89) (*Figure 50*). Of the SF Eel River sites, daily average temperatures recorded were lowest at Angelo Reserve (64.6-74.7˚F) and warmest at Phillipsville (67.1-79.6˚F). These data are consistent with Friedrichsen's and ERRP's findings. Temperatures recorded at Richardson Grove and Standish-Hickey SRA were intermediate between the other two SF Eel River locations. Lethal temperatures (≥75˚F) were recorded on 15 days in July and August at Richardson Grove, and on 9 days in July at Standish-Hickey SRA, both of which are located within the Western Subbasin boundary. At the Phillipsville site, located just north of the Western Subbasin boundary, daily average temperatures were above lethal limits for salmonids on 27 days from mid-July to early September. There were no lethal temperatures recorded at the Angelo Reserve site (Bouma-Gregson, UC Berkeley, personal communication 2014).

Maximum weekly average temperatures are momentary high points, and both MWAT and daily average temperatures are useful for general discussion. However, in order to understand temperature conditions and their effects on salmonids, it would be more informative to capture the duration that salmonids are exposed to stressful or lethal temperatures on a reach by reach basis, and to document the availability of cool water refugia areas near locations where poor MWAT values have been recorded. There are studies in development to address flow and temperature concerns in other parts of the SF Eel River Basin (e.g. Redwood Creek, near Redway (SRF 2013)), but additional studies are necessary in Western Subbasin streams, particularly in tributaries to larger creeks and in locations further upstream in tributaries sampled by Friedrichsen et al., ERRP, and Bouma-Gregson. Studies addressing temperatures during low flow periods are especially important to determine how low flow and diversion are affecting temperatures in tributaries, and the effects of these changes on salmonids throughout the subbasin.

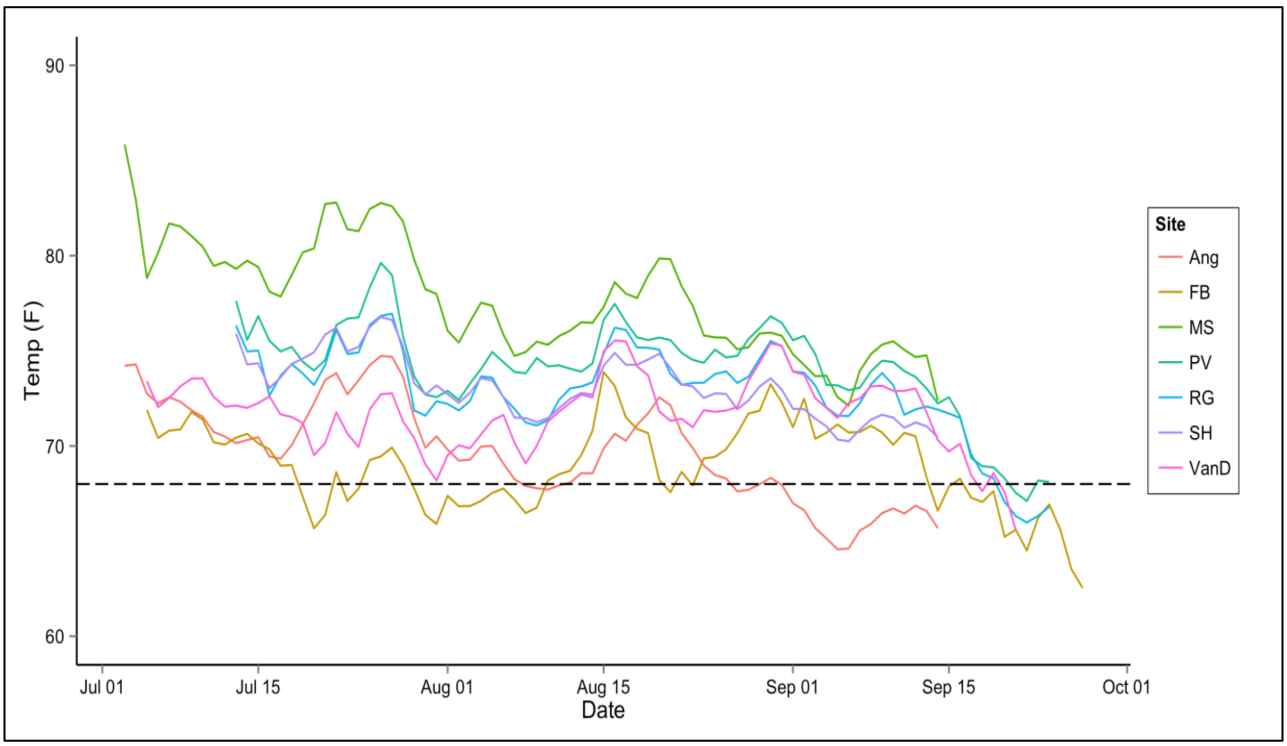



*Figure 50. Daily average temperatures (degrees F) from July 3 through September 24, 2013, recorded at 7 sampling locations in the Eel River Basin. Data and graph provided by Keith Bouma-Gregson (UC Berkeley, 2014). Ang = Angelo Reserve; FB = Fernbridge; MS = Mainstem Outlet Creek; PV = Phillipsville; RG = Richardson Grove; SH = Standish-Hickey SRA; VanD = Van Duzen River.*

## Flow

There are four sources of stream flow in a natural watershed:

- **Groundwater flow** into the channel provides base flow. In perennial streams, the water table is at the height of the stream surface;
- **Interflow** from the soil moisture zone;
- **Direct channel precipitation** at the surface; and
- **Surface runoff** as overland flow (Ritter 2013).

Instream flow is typically measured in cubic feet per second (cfs), and is a measure of how fast the water is moving through a cross-section of the stream. Flow velocity is directly related to the hydraulic radius and channel slope, and inversely related to channel roughness in a stream (Ritter 2013).

River morphology (width, depth, slope, and channel pattern) changes in response to the supply of sediment and water from the surrounding watershed (Pitlick and Wilcock 2001). In Western Subbasin streams, increased deposition and aggradation from high sediment input rates affect flow, particularly during summer months when natural flow sources are significantly reduced and diversion rates are high. These low flows and the predominance of sediment result in streams with subsurface flow during late summer and early fall months, which decreases the quantity and quality of salmonid habitat in many streams by reducing stream depth and available pool habitat, elevating water temperatures, and concentrating pollutants.

The USGS monitors flow at one location in the Western Subbasin (on the boundary line between the Eastern and Western subbasins), in the mainstem SF Eel River near Leggett (RM 66). Records from this gauge show a recently emerging pattern of atypical low flows (compared to the historic running average) occurring during the late summer to early fall months even during wet weather years (*Figure 51).* These low flows may be caused by reduced winter precipitation and an increase in both the number of diversions and the quantity of water diverted from subbasin streams and tributaries for agricultural and domestic uses.

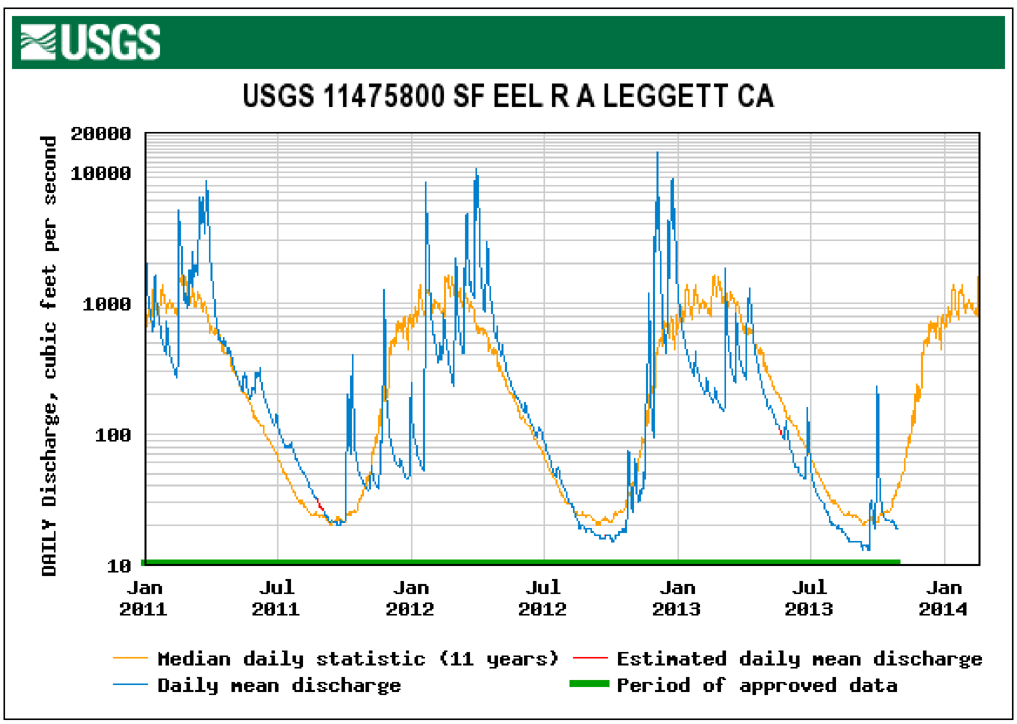



*Figure 51. Daily mean discharge (in cfs) and mean daily discharge (40-year average in cfs) for USGS gauging station at SF Eel River near Leggett, showing 2011-2014 data.*

## Recent Low Flow Studies

In response to the limited rainfall in the winter and spring of 2012-2013 and concern over extremely low flow conditions that were being reported/observed in the SF Eel River Basin, CWPAP staff conducted a brief low flow study in August and September, 2013. The staff collected information at six mainstem SF Eel River sites and in 37 tributaries with known coho distribution. The purpose of the study was to document extremely low flow conditions and its potential impacts on juvenile salmonids (stress, mortality, etc.) while comparing conditions in streams that are heavily diverted (due to marijuana cultivation and residential use) with those those that are not heavily diverted. In streams that were not affected by diversion (n = 15) and in streams that were not heavily diverted (n = 21), flows were typical of those seen in very low water years. In heavily diverted streams, conditions ranged from dry or isolated pools only in some streams, to connected streams with very low flow in others.

Six of the streams that were affected extensively by diversion were located in the Western Subbasin: Redwood (Redway), Twin, Sproul, Little Sproul, Jack of Hearts, and Little Charlie creeks. Of these six, one was dry (Twin Creek), and two were nearly dry, with isolated pools only (Redwood and Little Charlie creeks). CWPAP staff estimated flow rates of 0.5 cfs or less in the remaining three creeks.

In the summer of 2013, the Salmonid Restoration Federation (SRF) initiated a low flow study in Redwood Creek near Redway (RM 30), located within the Western Subbasin boundary. SRF collected baseline streamflow data at eleven sites in the Redwood Creek watershed. The furthest upstream site was located approximately 2.3 miles up Dinner Creek from the confluence of Redwood Creek, and other sampling stations were located on Pollock, China, Miller, Buck, Seely, and Redwood creeks. The furthest downstream site was located approximately 1800 feet upstream from the confluence of Redwood Creek and the SF Eel River. SRF measured flow using a variety of techniques, including a 4-inch diameter pipe, Parshall Flume, and Pygmy Current Meter (although flows were usually too low to get accurate readings with the meter). Findings included:

- Flow was intermittent in most streams from August through September;
- All sites had less than 1 gallon per minute (gpm) flow in mid-September (*Figure 52*);
- Bedrock substrate was the main factor in maintaining pools;
- Groundwater recharge was highly variable. After one inch of rain fell on September 20-21, connectivity was reestablished in China and Pollock Creeks. After three more inches of rain fell on September 28-29, all streams throughout the watershed were reconnected and remained flowing until the next rainstorm on November 18.

SRF staff concluded that flows were extremely low during August and September 2013, with some streams going dry during this time (*Figure 52*). After the first rainfall in in September, connectivity was restored in all monitored streams and flow increased in some streams even though no additional rain fell for 6 weeks. Some of the increased flow or slowed decrease in flow may come from slow moving ground water from the storms finally reaching streams (SRF 2013). SRF is currently seeking funding to develop a more comprehensive instream flow study, and will use the results of current and future research to inform their water diversion and voluntary conservation program discussed below.

SRF's findings most likely apply to other areas throughout the subbasin, particularly in areas with similar land use patterns such as the Sproul Creek watershed, and in streams with residential land use near Garberville, Redway, Leggett, and north of Branscomb.

## Water Diversion and Voluntary Conservation

The effects of low flow, diversions, and warm water temperatures on salmonids are major concerns in streams throughout the Western Subbasin. In 2013, the Salmonid Restoration Federation (SRF) and Humboldt State University (HSU) initiated a study to determine the feasibility of implementing a voluntary water conservation and storage program in Redwood Creek. This study is modeled after Sanctuary Forest's water storage tank and forbearance program in the Mattole River headwaters, where participating landowners store water in tanks during high flows for use during low flow times: (http://sanctuaryforest.org/wp-content/uploads/2014/02/FINAL-tanks-and-forbearance-brochure-text-12.5.07.pdf). This

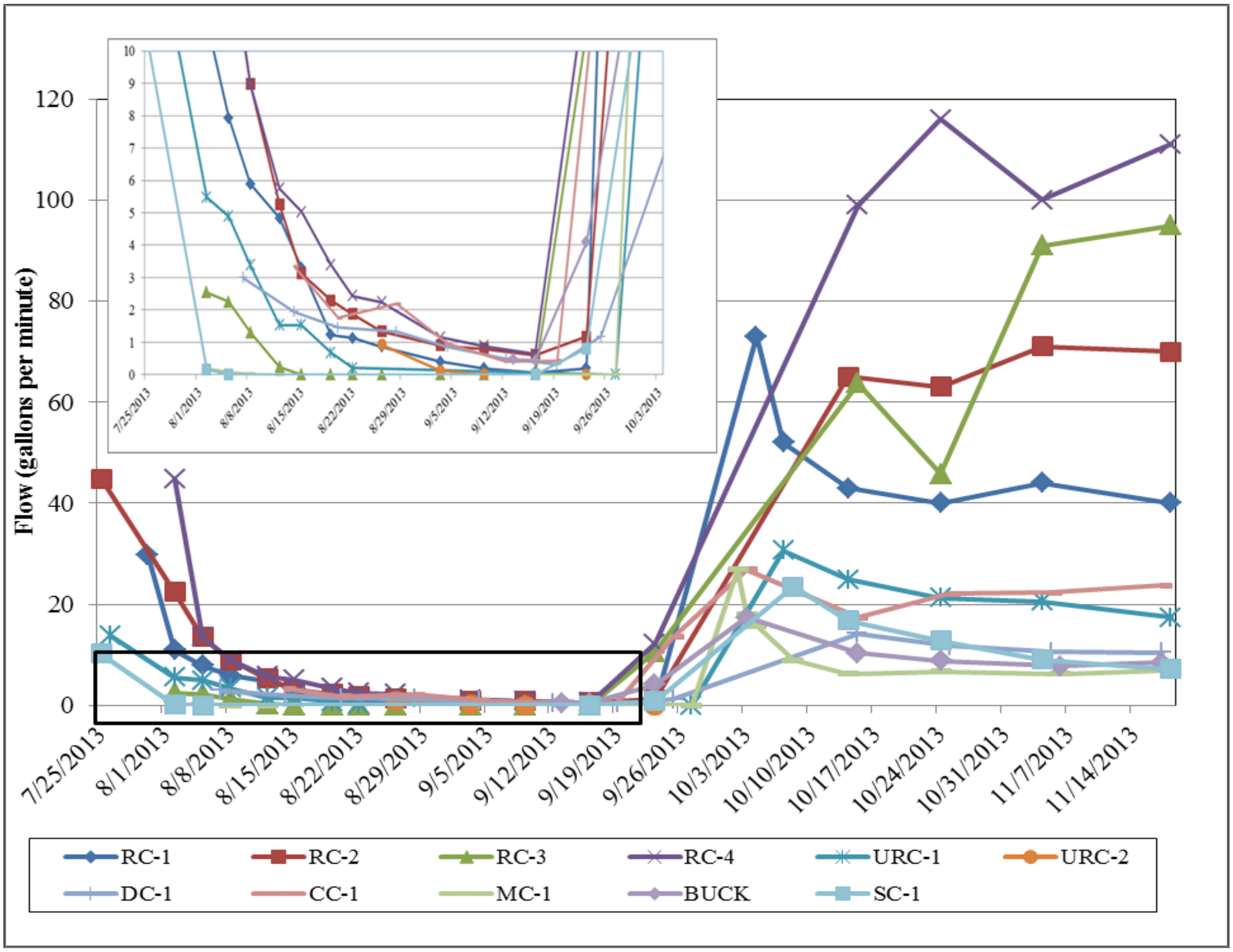



*Figure 52. 2013 summer streamflow in Redwood Creek (near Redway), with inset showing low flow from July through September (data and figure from SRF 2013). RC = Redwood Creek; URC = Upper Redwood Creek (Pollock Creek); DC = Dinner Creek; CC = China Creek; MC = Miller Creek; BUCK = Buck Creek; SC = Seely Creek.*

storage reduces diversions and increases flows to improve fish habitat and water quality during the low flow season. Due to the success of the program in the Mattole River Basin, SRF and HSU applied a similar design when developing the Redwood Creek Water Conservation Project.

There are two phases in the Redwood Creek study:

1) Surveys and data analysis. A survey questionnaire was sent out in early 2013 to all landowners in the basin (n = ± 400) requesting information on water sources(s), diversion rates, and on-site storage capacities. As of May 2013, 70 people had completed the survey (a 17.5% response rate);
2) Community outreach. Two local meetings were held to provide a forum for input from Redwood Creek residents. A total of 57 people attended the meetings, and discussion topics included: the Mattole Flow Program, designing a low flow study in Redwood Creek, suggestions for water conservation measures, storage tank options, and strategies to increase community awareness and participation (SRF 2013).

Sixty six percent of landowners who responded to the survey reported that they have mechanisms in place to prevent tank overflow, and 26% did not, illustrating the importance of developing affordable and accessible options to help prevent water loss. The survey responses also indicated that residents who valued the aesthetic beauty of the stream environment and habitat for salmon often spoke to others in the community about watershed health, and were more likely to voluntarily participate in water conservation efforts (SRF 2013).

SRF and HSU determined that there are landowners who are willing to take part in a voluntary water conservation program, however there are some obstacles. Tank installation requires a financial commitment, including the purchase of a new tank and additional property taxes when water storage is installed, which are currently financial disincentives for residents interested in participating in the water storage program. Several local non-profit agencies are currently investigating options for a new tax policy to provide financial incentives for residents interested in installing water tanks. Water rights are also problematic in the watershed: many landowners currently divert water for domestic and agricultural purposes, but only two residents have established water rights (SRF 2013). SRF, in cooperation with several local non-profit agencies, established a public forum to educate residents about water rights and compliance issues so that they can legally divert and store water.

The next steps in the study will include interpretation of data collected in additional low flow studies to develop information that will be used to determine how existing diversions are affecting flow, and to expand the community-led water conservation program that will improve habitat and benefit salmonids in the Redwood Creek watershed. For additional information and project updates, go to the SRF website at http://www.calsalmon.org/

This study emphasizes the need for specific information on water diversions and flow, and it is an example of successful community involvement in fisheries habitat monitoring and restoration efforts. Similar voluntary conservation programs could be applied in the future in other Western Subbasin watersheds.

In January 2014, Governor Brown declared a drought State of Emergency in California and directed state officials to take all necessary actions to prepare for water shortages. In March 2014, CDFW and the SWRCB announced that they would expedite the permitting and approval of storage tanks for landowners who currently divert water from rivers and streams in the Northern and Bay Delta regions of CA (CDFW regions 1 and 3). This action, which came under the State Water Board's Small Domestic Use (SDU) registration program, will relieve pressure for in-stream diversions during the drier months when fish need it most. This action was a direct result of suggestions made by local communities, SRF, Mattole River Sanctuary Forest, and Trout Unlimited (CDFW 2014).

## Water Chemistry

### Sediment

Sediment affects salmonids both directly and indirectly by modifying aquatic habitat. Coarse sediment, fine sediment, and suspended sediment may adversely affect adult and juvenile salmonids by altering channel structure and affecting production.

In 1999, the SF Eel Basin was listed by the USEPA as an impaired water body for sediment. In the TMDL analysis (USEPA 1999), the USEPA interpreted water quality standards, calculated existing sediment loads, set loading capacities, and established load allocations. The most significant sources of sediment found in the watershed included roads, timber harvest related activities, and natural sources. In order to interpret water quality standards and to determine the amount of sediment that will not adversely affect salmonids, USEPA developed a set of indicators: percent fines, turbidity, V star (V*), and the thalweg profile. Stillwater Sciences (1999) then completed a sediment source analysis, which was used to set TMDL loading capacity and allocations for the SF Eel River Basin. TMDL allocations were developed to assess the maximum allowable amount of sediment received by a stream while still meeting water quality requirements (*Table 30*).

*Table 30. USEPA sediment indicators and targets for the SF Eel River Basin (USEPA 1999).*

| Indicator | Target | Purpose |
|---|---|---|
| Substrate composition – percent fines | <14%<0.85 mm | 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 | Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities |

| Indicator | Target | Purpose |
|---|---|---|
| Residual pool filling (V*) | <0.10 | Estimate of sediment filling of pools from disturbance |
| Thalweg profile | Increasing variation from the mean | Estimate of improving habitat complexity & availability |

The USEPA and Stillwater Sciences did not subdivide the SF Eel River Basin into subbasins, so estimates and recommendations were developed for the entire basin. The USEPA calculated that existing sediment loading was approximately two times the natural rate, or for every ton/square kilometer/year of natural sediment, there was one ton/square kilometer/year of human-induced sediment (USEPA 1999). Stillwater Sciences (1999) found that sediment loading is variable, and roads are the largest anthropogenic contributors of fine sediment to streams throughout the basin.

The total sediment load was calculated to be 704 tons/square kilometer/year or 1.9 tons/square kilometer/day on a 15 year running average (*Table 31*). The ratio of human-induced sediment is approximately 1:1, but slightly more sediment is from natural sources (54% of total) than anthropogenic sources (46% of total). Earthflows are the primary source of natural sediment, and roads are the primary source of anthropogenic sediment in the basin.

*Table 31. USEPA basinwide estimates of sediment sources for the SF Eel River Watershed from 1981-1996 (USEPA 1999).*

| Sediment Source | Total sediment input (tons/year) | Unit area sediment input (tons/square kilometer/year) | Fraction of total |
|---|---|---|---|
| Natural Sediment Sources | | | |
| Earthflow toes and associated gullies | 478800 | 269 | 38% |
| Shallow landslides | 132500 | 74 | 11% |
| Soil creep | 62980 | 35 | 5% |
| **Subtotal** | **674280** | **378** | **54%** |
| Anthropogenic Sources | | | |
| Shallow landslides, roads and harvest | 216200 | 121 | 17% |
| Skid trail erosion | 21534 | 12 | 2% |
| Road surface erosion | 67512 | 38 | 5% |
| Road crossing failures and gullying | 276500 | 155 | 22% |
| **Subtotal** | **581746** | **326** | **46%** |
| **Total** | **1256026** | **704** | **100%** |

The loading capacity, or the amount of pollution that a stream can assimilate and still meet water quality standards, was set for all stream reaches in the basin based on a 1:4 ratio of human to natural sediment. Using this ratio, the allowable human-induced loading capacity would be 95 tons/square kilometer/year, and the TMDL for the basin would be 473 tons/square kilometer/year. Considerable erosion control measures will be required to meet the TMDL and loading capacity. For example, in order to meet the target ratio, road sediment would need to be reduced from current levels by 80%. Sediment from landslides would then require a 55% reduction in input levels.

In the Water Quality Control Plan for the North Coast Region, NCRWQB established basin-wide regulations that turbidity should not be increased more than 20 percent above naturally occurring background levels (NCRWQCB 2011). Additional prohibitions are included for erosion sources such as logging operations and constructions projects, so that organic material (including soil, bark, slash, sawdust, and other earthen material) from these operations is not directly or indirectly discharged into streams in quantities sufficient to harm fish and wildlife.

Road decommissioning, or the removal and stabilization of unwanted roads to a natural state, is an effective management technique used to reduce sediment input in watersheds with high road densities. McCaffery et al. (2007) found that watersheds with decommissioned roads had lower percentages of fine sediment in streams than those with roads in use. Many CDFW Fisheries Restoration Grant Program (FRGP) projects that have been completed in upslope areas in the Western Subbasin include road decommissioning and erosion control measures.

Pacific Watershed Associates (PWA) completed an evaluation of CDFW road decommissioning protocols and guidelines used on more than 51 miles of road in Northern California between 1998 and 2003 (PWA 2005). They determined that at decommissioned stream crossing sites:

- Sediment delivery was approximately 5% of the original pre-treatment fill volume;
- Unexcavated fill was the most common problem; and
- Protocols were effective but were not being uniformly followed at stream crossing sites.

At landslide sites and road drainages, PWA determined that protocols were effective and were being followed, but protocols for "other" sites were vague and ineffective. When done properly, road decommissioning projects resulted in decreased fine sediment input at most treated sites. Although PWA did not look at specific road decommissioning sites in the Western Subbasin, their findings are important to consider given the high road density and the potential to significantly reduce the amount of sediement input from legacy and failing roads. Other sediment reduction projects completed in the subbasin (see Fish Restoration Programs section) will also contribute to a reduction in overall sediment input, and will be monitored over time.

## Nutrients

UC Berkeley graduate student Keith Bouma-Gregson sampled nitrogen and phosphorous concentrations at seven Eel River Basin sites while collecting cyanotoxin and temperature data in the summer of 2013. Three of these sites were located in the mainstem SF Eel River, on the Western Subbasin boundary line: at Richardson Grove (RM 49), Standish-Hickey SRA (RM 66), and Angelo Reserve (RM 89). Bouma-Gregson is currently analyzing data and developing conclusions on the relationship between blue-green algae blooms, toxins, temperatures, nutrient levels, and blue-green algae and green algae associations in SF Eel River streams (K. Bouma-Gregson, UC Berkeley, personal communication 2014).

## Aquatic Invertebrates

Aquatic macroinvertebrates are the primary food source for salmonids, and can be used as indicators of stream health because they are directly affected by physical, chemical and biological stream conditions. They may also show effects of habitat loss and short- and long-term pollution events that may not be detected in traditional water quality assessments (USEPA 1997). High instream temperatures, reduced flow, and increased sediment input may result in decreased macroinvertebrate assemblages and abundance, and populations may be further reduced in watersheds where land use activities have intensified these conditions. Cover et al. (2006) documented decreases in invertebrate abundance in streams with increased fine sediment input from unstable hillslopes and land use activities in Klamath mountain streams, where instream conditions and land use practices were similar to those found in many Western Subbasin creeks.

In 1996, Friedrichsen (1998) sampled macroinvertebrate communities throughout the Eel River Basin. Sampling locations were selected by Scott Downie (CDFW) and reviewed by the project's technical advisory committee. Seven of the sampling sites were located within the SF Eel River Basin boundary, with two locations in the Western Subbasin (Redwood Creek near Branscomb, and Little Sproul Creek). Five metrics (explained in detail by Plafkin et al. 1989) of macroinvertebrate assemblages and community structure were used to assess stream condition:

- The Simpson Index (diversity of taxa and evenness of the community);
- Modified Hilsenhoff Index (tolerance values and number of organisms per taxa divided by the total number of invertebrates in the sample);
- EPT Index (number of species of Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies));
- Percent Dominant Taxa (the total number of organisms in the sample divided by the

number of invertebrates in the most abundant taxa); and

- Richness Index (total number of taxa).

These metrics may indicate if the stream is healthy or impaired, and can be used to determine how invertebrate assemblages respond to human and natural disturbances. Friedrichsen (1998) found that when all metric results were considered, Redwood Creek invertebrate populations were among the healthiest in the SF Eel River Basin. These invertebrate communities had good evenness, and a higher level of representation of taxa associated with cooler summer water temperatures. Conditions have most likely not changed significantly in the Redwood Creek watershed since Friedrichsen's study was completed; this stream is located on MRC land, and the primary concern in this watershed is sediment input from roads and harvest activities. Other streams in this subbasin are heavily diverted, particularly in areas where residential land use is high and water is diverted for illegal marijuana cultivation. In addition to reduced instream flow, water entering the stream near grow operations may be polluted with fertilizers, diesel fuel, rodenticides, human waste, and fine sediment, affecting water quality and, therefore, instream invertebrate communities. More information is necessary to determine invertebrate species tolerance levels for both pollution and elevated water temperatures, to assess the effects of increased diversions on aquatic invertebrate populations, and to determine how changes in invertebrate populations affect salmonid populations.

Food web ecology and aquatic invertebrates that support salmonids have been studied at Angelo Coast Range Reserve near Branscomb, as part of the Eel River Critical Zone Observatory (https://criticalzone.org/images/national/associated-files/Eel/EelRiverCZO_Project_Description.pdf). Scientists and students from UC Berkeley have monitored low flow food web dynamics and explored links between the mainstem SF Eel River and food webs in 12 tributary streams. For more information, and a list of publications, go to: http://angelo.berkeley.edu/angelo/

## Blue-Green Algae Blooms

Blue-green algae (cyanobacteria) are naturally occurring photosynthetic bacteria present in warm, slow-moving surface waters during temperate months in the late summer and early fall. Some forms of blue-green algae produce harmful toxins which may attack the liver (hepatotoxins) or the nervous system (neurotoxins). These toxins are released into the environment when cells rupture or die, and may be concentrated during algal blooms (Hoehn and Long 2008, Blaha 2009). The relationship between the timing of blooms and the concentration of cyanotoxins in the water column is currently unknown (K. Bouma-Gregson, UC Berkeley, personal communication 2014).

Cyanobacteria are found throughout the SF Eel River, in the water column, living within the cell walls of diatoms, growing directly on the substrate, and growing on certain types of filamentous green algae such as *Cladophora*. The color of *Cladophora* changes as epiphytic assemblages of diatoms, some containing nitrogen fixing cyanobacteria, develop on filaments. New *Cladophora* growth is green (*Figure 53*), turns yellow when colonized by non-nitrogen fixing diatoms, then turns rusty red colored as assemblages are dominated by nitrogen fixing diatoms (Power et al. 2009).

*Figure 53. Cladophora in Elder Creek, June 2013 (photo courtesy of ERRP).*

Rapid accumulations of cyanobacteria cells, or algal blooms, occur during warm summer months, under optimal conditions including elevated stream temperatures, high levels of nutrients (phosphorous and nitrogen, and the ratio of the two), increased periods of sunlight, and low flow. Human activities such as inadequate sewage treatment, or activities that result in increased agricultural and sediment input, lead to excessive fertilization (eutrophication) in water bodies. Eutrophication creates favorable conditions for blue-green algae blooms (WHO 2009) and decreased water clarity and reduced dissolved oxygen levels in streams (Trout Unlimited 2013).

Measures to prevent blooms should be designed to control anthropogenic influences that promote blooms, such as the leaching and runoff of excess nutrients. Management practices for nutrient input, specifically nitrogen and phosphorus, should be designed to reduce loadings from both point and nonpoint sources, including water treatment discharges, agricultural runoff, and stormwater runoff (USEPA 2012). This is especially important in Western Subbasin drainages where nutrients, sediment, and/or pollutants are entering streams from large marijuana cultivation operations (e.g. Redwood Creek).

The Humboldt County Department of Health and Human Services (HCDHHS) recently issued warnings notifying recreational users of the SF Eel River to avoid exposure to neurotoxins and liver toxins found in blue-green algae in the river (HCDHHS, Division of Environmental Health, 2011). The County provided the following recommendations for homeowners and land managers to reduce conditions favoring the spread of blue-green algae:

- Minimize the use of water, fertilizers, and pesticides;
- Recycle or dispose of spent soil that has been used for intensive growing – it may still contain high levels of phosphorous and nitrogen;
- Operate and maintain your septic system properly; have the system pumped every 3-4 years;
- Encourage the growth of native plants on riverbanks and shorelines to prevent erosion and filter water, with no fertilizers or pesticides required;
- Keep livestock out of surface waters and prevent surface runoff from agricultural areas; and
- Prevent sediment from roads, construction projects, and logging operations from entering streams.

In recent years, blue-green algae blooms have become more common in the mainstem SF Eel River during the late summer, when flows are at a minimum and air temperatures are high (>100˚F). These conditions are prevalent in the middle mainstem areas of SF Eel River in the Western Subbasin. The ERRP is currently collecting information on algal blooms, flows, pollutants, and temperatures throughout the Eel River Basin, and are currently developing recommendations to improve ecological conditions and reduce pollution. Bouma-Gregson obtained weekly average concentrations of dissolved cyanotoxins, nitrogen, and phosphorous at 7 sites in the Eel River Basin from July-September, 2013 (for a description of sampling locations, see the Temperature section of this subbasin report). The sites with the highest concentrations of toxins were located in the SF Eel River, though cyanobacteria were present at all sites except Fernbridge. *Anabaena* and *Phormidium*, two genera of cyanobacteria that produce cyanotoxins, were frequently observed at all of the monitoring sites except Fernbridge (Bouma-Gregson, UC Berkeley, personal communication, 2014). In the Western Subbasin, cyanobacteria blooms have been reported only in the mainstem SF Eel River. However, additional studies targeting Western Subbasin tributaries are necessary to address the following issues: specific locations of blue-green algae blooms; the relationship between blue-green algae and green algae; levels of nutrients and pollutants present; current sources of nutrient input; and ways to reduce the input of these and other harmful substances in order to improve salmonid habitat.

## Fish Passage Barriers

Barriers to fish passage occur on all natural streams, and are usually gradient or flow barriers near the headwaters. Barriers that occur downstream and limit the naturally occurring range and distribution of salmonids can be classified according to the cause of the barrier (natural or anthropogenic), the barrier's lifespan (temporary or permanent), and the barrier's effectiveness (partial or total). Natural barriers include gradient, landslide, and log debris accumulations (LDA); manmade barriers include culverts and dams. All types of barriers fragment the habitat available to different life stages of salmonids by reducing access to stream reaches that are used as migratory corridors, and spawning and rearing habitat.

Several fish passage barrier issues have been identified in the Western Subbasin. Most of the barriers are gradient barriers, followed by culvert barriers (6 partial, 4 total, and 2 temporal) (*Figure 54*). Data used to create the map were collected between 1981 and 2012, but additional barriers may occur as conditions change and information is added to the CalFish Passage Assessment Database.

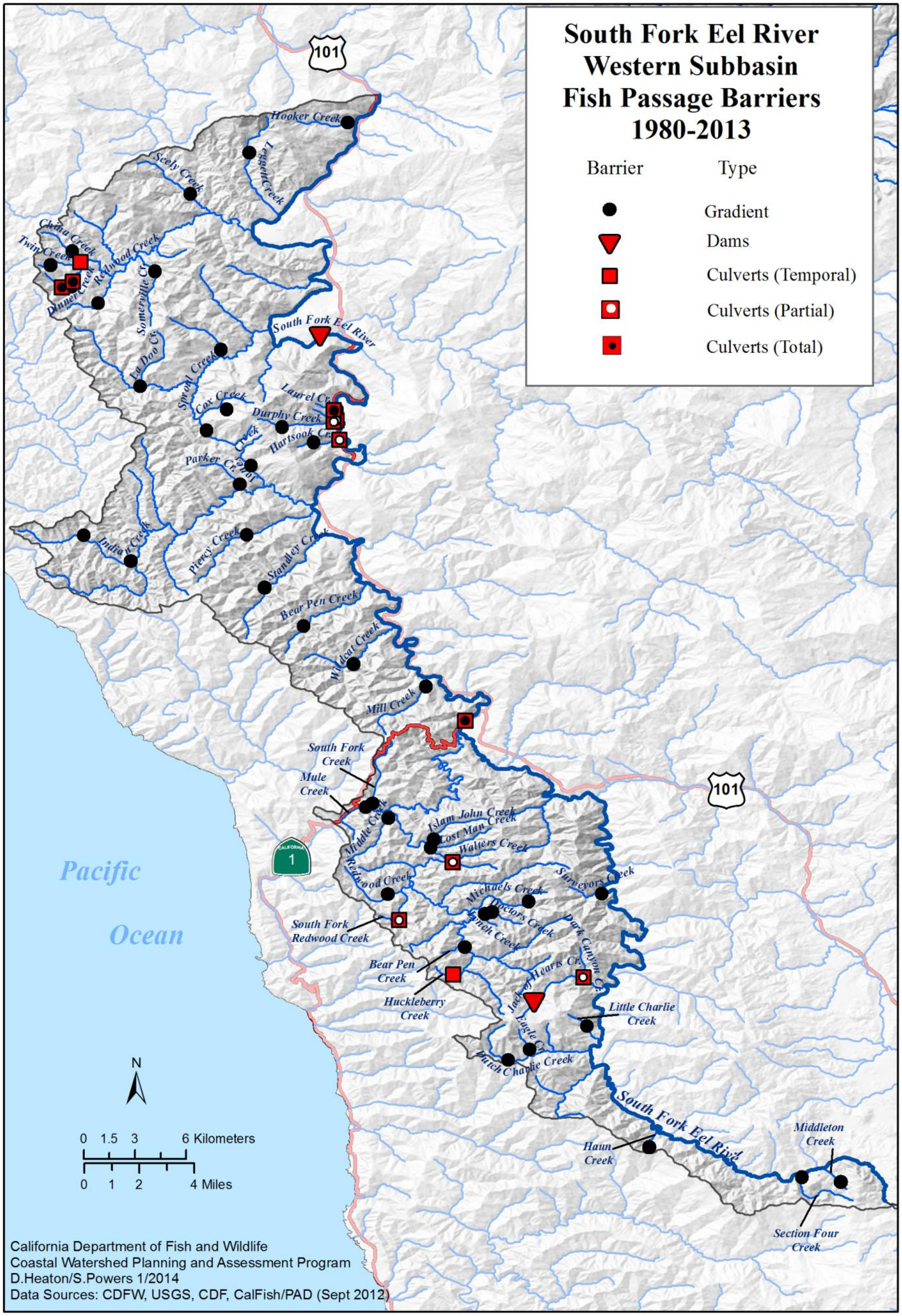



*Figure 54. Fish passage barriers in the SF Eel River Western Subbasin.*

Improper culvert placement where roads and streams cross can limit or eliminate fish passage (Gucinski et al. 2001). Highway 101, the only primary road in the subbasin, runs along the SF Eel River for the full length of the subbasin, with a secondary frontage road following the highway for most of its length. Many smaller roads, some permanent and some seasonal, connect Highway 101 with headwater areas in most of the larger watersheds. Many roads cross streams multiple times, and at each crossing, passage issues are a possibility. Five culvert barriers (three partial and one total) are located near the mainstem SF Eel River, where Highway 1 (RM 69), and Highway 101 and its frontage road cross tributaries (RM 46-47). Two partial barriers are located on Durphy Creek (*Figure 55*), and one on Hartsook Creek. Other culvert barriers located further up in tributary streams include partial culvert barriers located in the Upper Hollow Tree Creek drainage on MRC land (on Walters and SF Redwood creeks), and on lower Jack of Hearts Creek. Temporal culvert barriers are located on Huckleberry and Twin creeks.


*Figure 55. One of two partial culvert barriers located on Durphy Creek.*

Ross Taylor and Associates (2005) identified two culverts located on Dinner Creek, both of which are total barriers to fish passage. The first culvert is located 8.3 miles up Briceland Thorn Road from Redway (RM 0.85 from China Creek confluence; *Figure 56*) and the second culvert is located 8.8 miles up Briceland Thorn Road (RM 1.39 from China Creek confluence). Both sites were ranked as high priorities for treatment. The County of Humboldt recently submitted a proposal for FRGP funding to replace both of these culverts, in addition to a smaller culvert approximately 700 feet upstream from the second culvert. In their proposal, the County noted that in May 2012, coho salmon juveniles (YOY) were observed below the first culvert, and steelhead juveniles were observed


*Figure 56. Failing culvert on Dinner Creek, tributary to China Creek in the Western Subbasin (photo courtesy of Scott Bauer, CDFW).*

between the second and third culverts (S. Bauer, CDFW, personal communication 2014).

There are two dams in the Western Subbasin, only one of which is considered a total barrier. An earthen Dam located on Jack of Hearts Creek is a permanent, total barrier but is located near the headwaters and does not seem to shorten the length of anadromy significantly. Benbow Dam was was identified by CalFish (2012) and included on the barrier map for reference, however, the flashboards are no longer installed each summer to impound water, and it is not considered a barrier to fish passage at this time.

Gradient barriers caused by boulders or bedrock are found throughout Western Subbasin streams (*Figure 54*). Most of the gradient barriers mapped in this subbasin were waterfalls, which are considered extreme examples of gradient barriers. The largest waterfall barrier (38') in the Western Subbasin is located on Middle Creek, a tributary to Hollow Tree Creek, and other streams contain smaller waterfalls that are large enough to act as total barriers. Height or vertical drop of falls, plunge pool area and depth, and the jumping ability of each species must be considered when determining whether a waterfall is a barrier to fish passage (Powers and Orsborn 1985). Other gradient barriers included boulder runs and series of cascades.

Log jams, referred to in this report as LDAs, in streams can also become fish passage barriers. These are noted in CDFW stream inventories. LDAs are usually temporary barriers, because they shift or break apart during large flow events, but some trap sediment and additional material so that they may persist for decades as total barriers. Stream inventories in the Western Subbasin found no total LDA barriers, although many large debris jams were documented in stream surveys, especially following historic flood events. Restoration activities in the past concentrated on removing wood jams, including complete, partial, or potential barriers. These actions, combined with intensive industrial timber harvest activities, resulted in a lack of large wood in streams. Current restoration projects concentrate on adding large wood back into streams to scour pool habitat and provide cover for adult and juvenile salmonids.

# Habitat Conclusions

## Overall Suitability

CWPAP staff assessed changes in Western Subbasin salmonid habitat using historic data collected on surveys from 1938-1990, and stream habitat typing survey data collected from 1990-2010. Data from older surveys, collected prior to the establishment of a stream survey protocol (Flosi et al. 2010), provided a snapshot of the conditions at the time of each survey. Terms such as excellent, good, fair, and poor were based on the judgment of the biologist or scientific aid who conducted the survey. The results of these historic stream surveys were qualitative and were not used in comparative analyses with quantitative data provided by habitat inventory surveys collected beginning in the 1990s. However, the two data sets were compared to show general trends.

In historic surveys (prior to 1990), spawning habitat was generally good in Western Subbasin tributaries. High water temperatures were noted in the lower reaches of the mainstem SF Eel River. Log jams were the most common barrier type, but most were not classified as total barriers.

Average canopy density and embeddedness scores in Western Subbasin streams increased over time when comparing data collected in the 1990s with data from the early 2000s (*Table 32*). Most primary pool length scores were in the lowest suitability category during both time periods, and pool shelter scores decreased slightly over time. Although some increases in factor values were seen, average values were below target values for all streams except canopy density in the 2000-2010 sampling period. Embeddedness, primary pools, and pool shelter are likely limiting to salmonid populations in this subbasin.

Canopy density was suitable on most surveyed creeks. However, overall canopy density measurements do not take into account differences between smaller, younger riparian vegetation and the larger microclimate controls that are provided by old-growth forest canopy conditions. CWPAP staff considered the contribution of coniferous and deciduous components in the canopy, and found that the average percent of coniferous vegetation increased and percent open canopy decreased considerably in most Western Subbasin streams over time.

Primary pool length was in the lowest suitability category for nearly all streams during both sampling periods. The headwaters of the SF Eel River was the only stream sampled that showed improvement in the length of primary pool habitat over time.

Pool shelter was in the lowest suitability category in most Western Subbasin streams, and in streams that were sampled during both time periods, shelter suitability decreased from suitable to unsuitable in 7 streams (Bear Wallow, Butler, Doctors, Huckleberry, Low Gap, Moody, and SF Redwood creeks). Both pool habitat and pool shelter are likely limiting factors in Western Subbasin streams.

Cobble embeddedness suitability increased in most Western Subbasin streams over time, and went from the lowest to the highest suitability category in Michaels and Doctors creeks. Embeddedness values increased throughout the Hollow Tree Creek drainage over time. This improvement is most likely due to changes in timber harvest regulations, road decommissioning, numerous restoration and instream habitat improvement projects completed in this basin, and sediment from historic floods moving through the system. Although embeddedness suitability scores increased in many streams, average values were still below target values during both sampling periods.

Summer water temperature measurements showed that water temperatures were good for salmonids in headwaters areas above Branscomb (RM 95), but were stressful for salmonids at downstream sites and in larger tributaries. Sampling sites in tributaries with poor temperatures were located in the lower reaches of the largest streams in the subbasin (Hollow Tree and Sproul creeks) and in the mainstem SF Eel River from RM 25-86. Lethal temperatures were recorded in the mainstem SF Eel River at Piercy (RM 54) and Sylvandale (RM 25). Lower Hollow Tree and lower Sproul creeks are wide channels with little riparian canopy cover, and increased direct solar radiation results in higher stream temperatures. Warm water temperatures in Redwood Creek (Redway) are caused by reduced riparian canopy and increased water diversion for

*Table 32. EMDS-based Anadromous Reach Condition Model suitability results for factors in Western Subbasin streams (ND = no data available; LB = left bank; UT = unnamed tributary).*

| Stream | Survey Year | Mean Canopy Density (%) | Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|
| Anderson Creek | 2008 | ++ | ++ | ND | -- |
| Bear Pen Creek | 1992 | - | -- | -- | -- |
| | 2007 | ++ | + | -- | -- |
| Bear Wallow Creek | 1990 | ++ | ++ | -- | ++ |
| | 2002 | ++ | + | -- | - |
| Bond Creek | 1991 | -- | -- | -- | - |
| | 2003 | ++ | - | -- | - |
| Butler Creek | 1990 | + | ++ | -- | ++ |
| | 2002 | ++ | + | -- | -- |
| Butler Creek (UT - LB) | 2002 | ++ | ++ | -- | -- |
| China Creek | 1998 | ++ | -- | -- | -- |
| | 2009 | ++ | + | -- | -- |
| Cox Creek (SF Eel) | 1993 | + | - | -- | -- |
| | 2004 | ++ | - | -- | -- |
| Doctors Creek | 1991 | - | -- | -- | + |
| | 2003 | ++ | ++ | -- | - |
| Durphy Creek | 2006 | + | - | -- | -- |
| Durphy Creek (UT - LB) | 1993 | - | -- | -- | -- |
| | 2006 | ++ | + | -- | -- |
| Dutch Charlie Creek | 1992 | ++ | -- | -- | -- |
| | 2007 | ++ | - | - | - |
| Hartsook Creek | 1999 | ++ | - | -- | -- |
| | 2009 | ++ | + | -- | -- |
| Hollow Tree Creek | 1992 | -- | -- | -- | -- |
| | 2002 | ++ | + | -- | -- |
| | 2003 | ++ | + | -- | -- |
| Huckleberry Creek | 1990 | ++ | - | - | ++ |
| | 2002 | ++ | + | -- | -- |
| Indian Creek | 1993 | -- | + | -- | -- |
| | 2008 | ++ | ++ | -- | -- |
| Jack of Hearts Creek | 1992 | ++ | - | - | - |
| | 2005 | ++ | ++ | -- | -- |
| Leggett Creek | 1995 | + | -- | -- | -- |
| | 2007 | ++ | - | -- | -- |
| Little Sproul Creek | 1995 | ++ | -- | -- | -- |
| Little Sproul Creek (UT) | 2004 | ++ | - | ND | -- |
| Low Gap Creek | 1990 | -- | - | -- | + |

| Stream | Survey Year | Mean Canopy Density (%) | Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|
| Low Gap Creek (con.) | 2007 | ++ | + | -- | - |
| Lynch Creek | 1991 | - | -- | -- | -- |
| | 2003 | ++ | + | -- | - |
| Michaels Creek | 1991 | -- | -- | -- | -- |
| | 2003 | ++ | ++ | -- | - |
| Mill Creek | 2010 | ++ | + | -- | -- |
| Moody Creek | 1993 | ++ | -- | -- | + |
| | 2008 | ++ | ++ | -- | -- |
| Piercy Creek | 2007 | ++ | - | -- | - |
| Pollock Creek (Upper Redwood Creek) | 1998 | ++ | -- | -- | -- |
| | 2009 | ++ | - | -- | -- |
| Redwood Creek (Hollow Tree Creek) | 2003 | ++ | -- | -- | -- |
| Redwood Creek (Branscomb) | 1993 | ++ | -- | -- | -- |
| | 2007 | ++ | -- | - | + |
| Redwood Creek (Redway) | 2009 | - | ++ | + | -- |
| SF Eel River headwaters | 1996 | ++ | - | -- | -- |
| | 2007 | ++ | - | ++ | -- |
| SF Redwood Creek | 1991 | ++ | -- | -- | + |
| | 2003 | ++ | -- | - | -- |
| SF Redwood Creek (UT) | 2003 | ++ | -- | -- | -- |
| Sproul Creek | 2004 | ++ | - | -- | -- |
| Sproul Creek (tributary 5) | 2004 | ++ | -- | -- | -- |
| Standley Creek | 1992 | - | - | -- | -- |
| | 2007 | ++ | -- | -- | -- |
| | 2009 | ++ | ++ | -- | -- |
| Twin Creek (UT to China Creek) | 2009 | ++ | ++ | -- | -- |
| Waldron Creek | 1991 | + | -- | -- | -- |
| | 2002 | ++ | + | -- | -- |
| Warden Creek | 1992 | ++ | -- | -- | -- |
| | 2004 | ++ | - | -- | - |
| WF Sproul Creek | 1992 | ++ | -- | -- | -- |
| | 2004 | ++ | - | -- | - |
| WF Sproul Creek (tributary 8) | 2004 | ++ | - | -- | - |
| WF Sproul Creek (tributary 9) | 2004 | ++ | - | -- | + |
| Wildcat Creek | 1992 | - | - | -- | -- |
| | 2007 | ++ | ++ | -- | - |
| Wood Creek | 2002 | ++ | + | -- | -- |
| **Key: ++ = Highest Suitability -- = Lowest Suitability** | | | | | |

residential use and industrial marijuana cultivation operations. Water temperature is likely a limiting factor for salmonids in surveyed streams in this subbasin, and cold water seeps where springs or tributaries enter the mainstem may provide important patches of cooler water for salmonids during late summer months.

Sediment loading in the Western Subbasin is extremely high, and primary input sources include natural landslides and earthflows, road erosion and failure, and logging related erosion from skid trails and road construction. This subbasin has a very high road density, and road decommissioning projects have resulted in decreased fine sediment input at most treated sites, however, considerable erosion control measures will be required to meet the established TMDL and loading capacity. Sediment loading and turbidity conditions may be limiting factors for salmonid production.

## Restoration Projects

Increased funding and the associated tracking requirements have facilitated cataloging restoration projects. The California Habitat Restoration Project Database (CHRPD) houses spatial data on CDFW's Fisheries Restoration Grants Program (FRGP) projects and other projects with which CDFW has been involved. The CHRP data is available through CalFish (www.calfish.org) and includes some projects from agencies and programs outside of CDFW. 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, but are not comprehensive of all restoration projects completed in the Western Subbasin.

There have been 160 restoration projects, totaling more than 13 million dollars in funding, completed from 1982 to the present in the Western Subbasin (*Table 33*). The most common types of projects are cooperative rearing, followed by upslope watershed restoration and instream habitat improvement. Fifty four percent of all funding has been allocated to upslope watershed restoration projects (*Figure 57*) in this subbasin, which is similar to the percentage of total funding allocated for these types of projects in the entire SF Eel River Basin.

*Table 33. Western Subbasin restoration project type and funding (1982 to 2013).*

| Project Type | # of Projects | Total Project Funding |
|---|---|---|
| Bank Stabilization | 17 | $470,741 |
| Cooperative Rearing | 39 | $1,232,404 |
| Fish Passage Improvements | 15 | $715,554 |
| Instream Habitat Improvement | 30 | $1,224,544 |
| Land Acquisition | 1 | $715,554 |
| Monitoring | 4 | $308,416 |
| Other * | 4 | $167,781 |
| Riparian Habitat Improvement | 2 | $30,843 |
| Upslope Watershed Restoration | 34 | $7,203,745 |
| Watershed Evaluation, Assessment & Planning | 14 | $1,206,457 |
| **Total** | **160** | **$13,276,039** |
| * "Other" includes education/outreach, training, capacity building and public involvement. | | |

The majority of restoration projects in this subbasin have been completed in the Hollow Tree Creek basin and in Redwood Creek near Redway (*Figure 58*). In the Hollow Tree Creek watershed, restoration projects are primarily road decommissioning, with some instream and riparian habitat improvement, fish passage improvements, and cooperative rearing projects completed. In the Redwood Creek watershed, the most common project types are bank stabilization, cooperative rearing, and upslope watershed restoration.

*Figure 57. Example of upslope watershed restoration project in Hollow Tree Creek before (above) and after (below) treatment (Pacific Watershed Associates 2010).*

Additional information about specific projects can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/).

While site-specific projects are important at the reach scale, restoration that addresses land use issues, such as timber harvest and illegal marijuana cultivation that result in degradation and reduction of salmonid habitat on a watershed scale is essential for ecosystem recovery. Current management actions are needed to address diversion, flow, and pollution in residential areas, particularly in the larger watersheds such as Redwood Creek near Redway in the northern part of the subbasin.

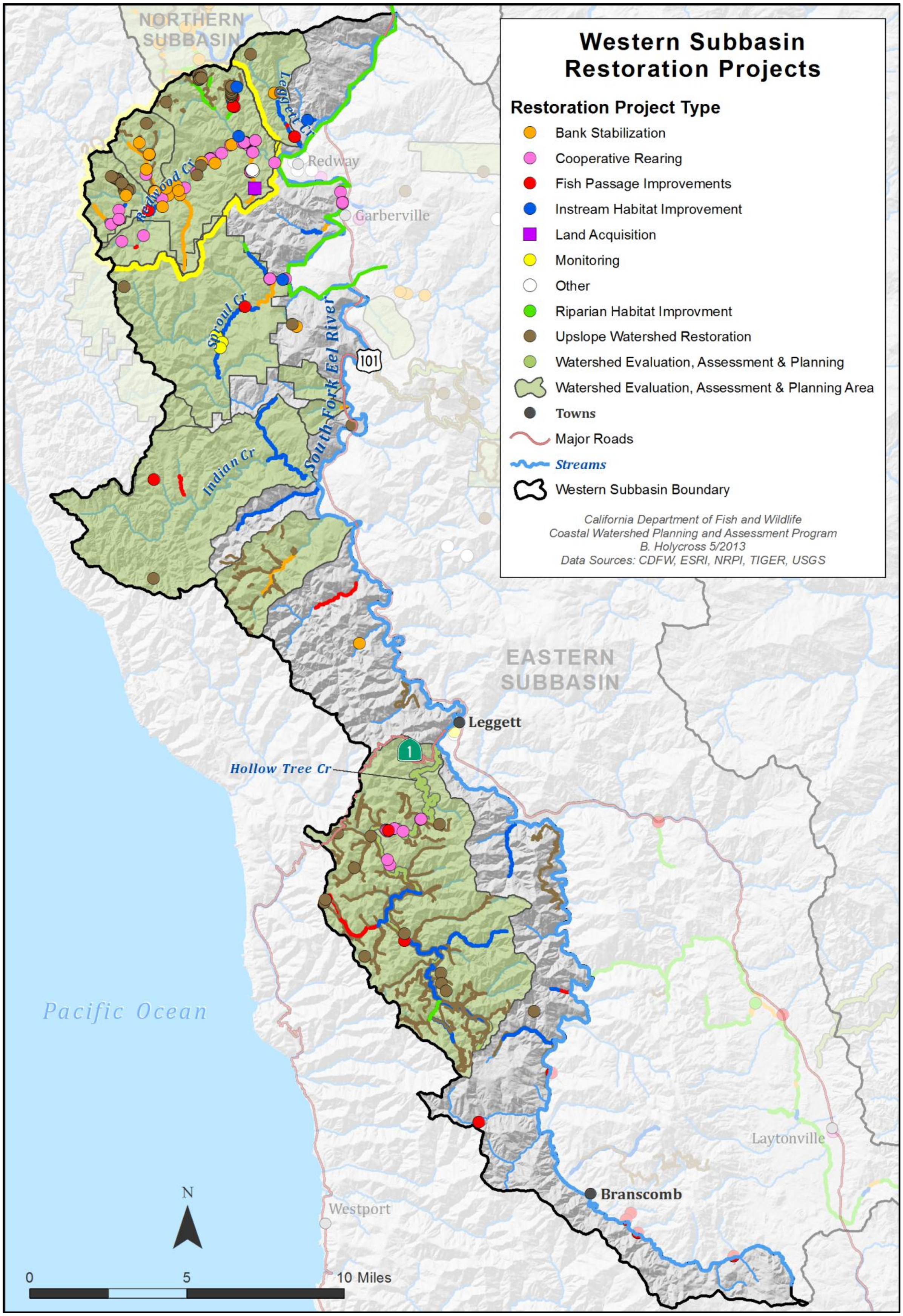



*Figure 58. SF Eel River Western Subbasin restoration projects.*

# Integrated Analysis

## Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFW stream inventories provide a list of recommendations that address those conditions that did not reach target values (see the Fish Habitat section of this subbasin). In the Western Subbasin, 62 streams were inventoried (109 surveys; 260 miles total) and recommendations for each were selected and ranked by a CDFW biologist (*Table 34*). The first recommendation in every CDFW stream inventory report is that the stream "should be managed as an anadromous, natural production stream". Because this recommendation is the same for every stream, and because it does not address specific issues, with associated target values, it was not included in the tributary recommendation analysis. The tributary recommendation process is described in more detail in the Synthesis section of the Basin Profile.

In order to compare tributary recommendations within the subbasin, the recommendations of each stream were collapsed into five target issue categories (*Table 35*). The top three recommendations of each stream are considered the most important, and are useful as a standard example of the stream. When examining recommendation categories by occurrence, the most important target issue in the Western Subbasin is instream habitat, followed by erosion/sediment and riparian/water temperature.

However, comparing recommendation categories in the subbasin by number of tributaries can be confounded by differences in the length of stream surveyed in each tributary. Therefore, CWPAP staff calculated the number of stream miles within the subbasin assigned to various recommendation categories (*Figure 59*). By examining recommendation categories by number of stream miles, the primary target issue remains instream habitat, followed by erosion/sediment and riparian/water temperature recommendations as the next most important target issues in Western Subbasin streams. Because of the high number of recommendations dealing with these target issues, high priority should be given to restoration projects that emphasize instream habitat restoration and improvement, in addition to sediment reduction and bank stabilization projects designed to reduce input from both natural and anthropogenic sources.

*Table 34. Occurrence of stream habitat inventory recommendations for streams in the SF Eel River Western Subbasin.*

| **Stream** | **Survey Length (miles)** | **Bank** | **Roads** | **Canopy** | **Temp** (A=study required) | **Pool** | **Cover** | **Spawning Gravel** | **LDA** | **Livestock** | **Fish Passage** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Anderson Creek (1993) | 5 | 4 | 5 | | | 1 | 2 | | 3 | | |
| Anderson Creek (2008) | 2.3 | | 3 | | A1 | | 2 | | | | |
| Barnwell Creek (1992) | 0.5 | 4 | | | A1 | 2 | 3 | | 5 | | 6 |
| Bear Creek (1992) | 0.4 | | | | | | | | 1 | | |
| Bear Pen Creek (1992) | 3.4 | 4 | | 5 | A1 | 2 | 3 | | 6 | | |
| Bear Pen Creek (2007) | 2.8 | 2 | | | A3 | | 1 | | | | |
| Bear Wallow Creek (1990) | 1.5 | 2 | | | | | 1 | | 3 | | |
| Bear Wallow Creek (2002) | 2.1 | 3 | 4 | | A1 | | 2 | | | | |
| Bond Creek (1991) | 1.8 | 4 | 5 | 3 | | 1 | 2 | | | | |
| Bond Creek (2003) | 2.6 | 2 | 3 | | A1 | 4 | 5 | | | | |
| Butler Creek (1990) | 1.2 | | | | | 2 | 1 | | | | |
| Butler Creek (2002) | 1.4 | | 4 | | A1 | 2 | 3 | | | | |

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Butler Creek Unnamed Tributary 1 (2002) | 0.3 | | 3 | | A1 | | 2 | | | | |
| China Creek (1993) | 1.8 | 1 | 2 | 3 | | | | | | | |
| China Creek (1998) | 2.9 | 4 | 3 | 5 | A1 | | 2 | | | | |
| China Creek (2009) | 2.2 | 3 | | | A1 | | 2 | | | | |
| Connick Creek (1993) | 2.2 | 2 | | 6 | A1 | 3 | 4 | | 5 | | |
| Coulborn Creek (1993) | 1.4 | 3 | 4 | | | 1 | 2 | | 5 | | |
| Cox Creek (1993) | 1.2 | 3 | 4 | | | 1 | 2 | | | | |
| Cox Creek (2004) | 1.3 | 4 | | | A1 | 2 | 3 | | 5 | | |
| Dinner Creek (1993) | 1.9 | 2 | | | | 3 | 1 | | | | |
| Doctors Creek (1991) | 0.2 | 2 | | | | 3 | | | 1 | | |
| Doctors Creek (2003) | 0.3 | | | | A1 | 2 | 3 | | | | |
| Durphy Creek (1993) | 1.6 | 3 | | 4 | | 1 | 2 | | | | |
| Durphy Creek (2006) | 1.8 | 4 | 5 | 7 | A1 | 2 | 3 | | | | 6 |
| Durphy Creek Unnamed Tributary (1993) | 0.4 | 4 | | 5 | | 2 | 3 | | | | 1 |
| Durphy Creek Unnamed Tributary (2006) | 0.5 | 2 | | | A1 | | | | | | |
| Dutch Charlie Creek (1992) | 3.5 | | 4 | | A2 | 3 | 1 | | | 5 | |
| Dutch Charlie Creek (2007) | 2.9 | 2 | | | A3 | | 1 | | | | |
| Hartsook Creek (1994) | 1.3 | 3 | 4 | | | 1 | 2 | | | | 5 |
| Hartsook Creek (1999) | 1.3 | 4 | | | A1 | 2 | 3 | | | | |
| Hartsook Creek (2009) | 1.3 | | | | A1 | 2 | 3 | | | | |
| Hollow Tree Creek (1990) | 2.1 | | | | | | 1 | | | | |
| Hollow Tree Creek (1991) | 4.7 | 3 | | 4 | | 2 | 1 | | | | |
| Hollow Tree Creek (1992) | 14.8 | 3 | 4 | 5 | A1 | | 2 | | | | |
| Hollow Tree Creek (2002) | 2.6 | 3 | 4 | | A1 | | 2 | | | | |
| Hollow Tree Creek (2003) | 3.6 | 3 | | | A1 | | 2 | | E4 | | |
| Hollow Tree Creek, SF (1992) | 0.3 | | 4 | | | 1 | 2 | | 3 | | |
| Huckleberry Creek (1990) | 1.2 | | | | | | 1 | | 3 | | 2 |
| Indian Creek (1993) | 11.1 | 6 | 7 | 2 | A1 | 4 | 3 | 5 | | | |
| Indian Creek (2008) | 9.8 | | 3 | | A1 | | 2 | | | | |

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Islam John Creek (1992) | 0.5 | 5 | | 6 | | 2 | 3 | | 4 | | 1 |
| Jack of Hearts Creek (1992) | 2.9 | 3 | 4 | | | 1 | 2 | | 5 | | |
| Jack of Hearts Creek (2005) | 3.1 | 4 | 5 | 6 | A1 | 2 | 3 | 7 | 8 | | |
| Jones Creek (1993) | 0.7 | | | | A1 | 2 | 3 | 4 | | | |
| La Doo Creek (1992) | 0.2 | | | | | | | | | | 1 |
| Leggett Creek (1992) | 3.2 | 3 | | | | 1 | 2 | | | | |
| Leggett Creek (1995) | 2.3 | 2 | 1 | | | 3 | 4 | | | | |
| Leggett Creek (2007) | 3.3 | 3 | 4 | | A5 | 2 | 1 | | | | |
| Little Sproul Creek (1989) | 1.9 | 1 | | 2 | | | 4 | | | | |
| Little Sproul Creek (1991) | 1.9 | 5 | | 2 | A1 | 3 | 4 | | | | |
| Little Sproul Creek (1995) | 1.7 | 1 | 4 | | | 2 | 3 | | | | |
| Little Sproul Creek (2004) | 2.5 | 4 | 5 | 6 | A1 | 2 | 3 | 7 | 8 | | |
| Little Sproul Creek Unnamed Tributary (2004) | 0.9 | 3 | | | A1 | | 2 | | | | |
| Lost Man Creek (1992) | 0.02 | | | | | | | | | | 1 |
| Low Gap Creek (Leggett) (1990) | 2.7 | 2 | | | | | 1 | | 3 | | |
| Low Gap Creek (Leggett) (2007) | 2.5 | 3 | | | A4 | 1 | 2 | | | | |
| Lynch Creek (1991) | 0.3 | 2 | | | | 4 | 3 | | 1 | | |
| Lynch Creek (2003) | 0.2 | | | | A1 | 2 | 3 | | | | |
| Michaels Creek (1991) | 1.7 | 1 | | | | 4 | 3 | | 2 | | |
| Michaels Creek (2003) | 2.6 | | | | A1 | 2 | 3 | | | | E4 |
| Middle Creek (1992) | 0.3 | 4 | | | | 1 | 2 | | 3 | | |
| Middleton Creek (1996) | 1 | | 4 | 5 | A1 | 2 | 3 | | | | |
| Mill Creek (Leggett) (1992) | 0.3 | | | 1 | | 3 | 4 | | | | 2 |
| Mill Creek (Leggett) (2010) | 0.3 | | | | A1 | | 2 | | | | |
| Miller Creek (1995) | 4.3 | | 3 | | A1 | 4 | 2 | | | | |
| Moody Creek (1993) | 1.6 | 3 | 4 | | | 1 | 2 | | 5 | | |
| Moody Creek (2008) | 1.7 | | 3 | | A1 | | 2 | | 4 | | |
| Mule Creek (1992) | 0.2 | | 4 | | | 1 | 2 | | 3 | | |

| **Stream** | **Survey Length (miles)** | **Bank** | **Roads** | **Canopy** | **Temp** (A=study required) | **Pool** | **Cover** | **Spawning Gravel** | **LDA** | **Livestock** | **Fish Passage** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Piercy Creek (1990) | 3.2 | 2 | | | | | 1 | | 3 | | |
| Piercy Creek (2007) | 2.2 | | 4 | | A3 | 2 | 1 | | | | |
| Pollock Creek, aka Upper Redwood (1993) | 2.4 | 1 | 2 | | | 4 | | | 3 | | |
| Pollock Creek (1998) | 2 | 3 | 4 | 5 | A1 | | 2 | | | | |
| Pollock Creek (2009) | 2.7 | 3 | | | A1 | | 2 | | | | |
| Redwood Creek (Branscomb) (1993) | 2.4 | 2 | 3 | | A1 | | 5 | | 4 | | |
| Redwood Creek (Branscomb) (2007) | 2.4 | | 1 | | A3 | | 2 | | | | |
| Redwood Creek (Hollow Tree) (1991) | 2.7 | 4 | | | | | 3 | | | 2 | 1 |
| Redwood Creek (Hollow Tree) (2003) | 2 | | 3 | | A1 | | 2 | | | | |
| Redwood Creek (Redway) (1993) | 7.9 | 2 | 1 | 5 | A4 | 3 | | | | | |
| Redwood Creek (Redway) (2009) | 7.4 | 3 | | 4 | A1 | | 2 | | | | |
| Redwood Creek, SF (1991) | 1.7 | 3 | | | | | 2 | | 1 | | |
| Redwood Creek, SF (2003) | 1.9 | 3 | 4 | | A1 | | 2 | | | | |
| Redwood Creek, SF Unnamed Tributary (2003) | 0.2 | | 2 | | A1 | | | | 3 | | |
| Sebbas Creek (1993) | 3.8 | 4 | 5 | | | 1 | 2 | | 3 | | 6 |
| SF Eel River Headwaters (1996) | 9 | 1 | 2 | | A7 | 5 | 3 | | 6 | 4 | |
| SF Eel River Headwaters (2007) | 5.4 | | | | A2 | | 1 | | | | |
| Somerville Creek (1993) | 1.9 | 1 | | 5 | | 3 | 4 | | | 2 | |
| Sproul Creek (1992) | 7.2 | | 4 | 2 | A1 | 6 | 3 | 5 | | | |
| Sproul Creek (2004) | 6.1 | 3 | | 4 | A1 | | 2 | | | | |
| Sproul Creek Unnamed Tributary 5 (1992) | 1.4 | | | | | 1 | 2 | | 3 | | |
| Sproul Creek Unnamed Tributary 5 (2004) | 0.5 | 4 | 5 | | A1 | 2 | 3 | | | | |
| Sproul Creek, East Branch of WF (1992) | 1.3 | 1 | | | | 4 | 3 | | 2 | | |
| Sproul Creek, WF (1992) | 5.5 | 1 | 2 | | | 4 | 3 | | 5 | | |
| Sproul Creek, WF (2004) | 5 | 4 | 5 | | A1 | 2 | 3 | | | | |

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sproul Creek, WF Unnamed Tributary 8 RB (2004) | 0.6 | | | | A1 | 2 | 3 | | 4 | | |
| Sproul Creek, WF Unnamed Tributary 9 LB (2004) | 1.5 | 4 | | | A1 | 2 | 3 | | | | |
| Standley Creek (1992) | 3.1 | 3 | 5 | 4 | | 1 | 2 | | 6 | | |
| Standley Creek (2007) | 3 | 3 | 2 | | A4 | | 1 | | | | |
| Standley Creek (2009) | 1.9 | | | | A1 | | 2 | | | | |
| Twin Creek (1993) | 0.9 | 4 | | | | 1 | 2 | | | | |
| Twin Creek (2009) | 0.5 | 3 | | | A1 | | 2 | | | | |
| Waldron Creek (1991) | 1.4 | 3 | 4 | | | 1 | 2 | | | | |
| Waldron Creek (2002) | 1.4 | 3 | 4 | | A1 | | 2 | | | | |
| Walters Creek (1992) | 0.8 | | 5 | | A4 | 1 | 2 | | 3 | | 6 |
| Warden Creek (1992) | 0.4 | 1 | 2 | | | 4 | 5 | | | | 3 |
| Warden Creek (2004) | 0.4 | 5 | | | A1 | 3 | 4 | | | | 2 |
| Wildcat Creek (1992) | 2.4 | 3 | | | | 1 | 2 | | | | |
| Wildcat Creek (2007) | 2.3 | 3 | | | A1 | | 2 | | | | |
| Wood Creek, SF Unnamed Tributary (2002) | 0.8 | 4 | | | A1 | 2 | 3 | | | | |

**Canopy** = shade canopy is below target values; **Bank** = stream banks are failing and yielding fine sediment into the stream; **Roads** = fine sediment is entering the stream from the road system; **Temp** = summer water temperatures seem to be above optimum for salmon and steelhead; **Pool** = pools are below target values in quantity and/or quality; **Cover** = escape cover is below target values; **Spawning Gravel** = spawning gravel is deficient in quality and/or quantity; **LDA** = large debris accumulations are retaining large amounts of gravel and could need modification; **Livestock** = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; **Fish Passage** = there are barriers to fish migration in the stream.

*Table 35. Top three ranking recommendation categories by number of tributaries in the Western Subbasin.*

| Western Subbasin Target Issue | Related Table Categories | Count |
|---|---|---|
| Erosion / Sediment | Bank / Roads | 72 |
| Riparian / Water Temp | Canopy / Temp | 64 |
| Instream Habitat | Pool / Cover | 145 |
| Gravel / Substrate | Spawning Gravel / LDA | 19 |
| Other | Livestock / Barrier | 11 |

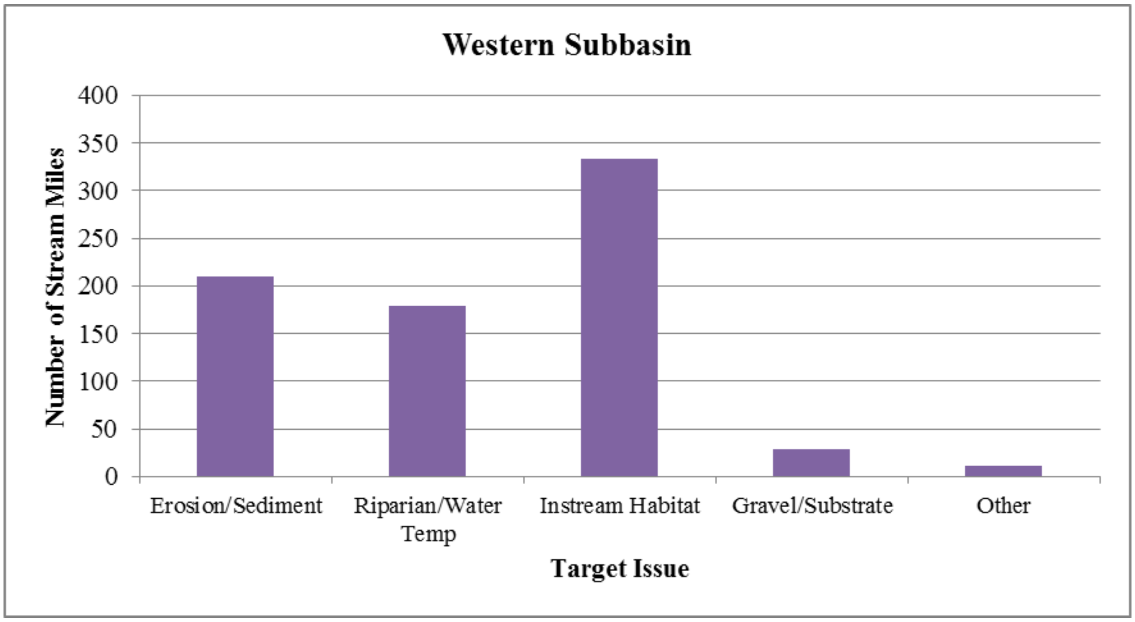



*Figure 59. Recommendation target issues by stream miles for the Western Subbasin.*

## Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Western Subbasin using 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-based analysis at the stream reach scale.

A total of 57 Western Subbasin streams were designated as salmonid refugia areas and were rated into one of the four refugia categories. Refugia categories were defined as:

- **High Quality** – relatively undisturbed habitat, with the range and variability of conditions necessary to support species diversity and natural salmonid production;
- **High Potential** – diminished but good quality habitat with salmonids present, currently managed to protect natural resources with the possibility to become high quality refugia;
- **Medium Potential** – degraded or fragmented instream and riparian habitat, with salmonids present but reduced densities and age class representation. Habitat may improve with modified management practices and restoration efforts;
- **Low Quality** – highly impaired riparian and instream habitat with few salmonids (species, life stages, and year classes). Current management practices and conditions have significantly altered the natural ecosystem and major changes are required to improve habitat.

The most complete data available in the Western Subbasin were for tributaries surveyed by CDFW. However, many of these tributaries were still lacking data for some factors considered. Five streams were rated as high quality refugia, 38 as high potential refugia, 12 as medium potential refugia, and 2 as low quality refugia habitat.

Three of the largest streams in the subbasin were divided into two sections because of significant differences in conditions and salmonid use between lower and upper areas:

- Hollow Tree Creek - the area below the old hatchery (downstream from the confluence of South Fork Creek) was rated medium potential, and the area above the hatchery was rated high quality, with some of the best salmonid habitat in the entire SF Eel River Basin;
- Connick Creek – the lower section (1 mile up from confluence of the SF Eel River) is

medium potential, and the upper section is low quality;

- Redwood Creek (Redway) – the lower section (below Sommerville Creek) is medium potential, and the upper section (also known as Pollock Creek) is high potential refugia habitat.

Five streams were rated as high quality refugia habitat: Indian, Moody, Anderson, Low Gap, and Upper Hollow Tree creeks. Moody and Anderson creeks are located in the upper Indian Creek watershed. This basin is owned primarily by Hawthorne Timber Company, and habitat is relatively good, with excellent canopy condition, good instream temperatures, good spawning gravels, and few diversions. The Upper Hollow Tree Creek drainage and most of the land surrounding Low Gap Creek is owned by MRC, and contains excellent spawning habitat, with cool stream temperatures, good canopy coverage, and adequate flow even during the late summer months.

The majority of Western Subbasin streams were rated as high potential habitat. The climate in this subbasin is relatively cool throughout out year due to the influence of the coastal marine layer, and the topography includes many steep walled canyons and relatively narrow valleys compared to Eastern Subbasin topography. These conditions, along with the resulting cool instream temperatures in most tributaries provide good overall conditions, but road related sediment input and timber harvesting activities have resulted in diminished high quality habitat. Current forest practice rules and practices, combined with restoration (especially road decommissioning) projects may lead to some of these streams becoming high quality refugia areas in the future.

Only two creeks in the entire subbasin were rated low quality: Little Charlie Creek and Connick Creek (*Figure 60*). These creeks are heavily diverted, with corresponding high impacts to salmonid habitat and populations from low flow and poor water quality.

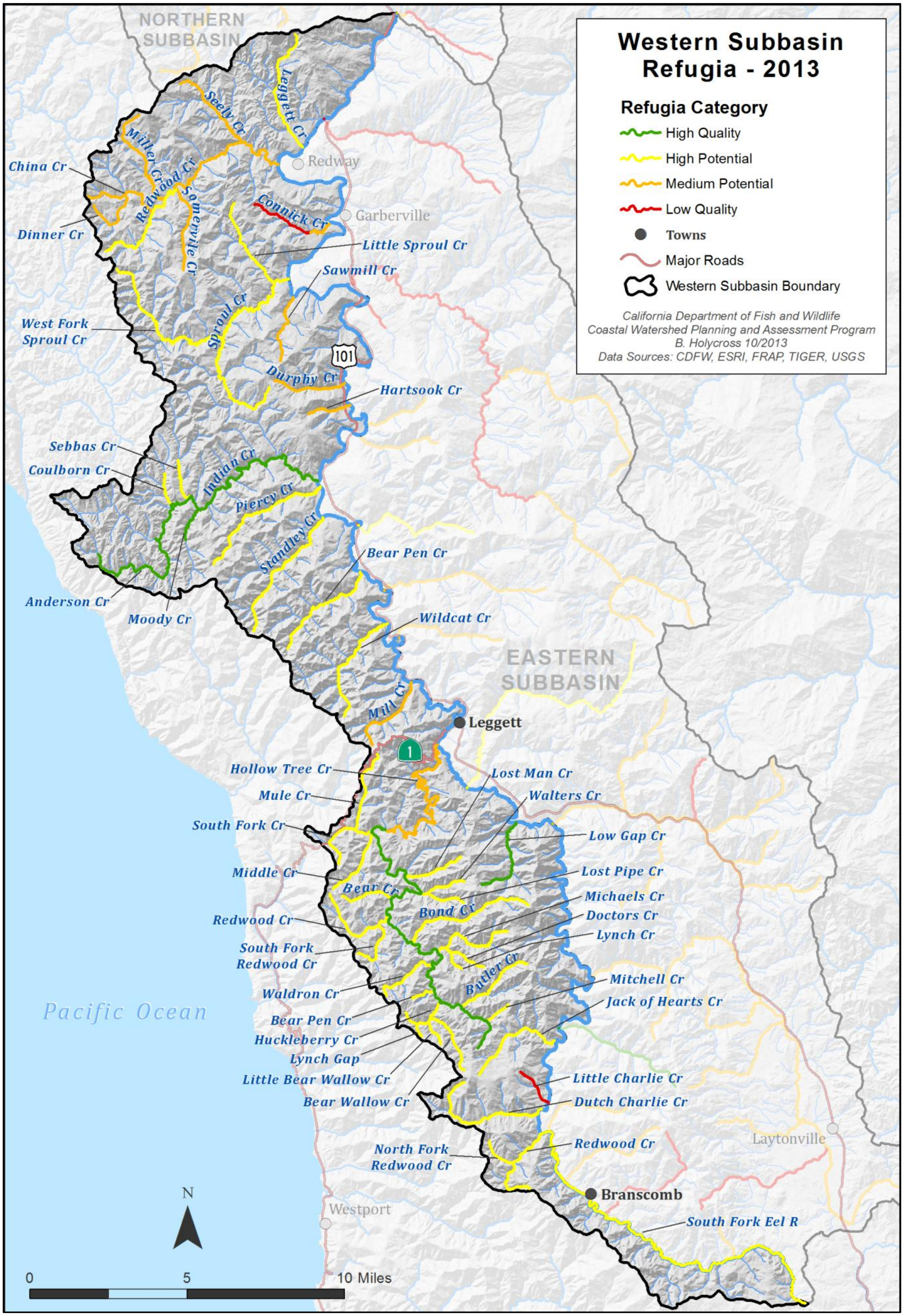



*Figure 60. Refugia ratings in SF Eel River Western Subbasin streams.*

## Key Subbasin Issues

- High levels of fine sediment input related to very high road density and timber harvest activities on unstable soils;
- Altered flow regimes, particularly during low flow periods in late summer, resulting from diversion and reduced winter precipitation patterns;
- Addition of fertilizers, pollutants, and sediment to streams from marijuana cultivation operations in watersheds with high residential land use (e.g. Redwood Creek);
- Erosion from landslides, roads, construction waste, and ground disturbance;
- Poor quality pool habitat (depth, shelter, and quality) in most Western Subbasin streams;
- Medium potential refugia habitat in lower Redwood Creek (Redway), which was historically a productive coho and Chinook salmon and steelhead trout stream;
- High instream temperatures in many streams, with above lethal temperatures recorded in the late summer in the mainstem SF Eel River;
- Sacramento pikeminnow documented in mainstem SF Eel River and in some Western Subbasin tributaries.

## Responses to Assessment Questions

**What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Western Subbasin?**

*Findings and Conclusions:*

- The Western Subbasin supports populations of Chinook salmon, coho salmon, and steelhead trout;
- Using data from one long term data set for salmonid populations in the SF Eel River Basin (Benbow Dam counts occurring from 1938-1975), trend lines for Chinook salmon, coho salmon, and steelhead trout abundance all show significant decreases throughout the sampling duration. These trends are most likely similar for salmonid populations throughout Western Subbasin streams;
- Populations of all three salmonids appeared to decline abruptly following the 1955 and 1964 floods;
- Current salmonid populations are not only less abundant, but they are less widely distributed than they were historically:
    - Historical and anecdotal accounts in 50 Western Subbasin streams dating back to the late 1930s indicate the presence of presence of Chinook salmon in 17 tributaries (34% of streams sampled), coho salmon in 28 tributaries (56% of streams sampled), and steelhead trout in 41 tributaries (82% of streams sampled) in the Western Subbasin;
    - Current salmonid distribution, based on data collected in 175 streams from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) indicate the presence of Chinook salmon in 44 tributaries (25% of surveyed streams), coho salmon in 34 tributaries (19% of surveyed streams), and steelhead trout in 53 tributaries (30% of surveyed streams) in the Western Subbasin;
- Historically and currently, steelhead trout have been found in more tributaries and in areas further upstream than both Chinook and coho salmon. This is due to their preference for habitats that are located farther inland, in smaller streams than Chinook and coho salmon (Moyle et al. 2008), their ability to tolerate a broader range of instream conditions, and their comparatively superior jumping abilities;
- Non-native Sacramento pikeminnow have been documented in most surveys beginning in the late 1990s and are now common in areas of the mainstem SF Eel River and in lower reaches of tributaries. Pikeminnow compete with and prey upon juvenile salmonids, and are adapted to withstand warmer water temperatures than native salmonids.

**What are the current salmonid habitat conditions in the Western Subbasin? How do these conditions compare to desired conditions?**

*Findings and Conclusions:*

**Flow and Water Quality:**

- Instream flow has been reduced through unpermitted diversion for residential and marijuana cultivation uses, particularly in areas where land use is primarily residential (e.g. Redwood Creek near Redway). Reduced flow (compared to historical averages) has been documented in Western Subbasin streams during the late summer and early fall;
- Low summer flows result in dry or intermittent reaches on streams, which may be stressful to salmonids and lead to juvenile mortality;
- The recent increase in industrial marijuana cultivation coupled with several drought years has led to the increased development or reliance on groundwater wells, which will only further exacerbate low flow conditions in the summer and early fall;
- Water diversion by industrial timber companies for road dust/sediment control has been estimated at 2,000-4,000 gallons/mile/day between May 15$^{th}$ and October 15$^{th}$. The amount of water used may be substantial at a time when stream flow is already low, particularly in areas with multiple users with high water demand;
- Water quality is reduced by input of fine sediments from roads throughout the subbasin; primarily seasonal roads that were originally used to access or haul timber, many of which are now also used to access residential areas in newly developed locations or where subdivision of larger parcels has occurred;
- Water quality is reduced by marijuana cultivation operations. Water quality is compromised in these areas by the input of fertilizers, pesticides, rodenticides, diesel fuel from generators, and sediment from improperly constructed roads, and clearing and construction activities at grow sites;
- Increased turbidity is stressful to salmonids, especially during the rainy winter months. High levels of turbidity occur during salmon and steelhead spawning season.

**Erosion/Sediment:**

- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing and feeding habitat for salmonids. High sediment input from natural and anthropogenic sources have resulted in low suitability pool habitat and reduced water quality in streams throughout the subbasin;
- Road density is high (4.8 miles/square mile) in the Western Subbasin, which is the highest density of all three SF Eel River subbasins, reflecting the dominant land use of industrial timber harvest. Legacy logging roads and use of substandard logging roads for hauling and residential access are sources of sediment input into streams throughout the Western Subbasin;
- Soils in the Western Subbasin are prone to erosion, and slides and streambank failures contribute fines to the streams;
- During the historic flood events of 1955 and 1964, very large quantities of sediment entered Western Subbasin streams, and legacy effects of the sediment input are still influencing Western Subbasin streams;
- Increased fine sediment in stream gravel has been linked to decreased fry emergence, decreased juvenile densities, reduced diversity and abundance of invertebrates, loss of winter carrying capacity, and increased predation (Gucinski et al. 2001).

**Riparian Condition/Water Temperature:**

- Canopy density met or exceeded target values in the early 2000s in nearly all surveyed streams in the Western Subbasin. Canopy density values increased over time (using habitat typing data collected during two time periods: 1990-1999, and 2000-2010); the largest increase was seen in Low Gap

Creek, where mean canopy density increased by 60.2% between surveys conducted in 1990 and in 2007;
- In the 1990s, 25% of the stream length surveyed had canopy densities below 50% and only 43% met target values of 80% or greater. Coniferous canopy cover was relatively low (< 50%) in most streams, and was less than 10% in Bond Creek, Hollow Tree Creek, Michaels Creek, and an unnamed tributary to Durphy Creek;
- In the early 2000s, there was no stream length with less than 50% canopy density, and 85% of surveyed stream length met target values of 80% or greater;
- Canopy density suitability improved over time, and most Western Subbasin streams were in the highest category in in the early 2000s. Suitability scores were in the lowest category on the lower reaches of Redwood Creek (Redway), and in the second lowest suitability category on lower Sproul Creek;
- The average percent of coniferous vegetation increased and percent open canopy decreased considerably in most Western Subbasin streams over time;
- Water temperature data collected by HCRCD (between 1996-2003), and ERRP (in 2012) indicated poor (≥66ºF) instream temperatures at 5 tributary sites and 9 mainstem SF Eel River sites; fair (63-65˚F) instream temperatures at 8 tributary and 1 mainstem sites; and good instream temperatures (50-62˚F) recorded at 40 tributary and 1 mainstem locations in Western Subbasin streams. There were two sites where lethal (≥75ºF) conditions were recorded, both in the mainstem SF Eel River near Piercy (RM 54) and Sylvandale (RM 25);
- Bouma-Gregson recorded average daily temperatures above lethal levels (≥75˚F) on 15 days between July and August 2013 in the mainstem SF Eel River at Richardson Grove (RM 49), and on 9 days in July 2013 at Standish-Hickey State Recreation Area (RM 66).

**Instream Habitat:**

- Only one surveyed stream met the >40% target value for pool depth: Redwood Creek (tributary to Hollow Tree Creek) had 42% of surveyed habitat length classified as primary pool habitat in 2003. The remaining 43 streams surveyed did not meet target values for primary pool habitat, and values ranged from a high of 34% in Indian Creek in 2008 to a low of 0% in two streams: an unnamed tributary to Durphy Creek in 1993 and Lynch Creek in 1991;
- Quality pool structure is lacking in Western Subbasin streams. The average mean pool shelter rating was 43.5 in the 1990s and 36.4 using habitat data collected between 2000 and 2010; these values are well below the target pool shelter value of 100 for salmonids. Pool shelter was the only habitat component analyzed that decreased in both rating and suitability between the 1990s and early 2000s;
- Boulders were the dominant pool shelter type during both sampling periods. Using habitat data collected in the 1990s, other shelter types were SWD, LWD, undercut banks, and terrestrial vegetation. Using data from the early 2000s, other shelter types were LWD, SWD, undercut banks, terrestrial vegetation, root masses, and whitewater;
- Although pool depths were generally shallow, pool riffle ratios were above optimal ratios (1:1) in Western Subbasin streams, and the percentage of pool habitat relative to riffle habitat increased slightly in recent years (2000-2010) compared to percentages recorded on surveys in the 1990s. In the 2000s, the pool riffle ratio was 60:40, which is generally considered to provide suitable holding area and habitat diversity for both juvenile salmonids and benthic invertebrates.

**Gravel/Substrate:**

- Cobble embeddedness conditions improved in most Western Subbasin streams over time, with average category 1 embeddedness values of 12.7% for data collected in the 1990s and 34.4% for data collected between 2000 and 2010. Although embeddedness values increased, they were still below target values (>50% category 1) during both time periods;
- The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled between the 1990s and early 2000s. The percent of pool tails in category 2 stayed nearly the same, and the

percent of pool tails in embeddedness category 3 was reduced by nearly 50% between the two time periods. Only categories 1 and 2 are suitable for salmonid spawning;

- Low substrate embeddedness suitability for salmonids in Western Subbasin streams in the 1990s was due to extensive sediment input from highly erosive soils, active landslides, roads, and historical flood events. Suitability scores increased as a result of sediment from historic floods moving through the system, and restoration projects including road decommissioning and bank stabilization.

**<u>Refugia Areas:</u>**

- Salmonid habitat conditions were generally rated as high potential refugia (38 of 57 rated stream areas), meaning that these streams have diminished but good quality habitat with salmonids present. Most are currently managed to protect natural resources, with the possibility to become high quality refugia;
- Five Western Subbasin streams were rated as high quality refugia habitat: Indian, Moody, Anderson, Low Gap, and Upper Hollow Tree creeks. These are creeks have relatively undisturbed habitat, with conditions necessary to support species diversity and natural production;
- Only two tributaries were rated low quality (Connick and Little Charlie creeks). These watersheds have few salmonids and highly impaired riparian and instream habitat, mainly because of water diversions for residential and agricultural uses. Current conditions and management practices have modified the natural environment extensively, and major changes are required to improve habitat conditions in these areas;
- The remainder of the tributaries rated (12 of 57) were rated as medium potential refugia, meaning that instream and riparian habitat is fragmented, and salmonids are present but in reduced densities and age class representation. Western Subbasin streams in this category were most of the Redwood Creek (Redway) watershed, lower Hollow Tree, lower Connick, Sawmill, Durphy, and Hartsook creeks.

**<u>Barriers and other concerns:</u>**

- Both natural barriers (landslides, gradient, and LDA) and anthropogenic barriers (culverts and dams) were mapped using information from stream inventories, field reconnaissance, and the CalFish Passage Assessment Database;
- Most culvert barriers, both total and partial, were located at road crossings along the mainstem SF Eel River, where Highway 101 and smaller roads leading into individual basins cross tributary streams. Two partial culvert barriers are located in the Hollow Tree Creek drainage on land owned by MRC;
- There are two culvert barriers located on Dinner Creek, both of which are total barriers to fish passage. The first culvert is located 8.3 miles up Briceland Thorn Road from Redway (RM 0.85 from China Creek confluence) and the second culvert is located 8.8 miles up Briceland Thorn Road (RM 1.39 from China Creek confluence). Ross Taylor and Associates (2005) recommended replacing both existing culverts with properly sized new culverts that provide unimpeded passage;
- Benbow Dam is located on the mainstem SF Eel River at RM 40. This is not currently a barrier to fish passage, but it has been in the past and is being considered for removal;
- One dam was identified on Jack of Hearts Creek. This was an earthen dam that was built in the summer, but is no longer installed and is not currently considered a barrier to fish passage;
- Forty gradient barriers, mostly waterfalls, were identified in Western Subbasin streams if they occurred in areas other than natural ends of anadromy in headwater areas. These barriers may be partial (a barrier to certain species or life stages), total, or temporal (only a barrier at certain times of the year).

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

*Findings and Conclusions:*

- Natural erosion rates in the Western Subbasin are high due to the following conditions:

  - All rock types in the SF Eel River Basin are considered lithologically soft, prone to erosion, and sensitive to land use. The major rock type underlying the Western Subbasin is the sandstone/argillite/conglomerate of the Coastal Terrane, which tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding especially upon steep stream banks and inner gorge areas;
  - The Western Subbasin is located in one of the most seismically active regions in North America, and fault movement can result in uplift or subsidence of the local landscape, increasing the potential for erosion or deposition;
- Floods periodically occur due to high winter precipitation levels and high runoff rates;
- During the rainy season, heavily silted water flows from steep upstream terrain, downstream to lower reaches, increasing turbidity and sediment levels in many subbasin streams;
- The predominant vegetation type is mixed conifer and hardwood forest, covering 73% of the Western Subbasin area. The average percent deciduous canopy was greater than coniferous canopy in surveyed streams, but the percent coniferous canopy increased between the late 1990s (17%) and early 2000s (22%).

**How has land use affected these natural processes?**

*Findings and Conclusions:*

***Changes in basin due to land use:***

- The majority (75%) of the land in the Western Subbasin is used for industrial timber harvest, and is owned by Mendocino Redwood Company and Hawthorne Timber Company. There is less harvest activity now than in the past, and newer forest practices and management actions (including road decommissioning) have prioritized habitat preservation and fisheries habitat management;
- Road density is higher in this subbasin (4.8 miles/square mile) than in either the Northern (3.7 miles/square mile) or Eastern (2.9 miles/square mile) subbasins. Most roads were originally built to access and haul timber, but many are now also used to access marijuana cultivation sites and residences, especially in areas where large parcels have been subdivided into smaller lots;
- Sediment input from land use activities, primarily roads and timber harvest, is particularly problematic in this subbasin due to highly erodible soils and active landslides;
- In the Redwood Creek (Redway) drainage, the primary land use is residential, and there has been a substantial increase in the number of marijuana cultivation operations in this watershed. In 2012, there were 549 grows (226 outdoor and 323 indoor) identified in this drainage alone, with an estimated 16.5 million gallons of water per growing season required to support these operations (Easthouse 2013). Water sources include direct diversion from streams, groundwater wells, and storage tanks, but little is known regarding how much water is supplied by each source.

***Possible effects seen in stream conditions:***

<u>Instream habitat conditions for salmonids are poor in some streams:</u>

- Low summer flows are exacerbated by diversions, which result in dry or intermittent reaches on streams (especially those that are affected by diversion), which are stressful to salmonids;
- In addition to low flows, water quality (temperature, pollution, turbidity) decreases in areas with high levels of instream diversion and input of fertilizers, chemicals, sediment, and waste from grow operations, resulting in decreased habitat suitability for salmonids;
- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing, and feeding habitat for salmonids. Sediment input from both natural (landslides and streambank erosion) and anthropogenic (timber harvest and road failures and/or degradation) sources are high, with correspondingly high turbidity levels which are stressful for salmonids. Substrate embeddedness values were high in most surveyed reaches, but have shown significant improvement over time;

- Average pool depth and pool shelter values did not meet target values in surveyed Western Subbasin streams (n = 44);
- Boulders were the dominant shelter type in pools, followed by LWD and SWD. Average percent shelter from LWD was less than 5% for data collected during both sampling periods.

Erosion related to timber harvest and roads on unstable soils is a concern:

- Industrial timber harvest occurred in most areas in the subbasin prior to the 1960s, and continues to be the primary land use in more than 75% of the subbasin. Historically, and to a lesser extent currently, sediment enters the streams from timber harvest activities and road related input, including both chronic erosion of fine sediments and catastrophic failure of roads prisms during winter storms;
- Timber harvest, while less of an issue than in the past, still occurred in the headwaters of nearly all Western Subbasin streams between 1991 and 2013. Erosion related to timber harvest is a concern throughout the subbasin due to highly erosive soils, active tectonics contributing to unstable slopes, and heavy rains received during winter months. Logging roads, which are often also used for residential purposes, are significant sources of fine sediment input to streams;
- Timber harvest impacts were magnified by the 1955 and 1964 floods, and sediment pulses from historic land use practices and floods are still moving through Western Subbasin streams.

**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 this subbasin, it appears that salmonid populations are limited by:

- Low summer flows;
- High summer water temperatures in the middle mainstem and downstream, and in larger tributaries;
- High levels of fine sediments in streams, mainly from roads and timber harvest activities;
- Loss of habitat area and complexity, particularly primary pool habitat and pool shelter;
- Competition with Sacramento pikeminnow.

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

- Most habitat recommendations from surveys conducted in Western Subbasin streams targeted instream habitat, including pool and cover categories. Most other recommendations targeted erosion/sediment (related to streambanks and roads) and riparian habitat/water temperatures (canopy and temperature);
- Road decommissioning projects are particularly important in this subbasin due to the very high road density and intensive historic and current timber harvest activities;
- Mendocino Redwood Company, Trout Unlimited, CDFW, and USFWS collaborated on a comprehensive restoration program in the Hollow Tree Creek watershed. This program involves upgrading all roads within the watershed, decommissioning roads that are no longer needed, and installing instream habitat enhancement structures. Three phases of restoration were originally planned, beginning in 2003 and extending through 2008, but additional projects and improvements are currently being completed. Monitoring to determine if these activities result in reduced sediment input to streams is ongoing, and additional problem roads may be identified and projects completed in the future;
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for road dust abatement/sediment control, and support actions designed to encourage efficient use of water;
- Ensure that water diversions used for domestic or irrigation purposes bypass sufficient flows to maintain all fishery resource needs;

- Support and expand projects designed to address solutions to low flow during the late summer months by reducing the number and magnitude of diversions (e.g. SRF's water conservation project in Redwood Creek). Public outreach is needed to increase awareness of land use practices and their impacts on the basin's natural resources;
- Restoration activities that will create additional pool habitat and scour existing shallow pools, while reducing sediment input from roads, are highly recommended throughout this subbasin;
- Identify areas where marijuana cultivation is occurring and quantify environmental effects at sites, including illegal diversions (especially during low flow times), input of pesticides and other pollutants, and sediment loading from these practices. Enforce existing regulations and develop new environmental regulations to target these activities;
- Replace two culverts in Dinner Creek that are total barriers to fish passage. The County of Humboldt recently submitted a proposal for FRGP funding to replace both culverts, in addition to a smaller culvert approximately 700 feet upstream from the second culvert;
- Conduct an upslope erosion inventory in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized and improved;
- Wood recruitment is low in most Western Subbasin streams, and projects that add LWD to streams are recommended. These projects could be combined with pool habitat creation/enhancement projects, since both primary pool habitat and pool shelter are limiting factors for salmonids in this subbasin;
- Consider replanting of native species, like willow, alder, redwood and Douglas fir in areas with little or no native vegetation, or in areas with non-native vegetation;
- Consider thinning hardwoods to increase growth of conifers where riparian forest is strongly dominated by hardwoods and shade canopy will not be adversely affected;
- Monitor streams near land development activities and existing rural residential areas for turbidity, pollution, and drainage issues;
- Continue to conduct biological sampling through the CMP to determine salmonid population abundance and diversity, including but not limited to current CDFW redd counts, adult spawner surveys, and carcass counts, with funding requested to establish and operate of a life cycle monitoring station in Sproul Creek in 2015;
- Consistently collect water quality data, including temperature, dissolved oxygen, and water chemistry throughout the year for several years in order to accurately characterize conditions. Support programs and organizations such as SRF and ERRP that develop studies to monitor the flow, temperature, diversion, and water quality of streams throughout the subbasin, particularly in developed areas.

## Subbasin Conclusions

The Western Subbasin covers an area of 219 square miles, or approximately one third of the total SF Eel River Basin area. This subbasin includes the SF Eel River mainstem and the drainage area on the west side of the mainstem between the confluence of Ohman Creek (RM 23) to the headwaters southwest of Laytonville (RM 105). Streams in this subbasin contain runs of Chinook and coho salmon, and steelhead trout. Current salmonid populations are considerably smaller and less well distributed compared to their historic range, but populations appear to be more abundant and widespread in Western Subbasin streams than in other SF Eel River subbasin tributaries. Maintaining or increasing these remaining populations is critical to the recovery of salmon and steelhead along the entire North Coast.

The fishery resources in the Western Subbasin have been adversely impacted by land use and resource development. Historically, these streams provided important spawning and juvenile rearing grounds that enabled salmon and steelhead populations to thrive. Currently, 75% of the land is used for industrial timber harvest. Barnum Timber Company, Hawthorne Timber Company, and Mendocino Redwood Company own most of the land in this subbasin, including nearly all of the land in the Hollow Tree, Indian, and Sproul Creek basins. Hollow Tree Creek and Sproul Creek basins contain some of the most important coho salmon production areas in the entire SF Eel River Basin. The next most significant land use category in the subbasin is residential areas, which compose 11% of the land use and occur mainly in the Redwood Creek drainage (near Redway) and in areas of Sproul Creek.

Road density in the Western Subbasin is very high (4.76 miles/square mile), and more than 80% of all roads in the subbasin are seasonal roads that were originally built to access and haul timber. Many roads are still utilized for these purposes, but some are also used to access residential areas, especially where large parcels have been subdivided. Road surface erosion, road crossing failures and gullies, skid trails, and landslides from roads are the primary anthropogenic sources of sediment input in Western Subbasin streams. Roads that are no longer used or those that were improperly constructed should be targeted for decommissioning and/or upgrading in order to reduce fine sediment input and associated turbidity, thereby improving salmonid habitat in tributaries throughout the subbasin. CDFW, USFWS, MRC, and Trout Unlimited cooperatively developed a restoration program in the Hollow Tree Creek basin that includes the upgrading and decommissioning roads, installing instream structures, and post-project monitoring.

Reduced streamflow, particularly during the dry summer months, due to an increase in the number and volume of diversions (for residential and agricultural uses, and for dust abatement/sediment control on industrial timber company lands), combined with longer dry periods (less precipitation) in the winter and early spring, have dramatically affected salmonids in the basin at all life stages. Low flows are particularly apparent in northern areas of the subbasin, especially in Redwood Creek near Redway, where most land use is residential and extensive industrial marijuana cultivation operations have been documented. These operations have increased dramatically in both number and magnitude in recent years. In 2012, CDFW Environmental Scientist Scott Bauer identified 549 grows (226 outdoor and 323 indoor/greenhouse) with a total of 18,500 plants (8,100 in greenhouses and 10,400 outdoors) estimated to be associated with these operations in Redwood Creek alone. These grow operations consumed more than 16.5 million gallons of water in one growing season (Easthouse 2013), much of which was diverted from nearby tributaries. Moreover, industrial marijuana cultivation expansion coupled with several drought years has led to the increased development or reliance on groundwater wells, which will only further exacerbate low flow conditions in the summer and early fall. Many cultivation operations also significantly reduce water quality by discharging pollutants including pesticides, herbicides, rodenticides, and diesel fuel into streams. Fine sediment input has also increased due to illegal or improperly constructed access roads and/or clearing crop locations, and some unpermitted timber harvest has occurred where land has been cleared at grow sites. These impacts have been increasing while enforcement has been challenging due to safety concerns, limited funding, and a lack of laws and regulations related to these activities. Future actions and regulations must address the detrimental environmental impacts of large-scale, illegal marijuana cultivation operations throughout the subbasin.

Sedimentation and in-filling from large historic flood events, natural landsliding, unstable geology, timber harvest, land subdivision activities, and road erosion and failures have resulted in increased fine sediment and an overall reduction in channel area in Western Subbasin streams. Large amounts of sediment fills in pool habitat, reduces the depth of existing pools, and increases embeddedness of substrate, resulting in a corresponding decrease in available salmonid spawning and rearing habitat. Although streams are designed to move sediment through the system naturally, Western Subbasin streams often do not have sufficient flow to flush out the quantities of sediment. Large volumes of sediment are continually entering streams from both natural and anthropogenic sources, and the basin is still inhibited by legacy effects of the 1955 and 1964 floods.

CDFW crews collected habitat typing data in 44 Western Subbasin streams during two time periods (1990-1999 and 2000-2010), and CWPAP staff analyzed data to determine changes in habitat suitability for salmonids over time. Although values for select factors (canopy density, embeddedness, and percent primary pool habitat) appear to be improving with time, overall suitability scores were still low (negative values) for most factors during both time periods. Average pool shelter complexity values decreased over time, remaining in the lowest suitability category during both sampling periods. Canopy density was in the highest suitability category during the early 2000s, most likely because of management practices promoting growth and recovery of riparian areas since historic damage from floods and intensive timber harvest.

CDFW currently conducts spawning ground surveys annually as part of the CMP on a select percentage of habitat in Western Subbasin streams; surveys include live fish or redd counts and carcass counts. A life cycle monitoring station will be established in the subbasin in the future to record counts of adults and outmigrating smolts. These counts will be used to calibrate spawning ground escapement estimates and freshwater and ocean survival. CDFW submitted a funding request in 2014 to establish a life cycle monitoring station in Sproul Creek in 2015, and information collected at this station will be used to assess the status of CC Chinook and SONCC coho salmon in the ESU.

Spawner survey information was also collected as part of CDFW's index reach sampling efforts in six Western Subbasin tributaries between 2002 and 2012. Surveys were completed between the beginning of November and the beginning of March each year in upper, lower, and WF Sproul (2002-2012) and in Redwood (Redway), Upper Redwood (Pollock), and China creeks (2002-2010). There were more coho salmon and Chinook salmon documented in WF Sproul Creek than in any of the other sampled creeks, with a maximum count of 81 live coho observed in WF Sproul Creek during the 2011-12 sampling season.

Diminishing runs of salmon and to a lesser extent steelhead in SF Eel River Basin streams are susceptible to being reduced to remnant populations. Regulations addressing environmental impacts and their effect on salmonids in the basin have primarily addressed timber harvest practices (and associated impacts from legacy and new roads) and ranching activities, and these rules and guidelines have resulted in decreased riparian impacts, decreased sedimentation from roads, and improved instream conditions in many areas of the basin. However, many regulations that are designed to help protect the basin's salmonid stocks, water resources, and associated stream habitats have not provided sufficient protection since the recent rapid expansion of marijuana cultivation throughout the basin, particularly in areas dominated by residential land use. While new regulations and management activities helped improve habitat in some areas within the subbasin, they have not been on large enough spatial or temporal scales to provide significant improvements to the overall habitat condition and ecosystem function necessary to restore salmonid populations to desirable numbers or ranges.

This subbasin contains critical habitat and runs of salmonids to help in the statewide recovery of salmonids. Both SF Eel River coho salmon and steelhead were recently selected as "salmon strongholds", which represent the healthiest wild Pacific salmon populations remaining, and recognize the high value of the habitats these populations occupy (Wild Salmon Center 2012). Identification of these strong populations is part of a larger conservation effort to complement recovery efforts for salmonids throughout the state. Larger Western Subbasin watersheds such as Hollow Tree and Sproul Creek are particularly important for coho salmon, Chinook salmon, and steelhead due to high quality habitat and relatively healthy, well-established populations.

A cooperative approach with concerted effort is necessary to address diversion, stream temperature, and water quality (fine sediment and pollution) issues in order to improve and expand spawning and rearing habitat for salmonids, and to increase overall ecosystem health in streams throughout the Western Subbasin. Additional monitoring efforts, including the establishment and operation of a life cycle monitoring station in this subbasin will be an important step in understanding population trends of SF Eel River salmonids.

*Juvenile coho salmon (photo courtesy of Teri Moore, CDFW).*

# SF Eel River Eastern Subbasin

## Table of Contents

## Table of Figures

## List of Tables

# Eastern Subbasin

## Overview

The Eastern Subbasin is the largest of the three subbasins in the South Fork (SF) Eel River Basin, covering an area of 320 square miles, or 46% of the total basin area (*Table 1*). This subbasin includes all of the land in the watershed east of the mainstem SF Eel River, including approximately 82 miles of mainstem and 359 miles of tributary stream (220 miles of perennial or blue line stream and 139 miles of intermittent stream), beginning at the confluence of Ohman Creek and the SF Eel River (RM 23) and ending at its headwaters just south of Laytonville (RM 105). The Humboldt/Mendocino County line runs directly across the subbasin at Cooks Valley, just north of Piercy; tributaries to the north are located in Humboldt County, and those to the south are located in Mendocino County. Sixty five percent of the SF Eel River Basin's population lives in the Eastern Subbasin, and the largest towns are Laytonville, Redway, and Garberville.

The primary land uses in the subbasin are timber production, grazing/nonindustrial timber harvest, and rural residential. Streams are characterized by warm summer temperatures, high gradient streams, and lack of canopy cover in many tributaries compared to Northern and Western Subbasin streams (*Figure 1*). Stream elevations range from approximately 225 feet at the confluence of the SF Eel River and Ohman Creek to approximately 4,491 feet in the headwaters near Cahto Peak. The Eastern Subbasin is located farther inland that the other subbasins, and with less of the coastal marine layer to moderate temperatures the climate is generally warmer and drier than the Northern and Western subbasins.

Many of the tributaries to the SF Eel River that are located in the southern part of the basin (upstream from Tenmile Creek) are more characteristic of Western Subbasin streams. These streams have dense canopy coverage and relatively cool air and instream temperatures due to the influence of the coastal marine layer. On the east side of Cahto Peak and Signal Peak, near Laytonville, the climate is dry and hot, and instream and riparian conditions are more similar to other areas of the Eastern Subbasin.

The only large tributary with documented coho distribution in this subbasin is the Tenmile Creek drainage in the southern part of the subbasin. Chinook salmon and steelhead trout have been documented in other large Eastern Subbasin watersheds including the East Branch SF Eel River, Cedar Creek, Rattlesnake Creek, and Tenmile Creek.

General attributes of this subbasin are listed in *Table 1*. *Figure 2* is a map of the Eastern Subbasin location in relation to other subbasins within the SF Eel River watershed.

*Table 1. Attributes of the SF Eel River Eastern Subbasin.*

| | |
|---|---|
| Area (square miles) | 320 |
| Privately Owned (square miles) | 266 |
| Publicly Owned (square miles) | 53 |
| Predominant Land Uses | Timber harvest, grazing, and rural residential |
| Predominant Vegetation | Mixed conifer and hardwood forest |
| Mainstem Miles | 82 (RM 23-105) |
| Tributary Miles | 359 |
| Total Stream Miles | 441 |
| Lowest Elevation (feet) | 225 |
| Highest Elevation (feet) | 4,491 |

*Figure 1. East Branch SF Eel River during September 2013 low flow.*


*Figure 2. South Fork Eel River Basin and Northern, Eastern, and Western subbasins.*

## Hydrology

The Eastern Subbasin is made up of 29 CalWater Units (*Figure 4*). There are 82 named and 86 unnamed tributaries, with more than 220 perennial and 139 intermittent stream miles in this subbasin. The mainstem South Fork Eel River is a fifth order stream using the Strahler (1964) classification, and the tributaries are first through fourth order streams. Stream drainage areas in this subbasin range from less than one square mile to the 77 square mile East Branch of the SF Eel River drainage (*Figure 5*).

Average annual precipitation in the Eastern Subbasin ranges from 51 inches near Williams Creek in the northern part of the subbasin, to more than 97 inches in the headwaters of the SF Eel River, west of Cahto Peak. Approximately 70 percent of this precipitation occurs between November and March and generates significant runoff during this five month period. During events that cause large amounts of sediment to enter the streams, and/or those that cause changes in hydrology, (e.g. 1955, 1964, 1997 floods, seismic activity, sediment accumulation, land use, water diversion, hydrologic connectivity, change in vegetation, climate, drought changes in land use, etc.), streams that have historically been perennial may change to intermittent.

There are four operational USGS stream gauges in the Eastern Subbasin, located near Miranda and Leggett in the mainstem SF Eel River (at RM 24 and RM 66), and in Cahto and Elder creeks (*Figure 3*). Stream flow from the Leggett gauge data represents 78% of the total SF Eel River drainage area, or 537.5 square miles. Average annual discharge data were available from 1966-2010, with missing or incomplete data for water years 1995-1999 and 2005-2007 (*Figure 6*). The highest average annual discharge (>1700 cfs) occurred in 1974 and 1983, and lowest average annual discharge (70 cfs) was recorded in 1977. These data were consistent with those recorded at other stations throughout the SF Eel River Basin (including the Miranda gauge, discussed in the Northern Subbasin section). The Cahto and Elder Creek gauges were not used to infer hydrologic trends throughout the basin due to very small drainage areas (5 square miles and 6 square miles, respectively), and because Cahto Creek is dry for part of each year.

*Figure 3. USGS Leggett stream gauge site photo (mainstem SF Eel River RM 66).*

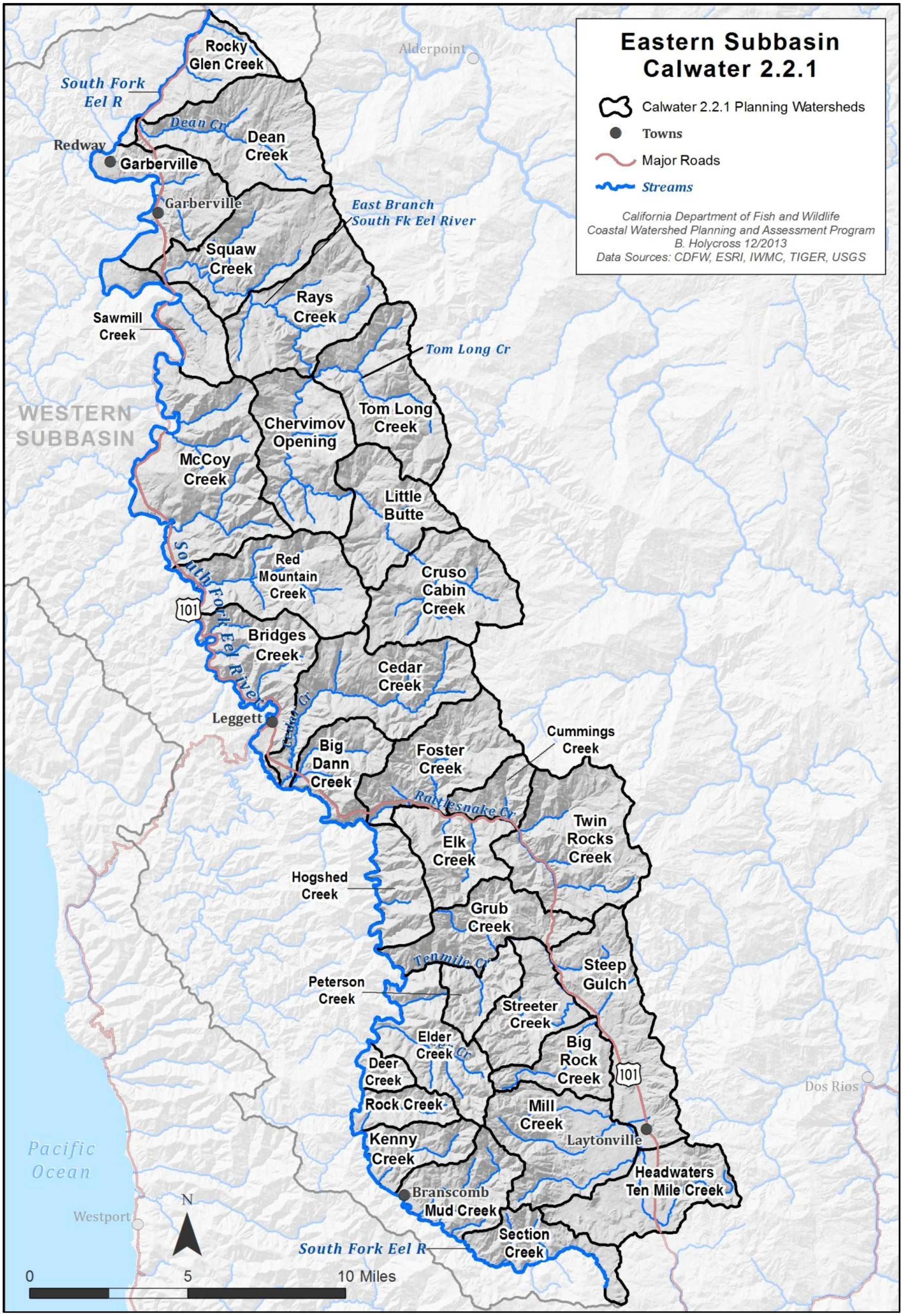



*Figure 4. Map of Calwater 2.2.1 Eastern Subbasin planning subwatersheds.*

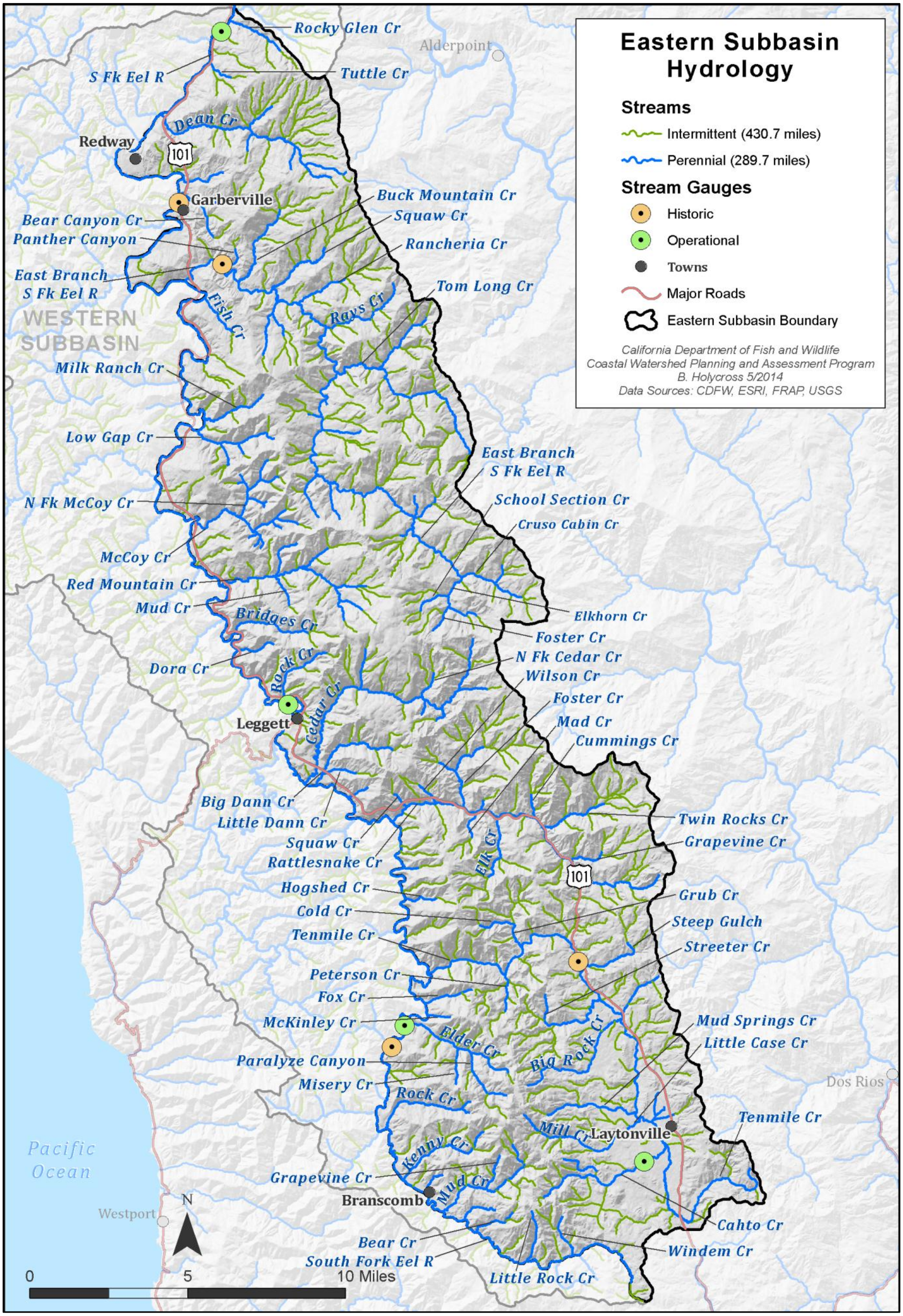



*Figure 5. SF Eel River Eastern Subbasin streams.*

*Table 2. Eastern Subbasin tributaries and statistics (int = intermittent stream).*

| Stream | Tributary to: | Length miles | Perennial miles | Intermittent miles | Drainage Area, $miles^2$ | Stream order |
|---|---|---|---|---|---|---|
| SF Eel River | Eel River | 76 | 76 | 0 | 320.472 | 5 |
| Rocky Glen Creek | S.F. Eel River | 2.9 | 2.071 | 0.829 | 1.955 | 1 |
| William's Creek | S.F. Eel River | 2 | 0 | 2 | 0.873 | int. |
| Tuttle Creek | S.F. Eel River | 1.5 | 1.025 | 0.475 | 1.38 | 1 |
| Dean Creek | S.F. Eel River | 7.8 | 7.419 | 0.381 | 15 | 2- |
| Bluff Creek | S.F. Eel River | 1 | 0 | 1 | 8.2 | int. |
| Bear Canyon Creek | S.F. Eel River | 2.7 | 1.98 | 0.72 | 3.5 | 2 |
| East Branch SF Eel River | S.F. Eel River | 21 | 21 | 0 | 77 | 3 |
| Panther Canyon | East Branch (EB) S.F. Eel River | 1.4 | 0.932 | 0.468 | 0.639 | 1 |
| Buck Mountain Creek | EB S.F. Eel River | 5.3 | 3.364 | 1.936 | 4.477 | 1 |
| Sqaw Creek | EB S.F. Eel River | 4.9 | 2.955 | 1.945 | 4.492 | 1 |
| Horse Pasture Creek | EB S.F. Eel River | 2.7 | 1.631 | 1.069 | 2.772 | 1 |
| Rancheria Creek | EB S.F. Eel River | 3.7 | 1.965 | 1.735 | 4.64 | 1 |
| Ray's Creek | EB S.F. Eel River | 3.3 | 3.3 | 0 | 2.937 | 1 |
| Tom Long Creek | EB S.F. Eel River | 8 | 7.073 | 0.927 | 13.6 | 2 |
| Elkhorn Creek | EB S.F. Eel River | 3 | 2.218 | 0.782 | 5.844 | 2 |
| Cruso Cabin Creek | EB S.F. Eel River | 3.2 | 2.326 | 0.874 | 4.713 | 2 |
| School Section Creek | Elkhorn Creek | 1.9 | 1.205 | 0.695 | 1.996 | 1 |
| Foster Creek | Elkhorn Creek | 1 | 1 | 0 | 1.285 | 1 |
| Fish Creek | S.F. Eel River | 2.3 | 1.535 | 0.765 | 2 | 1 |
| Mitzie Creek | S.F. Eel River | 0.7 | 0 | 0.7 | 0.335 | int. |
| Milk Ranch Creek | S.F. Eel River | 2.5 | 2.5 | 0 | 2.3 | 1 |
| Rancheria Creek | S.F. Eel River | 0.8 | 0 | 0.8 | 0.177 | int. |
| Low Gap Creek | S.F. Eel River | 2.9 | 2.9 | 0 | 3.9 | 2 |
| McCoy Creek | S.F. Eel River | 4.9 | 4.456 | 0.444 | 6.8 | 4 |
| North Fork McCoy Creek | McCoy Creek | 2.7 | 2.279 | 0.421 | 2.942 | 3 |
| Red Mountain Creek | S.F. Eel River | 6.1 | 5.53 | 0.57 | 12.4 | 2 |
| Holohan Gulch | Red Mountain Creek | 1.3 | 0 | 1.3 | 0.385 | int. |
| Mud Creek | Red Mountain Creek | 1.5 | 1.131 | 0.369 | 0.996 | 1 |
| Bridges Creek | S.F. Eel River | 3.9 | 2.833 | 1.067 | 3.1 | 1 |
| Dora Creek | S.F. Eel River | 1.3 | 1.3 | 0 | 0.691 | 1 |
| Rock Creek | S.F. Eel River | 3.2 | 2.731 | 0.469 | 2.071 | 1 |
| Cedar Creek | S.F. Eel River | 11.2 | 11.2 | 0 | 15.4 | 2 |
| North Fork Cedar Creek | Cedar Creek | 1.8 | 0.955 | 0.845 | 1.751 | 1 |
| Little Cedar Creek | Cedar Creek | 1.7 | 0.643 | 1.057 | 0.785 | 1 |
| Big Dan Creek | S.F. Eel River | 4.4 | 3.68 | 0.72 | 4.828 | 2 |
| Little Dan Creek | Big Dan Creek | 2 | 1.251 | 0.749 | 1.051 | 1 |
| Grizzly Creek | S.F. Eel River | 0.757 | 0.757 | 0 | 0.578 | 1 |
| Rattlesnake Creek | S.F. Eel River | 11.3 | 11.3 | 0 | 37.5 | 3 |
| Squaw Creek | Rattlesnake Creek | 1.2 | 0.667 | 0.533 | 0.675 | 1 |
| Measley Creek | Rattlesnake Creek | 1.2 | 0 | 1.2 | 0.167 | int. |
| Wilson Creek | Rattlesnake Creek | 1.4 | 0.85 | 0.55 | 0.774 | 1 |
| Foster Creek | Rattlesnake Creek | 4.8 | 2.815 | 1.985 | 8.87 | 2 |
| Mad Creek | Rattlesnake Creek | 1.9 | 1.058 | 0.842 | 1.021 | 1 |
| Elk Creek | Rattlesnake Creek | 3.8 | 2.856 | 0.944 | 3.9 | 1 |
| Cummings Creek | Rattlesnake Creek | 2.3 | 0.815 | 1.485 | 1.9 | 1 |
| Twin Rocks Creek | Rattlesnake Creek | 4.4 | 1.978 | 2.422 | 5.5 | 1 |
| Grapewine Creek | Rattlesnake Creek | 2.2 | 1.27 | 0.93 | 2.5 | 1 |
| Hogshead Creek | S.F. Eel River | 1.8 | 1.139 | 0.661 | 1.063 | 1 |
| Tenmile Creek | S.F. Eel River | 21.9 | 21.9 | 0 | 65.3 | 3 |
| Peterson Creek | Tenmile Creek | 2.4 | 1.287 | 1.113 | 2.309 | 1 |
| Grub Creek | Tenmile Creek | 2.7 | 1.277 | 1.423 | 3.761 | 1 |

| Stream | Tributary to: | Length miles | Perennial miles | Intermittent miles | Drainage Area, miles$^2$ | Stream order |
|---|---|---|---|---|---|---|
| Cold Creek | Grub Creek | 2.3 | 0.874 | 1.426 | 1.104 | 1 |
| Spring Creek | Temnile Creek | 1.5 | 0 | 1.5 | | int. |
| Steep Gulch | Tenmile Creek | 3.8 | 2.388 | 1.412 | 2.912 | 1 |
| Streeter Creek | Tenmile Creek | 3.7 | 3.7 | 0 | 4.8 | 1 |
| Lewis Creek | Tenmile Creek | 1.8 | 1.8 | 0 | 1.5 | 1 |
| Big Rock Creek | Tenmile Creek | 4.7 | 4.7 | 0 | 3.2 | 1 |
| Stapp Creek | Tenmile Creek | 0.72 | 0 | 0.72 | 0.119 | int. |
| Wilson Creek | Tenmile Creek | 2.1 | 0 | 2.1 | 1.856 | int. |
| Mud Springs Creek | Tenmile Creek | 3.8 | 0.598 | 3.202 | 2.723 | 1 |
| Little Case Creek | Tenmile Creek | 3.4 | 0.899 | 2.501 | 4.828 | 1 |
| Mill Creek | Little Case Creek | 3.9 | 3.9 | 0 | 2.99 | 1 |
| Tuttle Creek | Little Case Creek | 1.4 | 0 | 1.4 | 0.505 | int. |
| Cahto Creek | Ten Mile Creek | 5.8 | 5.337 | 0.463 | 5.6 | 2 |
| Fox Creek | S.F. Eel River | 1.6 | 1.6 | 0 | 1.2 | 1 |
| McKinley Creek | S.F. Eel River | 0.8 | 0.8 | 0 | 0.269 | 1 |
| Elder Creek | S.F. Eel River | 4.7 | 4.337 | 0.363 | 5.7 | 2 |
| Misery Creek | Elder Creek | 1.2 | 1.2 | 0 | 0.76 | 1 |
| Paralyze Canyon | Elder Creek | 2.108 | 2.108 | 0 | 1.829 | 1 |
| Deer Creek | S.F. Eel River | 1.4 | 0 | 1.4 | 1.184 | int. |
| Rock Creek (Jackson Valley) | S.F. Eel River | 3.6 | 3.6 | 0 | 3.1 | 2 |
| Muddy Gulch Creek | S.F. Eel River | 1 | 0 | 1 | 0.461 | int. |
| Kenny Creek | S.F. Eel River | 4.2 | 3.67 | 0.53 | 3.4 | 1 |
| Buck Creek- | S.F. Eel River | 0.914 | 0 | 0.914 | 0.449 | 0 |
| Mud Creek | S.F. Eel River | 5 | 4.472 | 0.528 | 4.9 | 2 |
| Grapevine Creek | Mud Creek | 1.3 | 1.3 | 0 | 0.65 | 1 |
| Taylor Creek | S.F. Eel River | 1.3 | 1.3 | 0 | 0.66 | 1 |
| Bear Creek | S.F. Eel River | 1.9 | 1.571 | 0.329 | 0.862 | 1 |
| Wise Gulch | S.F. Eel River | 1.1 | 0 | 1.1 | 0.443 | int. |
| Little Rock Creek | S.F. Eel River | 1.8 | 1.8 | 0 | 0.6 | 1 |
| Windem Creek | S.F. Eel River | 1.5 | 1.5 | 0 | 1.2 | 1 |

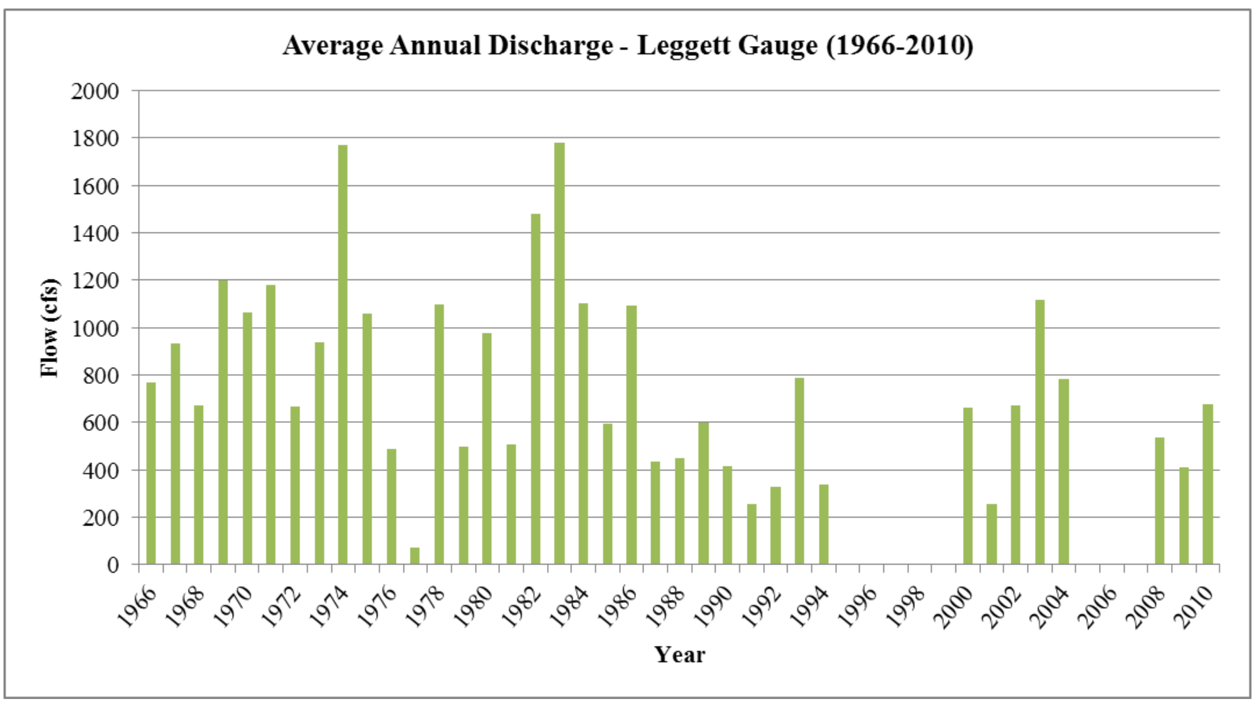



*Figure 6. Average annual discharge at the Leggett gauge, located at RM 66 on the mainstem SF Eel River.*

## Floods

Large floods have occurred roughly every decade in the SF Eel River drainage. The most devastating floods in recent memory occurred in 1955 and 1964. The effects of these floods on the watershed was exacerbated by extensive logging due to the advent of new post-WWII tractor technology, changes in local vegetation, and prior seismic events that further destabilized the hillslopes. The 1964 flood involved the melting of a large accumulation of snow in the higher elevations by a warm storm with sustained, heavy rains. Landslides and resulting sedimentation of the streams were unprecedented - these floods washed away entire towns, reset river patterns, and changed stream morphology for decades. In some cases, legacy effects are still apparent upon the landscape and in streams throughout the basin.

In the SF Eel River Basin the 1955 flood had a peak flow (at Miranda, just north of the subbasin boundary at RM 24) of 173,000 cubic feet per second (cfs). This flood exceeded 22 million dollars in damages, flooded 43,000 acres, and killed at least one person in the Eel River Basin. The 1964 flood had a peak flow (at Miranda) of 199,000 cfs, exceeded 100 million dollars in damages and killed at least 19 people in the Mad and Eel River Basins (Dyett and Bhatia 2002).

## Dams, Diversions, and Hydrologic Disturbances

The assessment team utilized features identified by field crews during stream inventories, field reconnaissance, and the CalFish Passage Assessment Database to locate, map, and discuss known fish passage barriers to salmonids.

There is one dam that is a permanent, total barrier to fish passage in the Eastern Subbasin. This dam is located near the headwaters of Grapevine Creek, tributary to Rattlesnake Creek and does not appear to shorten anadromous stream length significantly. There are three other dams that are classified as temporal barriers in the subbasin: two on Red Mountain Creek (RM 58 on the SF Eel River) and one at Benbow (RM 40). These dams are no longer installed in the summers and are not considered barriers to fish passage at this time; the history and current status of Benbow Dam is discussed in the Western Subbasin section. One "unassessed" dam was identified on Cahto Creek (CalFish 2012). For a detailed discussion of all Eastern Subbasin barriers, see the Fish Passage Barriers section of this subbasin report.

There are many illegal and unregulated water diversions associated with marijuana cultivation practices in Eastern Subbasin streams (*Figure 7*). These diversions remove water from streams throughout the growing season, and are of particular concern during the dry times of the year. A number of shallow groundwater wells in this subbasin supply water for rural residential and agricultural uses. The groundwater that these wells draw from is considered "surface water underflow", or water that has penetrated through the soil layer into the weathered bedrock layer atop the coherent bedrock. This water is critical to providing dry-season base flow to streams. When diversion pressure is high, streamflow is reduced and in some cases, streambeds may be dry and limited to subsurface flow.

*Figure 7. Example of illegal diversion on SF Eel River tributary.*

# Geology

## Bedrock

The Eastern Subbasin is composed of metamorphic, marine sedimentary, and igneous rock types of the Franciscan Complex and their associated overlap assemblage of sediments and sedimentary rock types. The Eastern Subbasin is made up of predominantly the Central Belt Mélange, but also includes some areas of Central Belt Sandstone and the juxtaposed Coastal Belt Yager Terrane. Descriptions of bedrock, including composition, depositional history, landscape morphology, strength, and erosional characteristics of each rock type represented on the geology map (*Figure 8*) will be briefly discussed below in order of their abundance within the subbasin. *Table 3* contains a brief summary of Eastern Subbasin geology types and their attributes.

### Central Belt Mélange

Mélange of the Central Belt of the Franciscan Complex is the most abundant rock type within this subbasin, making up approximately 34 percent of its surface area. Mélange is a completely sheared matrix of argillite (hardened mudstone existing in metamorphic grade between mudstone and shale) and sandstone containing very small (gravel sized) to very large (city block sized), mappable blocks of sandstone, limestone, blueschist, greenstone, serpentinite, and chert.

The Central Belt Mélange formed from 65.5 through 199.6 million years ago within the subduction trench between the Farallon and North American plates, as material from the oceanic crust and its overlying sediments were tectonically mixed with sediments washing off of the continent (Aalto 1981). This mixture was then accreted to the western edge of the continent beginning around 88 million years ago (McLaughlin et al. 2000). Mélange has undergone such a degree of internal shearing during its accretionary/tectonic history, that it tends to be quite weak and behaves more like an extremely viscous liquid than solid bedrock, slowly “flowing” over time. This movement exposes more coherent lithologic blocks known as “Franciscan Knockers” and creates a hummocky, rolling landscape. The Central Belt mélange is considered one of the most unstable rock types in the subbasin and highly prone to erosion and mass movement, especially when saturated with water and/or disturbed by land use. Mélange is especially prone to earthflows and secondary debris flows.

### Yager Terrane

Nearly 27 percent of this subbasin is compsed of Coastal Belt Yager Terrane. It consists of highly folded and faulted interbedded layers of well consolidated sandstone, argillite, and pebble conglomerate.

Sediments of the Yager Terrane were originally deposited between 65 and 34 million years ago by ancient rivers originating as far away as Idaho (Underwood and Bachman 1986). Sediments accumulated along the continental shelf to the deep ocean floor. The accumulation of sediment in the Yager Terrane likely more than 10 thousand feet thick in places (Ogle 1953). The sequence of interbedded argillite and sandstone represents stages of calm marine sediment deposition punctuated by large underwater landslide events. These subaqueous landslides were probably triggered by large seismic events, tsunamis, storm wave loading, and sediment loading (Goldfinger et al. 2003) attesting to the abundance of seismic activity in this region.

The Yager Terrane forms steep, sharp-crested ridges and associated valleys that give the landscape a steep and rugged appearance. The relative stability of the Yager Terrane develops soils that typically support lush forest growth.

The Yager Terrane is relatively stable; however, in areas where it is faulted and/or sheared it is prone to large-scale landsliding. The argillaceous interbeds of the Yager Terrane tend to crumble when repeatedly exposed to cycles of wet and dry, leading to undercutting of the stream bank along bedrock reaches and movement along bedding planes resulting in translational landslides. Excessive crumbling of argillite can also be a source of fine sediments in streams. The beds of the Yager Terrane are tilted by folding and faulting of this region. In areas where the dip of the beds inclines with the hillslope into the stream valley, large translational block landslides are more likely to occur. Yager Terrane is especially prone to debris sliding on steep stream banks (Kelsey et al. 1975).

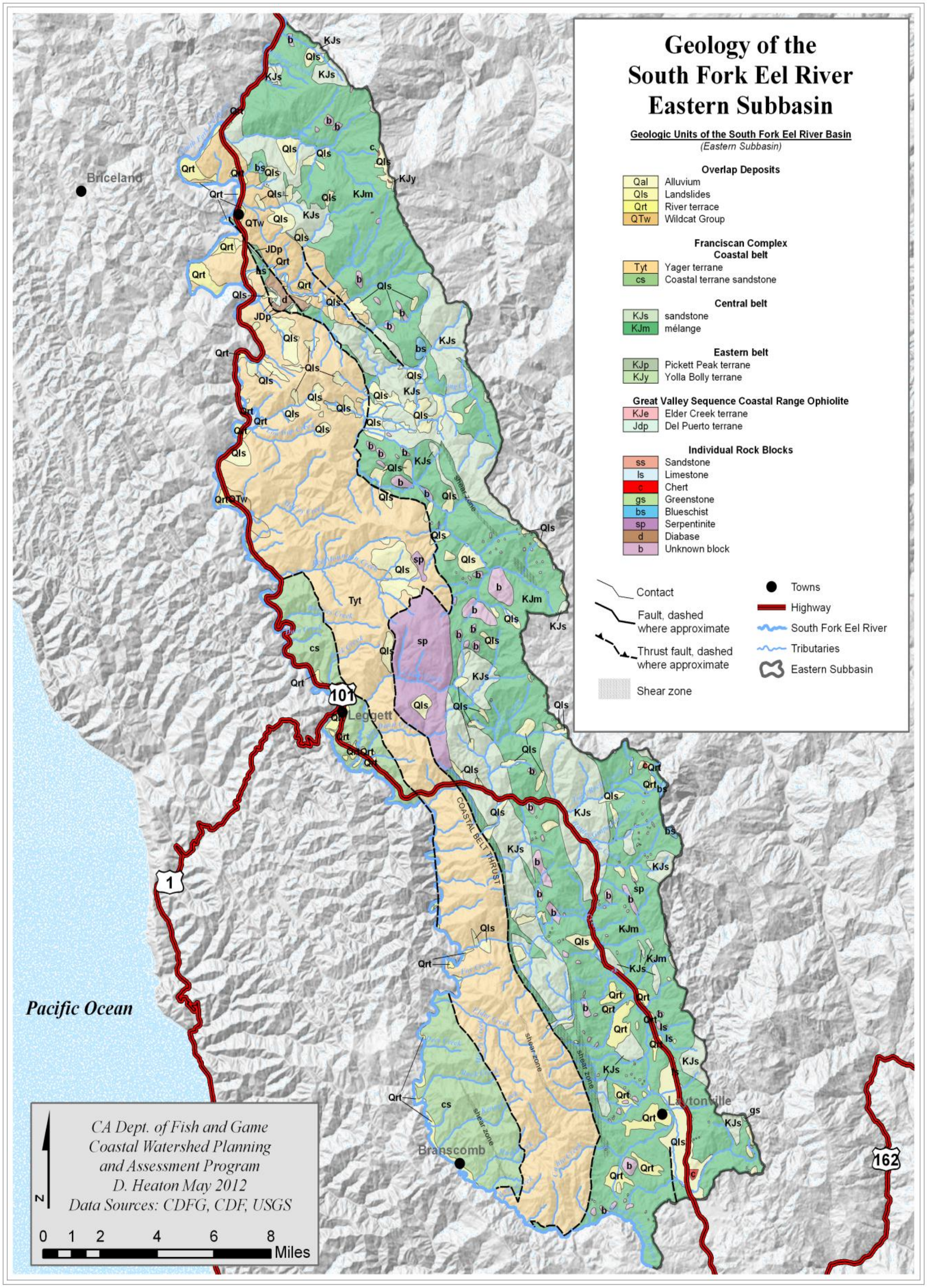



*Figure 8. Geologic Map of the Eastern Subbasin*

*Table 3. Eastern Subbasin bedrock descriptions (ma = millions of years before the present).*

| Unit | Belt/Rock Type | Formation / Terrane | Composition | Morphology/Erosion | Age (ma) | % Sub-basin Area |
|---|---|---|---|---|---|---|
| **Overlap Deposits** | Alluvium | | Unconsolidated river deposits of boulders, gravel, sand, silt, and clay. | Flat to gently sloping, bare, river banks, beds, and floodplains. Raveling of steep slopes. Sediment transport by fluvial and aeolian processes. | 0-0.01 | 1.3 |
| | Landslide | | Large, disrupted, clay to boulder debris and broken rock masses. | Rumpled, disordered hillslopes. Shallow debris slides. Rotational slumps on steep slopes or eroding toes. Surface erosion and gullying where vegetation is bare. | 0.01-2 | 5.7 |
| | River Terrace | | Unconsolidated river deposits of boulders, gravel, sand, silt, and clay that have been uplifted above the active stream channel. | Flat to gently sloping, vegetated, uplifted terrace benches bordering streams. Raveling of steep slopes. Transportation of sediments by fluvial and aeolian processes, gullying, debris slides, small earthflows. | 0.01-2 | 5.4 |
| | Wildcat Group | Carlotta formation | Partially indurated, nonmarine conglomerate, sandstone, and clay. Minor lenses of marine siltstone and clay. | Steep slopes/cliffs and prominent "Flat Irons". Shallow landslides, debris slides, and block slides along inward dipping bedding planes. Toppling along joints. Some rock-falls and ravel. | 0.78-1.8 | 0.3 |
| | | Scotia Bluffs Sandstone | Shallow marine sandstone and conglomerate. | Steep slopes/cliffs. Friable, typically fails in numerous small debris slides. | 1.8-3.6 | |
| | | Rio Dell Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes/cliffs. The Rio Dell Formation is one of the most susceptible to landsliding. Especially in zones between mudstone and sandstone beds with inward dip during saturation. | 1.8-3.6 | |
| | | Eel River Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes/cliffs. Debris slides/flows, slaking. | 3.6-5.3 | |
| | | Pullen Formation | Marine mudstone, siltstone, and sandstone. | Steep slopes, forested and highly dissected with sharp ridge crests and V-shaped canyons. Debris slides/flows, rotational slides, slumps, slaking. | 5.3-11.6 | |
| **Franciscan Complex** | Coastal Belt | Coastal Terrane | Slightly metamorphosed, interbedded arkosic sandstone and argillite with minor pebble conglomerate, and mélange with limestone lenses, and exotic blocks of rock. | Tends to form forested, sharp-crested ridges with well-incised sidehill drainage; susceptible to debris sliding especially upon steep stream banks. Mélange of the Coastal Terrane tends to form oak and grassland, rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows and secondary debris flows. | 1.8-99.6 | 7.3 |
| | | Yager Terrane | Deep marine, interbedded sandstone and argillite, minor lenses of pebble-boulder conglomerate. | Steep, straight, forested slopes, sharp ridge crests, V-shaped canyons. Prone to debris slides along stream banks. Translational rock slides, especially on inward dipping bedding planes between sandstone and argillite layers. | 33.9-65.5 | 26.9 |
| | Central Belt | Sandstone | Large blocks of metasandstone and metagraywake, interbedded with meta-argillite. | Forms forested, moderate to steep, straight to convex slopes, sharp ridge crests, and V-shaped canyons. Generally stable but prone to debris sliding along steep stream banks and in steep headwater drainages. | 65.5-161.2 | 14.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Mélange | Penetratively sheared matrix of argillite with blocks of sandstone, greywacke, argillite, limestone, chert, basalt, blueschist, greenstone, metachert. | Oak and grassland, rolling, hummocky terrain. Boulders protrude from surrounding mélange forming knockers. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation. | 1.8-65.5 | 33.9 |
| | Eastern belt | Yolla Bolly Terrane | Metagraywacke, argillite, and conglomerate with minor metachert and metavolcanic rocks. | Develops sharp-crested, forested ridges generally with V-shaped canyons. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation. | 99.6-199.6 | 0.0 |
| | | | Mélange – sheared matrix of argillite, sandstone, and conglomerate with blocks of greenstone, metachert, and metagreywacke. | Rolling, hummocky terrain. Boulders protrude from surrounding mélange forming knockers. Susceptible to mass movement by large earthflows and subsequent debris flows triggered by saturation. | | |
| **Great Valley Sequence** | Coast Range Ophiolite | Del Puerto Terrane | Highly sheared mudstone. | Present locally east of Benbow in limited areas. | 161.2 - 145.5 | 0.1 |
| | | | Dismembered Ophiolite: chert, basalt, diabase, serpentinite mélange, gabbro, and peridotite. | Correlated with a more extensive ophiolite 300 km to southeast, in the Del Puerto Canyon area near San Jose, California and forms Bear Buttes, approximately 6 miles northwest of Garberville. | 145.5 - 175.6 | |
| Sources: Kilbourne, 1985, Ogle, 1953, McLauglin et al. 2000, Kelsey and Allwardt 1975, Kilbourne 1985. | | | | | | |

## Central Belt Sandstone

Sandstone of the Central Belt makes up roughly 14 percent of the surface of the Eastern Subbasin. The Central Belt sandstone exists as very large blocks of slightly metamorphosed sandstone, greywacke ("dirty" sandstone), and argillite (McLaughlin et al. 2000). These blocks most likely formed from 65.5 through 161.2 million years ago as sediment eroded from the continent as far away as Idaho (Underwood and Bachman 1986), and blanketed the subduction trench between the Farallon and North American plates. These layers of sediment did not become as tectonically mixed as sediments within the mélange, and have been preserved in a relatively intact state. Although they have been metamorphosed, folded, and sheared, they are much more coherent than the mélange. The Central Belt sandstone is generally stable, forming forested, sharp-crested ridges and V-cut valleys. It is prone to debris sliding along steep stream banks and in steep headwater drainages (Kelsey and Allwardt 1975).

## Coastal Terrane

The Coastal Terrane, which occupies approximately seven percent of this subbasin, is a division of the Coastal Belt of the Franciscan Complex. This terrane consists mainly of slightly metamorphosed, interbedded sandstone and argillite with minor pebble conglomerate which has been folded, faulted, sheared and shattered in places, forming a mélange. Mélange is a highly sheared matrix of the former rock types containing limestone lenses and exotic blocks of rock (McLaughlin et al 2000).

Like the Yager Terrane, the Coastal Terrane sedimentary sequences (sandstone, argillite, and conglomerate) are interpreted to be turbidites (sedimentary deposits left from sub-aqueous landslides) and other mass-flow type deposits interbedded with calm oceanic mud deposits that accumulated in an east-dipping subduction zone along the western margin of North America between 140 and 28 million years ago. Limestone units and exotic blocks are interpreted to be the remnants of rocks and sediment that were carried into the trench and faulted into place within the Coastal Terrane sediments (Aalto 1981).

Sandstone/argillite/conglomerate of the Coastal Terrane tends to form sharp-crested ridges with well-incised sidehill drainage and is susceptible to debris sliding, especially on steep stream banks.

Mélange of the Coastal Terrane tends to form a rounded, hummocky landscape with irregular, poorly incised drainages. Mélange is prone to earthflows and secondary debris flows.

### Wildcat Group

Overlapping the Franciscan Complex is a relatively soft marine mudstone, siltstone, and sandstone layer grading upwards through the non-marine sandstone and conglomerate. This layer, known as the Wildcat Group, makes up less than one percent of this subbasin.

The sediments of the Wildcat Group were deposited within the last 11 million years, reflecting a time when this area went from a deep-sea to a shallow-sea environment. Capping the Wildcat Group are non-marine conglomerates and sandstones deposited in the last 2 million years, representing a time when this area was uplifted above sea level and became dominated by river systems.

The Wildcat Group consists of multiple formations. In the early 1950's Burdette Ogle divided the sedimentary deposits of the Lower Eel River (downstream of the confluence of the SF Eel River) into 5 formations based on composition, environment of deposition, and age: the Pullen Formation, Eel River Formation, Rio Dell Formation, Scotia Bluffs Sandstone, and Carlotta Formation. These divisions of the Wildcat Group did not carry over into the SF Eel River Basin and are mapped as either "Wildcat undifferentiated" or as just "Tertiary marine deposits".

The Wildcat Group is highly erodible, especially when disturbed by land use. Landsliding is most common in zones between mudstone and sandstone beds with inward dip, especially during episodes of saturation by heavy rain.

Erosion of the soft, sedimentary rock types of the Wildcat Group contributes fine sediments to stream channels. While the sediments that make up the Wildcat Group are considered bedrock, they are quite loosely cemented and friable, meaning that the sediment crumbles under light pressure. The size of the grains is relatively small, ranging from fine sand through clay sized particles. These erosional properties of Wildcat Group bedrock result in large amounts of fine sediment entering streams, causing high turbidity levels and embedded spawning gravels. The clay content within the bedrock, while easily suspended in water, tends to stabilize surface erosion by increasing the cohesion between grains. In areas where Wildcat Group bedrock goes through repeated cycles of wet and dry, the surface tends to crumble and slough off, and is a source of fine sediment input to streams.

Streams within Wildcat Group bedrock tend to form steep to vertical canyon walls, which are prone to undercutting and subsequent rock falls and translational rock-block sliding.

### Quaternary Landslides

Although not bedrock, large (tens to hundreds of acres) landslide features are geologically significant and over almost six percent of the subbasin surface area. Landslide deposits are typically a jumble of debris, soil, and underlying bedrock consisting of clay to boulder-size debris and broken rock masses that have moved down slope within the last two million years.

These deposits produce rumpled, jumbled hillslopes and may develop debris slides and rotational slumps on steep slopes or eroding toes. Where vegetation has been stripped, surface erosion and gullying typically occur (McLaughlin et al. 2000).

Landslides have the potential for continued sliding and are sensitive to land use because the coherency of the slide material has been disrupted. The toes of these landslides are typically eroded by stream channels causing subsequent, prevalent small-scale sliding and bleeding of fine sediments into the river system. If the toes of these large landslides erode enough or become saturated by heavy seasonal rain, or if there is a large, local seismic event, these landslides may reactivate.

Earthflows typically form in mélange due to its very low shear strength, and they are capable of contributing large amounts of sediment to streams. Large scale GIS mapping shows only a small percent of the probable extent of landslides within this subbasin. It is estimated based upon topographic diversity that approximately 70 percent of the material (in areas of mélange or in extensively sheared zones) in this subbasin has moved (Ellen et al. 2007).

### River Terrace Deposits

River terrace cover approximately five percent of this subbasin area. These deposits consist of unconsolidated through poorly consolidated cobbles, gravels, and fine sediments. River terraces are easily incised and therefore typically form steep channel banks that are prone to dry ravel and slumping.

These terraces were once river channel and flood-plain alluvium, which were raised during the last 2 million years by regional tectonic uplift above the hundred-year-flood level.

River terrace deposits make up extensive flat areas bordering the stream. Most of the towns within this subbasin are built upon such terraces due to their gentle topography and proximity to the river. Prominent river terrace deposit towns within this subbasin include; Redway, Garberville, Piercy, Leggett, Laytonville, and Branscomb.

### Alluvium

Alluvium covers approximately one percent of this subbasin. Alluvium includes any active stream channel sediments as well as unconsolidated bank deposits and floodplain deposits. Alluvium forms flat to gently sloping river beds, banks, flood plains, and fan plains.

## Faults and Shear Zones

The Eastern Subbasin is located to the east of the north-northwest trending boundary between the Pacific Plate and North American Plate. At present, most movement between the plates consists of grinding past one another at a rate of approximately 5 centimeters per year. The plate boundary also has a component of compression that causes uplift and the formation of mountain ranges. The plate boundary is not a single or narrow seam, but is better characterized as a region of crustal deformation that is approximately 65 miles wide. The Eastern Subbasin lies within this region of deformation and is sandwiched between two of the most active fault rupture zones in north coastal California: the San Andreas Fault that lies just off the coast to the west, and the Maacama Fault zone that lies several miles to the southeast. Both of these faults are right-lateral strike slip faults and are considered active by the State of California which means they exhibit evidence of displacement within the past 11,000 years. Estimations of the recurrence interval between large seismic events for the northern segment of the San Andreas Fault range from 250–100 years. The Eastern Subbasin is underlain by major, mapped, active faults including the Maacama Fault, Garberville Fault, and the Brush Mountain Shear Zone. Strong seismic shaking should be anticipated to occur if the San Andreas, Garberville, or Maacama faults rupture.

Major, mapped faults with significant influence on the Eastern Subbasin are described below, with summary information included in *Table 4*.

### San Andreas Fault (Northern Segment)

The San Andreas Fault marks the area of translational interaction between the North American Plate to the east and the Pacific Plate to the west. The SF Eel River Basin is situated within a 70 to 1000 kilometer wide deformation zone created by this interaction (Kelsey and Carver, 1988). Within this zone of deformation, stresses produced along the San Andreas Plate boundary affect several dextral faults that influence geology and topography in the Eastern Subbasin.

The San Andreas Fault is an active dextral fault that runs just off shore, west of the SF Eel River Basin. It is capable of large (magnitude (M) 7 and greater) earthquakes that can significantly affect the basin with seismic shaking, deformation, and associated mass wasting/erosion. Although not well documented in the SF Eel River Basin, the 1906 earthquake, or "San Francisco earthquake", which occurred on the northern San Andreas Fault, caused significant damage to surrounding communities, triggered multiple landslides, and caused liquefaction of low-lying, saturated sediments (Dengler 2008).

### Maacama Fault

The Maacama is an active, 15 mile wide right-lateral fault zone that runs north by northwest through the southern portion of this subbasin (Castillo and Ellsworth 1993). It is related to translational plate boundary tectonics between the Pacific and North American plates. The Maacama Fault is capable of producing earthquakes of up to approximately M 7.1 and has an estimated reoccurrence interval of about 220 years (Hart and Bryant 2001). Over half an inch of right-lateral movement is taken up by the Maacama Fault per year on average. About half of this movement is thought to be accommodated by aseismic creep, meaning that the fault slowly and steadily moves without producing perceptible earthquakes. In the town of Willits, 0.26 inches of creep per year was measured over a 10-year period (Galehouse and Lienkaemper 2003). The northern termination of the Maacama Fault roughly coincides with the southern edge of the Gorda Plate, which is subducting southeast through the middle of the SF Eel River Basin (Anderson 2009, Castillo and Ellsworth 1993).

### Garberville Fault

The Garberville Fault zone consists of several widely spaced, steeply dipping reverse faults with evidence of right-lateral slip that bound elongate northwest-oriented slivers of marine and nonmarine overlap deposits (the Wildcat Group). The Garberville Fault appears to be part of a 30 mile-wide zone of faults exhibiting reverse and right-lateral strike slip movement associated with the San Andreas and Mendocino Triple Junction tectonic regimes (Castillo and Ellsworth 1993). Earthquakes along the Garberville Fault have deep epicenters (greater than 10-12 km) and may be generated from the underlying Gorda Plate (McLaughlin et al. 2000).

### Brush Mountain Shear Zone

The Brush Mountain Shear Zone is situated between the Maacama Fault Zone to the southeast and the Garberville/Briceland Fault to the northwest. This shear zone is most likely related to the Maacama Fault Zone and has similar right-lateral shear, and it appears to be a transitional zone between the Maacama and Garberville/Briceland faults. The Bursh Mountain Shear Zone is situated within a tectonic regime that is changing due to compression caused by the subducting Gorda Plate generating reverse and thrust faults and due to translational shear from the Pacific Plate grinding laterally past the North American Plate generating right-lateral strike-slip faults.

### Coastal Belt Thrust

The Coastal Belt Thrust Fault is the major fault that runs between the Coastal Belt of the Franciscan Complex with the Central Belt. This fault trends north by northwest through the Eastern Subbasin. It is most likely the zone which accommodated movement between the subducting Farallon Plate and the North American Plate before accretion of the Coastal Belt when the active subduction moved west to its present location along the Cascadia Megathrust to the northwest of SF Eel River Basin.

*Table 4. Eastern Subbasin fault and shear zone descriptions (M = magnitude; R Int. = recurrence interval).*

| | Active Faults: | Fault Type | M | R. Int. | Description |
|---|---|---|---|---|---|
| San Andreas Fault Zone | San Andreas Fault (Northern Segment) | Dextral | 7.3-8.3 | 200-300 | The San Andreas Fault (Northern Segment) is an active dextral fault that runs just off shore, southwest of the SF Eel River River Basin. It is capable of large earthquakes (~M 7) that can significantly affect the basin by seismic shaking, deformation, and their associated mass wasting/erosion effects. |
| San Andreas Fault Zone | Maacama Fault (Northern Segment) | Dextral | 7.1 | 370-500 | Creep rate 7.3mm/year (Galehouse 1995). Slip rate 9mm/year (WGNCEP 1996). Mapped from Latonville southward into Sonoma County. Interpreted as a right-stepping, northern extension of the Roger's Creek Fault. The most recent event is estimated to have occurred between 1520 and 1650 A.D. |
| | Brush Mountain Shear Zone | Dextral | | | Inferred extension of the Maacama Fault. |
| | Garberville Fault | Dextral | 6.9 | 220 | Associated with the San Andreas Fault Zone. |
| | Briceland Fault | Dextral | 6.9 | 220 | Associated with the Garberville Fault. |
| **Inactive Faults:** | | | | | |
| | Coastal Belt Thrust (Freshwater Fault) | Thrust | | | The Coastal Belt Thrust Fault is the major fault that juxtaposes the Coastal Belt and the Central Belt. It trends north by northwest through the SF Eel River Basin. |
| Sources: USGS 2011, McLaughlin 2000 | | | | | |

### Uplift

Most of the land in the Eastern Subbain is undergoing high rates of uplift of 1 to 5 millimeters per year. Uplift in this area is due to several factors. Northeast-southwest compression generated by oblique translation of the Pacific Plate against the North American Plate tends to warp and contract the land mass in a series of folds and thrust faults, which contribute to regional uplift. Compression generated by the Mendocino Triple Junction may also be causing similar contraction and uplift, especially in the northern portion of the subbasin. South of Leggett a slab window is believed to exist which allows upwelling of the asthenosphere under the North American Plate in the vicinity of the southern portion of this subbasin. To the north of Leggett the Gorda Plate is plunging under the North American Plate separating it from the asthenosphere. South of the boundary of the Gorda Plate, the North American Plate is in direct contact with the asthenosphere and upwelling causes accelerated uplift of this region.

Uplift of this area has increased the potential energy of the streams allowing them to incise and erode the landscape at high rates, leaving steep canyon walls above the streams. As tectonic forces push the land up, gravity tries to pull it down, and the result is usually landslides and rock falls. Landsliding is further exacerbated by heavy seasonal rainstorms that saturate the hillslopes, making them unstable and even more prone to landsliding.

## Landslides and Erosion

The Eastern Subbasin is underlain by soft, weak, and erodible rock types of the Central Belt and Coastal Belt of the Franciscan Complex. The majority of natural sediment entering the streams is produced by landslides. The term "landslide" is used in a general sense to refer to the various processes of mass wasting of soil, unconsolidated sediment, or bedrock within this subbasin.

Central Belt Mélange and sandstone are the dominant bedrock types in this subbasin. Mélange is very susceptible to erosion because internal shearing within mélange has decreased the rock-strength to such an extent that it has become an incoherent matrix of completely sheared argillite, sandstone, and conglomerate. Due to the lack of internal strength, mélange tends to flow downhill over time via small through very large, deep-seated earthflows. Mackey and Roering (2011) estimated that while only about 7 to 8 percent of mélange terrain seems to be active at a given time, approximately 70 to 80 percent of the landscape moves over geologic time (i.e. the last 2 million years).

Large, active, deep-seated earthflows are capable of delivering tens of thousands of tons of sediment per square mile of surface area each year (Kelsey 1977). Even when dormant, the toes of these earthflows erode and their surface is affected by gullying and enhanced surface erosion, which providing a constant source of fine sediments to adjacent streams. If erosion of the toe progrades far enough, if heavy rainfall saturates the earthflow, or if there is local seismic shaking, dormant earthflows may reactivate. The instability of active earthflows inhibits the growth of deeply rooted vegetation; therefore, grasses are the most common vegetation type.

Sandstone of the Central Belt is generally stable but is prone to debris sliding along steep stream banks and in headwater drainages, and also in areas where it has been broken or disrupted by faulting or shearing. Sandstone is typically the dominant clast type in spawning gravels in areas of the subbasin with Central Belt geology.

The Yager Terrane is prone to debris slides and translational rock slides, especially on bedding plains between sandstone and argillite layers that dip toward the stream valley axis. Argillite in the Yager Terrane tends to crumble when repeatedly exposed to cycles of wetting and drying, and can undercut bedrock stream banks perpetuating these rock slides as well as contributing fine sediments to the streams. Areas where faults or shearing have disrupted the coherency of the bedrock are prone to rockslides, debris flows, and enhanced surface erosion.

Sandstone, argillite, and conglomerate of the Coastal Terrane is relatively competent, however, it is susceptible to debris sliding especially upon steep stream banks. Mélange of the Coastal Terrane is prone to earthflows as well as secondary debris flows and contributes sediment at high rates. Coastal Terrane sandstone is typically the dominant clast within observed spawning gravel within Coastal Terrane geology in this subbasin.

The Wildcat is made of softly cemented sediments, and is prone to shallow landslides, debris slides, slumping, and block slides, especially in zones between mudstone and sandstone beds with inward dip and during storm events where ground saturation occurs. Toppling along joints, rock-falls, and ravel are also common. Wildcat bedrock is easily incised by streams, leaving narrow, steep-banked canyons, especially in areas affected by regional uplift. The fine-grained nature of the bedrock contributes to turbidity when eroded. In areas where stream banks go through repeated cycles of wetting and drying, crumbling of the bedrock is common. This leads to undercutting of banks, input of fine sediments, and increasing turbidity in nearby streams. In areas where there is higher clay content, the rock is more coherent (based on grain interaction) and is slightly less susceptible to erosion.

Terrace deposits are easily incised, leaving behind steep banks of perched, unconsolidated sediment.
The surface and banks of terrace deposits are affected primarily by transportation of sediments by fluvial and aeolian processes. Gullying, debris slides, small-scale slumping, and stream-bank ravel are common (*Figure 9*).

There are both advantages and disadvantages of natural landslides on salmonid populations. Landslides typically contribute large woody debris, large boulders, and spawning gravels from the hillsides and create stream channel diversity like plunge-pools, riffles, meanders, and side channels. However, landslides can also contribute an abundance of fine sediments, strip riparian vegetation, and fill channels and pools. Fish have evolved over time to thrive in the delicately balanced, highly unstable, natural landscape of this area, but anthropogenic activities that result in additional fine sediment input may disrupt this balance.

The likelihood of landslides occurring in an area is related to numerous variables. Major factors that tend to increase the likelihood of landsliding include: steep hillslopes, high pore pressure between grains (water saturated ground), bedding planes and/or planes of weakness within the soil or bedrock, undercutting of slopes, poor vegetation cover, seismic shaking, and weak hillslope material. In the Eastern Subbasin, weak rocks, alternating wet and dry conditions, and the dynamic tectonics of northwestern California create a landscape prone to landsliding. In the past, anthropogenic processes such as road building and timber harvest enhanced the susceptibility of the landscape to landsliding.

Six percent of this subbasin has been mapped with large Quaternary landslide features. These landslides reflect only what has been mapped on a large scale, without detailed field investigations. Many smaller and/or less obvious landslides exist that have not been mapped, or have been mapped as part of landslide inventories at a much more detailed scale.

The most notable, mapped landslide in the Eastern Subbasin is the Red Mountain Creek landslide. This landslide complex is within geology of the Yager Terrane and is associated with a shear zone as well as the Coastal Belt Thrust, which runs between the Coastal and Central belts.

*Figure 9. Landslide on the bank of the mainstem SF Eel River.*

# Fluvial Geomorphology

The overall fluvial geomorphology of the Eastern Subbasin may be described by gentle to moderately graded streams with steep reaches containing large boulder runs and cascades (generally at the toes of earthflows) and significant changes in stream elevation where they cross large resistant rock blocks, draining into a low gradient main stem.

The landscape of this subbasin is predominantly controlled by mélange geology, which is relatively incompetent, lacking mechanical rock-strength. This geology produces a landscape of hummocky hills and ridges typified by oak woodlands and interspersed patches of grasslands. Ridge-valley sets of mélange units are strikingly more rounded and of lower relief compared with sandstone units. Exotic rock blocks within mélange protrude from the landscape forming knockers jutting out from the terrain. Mélange typically moves via large, slow-moving (2-4 meters/year) earthflows. Where active earthflows terminate at a stream, toe erosion is a source of input of fine sediment and large boulders of exotic rock types. This creates chronic turbidity and forms boulder-runs and cascade reaches, which may become barriers to fish passage.

The other major geology type, the Yager Terrane, typically produces a rugged landscape with steep sharp ridges and valleys. The orientation of major ridges, valleys, and their streams follows the trend of tectonic structures (folds and faults) within the basin. The trend of these features (~N25°W) is mainly controlled by regional folding and faulting induced by Mendocino triple Junction and San Andreas tectonics.

## Sediment Transport

Processes of stream sedimentation are predominantly controlled by stream power, which is a combination of discharge and the slope over which a stream runs (velocity), and sediment supply. Sediment is eroded from steep headwater reaches and steepened knick-zones, transported along moderately steep reaches, and deposited within gentle gradient reaches. Streams are typically divided into a source reach (channel gradient of >20%), transport reach (channel gradient 4-20%), and depositional reach (channel gradient <4%) in terms of sedimentation based on stream channel slope. Although streams are broadly divided into these three regions, forms of erosion, transport, and deposition occur on all reaches of a given stream at any given time, and seasonal variations in stream flow and local bedrock morphology alter where and when such processes occur.

The speed of movement of large earthflows increases in activity during the rainy season. Most streamside landslides deliver sediment to the channel in a punctuated event but earthflows can meter out large amounts of fine sediment for decades to centuries causing chronic turbidity and sedimentation of habitat within streams.

The recruitment and transport of the majority of sediment through the system occurs during large storm events that typically occur between October and April. Heavy, long duration rainstorms can completely saturate hillslope soil and trigger landslides and surface erosion. The sediment-pulses from these storms migrate slowly downstream and tend to affect the stream for tens of years. Land use can significantly increase the natural rate of erosion and sediment input to the streams. Very large storm/flood events (e.g 1955 and 1964 floods) mobilize enough sediment that it may take up to a century for the stream to naturally flush it out.

Terrace deposits are present at several places along the mainstem of the SF Eel River and in some of its tributaries. Stream terraces can be formed in a variety of ways. In a period of tectonic quiescence, stream valleys widen and sediment is deposited within the flood plain; if regional uplift occurs the stream will respond by incising and eventually the flood plain will be left perched above the active stream channel. These terraces have been developed because their flat morphology is easy to build on, and the sediment supports good crop growth and forest cover. The towns of Redway, Garberville, Benbow, Leggett, and Branscomb are all built on these terrace deposits.

The tributaries of the Eastern Subbasin are mostly bedrock controlled, and the fluvial geomorphology is created by streams gradually wearing away the bedrock. Local geology dictates channel slope, bedforms, pool-riffle-run morphology, bars, flood-planes, and terraces. Regional uplift, folding and faulting, and the mechanical strength and behavior of bedrock control the overall morphology of the streams.

Although controlled by bedrock, Eastern Subbasin streams are still subject to influence from available sediment input. This input is typically from various hillslope processes such as landsliding and erosion, which are often enhanced by land use and management activities.

The 1955 and 1964 floods recruited massive amounts of sediment into the streams, aggrading the channels and completely burying bedrock within them. Filling-in of the channels with sediment effectively forced the water up and out of the channel, causing excessive streambank erosion channel widening to accommodate flow.

### Spawning Gravel

Cobble and gravel sized sediment required by salmonids for redd construction, egg emplacement, and rearing, is typically introduced into the stream through landslides, rock falls, and bank erosion. This sediment is sorted by flow dynamics in and around relatively large, semi-permanent features such as boulders, large woody debris, and resistant bedrock exposures.

In Eastern Subbasin streams, dominant spawning gravel substrate types are Yager Terrane and Central Belt Sandstone, and resistant rock types found within the mélange matrix.

## Knickzones

Knickzones are areas of locally steepened stream channel. Most major knickzones in the Eastern Subbasin are formed by regional uplift causing stream incision, leading to a lower stream base level, and local changes in bedrock or faulting.

Knickpoints form in series throughout the knickzone and tend to congregate or "bunch up" in areas with limited stream power (Foster 2010). Knickzones provide a record of regional uplift or base-level lowering within the subbasin, and may create gradients steep enough to become obstacles or barriers to fish passage.

The major knickzone in the Eastern Subbasin is located in the mainstem SF Eel River from Rattlesnake Creek and extends upstream approximately eight miles to Ten Mile Creek. This knickzone may be the result of cumulative past base-level lowering events stalling near Rattlesnake Creek which includes about 22% of the upstream drainage area. Studies of stream channel steepness in this area indicate local uplift (Foster 2010).

CDFW field crews identified the probable end of anadromy on habitat surveys. Of the 23 tributaries surveyed in the Eastern Subbasin, the end of anadromy in 16 of these streams (70%) was easily associated with a knickzone and usually located towards its downstream end.

Bedrock waterfalls and cascade reaches marked the end of anadromy for 15 of the 37 tributaries (41%). Eleven of these waterfall/cascade reaches were easily associated with local stream knickzones.

## Channel Type

The fluvial geomorphology of individual streams within a system can be used to understand current as well as past fluvial regime changes. Rosgen (1996) defined basic morphologic stream patterns based on entrenchment, sinuosity, and slope of streams (*Figure 10*). Rosgen channel types A, B, C, D, F, and G were recorded in Eastern Subbasin triburaries on stream surveys conducted between 1983 and 2010 (*Table 5*).

Type B channels were most common in Eastern Subbasin streams, making up almost 43% of the total surveyed length.

Type F streams were the second most common channel type in Eastern Subbasin tributaries (25% of the total surveyed habitat length), followed by C (23.7%), A (5.6%), D (2.0%), and G (1.0%) channel types.

In addition to channel type, Rosgen's system includes a "level II" classification, which describes the size of channel material or D50 (median particle size). Material size classes include the following:

- 1 - Bedrock (>2048 mm);
- 2 - Boulder (256-2048 mm);
- 3 - Cobble (64-256 mm);
- 4 - Gravel (2-64 mm);
- 5 - Sand (0.062-2 mm); and
- 6 - Silt/clay (<0.062 mm).

The total distance surveyed by CDFW habitat typing crews in Eastern Subbasin streams was 612,372 feet. The most common channel types using the level II classification system were B3 (120,393 ft., or 20% of all surveyed habitat) and C2 (102,804 ft., or 17% of the surveyed habitat) (*Table 6*).

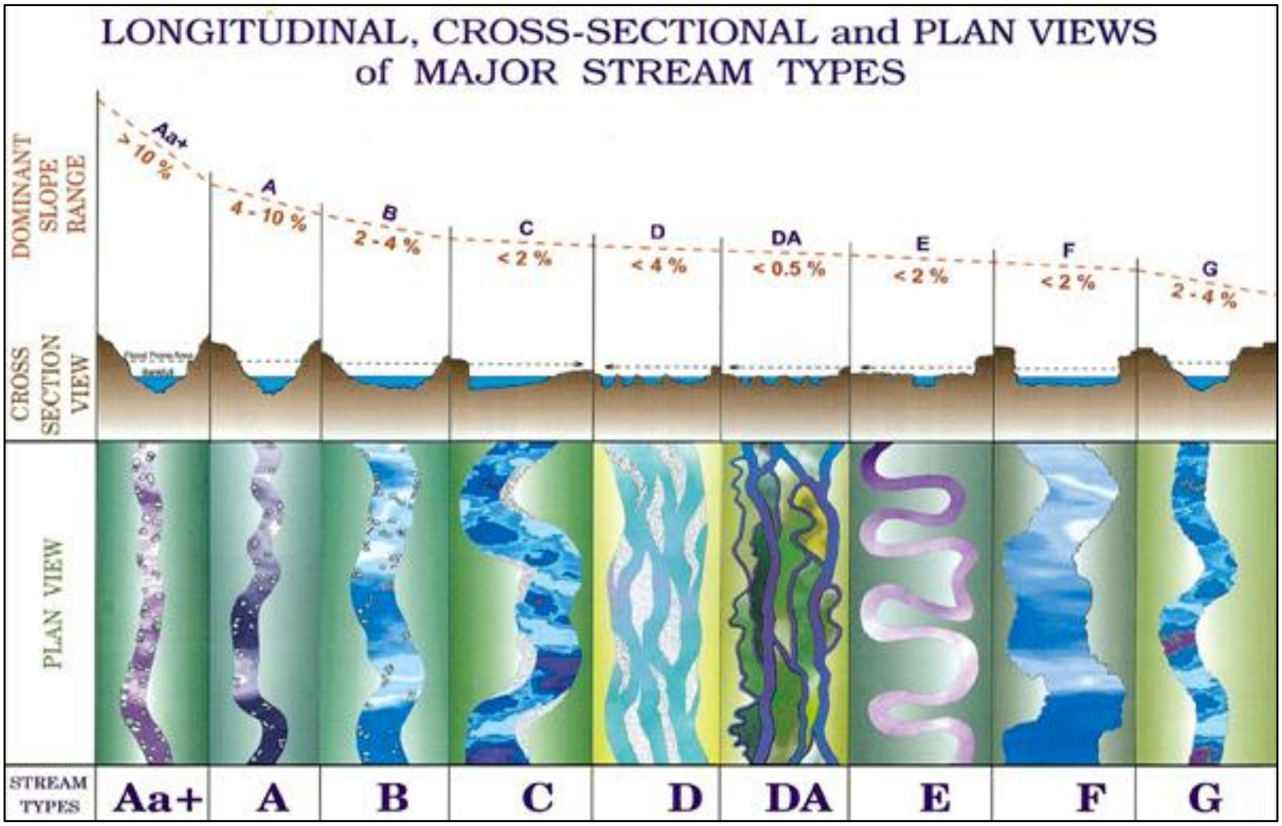



*Figure 10. Illustration of channel types A-G (Rosgen 1996, courtesy of Wildland Hydrology).*

*Table 5. Surveyed channel types by percent of subbasin.*

| Type | % | Eastern Subbasin General Channel Types<br>Description |
|---|---|---|
| **A** | 5.6% | Type A reaches have a moderate to steep slope (4-10%), flow through steep V- shaped valleys, do not have well-developed floodplains, and have few meanders. |
| **B** | 42.7% | Type B stream reaches are wide, shallow, single thread channels. They are moderately entrenched, moderate gradient (2-4%) reaches, which are riffle-dominated with step/pool sequences. Type B reaches flow through broader valleys than type A reaches, do not have well-developed floodplains, and have few meanders. |
| **C** | 23.7% | Type C stream reaches are wide, shallow, single thread channels. They are moderately entrenched, low gradient (<2%) reaches with riffle/pool sequences. Type C reaches have well-developed floodplains, meanders, and point bars. |
| **D** | 2.0% | Type D channels are wide, shallow, alluvial channels typically exhibiting meandering, braiding and/or multi-channeled morphology. |
| **F** | 25.0% | Type F stream reaches are wide, shallow, single thread channels. They are deeply entrenched, low gradient (<2%) reaches and often have high rates of bank erosion. Type F reaches flow through low-relief valleys and gorges, are typically working to create new floodplains, and have frequent meanders. |
| **G** | 1.0% | Type G, or gully stream reaches, are similar to F types but are narrow and deep and have a steeper gradient (2-4%). With few exceptions, type G reach types possess high rates of bank erosion as they try to widen into a type F channel. They can be found in a variety of landforms, including meadows, developed areas, and newly established channels within relic channels (Flosi, et al. 1998). |

*Table 6. Surveyed Channel types of the Eastern Subbasin.*

| Creek | Length (ft) | Channel Type |
|---|---|---|
| Dean Creek | 1,009 | A2 |
| | 17,607 | B2 |
| | 3,443 | B3 |
| | 6,555 | D1 |
| | 1,417 | F3 |
| Bluff Creek | 7,268 | F2 |
| Bear Canyon | 1,946 | A3 |
| | 3,316 | F4 |
| | 2,340 | G4 |
| East Branch South Fork Eel River | 6,789 | A2 |
| | 835 | B1-1 |
| | 11,843 | B2 |
| | 8,058 | B3 |
| | 69,512 | C2 |
| | 12,932 | F2 |
| Tom Long Cr. | 651 | A1 |
| | 13,565 | B1 |
| | 5,747 | B2 |
| | 1,665 | C1 |
| Foster Cr. | 3,914 | A2 |
| | 4,085 | G3 |
| Milk Ranch Creek | 7,904 | B2 |
| | 17,041 | B3 |
| McCoy creek | 4,106 | F4 |
| N.F. McCoy Cr. | 7,416 | B3 |
| | 10,937 | F3 |
| Red Mountain creek | 16,472 | B4 |
| Bridges creek | 2,343 | B1 |
| | 7,291 | B1-1 |
| | 3,589 | C2 |
| Rock Creek | 1,644 | A2 |
| | 39,415 | B3 |
| | 13,390 | F3 |
| Cedar Creek | 1,555 | A2 |
| | 12,634 | B3 |
| | 1,368 | B4 |
| Grizzly Creek | 1,578 | B2 |
| | 16,943 | C1 |
| | 26,959 | C2 |
| Rattlesnake Creek | 2,190 | B2 |
| | 2,744 | C2 |
| | 9,502 | C3 |
| | 2,354 | D1 |
| Cummings Cr. | 2,208 | B2 |
| Twin Rocks Cr. | 1,627 | A3 |
| | 7,148 | B2 |
| | 1,918 | F3 |
| Grapevine Cr. | 4,205 | B2 |
| Ten Mile Creek | 3,985 | B1 |
| | 17,851 | B4 |
| | 14,020 | C4 |
| | 8,026 | F2 |
| | 49,198 | F4 |
| Cold Cr. | 4,027 | B3 |
| Streeter Cr. | 4,879 | F3 |
| Lewis Cr. | 1,770 | B2 |
| | 5,138 | B3 |
| Big Rock Cr. | 11,243 | A3 |
| | 9,777 | F4 |
| Cahto Cr. | 4,283 | F3 |
| | 11,855 | F4 |
| Fox Creek | 3,752 | A3 |
| Elder Creek | 8,601 | B2 |
| Kenny Creek | 6,970 | B3 |
| | 6,601 | F3 |
| Mud Creek | 1,391 | B2 |
| | 12,558 | B3 |
| | 3,269 | D4 |
| Grapevine Cr. | 3,693 | B3 |
| Taylor creek | 5,068 | B4 |
| Windem Creek | 3,439 | F4 |

## Stream Channel Geometry

### Longitudinal Stream Profiles

A stream in a topographically steady state of slope (at equilibrium) tends to form a convex slope that gets exponentially steeper towards its headwaters. A stream that is out of equilibrium tends to deviate from this basic pattern along various portions of its length. In Eastern Subbasin streams, reasons for deviance from profile equilibrium are typically caused by changes in underlying geology, regional uplift, movement along fault lines, large landslides, and large amounts of sedimentation (aggradation of the stream channel). These processes generally cause the longitudinal profile of a particular stream to become progressively convex (*Figure 11*). Changes in the natural resistance of the bedrock to erosion may also cause variations in the longitudinal profile. Sections of the stream channel that are significantly out of equilibrium may become too steep (>10% channel slope) to allow passage of fish and will decrease the length of anadromy. In Eastern Subbasin streams, only nine out of 37 (24%) of the surveyed tributaries of the SF Eel River with identified probable ends of anadromy have profiles that are consistent with the basic pattern of equilibrium. Twenty two streams had profiles that were clearly out of equilibrium. Uplift or basal lowering has created multiple knickzones that are apparent on longitudinal stream profiles of tributaries are out of equilibrium. These areas may be considered sensitive to disturbance and fish passage over time. Land use and management practices should be studied closely when planning activities that may alter the fluvial morphology or regime of each stream.

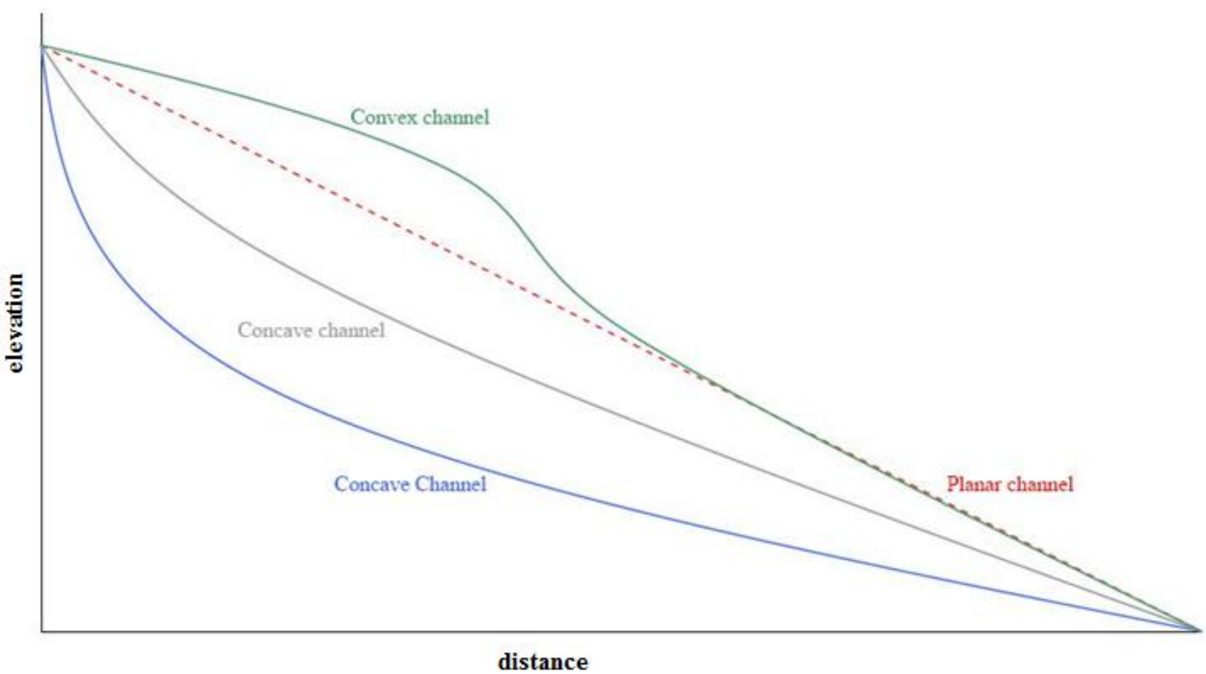



*Figure 11. Basic channel profile shapes.*

### Profiles of Eastern Subbasin Streams

Stream profiles were completed for 37 Eastern Subbasin streams (*Figure 12*). Knickzones and ends of anadromy (EOA) were included on profiles where applicable. Twenty three of the 37 streams had EOAs identified on habitat typing reports. Of these 23, 78% had EOAs associated with knickzones, and 62% of EOAs were located at the downstream end of a knickzone.

Waterfalls in this subbasin are generally associated with knickzones, local faulting, or abrupt changes of the underlying geology (*Figure 13*). All occur within the Yager Terrane and the Coastal Terrane of the Coastal Belt. Fifteen waterfalls

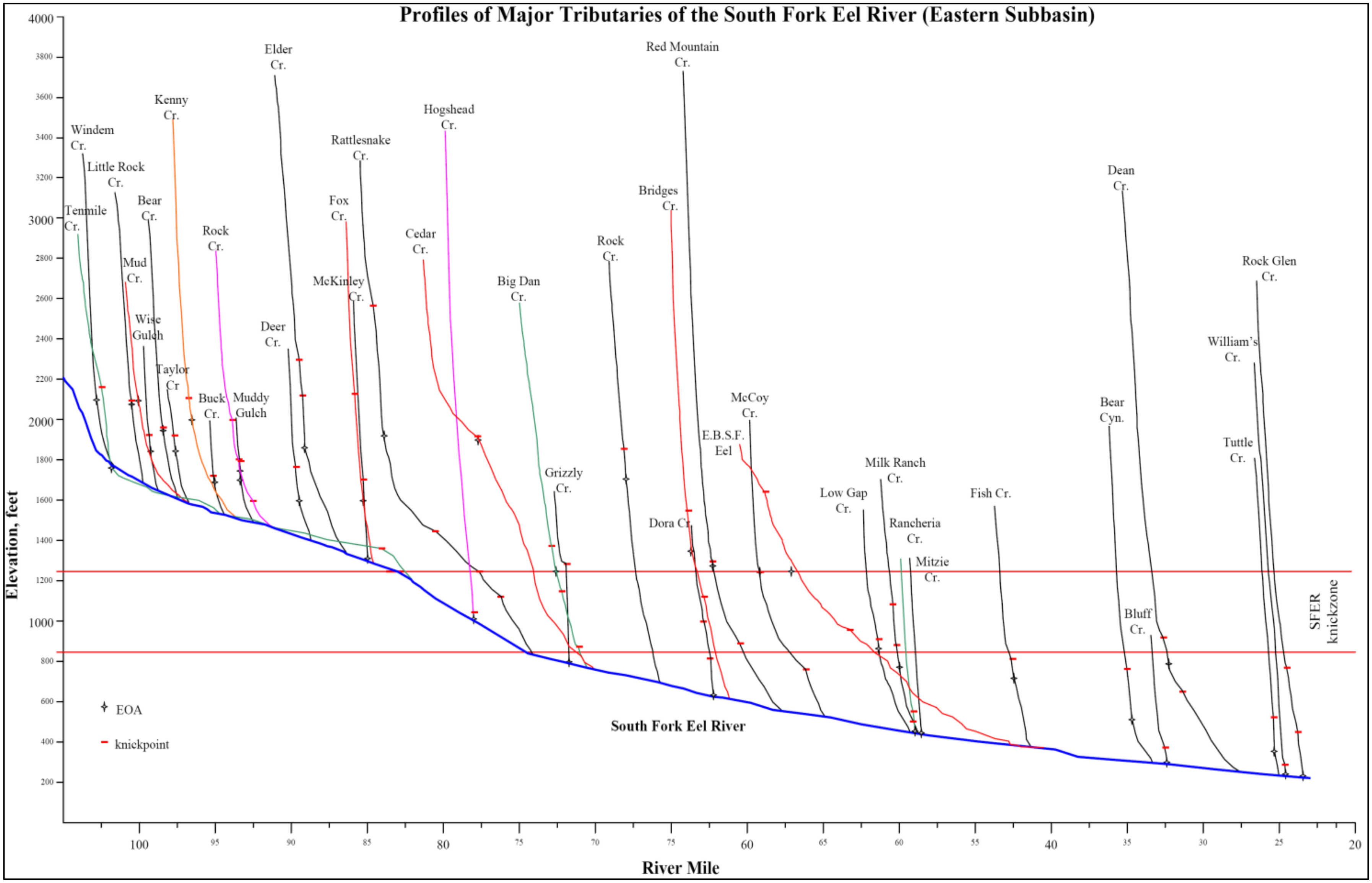



*Figure 12. Longitudinal stream profiles of SF Eel River Eastern Subbasin streams.*

considered to be barriers to fish passage have been documented within the Eastern Subbasin.

Other EOAs occur where earthflows are present and the stream channel is clogged with large (car to house-sized) boulders derived from coherent, exotic rock-blocks within mélange matrix material. These large boulder runs can become steep and form a series of rapids and cascades that make fish passage difficult (*Figure 14*).

Central Belt geology of the Coastal and Yager terranes also create high gradient reaches of rapids and cascades. These typically develop in association with knickzones, local faulting, or abrupt changes of the underlying geology. Five of the surveyed ends of anadromy are attributed to steep gradient cascade reaches within sandstone units of the Coastal Belt. For additional information on gradient barriers, waterfalls, and ends of anadromy, see the Fish Passage Barriers section of this subbasin report.

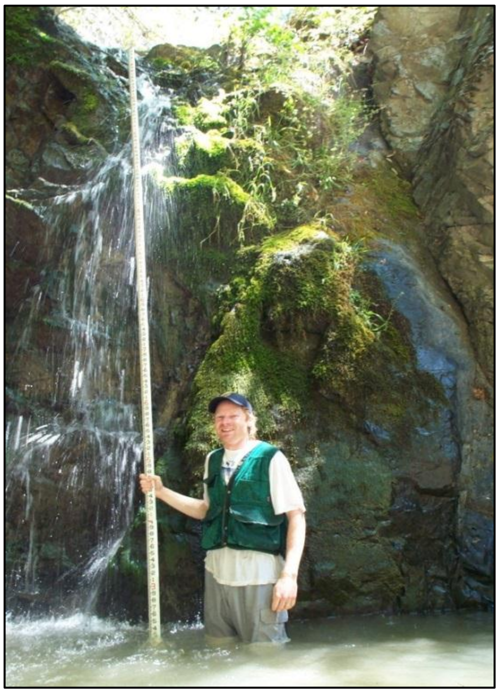


*Figure 13. A waterfall that developed in response to a knickzone within the geology of the Yager Terrane on Milk Ranch Creek.*

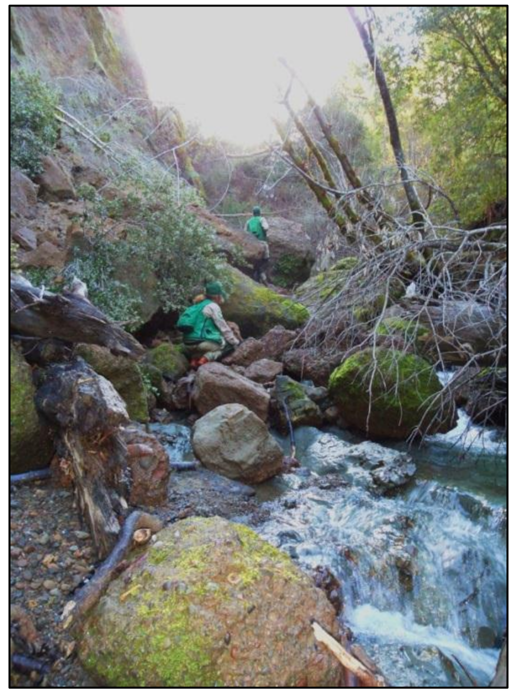


*Figure 14. Tributary of Bear Canyon with steep gradient cascade boulder reach that formed in response to a knickzone within Wildcat geology.*

## Soils

In this assessment the term "soil" refers to any loose material derived from the weathering of bedrock and mixed upward by biogenic, chemical, and/or mechanical processes. Like the other SF Eel River subbasins, the Eastern Subbasin is mantled with sensitive, unstable soils.

Meadows and grasslands in the Eastern Subbasin are often a result of unstable ground. Movement from deep-seated earthflow and shallow soil-creep make it difficult for conifers to take hold, leaving grasslands and oak as the predominant vegetative cover. These areas are susceptible to surface erosion, headward erosion, and gullying.

Soil texture is a measure of the relative constituents of clay, silt, sand, and gravel. The arrangement of these particles within a soil create its structure. Soil texture and structure dictate how a soil will behave over time when acted upon by water, gravity, and temperature. The underlying bedrock is generally responsible for a soil's texture, structure, and erosional characteristics. The sediment contribution from soils found in the Eastern Subbasin depends largely on strength of underlying bedrock, slope, amount and duration of local rainfall, soil texture and structure, type and amount of covering vegetation, and local land use.

The majority of bedrock throughout the subbasin is composed of various sedimentary rock types of the Central Belt and Coastal Belt of the Franciscan Complex, producing associated soil types ranging from loam to extremely gravely sandy loam that are prone to mass wasting, surface erosion, and transport by fluvial processes. 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. However, some of the erodible ground within the basin consists of active earthflows which are deep-seated mass movement features related to mechanically weak, sheared matrix rock material of mélange bedrock. Mélange bedrock tends to produce associated fine-grained soils with high clay content. The Wohly-Holohan-Casabonne soil series covers about 57% of this subbasin and is associated with the Central Belt mélange and sandstone as well as the Coastal Belt Coastal Terrane and Yager Terrane (*Figure 15*). These are very deep, well drained soils that formed from weathered sandstone and shale (*Table 7*).

Gradual, shallow downslope movement of soil caused by gravity, weathering, saturation and rain-splash, and biogenic activity (soil creep) is present within the soils of this subbasin and delivers a substantial amount of sediment to the streams (Stillwater Sciences 1999).

Vegetation cover tends to stabilize soil. A mesh of intertwining roots increases the tensile strength, shear strength and cohesion of the soil (Menashe 2001). Roots also draw water out of the soil, decreasing the likelihood of pore pressure related slope failure. When vegetation (especially trees) is removed from a slope, the roots tend to decay and lose their stabilizing influence before new vegetation can restabilize the soil. This window of enhanced instability usually occurs within 5 to 8 years.

Due in part to its unstable nature and its abundance of prairie grasslands, much of the Eastern Subbasin has historically been used for grazing. Natural, deep-rooted grasses have been replaced by non-native, shallow rooted varieties, allowing the soils to erode at relatively higher rates (Kelsey 1978).

Within the Central Belt Mélange there are large blocks of serpentinized peridotite, an upper-mantle, ultra mafic rock type, that crop out of the surface and create large knobs upon the landscape. These blocks are made up of olivine and pyroxene and contain mineable amounts of chromium, cobalt, and nickel. Weathering of this material produces a distinctly red soil that supports relatively rare vegetation communities. Red Mountain, named for these red soils, is one such peridotite block (Leggett peridotite) and supports growth of several species of pine and spruce, McDonald's rock-cress, Kellogg's buckwheat, Red Mountain stonecrop, and Red Mountain catchfly; the latter four are only found on Red Mountain (USBLM 1990). The Red Mountain Leggett peridotite is associated with the Dingman-Beaughton soil series, which occupies approximately 3% of this subbasin.

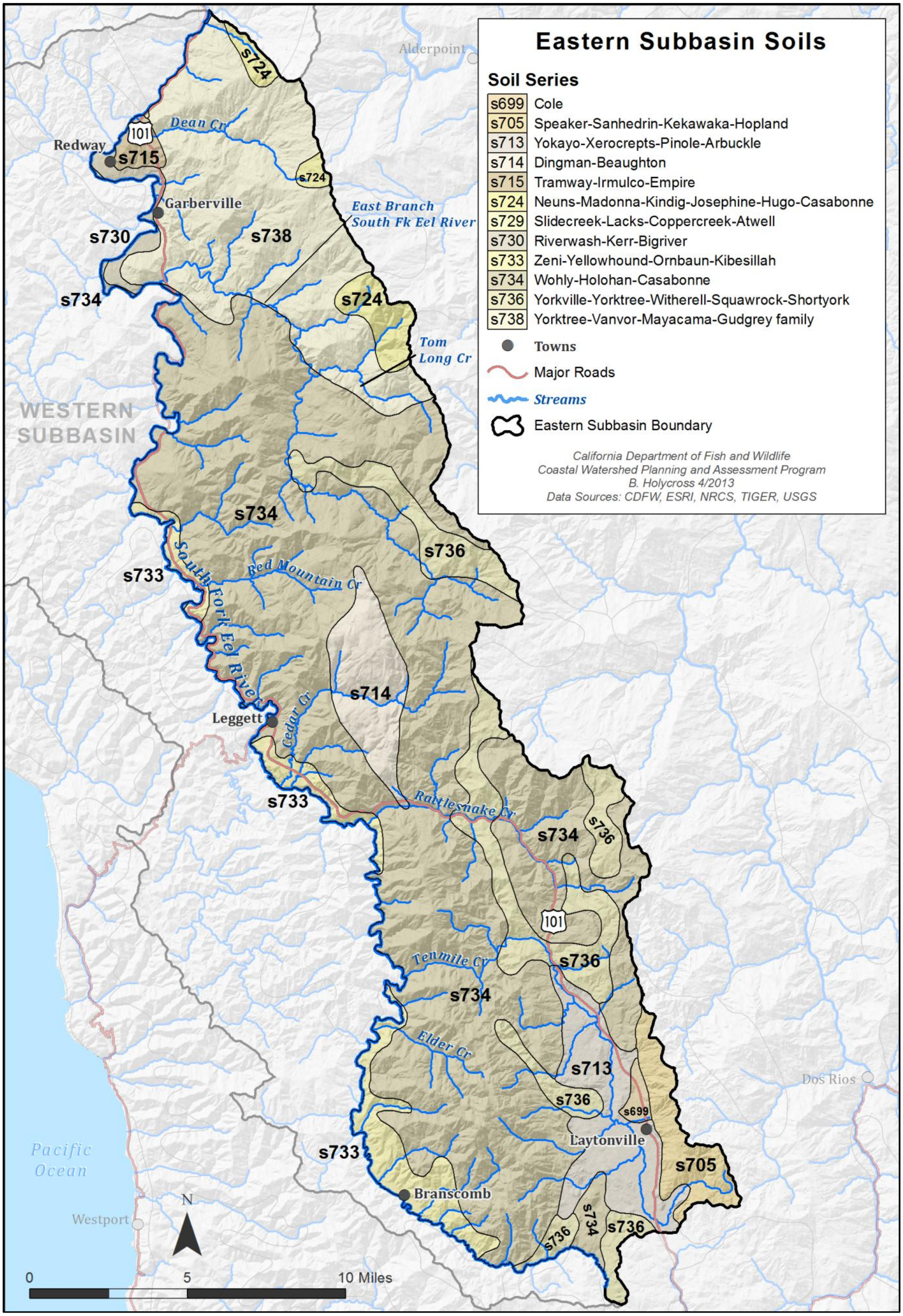



*Figure 15. Eastern Subbasin soils map.*

*Table 7. Eastern Subbasin soil descriptions.*

| Soil series | Texture | Description | Parent Bedrock | Slope % |
|---|---|---|---|---|
| **Wohly-Holohan-Casabonne (57%)** | | | | |
| WOHLY | loam | Very deep, well drained soils that formed in residuum weathered from sandstone and shale. | Central Belt Mélange and sandstone. Coastal Belt Coastal and Yager Terrane. | 9 - 75 |
| HOLOHAN | extremely gravelly sandy loam | Very deep, well drained soils formed in colluvium weathered from sandstone. | | 9 - 75 |
| CASABONNE | gravelly loam | Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale. | | 9 - 75 |
| **Yorktree-Vanvor-Mayacama-Gudgrey family (16%)** | | | | |
| YORKTREE | loam | Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone. | Central Belt Sandstone. | 15 - 75 |
| VANVOR | very gravelly sandy clay loam | Moderately deep, well drained soils on mountains. These soils formed in colluvium from metavolcanic rock. | | 30 - 75 |
| MAYACAMA | very gravelly sandy loam | Moderately deep, somewhat excessively drained soils formed in material derived from sedimentary and metasedimentary rocks. | | 9 - 75 |
| GUDGREY | gravelly sandy clay loam | Deep, well drained soils formed in material weathered from sandstone, schist or shale. | | 8 - 75 |
| **Yorkville-Yorktree-Witherell-Squawrock-Shortyork (9%)** | | | | |
| YORKVILLE | loam | Very deep, well drained soils that formed in material weathered from chloritic schist and other sedimentary and metamorphic rocks. | Central Belt Sandstone and Mélange. | 5 - 75 |
| YORKTREE | loam | Very deep, well drained soils formed in material weathered from graywacke, shale, siltstone or sandstone. | | 15 - 75 |
| WITHERELL | loam | Very deep, somewhat excessively drained soils formed in material weathered from sandstone. | | 5 - 75 |
| SQUAWROCK | cobbly loam | Moderately deep, well drained soils formed in material weathered from sandstone or graywacke. | | 15 - 75 |
| SHORTYORK | gravelly loam | Very deep, well drained soils formed in material weathered from sandstone, schist, shale and graywacke. | | 8 - 75 |
| **Yokayo-Xerocrepts-Pinole-Arbuckle (5%)** | | | | |
| YOKAYO | sandy loam | Deep, well drained soils formed in material weathered from old alluvium from sedimentary rock. | Alluvium and river terrace deposits. | 0 - 30 |
| XEROCREPTS | gravelly loam | Moderately deep, well drained soils formed in material derived from colluvium from metasedimentary rocks. | | 5 - 75 |
| PINOLE | gravelly loam | Very deep, well drained soils formed in alluvium weathered from sedimentary and other rock sources. | | 0 - 30 |
| ARBUCKLE | sandy loam | Very deep, well drained soils that formed in alluvial materials from mainly conglomerate and metasedimentary rocks. | | 0 - 75 |
| **Zeni-Yellowhound-Ornbaun-Kibesillah (4%)** | | | | |
| ZENI | loam | Moderately deep, well drained soils formed in material weathered from sandstone or mudstone. | Coastal Belt Coastal Terrane | 9 - 75 |
| YELLOWHOUND | gravelly loam | Deep, well drained soils formed in material weathered from sandstone or conglomerate. | | 9 - 99 |
| ORNBAUN | loam | Deep, well drained soils formed in material weathered from sandstone and mudstone. | | 9 - 75 |
| KIBESILLAH | very gravelly loam | Moderately deep, well drained soils formed in material weathered from sandstone. | | 9 - 99 |

| Soil series | Texture | Description | Parent Bedrock | Slope % |
|---|---|---|---|---|
| **Dingman-Beaughton (3%)** | | | | |
| DINGMAN | cobbly clay loam | Moderately deep, well drained soils formed in material weathered from serpentine and peridotite. | Central Belt Mélange - peridotite block | 5 - 50 |
| BEAUGHTON | gravelly loam | Shallow, well drained soils that formed in material weathered from serpentinized peridotite rocks. | | 5 - 60 |
| **Speaker-Sanhedrin-Kekawaka-Hopland (2%)** | | | | |
| SPEAKER | gravelly loam | Moderately deep, well drained soils that formed in colluvium weathered from sedimentary and metamorphic rocks. | Central Belt Mélange. | 2 - 75 |
| SANHEDRIN | gravelly loam | Very deep, well drained soils formed in colluvium and residuum weathered from sandstone, shale and siltstone. | | 2 - 75 |
| KEKAWAKA | loam | Very deep, well drained soils formed in material weathered from sedimentary rocks. | | 2 - 75 |
| HOPLAND | loam | Very deep, well drained soils formed in colluvium and residuum weathered from sandstone or shale. | | 9 - 75 |
| **Neuns-Madonna-Kindig-Josephine-Hugo-Casabonne (2%)** | | | | |
| NEUNS | gravelly loam | Moderately deep, well drained soils that formed in slope alluvium and colluvium from metamorphosed igneous and sedimentary rocks. | Central Belt Sandstone and Mélange. | 15 - 80 |
| MADONNA | loam | Moderately deep, well drained soils that formed in material weathered in residuum from sandstone and shale. | | 15 - 75 |
| KINDIG | gravelly loam | Deep, well drained soils that formed in residuum and colluvium from metamorphosed igneous and sedimentary rocks. | | 15 - 80 |
| JOSEPHINE | gravelly loam | Deep, well drained soils that formed in colluvium and residuum weathered from altered sedimentary and extrusive igneous rocks. | | 2 - 75 |
| HUGO | gravelly sandy clay loam | Deep, well drained soils that formed in material weathered from sandstone, shale, schist, and conglomerate. | | 9 - 75 |
| **Riverwash-Kerr-Bigriver (1%)** | | | | |
| RIVERWASH | N/A | Unstablilized sand silt, clay or gravel reworked by frequently by stream activity. | Alluvium and river terrace deposits. | 0 - 5 |
| KERR | loam | Dark olive gray recent moderately well drained alluvial soils without profile development that are formed in material derived mainly from micaceous schists. | | 0 - 5 |
| BIGRIVER | loamy sand | Very deep, well drained soils formed from alluvium derived from mixed sources. | | 0 - 5 |
| **Tramway-Irmulco-Empire (1%)** | | | | |
| TRAMWAY | loam | Moderately deep, well drained soils formed in material weathered from sandstone. | Wildcat Group. | 9 - 75 |
| IRMULCO | loam | Deep or very deep well drained soils formed in material weathered from sandstone. | | 9 - 75 |
| EMPIRE | loam | Moderately deep, well to moderately drained soils formed in material derived from soft sedimentary rocks. | | 10 - 40 |
| **Cole (<1%)** | | | | |
| COLE | clay loam | Very deep, somewhat poorly drained soils that formed in alluvium from mixed sources. | Alluvium/ river terrace deposits. | 0 - 5 |
| **Slidecreek-Lacks-Coppercreek-Atwell (<1%)** | | | | |
| SLIDECREEK | gravelly loam | Very deep, well drained soils that formed in colluvium and residuum weathered from sandstone and mudstone. | Central Belt Mélange. | 9 - 75 |
| COPPERCREEK | loam | Very deep, well drained soils that formed in colluvium and residuum from schist, sandstone, and mudstone. | | 9 - 75 |
| ATWELL | silt loam | Very deep, moderately well drained soils formed in material from sheared sedimentary rocks | | 15 - 50 |

## Vegetation

Two of the main factors in the decline of salmonids within the SF Eel River over the past century have been an overabundance of fine sediments in the streams and warming of the streams. Vegetation of the landscape has direct influence on both of these conditions. Hillslope vegetation intercepts and slows the velocity of rainwater and also provides leaf litter and duff layers to the surface of soils, which intercepts and disperses rainwater and increases resistance to surface erosion. Leaf and duff layers also provide an intricate irregular, permeable interface that allows surface water to pond and be absorbed rather than flow downhill as runoff. Vegetation also increases transpiration, reducing pore pressure between soil grains during heavy rain and reducing slope failure. Root systems increase the tensile slope strength of unstable soils, reducing landslides, erosion and sedimentation.

Riparian vegetation shades streams and reduces solar radiation and corresponding stream temperatures. Stream bank roots and low hanging branches provide cover for fish. Large woody debris generated by riparian vegetation and recruited by the stream provides habitat and stream channel diversity. Stream-bank root systems increase the tensile slope strength of unstable soils, reducing bank failure and subsequent sedimentation.

In the Eastern Subbasin, the predominant vegetation cover type as described by the USFS CALVEG data is mixed conifer and hardwood forest. This vegetation type occupies approximately 38 percent of the subbasin (*Figure 16*). This vegetation type consists of forests and woodlands where conifers are primary and hardwoods are present secondarily. Pacific Douglas-Fir is the primary vegetation type (88%) in this classification, followed by mixed redwood – Douglas-Fir (8%) and Douglas-Fir – ponderosa pine (2%) (*Table 8*).

Hardwood forest is the second most abundant vegetation type in the Eastern Subbasin, covering approximately 27 percent of the total area (*Figure 16*). Hardwood forest is primarily associated with geology and soils of the Central Belt Mélange.

Grassland/prairie (herbaceous) vegetation is the next most abundant vegetative cover making up 16 percent of the total. This vegetation type is found in small, interspersed hillside prairies throughout the subbasin, but is more dominant in the eastern half. Grasslands and prairies are especially associated with earthflows and unstable soils within geology of the Central belt mélange. Herbaceous vegetation is also found in some of the low-lying areas along the mainstem SF Eel River.

Historically grasslands were composed of native prairie bunch grasses with relatively deep root systems. In the late 1800’s ranchers began seeding European short-rooted annual grasses for grazing and these soon replaced the bunch grasses. Annual grasses and forbs now occupy about 99 percent of this vegetation cover type within the Eastern Subbasin. Replacement of the deeper rooted grasses with the shallower rooted annual grasses is believed to have increased surface erosion and hillslope soil stability (Kelsey 1980).

Conifer forest is the fourth most abundant vegetation type in this subbasin, covering approximately 16% of the subbasin area.

Approximately one percent of the subbasin is classified as barren, and mostly reflects large rock outcrops and non-vegetated alluvium along the mainstem SF Eel River. The remainder of the Eastern Subbasin cover types are shrub, urban, or water, each covering 1% or less of the subbasin area.

GIS data indicates that less than one percent (0.24%) of this subbasin is covered by agriculture, however this may be an under-representation because pastures used for grazing of livestock may not be included in this vegetation designation since land use is often difficult to ascertain remotely. For this reason, it may be assumed that areas mapped as grassland/prairies may also be agricultural in nature and the overall percentage of agricultural lands is likely to be greater than depicted. Agricultural land in this subbasin is located primarily on low-lying river terraces near the communities of Garberville, Laytonville, and Redway.

Undocumented marijuana cultivation is also not represented in these figures but can have a significant impact on the subbasin’s natural resources. Both legal and illegal marijuana cultivation are becoming large-scale problems when considering water diversion and water quality within

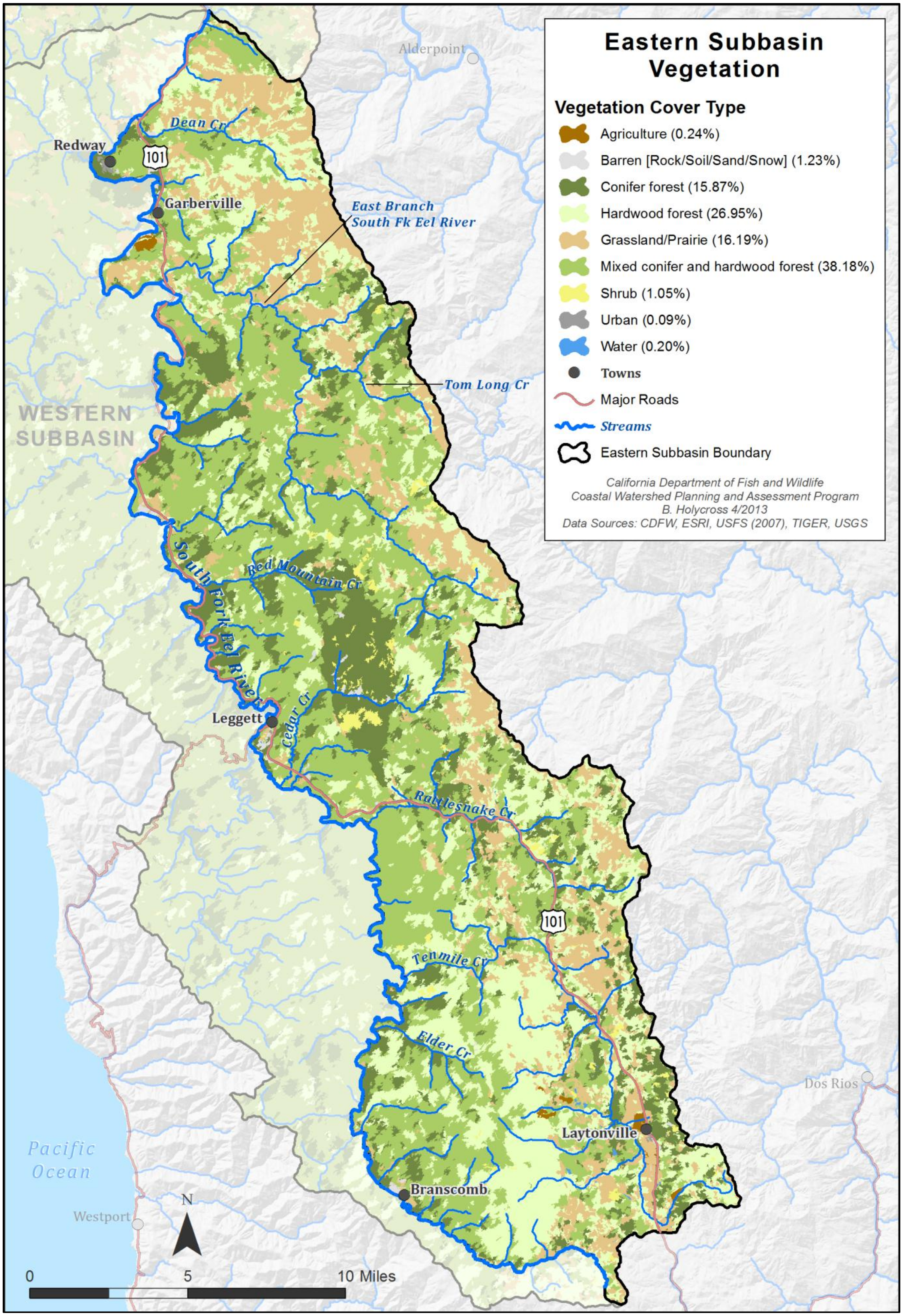


*Figure 16. Eastern Subbasin vegetation map.*

the subbasin. Illegal grow sites are periodically established in remote residential areas, on private timber company land and on publicly owned land. To supply a constant, reliable source of water to their plants, growers will typically divert water through plastic pipes from nearby streams or springs to their cultivation sites. The dry and hot portion of the season is when plants require the most water, including plants in the surrounding forest as well as those that are cultivated. Consequently, this is the time period when stream base flows are at their lowest. When low base-flow conditions exist, suitable stream habitat diminishes and stressors on salmonids increase. During these times when water flow is minimal (usually in the late summer through early fall), even a single diversion can significantly reduce stream flow. Because these diversions are purposefully concealed, especially when grows are located on public parkland or privately owned timber land, they cannot be managed. Sedimentation and pollution associated with grow operations are also increasing and becoming a greater concern. For additional information, see the Industrial Marijuana Agriculture section of this subbasin report.

The Eastern Subbasin is home to a variety of very rare and endangered plants that are included in the shrub category as "ultramafic mixed shrub" (*Table 8*). The underlying geology of the Eastern Subbasin includes blocks of serpentinized peridotite, which make up about 8% of the mélange in this subbasin. As serpentinized peridotite weathers, it creates relatively rare oxisols soils, which are characterized by their distinct orange-red color. These soils support rare and unique plants. Red Mountain, located in the approximate center of this subbasin, is composed of soils unique within the United States due to their low nutrient levels and high concentrations of iron, cobalt, and nickel. McDonald's rock-cress (*Arabis macdonaldiana*), currently listed as endangered, has been found only on Red Mountain. Three other plant species are endemic to this area are Kellogg's buckwheat (*Eriogonum kelloggii*), Red Mountain stonecrop (*Sedum laxum* ssp. *eastwoodiae*), and Red Mountain catchfly (*Silene campoanulata* ssp. *campanulata*) (USBLM 1990).

*Table 8. Vegetation of the Eastern Subbasin (USFS CALVEG).*

| Vegetation Cover Type | % of Basin | Primary Vegetation Type | % of Type |
|---|---|---|---|
| Mixed conifer and hardwood forest/woodland | 38.18% | Pacific Douglas-Fir | 88.21% |
| | | Redwood - Douglas-Fir | 7.90% |
| | | Douglas-Fir Ponderosa Pine | 1.94% |
| | | Ponderosa Pine | 1.91% |
| | | Redwood | 0.02% |
| | | Jeffrey Pine | 0.01% |
| Hardwood forest/woodland | 26.95% | Tanoak (Madrone) | 41.85% |
| | | Oregon White Oak | 37.53% |
| | | Canyon Live Oak | 13.98% |
| | | Black Oak | 4.79% |
| | | California Bay | 0.74% |
| | | Valley Oak | 0.56% |
| | | Interior Live Oak | 0.22% |
| | | Montane Mixed Hardwood | 0.18% |
| | | Interior Mixed Hardwood | 0.11% |
| | | Riparian Mixed Hardwood | 0.05% |
| | | Willow | 0.01% |
| Grassland/Prairie | 16.19% | Annual Grasses and Forbs | 98.96% |
| | | Pastures and Crop Agriculture | 0.83% |
| | | Non-Native/Ornamental Grass | 0.14% |

| **Vegetation Cover Type** | **% of Basin** | **Primary Vegetation Type** | **% of Type** |
|---|---|---|---|
| | | Perennial Grasses and Forbs | 0.08% |
| Conifer forest/woodland | 15.87% | Pacific Douglas-Fir | 64.65% |
| | | Ultramafic Mixed Conifer | 12.00% |
| | | Redwood - Douglas-Fir | 11.59% |
| | | Ponderosa Pine | 4.45% |
| | | Sargent Cypress | 2.27% |
| | | Redwood | 1.77% |
| | | Douglas-Fir Ponderosa Pine | 1.55% |
| | | Jeffrey Pine | 1.38% |
| | | Mixed Conifer - Pine | 0.34% |
| Barren | 1.23% | Barren | 55.20% |
| | | Urban-related Bare Soil | 44.77% |
| | | Dune | 0.02% |
| Shrub | 1.05% | Lower Montane Mixed Chaparral | 29.47% |
| | | Scrub Oak | 27.51% |
| | | Manzanita Chaparral | 14.54% |
| | | Ultramafic Mixed Shrub | 11.01% |
| | | Chamise | 10.73% |
| | | Blueblossom Ceanothus | 5.85% |
| | | Coyote Brush | 0.42% |
| | | Willow (Shrub) | 0.25% |
| | | Upper Montane Mixed Chaparral | 0.22% |
| Agriculture | 0.24% | Agriculture (General) | 100.00% |
| Urban | 0.09% | Urban/Developed (General) | 100.00% |
| Statistics exclude classification of water | | | |

## Fire

Historically, fire has shaped ecosystems throughout California. There are three periods where human influences have managed both fire and fire environments differently: 1) prior to European settlement (before 1700); 2) the settlement period (1700 to 1920); and 3) the suppression era (1920 to present). Fire patterns in pre-European times resulted in many millions of acres burning in California each year, with fire acting as a major cause of ecosystem change (CalFire 2003). Fires renewed mature vegetation communities that required fire to restore vegetation life cycles.

Habitat structure and composition, climate, weather, prior fire history, land management activities, and physical properties such as elevation and aspect influence the frequency, size, and severity of fires (Flannigan et al. 2000, Pilliod et al. 2003). Most fires are effectively suppressed using advanced technology and increased early efforts to protect resources, commodities, and people. To reduce the potential for severe, widespread fires, fuel treatments are considered the only practical means of altering potential wildfire behavior (CalFire 2003). In some areas where cutting and removal of fuel is controversial, infeasible, or prohibitively expensive, fire has been used as a tool to reduce fuel loads. The extent, effects, and severity of subsequent fires may be limited by these prescribed burns (Collins et al. 2008).

Fire is one of the primary natural disturbance factors influencing vegetation structure in the Eastern Subbasin. Natural post-fire stands are usually a mosaic of burn severities, from unburned to stand-replacing, within a watershed. Historically, Native Americans and settlers used fire to manage grasslands and prairies, and to maintain the ratio of conifers to oaks in tanoak stands (USBLM et al. 1996).

Modern land use practices have influenced the likelihood and effects of wildfire throughout the subbasin. Residential development, logging, and agricultural activities on highly erodible hillslopes have altered the natural hydrology, and construction of roads and stream crossings causes additional erosion and sediment runoff at greater levels than would have occurred naturally. This is a particular concern in Eastern Subbasin streams, where timber harvest (both industrial and non-industrial) and residential development are the major land uses, and road density is relatively high (2.88 miles/square mile). Many of the roads in the subbasin are seasonal roads, which were originally constructed to access and haul timber, but are now used to access residential areas and marijuana cultivation operations.

Human settlement has also affected wildland fire patterns and occurrences. Areas where residential communities border parklands or industrial timberlands are known as the wildland-urban interface. In this interface, a combination of fuel, weather, and topographical conditions may create an environment of increased wildland fire risk.

Twenty percent (64 square miles) of the Eastern Subbasin has burned since the early 1900s (Figure 17). The largest area burned between 1950 and 1969 (27 square miles, or 8.5% of the total subbasin area), with most fires burning near the towns of Garberville, Leggett, and Branscomb. The Eastern Subbasin had more fires (35) than either the Northern (19) or Western (16) subbasins, and a larger number of square miles burned than either of the other subbasins (35 in the Northern and 48 in the Western). However, the percentage of the total subbasin area burned was similar to the other two subbasins (23% of Northern and 22% of Western subbasin area burned).

Fire behavior is strongly influenced by vegetation type and fuel moisture content. The Eastern Subbasin has a higher percentage of grassland/prairie and shrub vegetation than either the Northern or Western subbasin, and fuel moisture is lower due to the drier climate and aspect/exposure. Very little of the Eastern Subbasin area is influenced by the coastal marine layer.

The most recent large fire was the Red Mountain Fire, which occurred in 2008 in the upper Cedar Creek watershed. This fire was started by lightning, and burned a total of 7,513 acres. More than half of the area burned was BLM land (3,597 acres), most of which were designated wilderness (3,200 acres) in the Red Mountain Unit of the SF Eel River Wilderness. The BLM's firefighting policy in that area was full suppression, with restrictions on the use of heavy equipment; retardant and foam were restricted within 300 feet of any watercourse, unless there was an immediate threat to public or firefighter safety (T. Jones, Fire Management Officer, USBLM, personal communication 2014). Vegetation types in the burned area were a mix of conifer forest, mixed

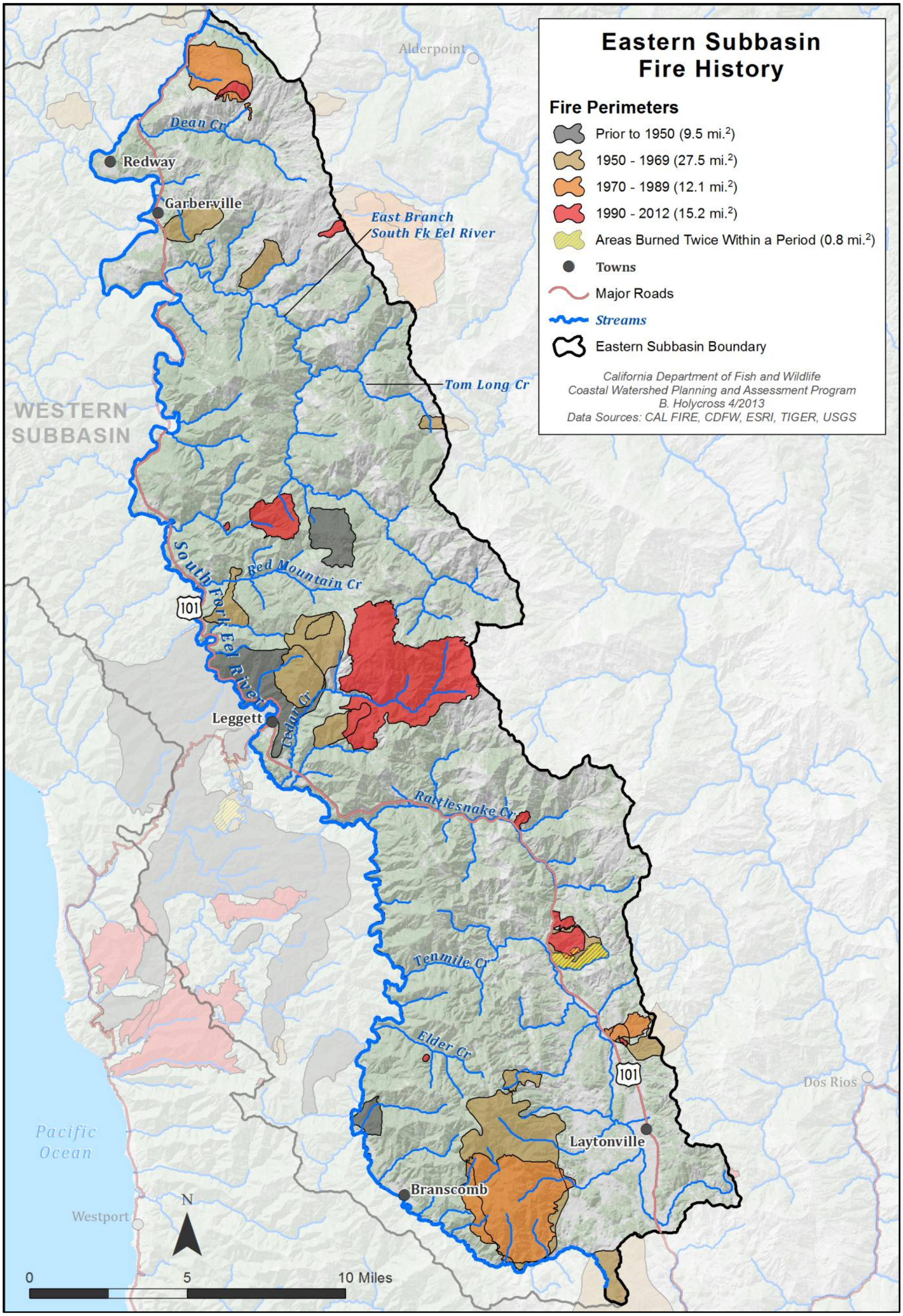



*Figure 17. SF Eel River Eastern Subbasin fire history, with total square mileage burned within each time period.*

conifer/hardwood forest, shrub, and grassland/prairie. The fire was a low intensity understory burn, with 80% mortality of brush and 10% tree mortality that left many of the crowns of taller trees (> 20 m tall) intact (Kauffmann 2013, USFWS 2013). The USBLM did not thin or treat vegetation in Cedar Creek prior to the Red Mountain Fire, or in McCoy Creek to the north, where 1,014 acres (712 of which were on BLM land) burned in 2006 (T. Jones, USBLM, personal communication 2014).

Fire-fighting practices may directly affect the landscape and streams within the subbasin. Actions and their effects include the following:

- Construction of fire roads and fire breaks, which may increase erosion and sediment input to streams;
- Aerial application of fire retardant in upslope and riparian areas (and directly in streams when mis-applied), which may result in the input of toxic chemicals to stream habitats;
- Prescribed burning, which may affect LWD recruitment, soils, and stream habitat (Pilliod et al. 2003).

Climate change has the potential to affect fire behavior, fuels, ignition, season duration, and management strategies. Global climate change models predict drier conditions for northwestern California, which will result in an increased probability of large fires (Westerling and Bryant 2008). Drier conditions, including warmer temperatures and reduced precipitation, will lead to decreased fuel moisture and increased flammability, both of which increase wildfire spread rate, intensity, and duration. Higher temperatures will also extend fire seasons, resulting in larger total burn areas from fires occurring both earlier and later than expected (Fried et al. 2004, McKenzie et al. 2004). Fire behavior will be less predictable due to changes in temperatures, precipitation, fire frequency and fire severity (Tetra Tech 2013). Resource management strategies such as the modification of vegetation structure and fuels can help mitigate the effects of climate change throughout the subbasin.

Reduced rainfall and drier conditions resulting from climate change may also affect the natural fire regime (Flannigan et al. 2000, Fry and Stephens 2006). The fire season in Humboldt County generally begins in June, peaks in August, and ends in October, but this may vary with local geography. According to the County of Humboldt (2012), temperatures in the eastern portion of the county are much higher in the summer months, and more precipitation is received during the winter in the form of snow, compared to the western portion. As a result, the eastern half of the county has a fire season that is generally longer than the western.

Despite the generally damp climate prevailing in the county's forests, studies have suggested a fire return interval of 50 to 100 years in the northern part of the county, and 12 to 50 years in the south (CalFire 2005).

The effects of wildfire in watersheds may include the following:

- Loss of vegetative cover;
- Increased runoff;
- Hydrophobic (water repellent) soils;
- Severe erosion; and
- Increased sediment production.

Post-fire erosion may increase sediment loads in both streams and riparian areas. In some areas where large-scale fires have occurred, accelerated sediment production has been documented (Humboldt County 2012). Increased erosion and sediment production following fires are of particular concern in the Eastern Subbasin due to very high natural and anthropogenic sediment input that already exists.

Depleted vegetation in riparian areas following wildfires reduces instream shading, resulting in increased water temperatures that threaten fish and other aquatic life (Pilliod and Corn, 2003). Reduced canopy cover and increased water temperatures during low flow times are already major concerns for salmonids in many areas of the Eastern Subbasin. Low flows occur during late summer and early fall, which correspond to the times of highest fire danger. Post fire monitoring and the development of management strategies are essential for areas where the loss of riparian vegetation and associated shade results in elevated instream temperatures. Active fuels management in riparian zones, including hazardous fuels reduction and habitat restoration, is increasingly common among land managers (Dwire et al. 2011).

The most recent large fires in the Eastern Subbasin occurred in areas of moderate to very high fire threat (Figure 18). Approximately 63% of the land in the

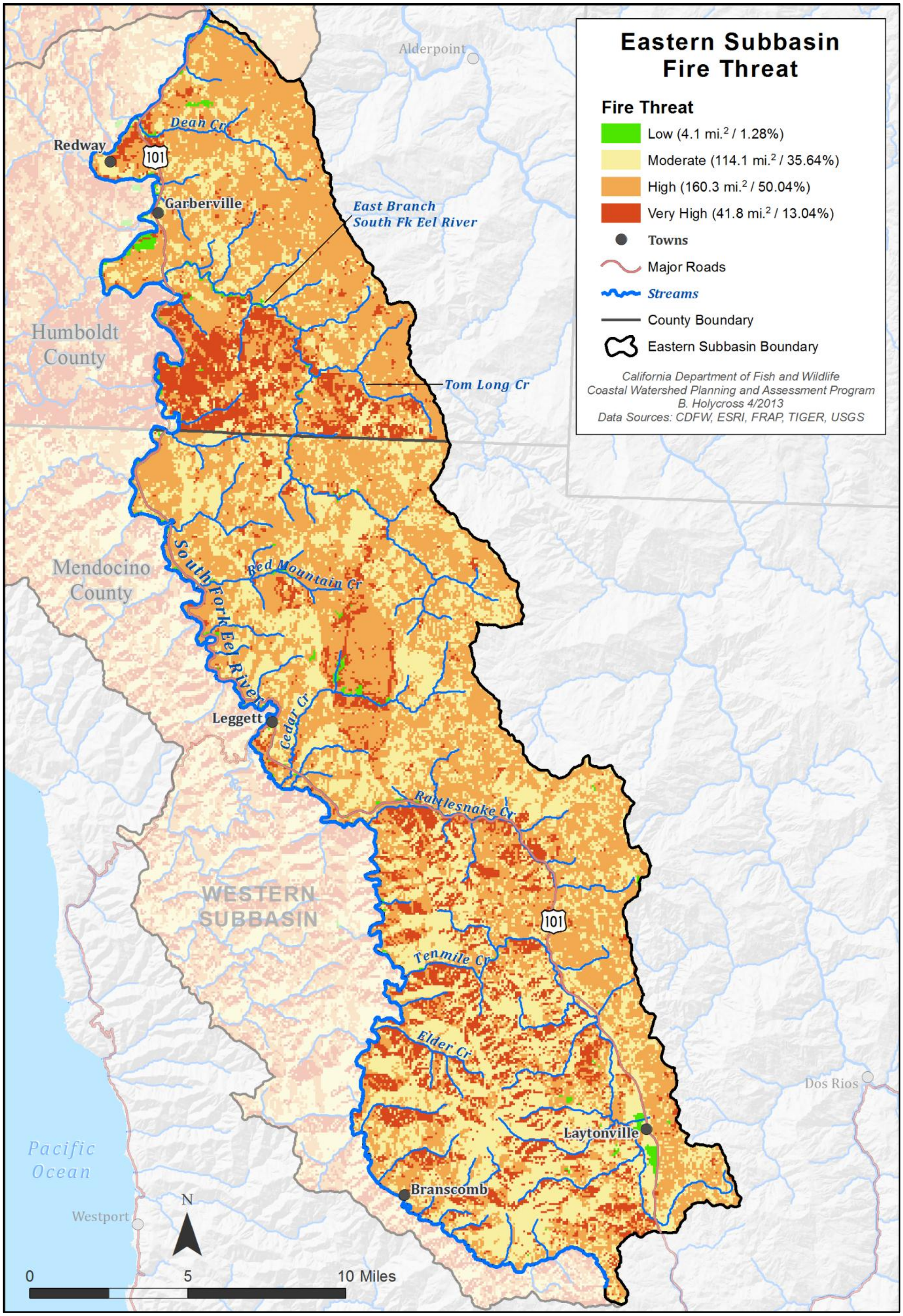



*Figure 18. SF Eel River Eastern Subbasin fire threat, with percentage of total basin area in each threat category.*

subbasin is classified as either very high or high fire threat. In a high fire threat area, all fine dead fuels ignite readily and fires start easily from most causes; fires spread rapidly and high intensity burning may develop on slopes or in concentrations of fine fuels; and fires may become severe and their control difficult unless they are attacked successfully while small (National Wildfire Coordinating Group 2002). Thirty six percent of the subbasin area is classified as moderate fire threat, and one percent as low threat (agricultural regions). Threat rankings address wildfire related impacts on ecosystem health, with ecolsystems defined as unitque vegetation types by tree seed zones (http://www.fire.ca.gov/index.php).

CalFire's Fire and Resource Assessment Program (FRAP) data used to produce fire threat maps are related to:

- stand-level data: estimated fire frequency and fire behavior characteristics at a fine scale, and
- landscape-level data: the risk of widespread landscape-level damage to an entire ecosystem, based on the percentage of an ecosystem at risk of losing key ecosystem components or functions.

Sudden oak death (SOD) has spread throughout southern Humboldt County, and cases have been confirmed in the SF Eel River Basin. In one SOD hot spot north of Garberville, the rate of expansion of diseased areas was approximately1,500 acres per year from 2004 through 2010 (Valachovic 2011). The OakMapper website (Kelly et al. 2004; http://www.oakmapper.org/oaks/index/4132) shows the location of diseased trees within the SF Eel River hot spot area (*Figure 19*). Confirmed cases east of the mainstem SF Eel River (blue line) are located within the boundaries of the Eastern Subbasin. Affected stands can detrimentally affect fuel loading and fire behavior because SOD causes 100% mortality in tanoak, and infected areas have higher fuel loads and trees that are prone to rapid failure during fires (CalFire 2012). The duration of infection in stands is also important when considering fire behavior; late-phase (>8 years) diseased forests may show increased rates of fire spreading, flame length, and fireline intensity, which reduces the effectiveness of firefighting strategies and techniques (Valachovic et al. 2011).

In summary, fire is a natural and important part of the disturbance regime of the Eastern Subbasin. Direct effects to salmonids, particularly increased sedimentation and reduced riparian canopy (which result in increased stream temperatures), may be compounded after fires in areas where human activities have modified natural hydrologic processes.

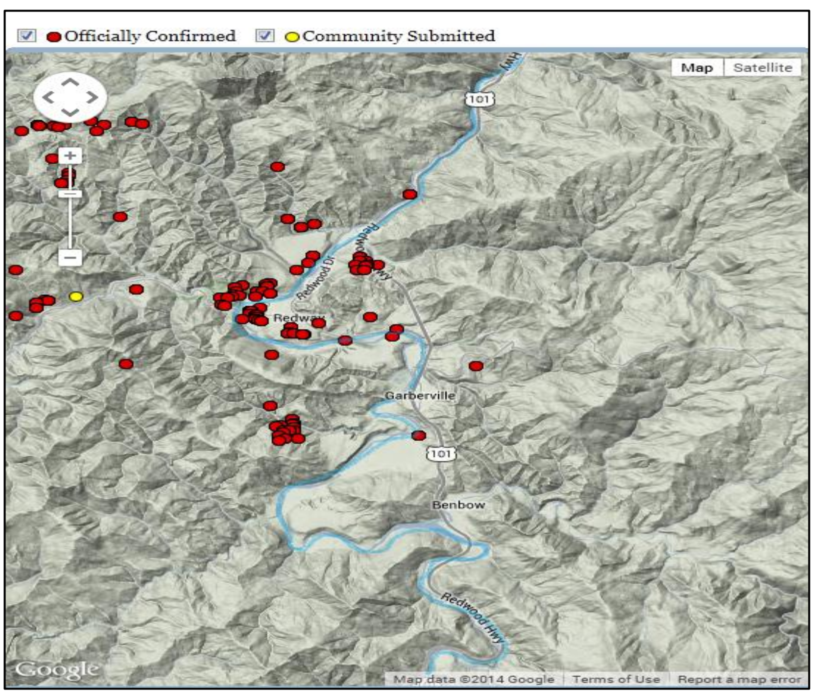



*Figure 19. Confirmed (red) and reported (yellow) cases of Sudden Oak Death (SOD) in the SF Eel River Basin, from Oak Mapper website (accessed 2/27/2014).*

# Land and Resource Use

## Historic Land Use

The Cahto and Sinkyone, subgroups of the Coastal Southern Athabaskans, were the first Native American inhabitants occupying the Eastern Subbasin of the SF Eel River Basin. The Sinkiyone occupied the northern part of the Eastern Subbasin and the Cahto were found in the southern portions, mainly in Long and Cahto Valleys (USBLM et al. 1996). These Native Americans groups subsisted primarily on anadromous fish, with secondary resources of upland game and acorns, and their cumulative impact on the environment and natural resources of the Eastern Subbasin was relatively minor (Yoshiyama and Moyle 2010). Native Americans occupied the North Coast Ranges and the Eel River Basin for at least 4,000 years prior to the arrival of the first European settlers in the early 1850s (JMWM 2000). These first settlers were mostly trappers who were encouraged by the Homestead Act of 1862, which allowed them to purchase affordable land, and also by the disappearance of the Native Americans due to violence, disease, and relocation (JMWM 2000). These homesteaders trapped, farmed, harvested timber, and grazed livestock throughout the Eastern Subbasin.

Coniferous forest habitat is found primarily along the western side of the subbasin, and in the central area east of Leggett. Historic logging activity resulted in the removal of nearly all accessible old growth redwood along creek mouths throughout the Eastern Subbasin. Prior to WW II, Douglas-fir was considered unmerchantable timber, but after the war, nearly all Douglas-fir in the watershed was harvested in addition to redwood in an effort to keep up with the post-war building boom (USBLM et al. 1996). Access to remote areas with steep terrain became possible with the development of new technologies and additional transportation options, resulting in increased logging operations throughout the subbasin. In the 1950s, there were many small mills set up throughout the SF Eel River Basin. Some were “brush mills”, temporary mills set up close to large stands so that trees could be cut and skidded to the mills easily. The mills were dismantled and moved to new locations when stands were depleted (JMWM 2000). Roads, skid trails, and landings were often located in creeks so logs could be skidded downhill easily. During this time, extensive damage to streams and poor road building techniques combined with unstable geology led to increased sedimentation in streams throughout the subbasin (JMWM 2000).

The major flood events of 1955 and 1964 exacerbated the impacts of intensive timber harvest, grazing practices, and poor road building practices in a naturally fragile landscape, resulting in large-scale soil erosion and sedimentation throughout the SF Eel River Basin (Yoshiyama and Moyle 2010). Major aggradation during the floods also buried or destroyed natural armoring of stream banks, allowing high flows to scour banks, causing an increase in bank failures and slides (JMWM 2000). During one 48-hour period in December 1964, 22.7 inches of rain was recorded near Laytonville, and sediment loads throughout the Eel River Basin following the floods were more than 10 times the previous maximum daily suspended load (Waanenen et al. 1971).

Almost all merchantable timber had been removed from the Eastern Subbasin by the late 1960s, and land developers bought up large tracts of land, subdivided the smaller parcels (40-80 acres), and sold them to “new settlers”, also known as “back-to-the-landers”. Significant changes to the watershed from these activities included the development of roads to access every parcel, an increase in the number of diversions, and an increase in the total volume of water diverted from streams in the basin to supply additional residences. Many of these “back-to-the-landers” also began cultivating marijuana, and development of this underground industry in the 1970s provided a boost to the economy throughout the subbasin (JMWM 2000). Since the passage of Proposition 215 in 1996 and SB420 in 2003 in California, these operations have expanded in both size and number. Today, many industrial-scale marijuana plantations throughout the SF Eel River Basin are run by out of the area commercial growers rather than local “back-to-the-landers” (Mozingo 2012). These activities and their impact on the ecosystem and economy are discussed in greater detail in the Industrial Marijuana Agriculture section of this subbasin report.

## Current Land and Resource Use

The four principal land uses as of June, 2012 in the Eastern Subbasin of the SF Eel River were commercial timber production, grazing/non-industrial timber harvest, residential, and open space/parks (*Table 9*). Timber harvest and residential areas are dispersed throughout the subbasin, and grazing occurs primarily in the higher elevation grassland areas on the eastern side of the subbasin. Open space/parkland areas are located mostly in the southern part of the subbasin (*Figure 20*).

*Table 9. Four principal land uses in the Eastern Subbasin.*

| Land Use | square miles | acres | % of total area |
|---|---|---|---|
| Timber production | 103 | 65,920 | 32 |
| Grazing/timber | 80 | 51,200 | 25 |
| Residential | 72 | 46,080 | 22 |
| Open space/parks | 58 | 37,120 | 18 |

### Timber Production

Commercial timber production is the primary land use in the Eastern Subbasin, occurring in 32% of the subbasin, (*Table 9*). This number is relatively low compared to the other subbasins in the SF Eel Basin, mainly because there is less timber to harvest in this subbasin due to differences in vegetation structure, climate, geology, and topography. While mixed conifer/hardwood forest is the dominant vegetation type, covering 38% of the subbasin area, this is significantly less when compared to 55% in the Northern Subbasin and 73% in the Western Subbasin.

Between 1995 and 2012, timber harvests ranged in size from 194 acres to less than one acre (Figure 21). Most harvests were located in the middle of the subbasin between the East Branch of the SF Eel River, south to Red Mountain Creek. Additional harvests occurred in the southern part of the subbasin, near Branscomb and Laytonville; there were no approved THPs north of Garberville.

Plans detailing the amount and method of planned harvest are required for all types of timber harvesting activities. Plans are based on the area of timberland owned and whether or not the landowner is an individual/family or a corporation. Non-industrial timber management plans (NTMPs) were established in 1989 to allow non-commercial landowners with fewer than 2,500 acres of timberland to develop harvest plans that were less expensive and time-consuming than THPs (CalFire 2003). Once an NTMP has been approved, the actual harvest is reported in a notice of timber operations (NTO). Commercial harvest by timber companies and private landowners with more than 2,500 acres of timberland requires the development of a timber harvest plan (THP). Based on CalFire data collected between 1997 and 2012, most timber harvest in the Eastern Subbasin is commercial (THPs), as opposed to non-commercial (NTOs), and occurred in areas East of Piercy and West of Laytonville (Figure 21).

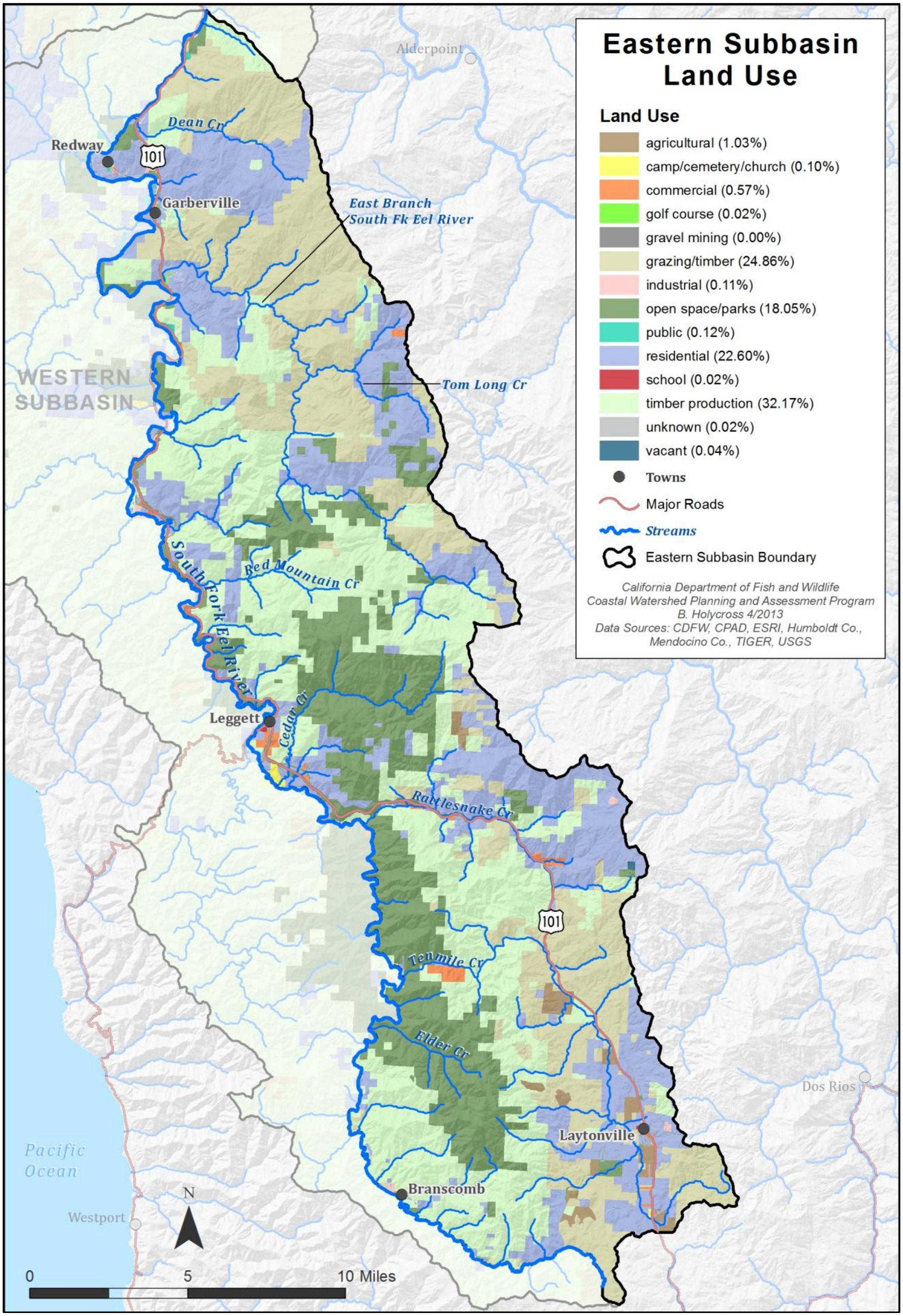



*Figure 20. Land use in the Eastern Subbasin of the SF Eel River Basin.*

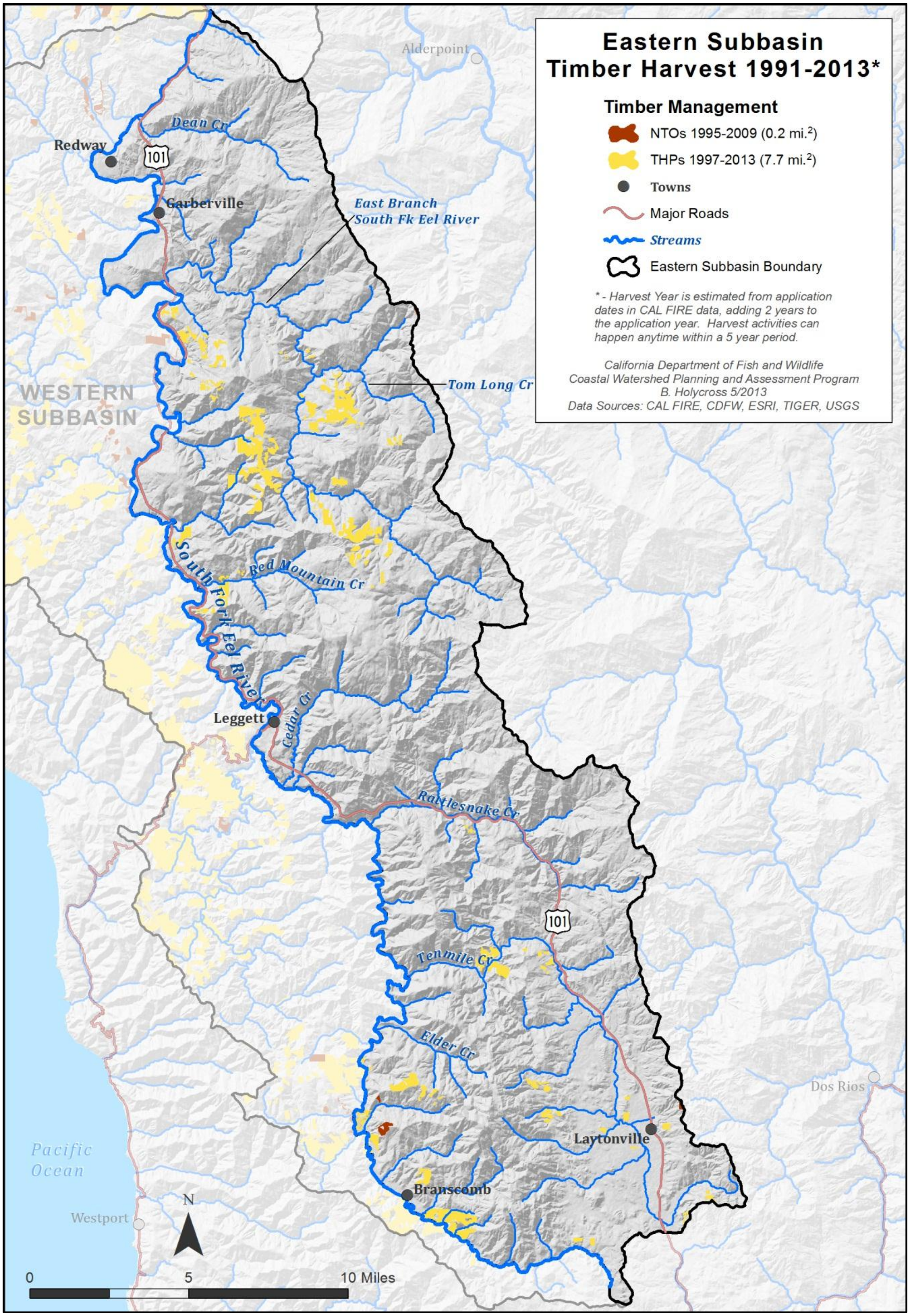



*Figure 21. Timber Harvest (NTOs and THPs) between 1995 and 2012 in the SF Eel River Eastern Subbasin.*

The Eastern Subbasin had the smallest number of acres harvested (16% of total SF Eel River Basin harvest) compared to the other subbasins (29% in Northern and 55% in the Western). Subbasin-wide timber harvest area (THPs and NTOs) totaled 6,095 acres, with 1,490 acres in Humboldt County and 4,605 acres in Mendocino County (*Table 10*). Total THP harvest area was 5,992 acres (1,489 acres in Humboldt County and 4,503 acres in Mendocino County), with individual operations ranging in size from 194 acres to less than one acre. NTO harvest area in the subbasin totaled 103 acres (1 acre in Humboldt County and 102 acres in Mendocino County) and the largest harvest was 25 acres in size.

*Table 10. Timber harvest by plan type (THP or NTO) for the SF Eel River Eastern Subbasin (data from CalFire 2012).*

| **Eastern Subbasin** | **Plan Type** | **Acres** | **County** |
|---|---|---|---|
| | THP | 1489 | Humboldt |
| | THP | 4503 | Mendocino |
| | **Total THPs** | **5992** | |
| | NTO | 1 | Humboldt |
| | NTO | 102 | Mendocino |
| | **Total NTOs** | **103** | |
| | **Subbasin Total** | **6095** | |

The primary silviculture methods used in the subbasin from 1991-2011 were as follows: seed tree removal cut (20% of harvested area); rehabilitation of understocked areas (20% of harvested area); and alternative prescription (11% of harvested area) (Figure 22). Seed tree removal cuts are defined as the cutting of widely dispersed seed trees after regeneration is established (Adams et al. 1994). Rehabilitation of understocked areas (stands where growing space is not effectively occupied by crop trees) is defined in the 2013 CA Forest Practice rules as harvesting trees in an area for the purposes of restoring and enhancing the productivity of commercial timberlands. These areas must be restocked, with a regeneration plan included in the THP. Alternative prescriptions are modifications of a recommended practice when an alternative could provide better results for forest resource stewardship; these differ on a case-by-case basis. Each alternative prescription requires a written analysis of pre- and post-harvest timber stand conditions, and a description of silvicultural practices and systems to be used in lieu of standard methods (CalFire 2012).

Each type of silvicultural and yarding technique results in different levels of landscape disturbance and modified stream flows (Harr 1979, USFS 1985, Keppeler and Ziemer 1990). In general, clear-cutting has the highest level of disturbance of any silviculture method (USFS 1985). This includes both a terrestrial disturbance component (soil exposure and instability due to tree removal), and an aquatic disturbance component (removal of shade and reduced large woody debris contribution). The least disturbing method of timber harvest is commercial thinning (USFS 1985), where trees are felled and cut into segments (bucked), either manually or, where the terrain is not too steep, by machine.

Water drafting, a process used by large timber companies as a road dust/sediment control measure, is an important consideration due to the amount of water diverted and the possible direct and indirect effects of this practice on salmonids. This will be discussed further in the Water Use: Diversions, Dams, and Hydrologic Disturbances section of this report.

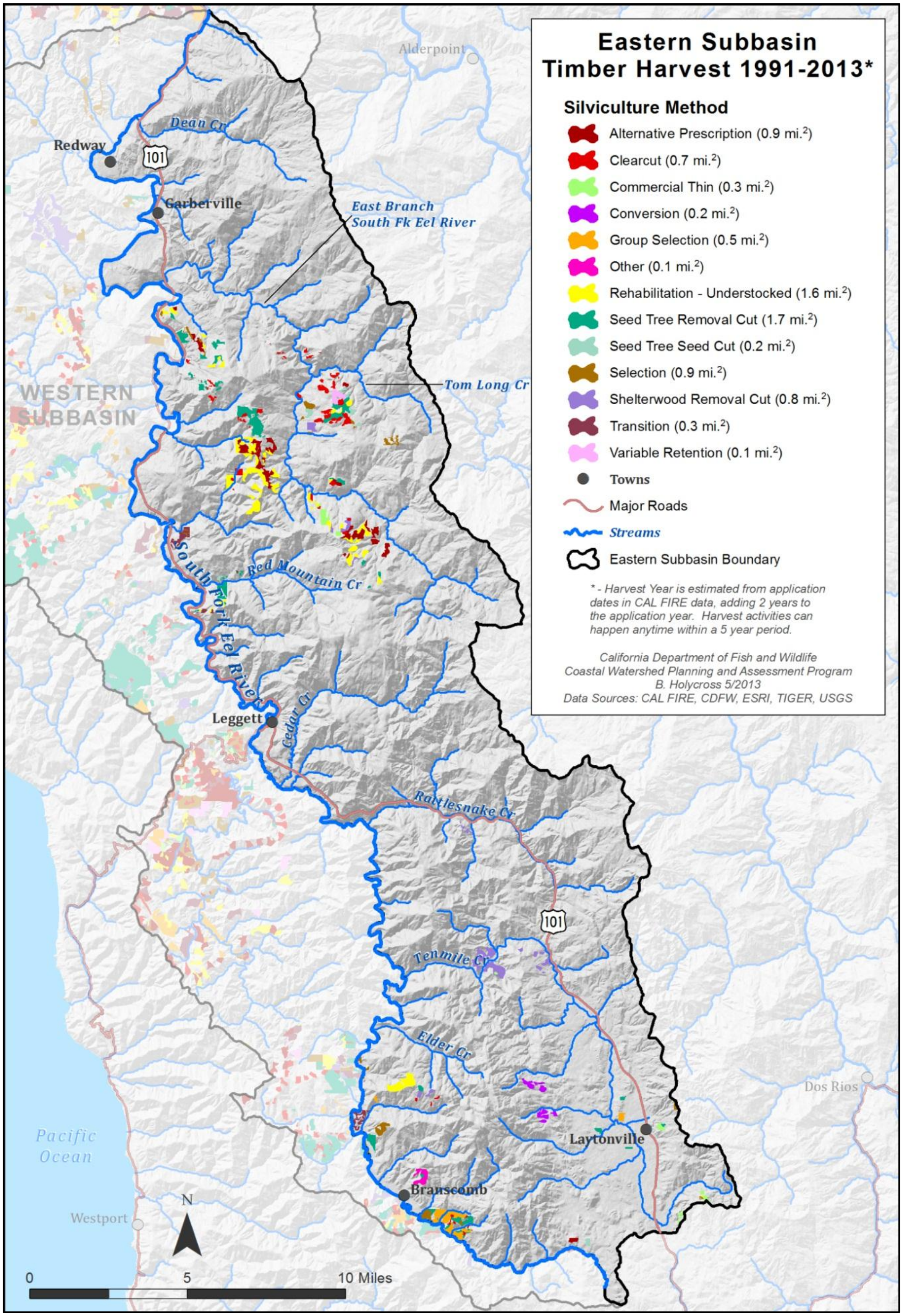



*Figure 22. Timber harvest activity by silvicultural method in the SF Eel River Eastern Subbasin.*

### Grazing/Timber

Nearly 25% of the land in the Eastern Subbasin is used for grazing/timber, and this is the primary land use type in the Dean Creek, East Branch SF Eel River, and Rattlesnake Creek drainages (*Figure 20*). This land use category includes both nonindustrial timber harvest (usually on a much smaller scale than industrial harvests) and cattle and sheep grazing in grassland habitats throughout the eastern sections of the subbasin.

This type of land use is higher in the Eastern Subbasin than in the Northern or Western subbasins, due to the higher percentage of grassland (primarily annual grasses and forbs) habitat. Approximately 16% of land in the Eastern Subbasin is grassland/prairie vegetation cover type, compared to 9% in the Northern and 3% in the Western subbasins. Differences in vegetation type are caused by climate differences as well as the underlying geology and topography between subbasins.

Livestock grazing may negatively affect salmonid streams by:

- Modifying stream morphology;
- Increasing fine sediment input from slopes and riparian areas;
- Increasing bank degradation/failures;
- Reducing aquatic invertebrate food production;
- Increasing nutrient loads; and
- Reducing streamside vegetation, resulting in increased stream temperatures (Armour et al. 1991).

In the SF Eel River Eastern Subbasin, the effects of grazing on salmonid habitat were studied in areas of the Cedar Creek drainage near Leggett (USBLM 1975). Most of the land in this watershed is owned by the USBLM, and provides excellent anadromous salmonid and resident rainbow trout habitat. Severe stream bank erosion and disturbed riparian habitat were documented in areas in the upper watershed, and may have been caused by cattle grazing and timber harvest activities (USBLM 1975).

Increased nutrient input is especially concerning in Eastern Subbasin streams, where eutrophication occurs in warm summer months when flow is reduced and temperatures increase throughout the subbasin (*Figure 23*). Algal blooms have been documented, with health warnings for people and their pets issued during recent years by the Humboldt County Department of Health and Human Services for toxic blue green algae (cyanobacteria).

*Figure 23. Algal growth in Tenmile Creek, August 2013 (fish present are juvenile Sacramento pikeminnow).*

### Residential

Approximately 65% of the population in the SF Eel River Basin lives in the Eastern Subbasin; population density is 18.27 people/square mile (2010 US Census data). This population estimate was obtained by looking at all of the census blocks within the Eastern Subbasin boundary, adding the population in those blocks that were fully contained within the boundary, then identifying any blocks with areas outside the subbasin boundaries ("straddling blocks"). The population in these straddling blocks was estimated proportionally based on the amount of each block area that was within the subbasin boundary, and was added to the total population estimate.

The largest town in the Eastern Subbasin is Laytonville (population 1,227), located in the southern part of the subbasin, followed by Redway (population 1,225) and Garberville (population 913) in the northern part of the subbasin. Of the 72% of the Eastern Subbasin that is privately owned, 54% are parcels >40 acres, and 18% are ≤40 acres in size.

Small community service districts provide water and some wastewater services to communities in the Eastern Subbasin (*Table 11*). Municipal water providers include the Garberville Sanitation District (GSD) and Redway Community Services District in the Garberville groundwater basin; and the Laytonville Water District in the Laytonville groundwater basin (Mendocino County 2009, Chapter 3; Humboldt County 2012). The largest surface water storage in the subbasin is GSD's 30,000 gallon tank, which will soon be replaced with a 200,000 gallon tank (LACO Associates 2013). Other water projects in the subbasin are surface water diversions, some small dams and reservoirs, and many small stock watering ponds (Mendocino County 2009, Chapter 3). In both Humboldt and Mendocino counties, marijuana cultivation operations are rapidly increasing in both number and magnitude. These operations often occur in residential areas, and they require extensive amounts of water. Growers rely on illegal diversion from streams and groundwater reserves to support these operations. Marijuana cultivation and its impacts on the environment in the SF Eel River Basin will be discussed further in the Industrial Marijuana Agriculture section of this report.

The Eastern Subbasin normally receives substantial wintertime precipitation and most residences obtain water from individual wells or surface water diversion. This can be problematic during low flow times in late summer, so some residences use tanks to store water received in the winter for use in late summer, thereby reducing diversions.

The Garberville Sanitation District and the Redway Community Services District provide wastewater treatment (*Table 11*). A lack of wastewater infrastructure has limited development in some areas in the basin. The community of Laytonville in the southeastern part of the subbasin is currently served by individual septic systems, but these systems do not function well in an area with high rainfall and an elevated water table. Developers are currently studying the feasibility of installing a wastewater treatment system for the town and surrounding community (Mendocino County 2009, Chapter 3).

*Table 11. Municipal water service providers in the SF Eel River Eastern Subbasin (data from Humboldt County General Plan Update Draft EIR 2012 and Mendocino County General Plan 2009).*

| **Water Provider** | **Connections** | | **Capacity** | | | **Usage** | |
|---|---|---|---|---|---|---|---|
| | **Existing** | **Available** | **Supply (mgd)** | **Treatment (mgd)** | **Storage (mg)** | **Peak Day (mgd)** | **Connection (gpd)** |
| Benbow Water Company | 113 | 0 | 0.327 | 0.200 | 0.150 | 0.382 | 3,381 |
| Garberville Sanitation District | 396 | 25 | 0.461 | 0.330 | 0.270 | 0.310 | 787 |
| Laytonville County Water District | ND* | ND | ND | ND | ND | ND | ND |
| Redway Community Services District | 600 | 180 | 0.838 | 0.460 | 0.375 | 0.475 | 792 |
| **Wastewater Service Provider** | **Subbasin Served** | **Connections** | | **Permitted Capacity (mgd)** | | **Flows (mgd)** | |
| | | **Existing** | **Available** | **Dry Weather** | **Wet Weather** | **Existing Dry Weather** | **Peak Wet Weather** |
| Garberville Sanitation District | Eastern, Western | 420 | 180 | 0.162 | 0.235 | 0.140 | 0.55 |
| Redway Community Services District | Eastern, Western | 524 | 175 | 0.186 | 0.64 | 0.140 | 0.43 |
| * No data available | | | | | | | |
| From Humboldt County General Plan Draft EIR (2012) and Mendocino County General Plan (2009) | | | | | | | |

The North Coast Regional Water Quality Control Board (NCRWQCB 2005), Humboldt County Local Agency Formation Commission (Humboldt Lafco 2009) and Humboldt County General Plan Update EIR (2012) reviewed existing system services, water quality issues, and possible future system modifications. Water quality issues associated with residential communities in the Eastern Subbasin include groundwater and surface water contamination from sewage treatment facilities, gas stations, and other nonpoint sources such as herbicide application, leaking generators and fuel tanks on private lands (NCRWQCB 2005). In August 2000, the Humboldt County Environmental Health Officer documented deficiencies with the Garberville sewage treatment facility and failing septic systems within the District. In 2002, the State Water Resources Control Board approved a loan for the Garberville Sanitation District sewer system relocation project to re-route the collection system to eliminate aerial spans and to connect homes with failing septic systems to the sewer system.

In their 2005 water quality problem identification and assessment, the NCRWQCB documented

leaking underground tanks at gas station sites and a leaking bulk oil tank in the town of Garberville. Most sites were remediated/repaired, but three sites are currently eligible for closure. For a complete list of facility type and cleanup status, go to the State Water Resource Control Board's online cleanup database Geotracker:
http://geotracker.waterboards.ca.gov/search.asp?cmd=search&hidept=True&status=&reporttitle=Humboldt+County&county=Humboldt

In the surrounding areas, private growers have problems with leaking fuel tanks on electrical generators contaminating soil and possibly surface and ground water (NCRWQCB 2005). Herbicide application on private and public lands entering ground and surface water was also a concern to NCRWQCB staff in rural areas throughout the Eastern Subbasin.

The Laytonville County Water District was established in 1979 and expanded to serve Rancheria residents in 1984. As of 2009, the system supplied approximately 33% of the housing units in the service area (Agency for Toxic Substances and Disease Registry (ATSDR) 2005). When originally established, there were two wells (423 and 528 feet deep) but one was abandoned in 1999 because the water level was too low. At the Laytonville dump the local Indian tribe obtained a grant from USEPA to conduct ground water monitoring and they detected arsenic in water supplied by the district's treatment system and in local private wells. The treatment system received federal funding to upgrade the system to meet the arsenic drinking water standard, which took effect in 2006.

### Open Space/Parks

Eighteen percent (58 square miles, or 37,120 acres) of the Eastern Subbasin is open space/parkland, occurring in patches along the SF Eel River and in the inland portions of the southern area of the subbasin. The largest designated reserved land is the 11,271-acre Elkhorn Ridge Wilderness. Managed by BLM the wilderness is southeast of Leggett and overlaps the SF Eel River and extends into the Western Subbasin. East of Leggett is the Little Red Mountain Ecological Reserve, 1,227 acres of land established as a reserve by the California Department of Fish and Game in 1988.

The Angelo Coast Range Reserve, part of the University of California Natural Reserve System, is located south of Elkhorn Ridge, and is made up of two protected areas. The land was originally sold by Heath and Margorie Angelo to the Nature Conservancy in 1959 with the hope of protecting the land in perpetuity. One tract consists of 4055 acres of forested land near Fox and Barnwell Creeks, and the other includes the entire 3500 acre Elder Creek watershed, designated an Environmental Protected Area by the Bureau of Land Management, and joined to the Reserve in 1961 by a use agreement with BLM. The entire reserve is currently managed by the University of California at Berkeley (http://angelo.berkeley.edu/).

## Roads

There are approximately 921 miles of road within the Eastern Subbasin (road density = 2.88 mi/square mile). This is the lowest road density of any of the SF Eel River subbasins. Cal Fire categorizes roads based on capacity, surface material, and frequency of use. Permanent roads include primary (4+ lanes) and secondary (2-3 lanes) paved roads and rocked (improved) roads; seasonal and temporary roads are considered unimproved. Sixty percent (557 miles) of the roads in the subbasin are seasonal roads, followed by 18% (163 miles) permanent roads and 12% (111 miles) temporary and 4 WD roads (*Figure 24*).

In their South Fork Eel TMDL Sediment Source Analysis, Stillwater Sciences (1999) studied sediment sources and rates of input between 1966 and 1981 and between 1981 and 1996 in the Tom Long Creek Basin (total area 13 square miles), located southeast of the town of Benbow in the Eastern Subbasin. This area differed in land use and vegetation from other study area basins in the Northern and Western subbasins in terms of geography and land use. Land uses around Tom Long Creek consist primarily of grazing and small-scale timber harvesting, and most land in the basin is privately owned (Stillwater Sciences 1999). Sediment input was higher between 1966 and 1981 averaged (3,295 t/km$^2$/yr) than between 1981 and 1996 (1,245 t/km$^2$/yr), and both of these amounts were larger than those seen in other study areas of the South Fork Eel Basin (Stillwater Sciences 1999). Earthflow toes and associated gullies were the primary sediment sources in the basin (accounting for 65% of the total loading), followed by road crossing and gully erosion (18%). Sediment yield

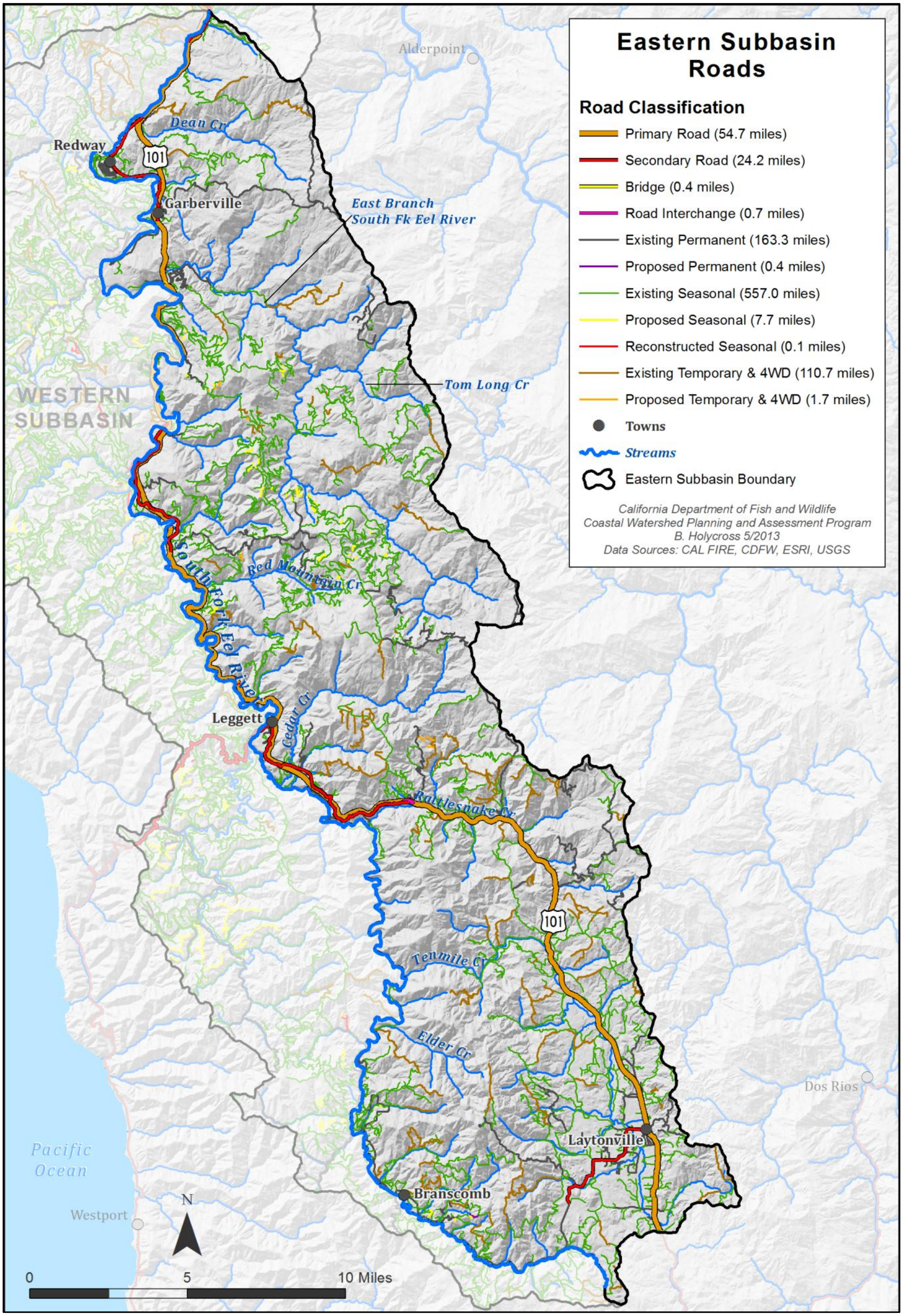



*Figure 24. Roads in the SF Eel River Eastern Subbasin.*

was dependent on local geology; mélange areas had significantly higher yields than Coastal Belt areas. These observations are consistent with Mackey and Roering (2011), who found that slow-moving earthflows, occurring mainly in mélange lithology, were the primary erosion processes in the Eel River Basin. Roads in the Tom Long Creek Basin are poorly maintained, are generally insloped with inside ditches, and likely contribute to sheetwash erosion. Basin residents noted that many road crossing failures occurred in the early 1980s, particularly during the wet winter of 1982-1983 (Stillwater Sciences 1999).

Most roads in the Eastern Subbasin were constructed before 1966, to access and haul timber. Many of these roads are currently used to access residential and agricultural areas, particularly in areas where marijuana cultivation operations are abundant.

Pacific Watershed Associates completed the Reed Mountain Erosion Assessment and Erosion Prevention Planning Project in 2001 and inventoried 164 potential sediment delivery sites along the East Branch of the SF Eel River. This area was logged extensively in the 1960s and 1970s, with additional selective logging in the 1980s and1990s (PWA 2001). They classified 31 sites with high to high-moderate treatment immediacy, with a potential delivery of approximately 7,970 square yards of sediment input to streams; 90 sites with moderate or moderate-low treatment immediacy, with 28,270 square yards of potential sediment delivery; and forty three sites with low treatment immediacy, with 8,050 square yards of potential sediment input (PWA 2001). They stated that the most important element necessary for long-term restoration of salmon and steelhead habitat in the East Branch of the SF Eel River is the reduction of accelerated erosion and sediment delivery to the stream system. Recommended treatments included upgrading and decommissioning measures such as culvert replacement and repair, flared inlets, rolling dips, and ditch relief culverts on existing roads (PWA 2001).

NMFS (1996) classified basins with road densities of <2 mi/square mile with no valley bottom roads as “properly functioning”, those with densities of 2-3 mi/square mile with some valley bottom roads as “at risk”, and those with densities of >3 mi/square mile with many valley bottom roads as “not properly functioning” when developing restoration initiatives. According to this classification system, the Eastern Subbasin, with an overall road density of 2.88 mi/square mile, is considered “at risk”, and road decommissioning and rehabilitation projects should be considered by watershed managers.

Landowners along the East Branch of the SF Eel River have shown great concern over the negative effects of road systems on salmonids, and were interested in participating in planning and assessment efforts and restoration projects (PWA 2001). Between 1998 and 2001, landowners replaced two failing bridges and upgraded more than 50 undersized or improperly designed culverts. Additional restoration activities will be discussed in the Restoration Projects section of this report.

## Gravel Mining

Gravel mining operations are permitted by the US Army Corps of Engineers (USACE), and SF Eel River operations listed in *Table 12* are authorized under LOP (letter of permission) 2004-1 (USACE 2004). In 1992, the Humboldt County Board of Supervisors appointed the County of Humboldt Extraction Review Team (CHERT) to provide scientific oversight and recommendations on extraction designs at Mad River sites, and their role was expanded to include most Humboldt County rivers in 1996. Recommendations are based on the minimization of potentially cumulative effects by ensuring that sustainable volumes are harvested, and that site-specific extraction methods protect local habitat (Klein et al. 2011). Cross section surveys are used to evaluate river conditions annually, and individual operations are reviewed to reduce or eliminate impacts and develop protection/mitigation strategies. Surface Mining and Reclamation Act documents related to gravel mining in the SF Eel River, including CHERT’s post extraction reports from 1998-2013 are available at: http://co.humboldt.ca.us/planning/smara/default.asp?inc=slm.

*Table 12. SF Eel River gravel extraction sites, locations, and lengths.*

| Bar Name | Location (RM) | Length (ft) |
|---|---|---|
| Cook’s Valley | Humboldt/Mendocino County line (49.5) | 809 |
| Home Bar | Garberville (34.0) | 1218 |
| Tooby Park Bar | Garberville (34.0) | 2097 |
| Wallan and Johnson Bar | Between Redway and Garberville (33.5) | 1854 |

Gravel mining occurs at two relatively isolated extraction sites on four bars (banks) of the SF Eel River between Cooks Valley (± RM 50) and Garberville (RM 33.5). Two of the Garberville operation sites are located at Tooby Park, southwest of Garberville (*Figure 25*).

*Figure 25. Two gravel mining operations at Tooby Park, near Garberville, on the banks of the mainstem SF Eel River.*

The total extracted volume at all SF Eel River sites from 1997 to 2010 averaged 49,578 cubic yards (cy) per year, and ranged from a high of 75,900 cy in 1999 to a low of 24,833 cy in 2008 (*Table 13*). Extracted totals averaged 71% of the annual percent approved, ranging from 110% in 1997 to 38% in 2006. The average extracted volume for the SF Eel is relatively low compared to other north coast streams (*Table 14*). The Lower Eel River had the highest average extracted volume per year (198,923 cy), followed by the Mad River (149,300 cy) and Van Duzen River (107,580 cy). The percent extracted versus percent approved each year ranged from a high of 91% for the Mad River to a low of 64% on the Lower Eel River. The average volume extracted from the Lower Eel River is more than four times the volume extracted from the SF Eel River, and the amount extracted would have been more than six times greater if the approved volume had been removed from the Lower Eel River sites.

*Table 13. SF Eel River Annual Extraction (1997-2010) (Klein et al. 2011).*

| Year | Recommended Volume (cy) | Extracted Volume (cy) | Percent of recommended volume extracted |
|---|---|---|---|
| 1997 | 67,700 | 74,700 | 110% |
| 1998 | 75,400 | 70,100 | 93% |
| 1999 | 85,400 | 75,900 | 89% |
| 2000 | 75,700 | 53,700 | 71% |
| 2001 | 66,000 | 43,100 | 65% |
| 2002 | 58,163 | 48,122 | 83% |
| 2003 | 87,060 | 54,660 | 63% |
| 2004 | 80,730 | 50,745 | 63% |
| 2005 | 82,770 | 36,480 | 44% |
| 2006 | 92,000 | 35,075 | 38% |
| 2007 | 90,737 | 73,956 | 82% |
| 2008 | 32,358 | 24,833 | 77% |
| 2009 | 40,170 | 24,986 | 62% |
| 2010 | 42,864 | 27,732 | 65% |
| **Totals** | **894,018** | **641,371** | **72%** |
| **Averages** | **69,789** | **49,578** | **71%** |

Gravel mining can have serious impacts on stream channels, with possible effects including:

- Altered channel morphology and instability;
- Increased sediment input;
- Modified channel hydraulics;
- Modified instream temperatures;
- Reduced groundwater elevations; and
- Loss of riparian vegetation (Packer et al. 2005).

These effects on stream channels can also affect 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 et al. 2000). 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 migration, and creating the potential for fish entrapment (Packer et al. 2005). Additional impacts to salmonids can occur due to destruction of riparian zones, decreased food (macroinvertebrates) in stream channels, and toxic chemical spills that could occur during mining activities (Packer et al. 2005). Increased stream temperatures due to gravel mining activities that result in shallower pool depths or reduced pool habitat and decreased riparian cover may also adversely affect adult and juvenile salmonids (Spence et al. 1996). The USACE (2004) recognized that the SF Eel River sites provided habitat for Chinook, coho salmon, and steelhead (particularly spawning habitat for Chinook), and recommended the use of alternative extraction techniques such as horseshoe extractions, wetland pits, trenches, and dry trenches, as opposed to traditional skimming techniques. Extraction methods currently used at SF Eel River sites include wide offset and shoreline skim, and wet trench (Klein et al. 2011).

*Table 14. Historical extraction volume summaries for selected rivers in Humboldt County from 1992 - 2010. Mad River data from 1992-2010; all other river data from 1997-2010 (Klein et al. 2011).*

| **River** | | **Approved volume (cy*)** | **Extracted volume (cy)** | **Percent extracted vs approved** |
|---|---|---|---|---|
| South Fork Eel River | Total (all years) | 894,018 | 641,371 | 72% |
| | Average (annual) | 69,789 | 49,578 | 71% |
| Lower Eel River | Total | 3,923,757 | 2,489,719 | 63% |
| | Average | 311,531 | 198,923 | 64% |
| Middle Eel River | Total | 1,013,087 | 744,292 | 73% |
| | Average | 72,363 | 53,164 | 73% |
| Van Duzen River | Total | 1,968,094 | 1,362,964 | 69% |
| | Average | 165,162 | 107,580 | 65% |
| Mad River | Total | 3,037,319 | 2,751,126 | 91% |
| | Average | 164,814 | 149,311 | 91% |
| Trinity River | Total | 570,437 | 397,368 | 70% |
| | Average | 42,936 | 28,504 | 66% |
| * cy = cubic yards | | | | |

## Water Use: Diversions and Hydrologic Disturbances

### Diversions

Water rights are defined as "the legal entitlement authorizing water to be diverted from a specified source and put to beneficial, nonwasteful use" (SWRCB 2013). There are many types of water rights in CA, including: appropriative (for commercial use), registered (for small domestic or livestock use), and riparian (for use on land adjacent to the water body). Appropriative rights require an application, environmental review, public notification, permit issuance, and finally licensing, providing "beneficial use" of the requested amount has been demonstrated. Registered users divert water from streams for use in non-riparian areas, and are permitted to use a specific amount of water. Riparian rights have a higher priority than appropriative rights, and there are no permits, licenses, or government approvals required. Riparian rights apply to water that would naturally flow in the stream, and users are not entitled to divert water for storage, for use during the dry season, or to use on land outside the watershed (SWRCB 2013). Beginning in 2010, riparian users were required to file a statement of use with the SWRCB, but few have complied and the magnitude of the diversions and the impact on fish and wildlife in Eastern Subbasin streams remains largely unknown. For additional information on water rights and diversion, go to: http://www.calsalmon.org/srf-projects/water-rights-education.

The Eastern Subbasin has the highest number (n = 23) of permitted and licensed water diversions of the three subbasins (*Table 15*). This is due in part to the dry conditions and predominant grassland vegetation in this subbasin relative to the other subbasins, and also to the increased percentage of land used for grazing/timber (25% of the land use in the basin, compared to 9% in the Northern Subbasin and 5 % in the Western Subbasin). In addition to the water rights located within the boundary of the Eastern

Subbasin, there are also 11 registered diversions located on the boundary between the Eastern and Western subbasins, in the mainstem SF Eel River (*Table 15*). Four of these applications were filed in the 1990s and were approved with a conditional use date and are no longer active. The total maximum application diversion from both Eastern Subbasin and boundary water rights is 2,988 afy, of which 436 afy is diverted for storage. Water diverted for irrigation and recreational use at Benbow Lake (723 afy) is the largest single diversion, and accounts for 24% of the total water diverted annually.

*Table 15* does not include diversions that are not registered with the State Division of Water Rights, including illegal diversions for residential and/or marijuana growing operations. Water diversion during low-flow times (June through October) and pollution are some of the most devastating results of the rapidly expanding marijuana industry, and are associated with large, cultivation operations, often located on public land (Evers 2010).

*Table 15. Water rights in the SF Eel River Eastern Subbasin, and on the border between the Eastern and Western subbasins on the SF Eel River (WRIMS 2012).*

| Creek | Application Number | Direct Diversion | Maximum Application Direct Diversion | Diversion Storage | Purpose |
|---|---|---|---|---|---|
| | | **Eastern Subbasin** | | | |
| East Branch SF Eel River | A004413 | 0.52 cfs | 722.7 afy | | Irrigation and recreation (Benbow dam) |
| Mad Creek | A005356 | 0.05 cfs | 36.2 afy | | Domestic and irrigation |
| Big Dann Creek | A006426 | 10,250 gpd | 11.5 afy | | Domestic and irrigation |
| Elder Creek | A007409 | 11,000 gpd | 12.3 afy | | Domestic and irrigation |
| Cedar Creeek | A008060 | 5000 gpd | 5.6 afy | | Domestic |
| Big Dann Creek | A009518 | 11,500 gpd | 12.9 afy | | Domestic |
| UNSP, Mad Creek | A013240 | 6500 gpd | 7.3 afy | | Domestic |
| Mill Creek | A013912 | 0.09 cfs | 30.4 afy | | Irrigation |
| East Branch SF Eel River | A014691 | 0.5 cfs | 183.5 afy | | Irrigation |
| Mill Creek | A016449 | 2000 gpd | 1.3 afy | | Domestic |
| Cahto Creek | A017809 | 0.25 cfs | 76.4 afy | | Irrigation |
| UNST, Mud Springs Creek | A018702 | 0.5 cfs | 182 afy | | Irrigation, stock watering, and recreation |
| Harmony Spring #1, Little Dean Creek | A019533 | 2500 gpd | 2.8 afy | | Domestic |
| Cedar Creek | A019712 | 1200 gpd | 1.3 afy | | Domestic |
| Holland Lake, Cahto Creek | A020971 | | 220 afy | 380 afy | Irrigation, recreation, stock watering, and fish culture |
| UNCR, Lewis Creek | A021811 | | 2 afy | 2 afy | Recreation and fire protection |
| Mill Creek | A021922 | 900 gpd | 1 afy | | Domestic |
| UNST, Mud Springs Creek | A022328 | | 42 afy | 42 afy | Irrigation, stock watering, recreation, and fire protection |
| Cedar Creek | A023021 | 5000 gpd | 3 afy | | Domestic |
| Grapewine Creek | A025138 | | 11 afy | 11 afy | Recreation and fire protection |
| UNSP, Fish Creek | A025693A | 420 gpd | 0.1 afy | | Domestic |
| UNST, Rattlesnake Creek | A027792 | 10,080 gpd | 11.3 afy | | Domestic |
| UNSP, UNST, Dean Creek | A029049 | 0.12 cfs (irrigation), 420 gpd (stock watering and domestic) | 7 gpd | 1 afy | Storage: fire protection, irrigation, recreation, and stock watering. Direct Diversion: irrigation, stock watering, and domestic |
| **TOTAL (n = 23)** | | | **1583.6 afy** | | |

| Creek | Application Number | Direct Diversion | Maximum Application Direct Diversion | Diversion Storage | Purpose |
|---|---|---|---|---|---|
| **Mainstem SF Eel River (boundary between Eastern and Western subbasins)** | | | | | |
| SF Eel River | A005317 | 0.15 cfs | 41.4 afy | | Domestic and irrigation |
| SF Eel River | A009686 | 0.155 cfs | 112.2 afy | | Municipal |
| SF Eel River | A011876 | 0.223 cfs | 161.5 afy | | Domestic |
| SF Eel River | A016088 | 0.14 cfs | 34.2 afy | | Irrigation (2 sites) |
| SF Eel River | A023691 | 0.337 cfs | 81 afy | | Irrigation, domestic, stock watering |
| SF Eel River | A023017 | 1.05 cfs | 441 afy | | Municipal and domestic (use by 12/1995) |
| UNSP, SF Eel River | A023018 | 0.123 cfs | 52 afy | | Municipal and domestic (use by 12/1989) |
| UNST (AKA Marshall Creek) | A025436 | 0.04 cfs | 13.5 afy | | Domestic |
| UNSP, Rancheria Creek | A025693B | 420 gpd | 0.1 afy | | Domestic |
| SF Eel River | A029329 | | 37.5 afy | | Industrial and mining (use by 12/1997) |
| SF Eel River | A029981 | | 430 afy | | Municipal (use by 12/1999. 2 sites) |
| **TOTAL (n = 11)** | | | **1404.4 afy** | | |

## Water Drafting for Dust Abatement

The following section is based on information provided by the North Coast Regional Water Quality Control Board (NCRWQCB) in June of 2014 (J. Burke, Senior Engineering Geologist, Southern Timber Unit, NCRWQCB, personal communication 2014).

Water is used for dust abatement/sediment control on timber company roads throughout Humboldt and Mendocino counties between May 15th and October 15th. Timber companies draw water from streams near active harvest operations and apply it to unpaved roads to maintain safety and visibility, minimize input of fine sediment to adjacent streams, and to maintain infrastructure. The amount of water used may be substantial at a time when stream flow is already low. Estimates for the amount of water used each harvest season range from 2,000 to 4,000 gallons/mile/day (treating two times each day). Quantities vary depending on the volume of traffic, road surface, exposure/aspect (east side roads tend to be drier and require more treatment than west side roads), and the use of additional treatments such as magnesium chloride, which may reduce the amount of water required by approximately 50%. It is difficult to make generalizations about the amount of water used, but one timber company with approximately 400,000 acres located in Northwestern California estimated an annual use of two million gallons for dust abatement.

Regulations and limitations currently exist for surface water drafting, including the following:

- Lake and Streambed Alteration Agreements – any landowner that is drafting water must notify CDFW and develop a Streambed Alteration Agreement. These agreements generally contain requirements pertaining to water depth, bypass stream flow, and stream velocity. However, there are no consistent region- or state-wide standards regarding the specific conditions of these agreements;
- Anadromous Salmonid Protection (ASP) Rules – these stipulate the following conditions:
    - Bypass flows during drafting shall be at least 2 cubic feet per second;
    - Diversion rates are limited to 10 percent of surface flow; and
    - Pool volume reduction shall not exceed 10 percent.
- Board of Forestry Emergency rules for water drafting – these require users to comply with CDFW Streambed Alteration Agreements, but do not include specific recommendations for bypass flows;
- Statement of Water Diversion and Use – these are required by the State Water Board for all individuals or organizations that divert surface water or pump groundwater. Beginning January 1, 2012, users are

required to measure and report the amount of water diverted each month.

Until recently, the amount of water used and the timing and location of withdrawals has not been carefully documented by industrial timber companies. Drought conditions in California, which are expected to persist through the 2014 logging season, will result in reduced water availability in areas throughout the SF Eel River watershed. In February 2014, staff from timber harvest review agencies including CDFW, CalFire, State and Regional Water Quality Control Boards, and the California Geologic Survey met to discuss water drafting on industrial timber harvest lands, limitations associated with these activities that further reduce instream flows, and the impacts of these activities in relation to current drought conditions. The interagency group developed a list of actions that could be developed to ensure the efficient use of water for dust control, including the following:

- Investigate current scope of use by requesting information from large landowners in an effort to quantify amounts used and specific data available on withdrawal locations and applications. This information will be used to determine if current use is significant to warrant changes in practices;
- Education and outreach to address efficient water use and alternatives to current drafting methods;
- Establish a list of best management practices (BMPs) to present in timber review correspondence;
- Develop regulatory solutions and recommendations; and
- Evaluate prudent use of alternatives to water for dust abatement, especially in areas with existing high industrial or agricultural runoff rates.

Existing ASP rules and regulations specifying minimum bypass flows and diversion rates may be adequate to minimize the impacts to water supplies solely from water drafting for industrial timber harvest operations in most situations. However, additional regulations/actions may be required in watersheds throughout the SF Eel River Basin where significant volumes are already diverted in response to high water demands from industrial marijuana cultivation and residential use.

## Industrial Marijuana Agriculture

The permitted water diversions discussed above do not include illegal diversions from the recent proliferation of industrial marijuana agricultural operations throughout the SF Eel River Basin. During the late 1960s and early '70s, a large influx of "back to the landers" came to the Basin in search of an independent, peaceful, and rural lifestyle (USBLM et al. 1996). With the decline of the timber and fisheries industries, also in the 1970s, the local economy began to dwindle. With favorable climate conditions and available land, back to the landers, displaced forest workers, and successive generations of homesteaders turned their ingenuity and agricultural talents to cultivating marijuana to accommodate the rising demand both locally and throughout the state. Mendocino and Humboldt Counties are home to the largest marijuana growing operations in the state, and these operations are increasing in both size and number, with a corresponding increase in local revenue currently accounting for nearly two-thirds of Mendocino County's economy (Evers 2010).

Since the passage of Proposition 215 in 1996 and SB420 in 2003 in California, CDFW field staff, local law enforcement agencies, and other state and federal agency representatives have discovered increasing numbers of large marijuana grows on private lands, presumably for medical purposes.

CDFW staff and others have documented extensive illegal and unpermitted clearcutting, road building, and water diversion associated with marijuana cultivation throughout the Basin (S. Bauer, CDFW, personal communication 2013, www.arcataeye.com). In the Salmon Creek and Redwood Creek watersheds, two coho salmon strongholds in the SF Eel River Basin, CDFW Environmental Scientist Scott Bauer used satellite photography to assess the number of indoor and outdoor grows, then estimated the number of plants grown in greenhouses, and the total amount of water necessary to supply these operations during each growing season (Easthouse 2013). Bauer identified 567 grows (281 outdoor and 286 indoor/greenhouse) in the Salmon Creek drainage, and 549 grows (226 outdoor and 323 indoor) in the Redwood Creek watershed (*Figure 26*, *Figure 27*). The total number of plants estimated to be associated with these grow operations was: 20,000 (8,700 in greenhouses and 11,300 outdoors) in Salmon Creek; and 18,500

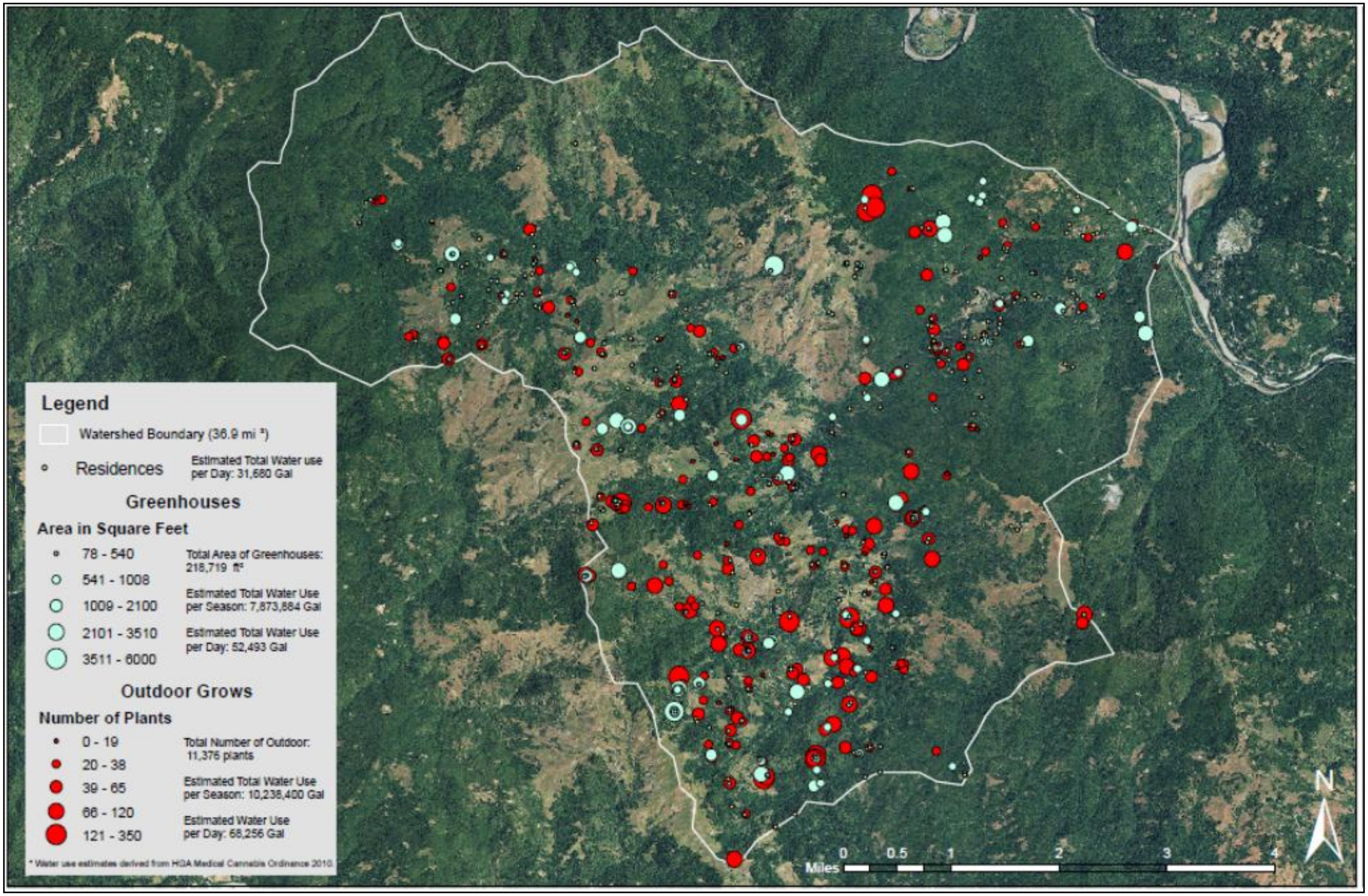



*Figure 26. Marijuana cultivation operations from satellite images, with estimated total water use by grow type in Salmon Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW).*

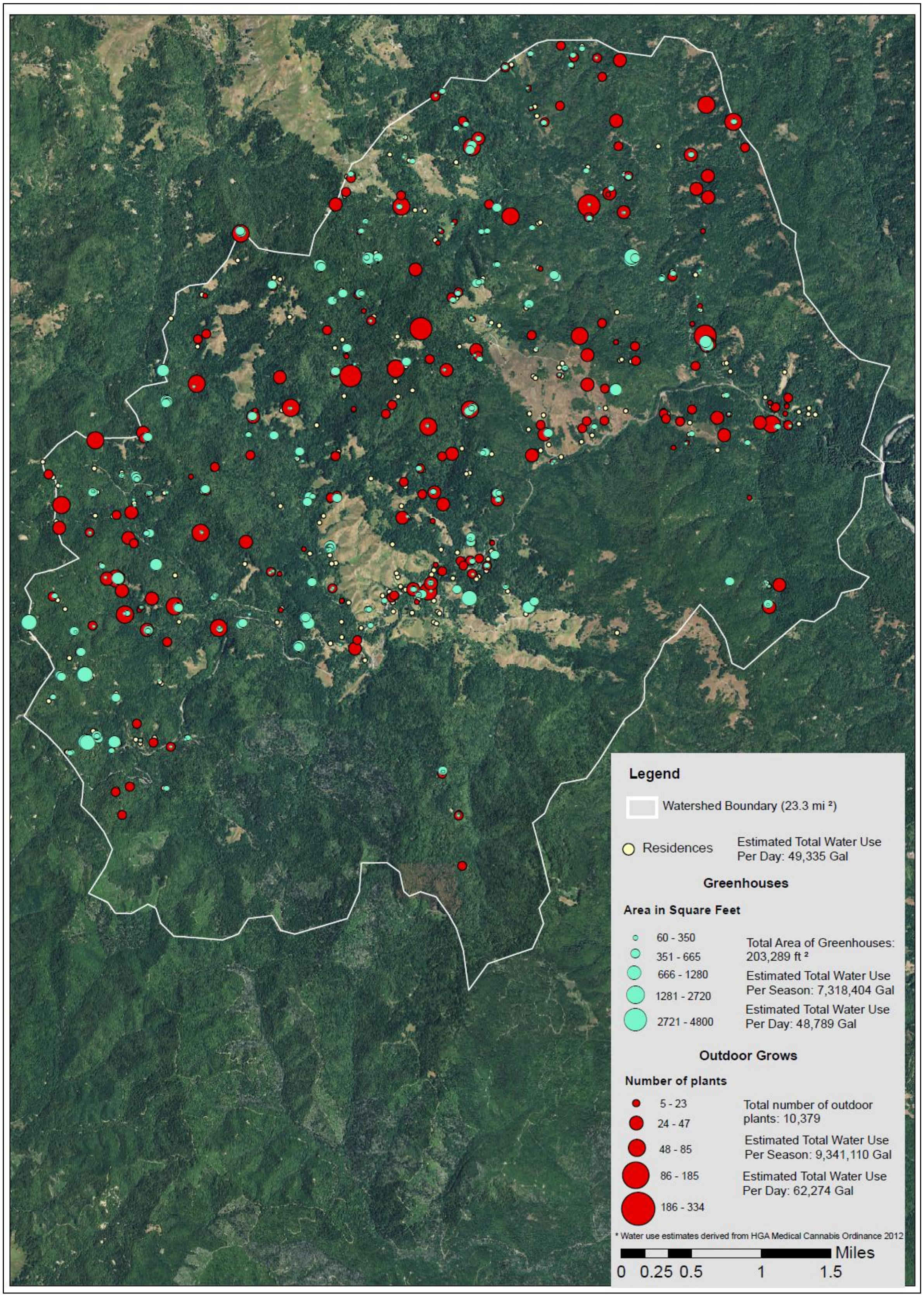



*Figure 27. Marijuana cultivation operations from satellite images, with estimated total water use by grow type in Redwood Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW).*

(8,100 in greenhouses and 10,400 outdoors) in Redwood Creek. Bauer estimated that grow operations in Salmon Creek are consuming more than 18 million gallons of water per growing season and more than 16.5 million gallons per season in Redwood Creek. This usage during the growing season is nearly 30% of the total streamflow in these basins (Easthouse 2013).

This type of documentation has not been completed for watersheds in the SF Eel River Eastern Subbasin, but Bauer completed a similar analysis in the Outlet Creek watershed (tributary to the Eel River). This watershed is located southeast of Laytonville, in an area with predominantly residential land use. Bauer found 633 outdoor grows and 321 greenhouses, and he estimated that these are using more than 23 million gallons per growing season in this watershed alone.

In the SF Eel River Eastern Subbasin, areas with with high residential land use (especially near the towns of Garberville and Laytonville, and in areas of the East Branch SF Eel River and Rattlesnake Creek) are expected to have high diversion rates to supply marijuana cultivation operations. Because conditions in the Eastern Subbasin are hotter and drier than in Northern and Western subbasins, water diversion during late summer months in Eastern Subbasin tributaries will most likely have a greater impact on salmonids by reducing already low flows and reducing the quality and quantity of rearing habitat and instream shelter.

CWPAP staff documented extremely low flow conditions in select Eastern Subbasin creeks in August and September 2013 as part of a study designed to compare conditions in SF Eel River streams that were heavily diverted with those that were not heavily diverted. Low flow conditions existed from limited rainfall in the winter and spring of 2012-2013 and were exacerbated by an increase in the number of diversions due to extensive marijuana cultivation operations. Eastern Subbasin streams that were affected extensively by diversion were Tenmile and Cahto creeks, and the East Branch SF Eel River. Flows decreased dramatically during the study, primarily because of active diversions supplying water to grow operations throughout the watershed. For a full description of the CDFW study and other low flow projects and results, see the Flow section of this subbasin report.

While numerous factors may be relevant (wet spring vs dry spring, overall summer temperatures, etc.) a 10,000 square foot outdoor marijuana grow operation uses approximately 250,000 gallons of water in a five-month growing season (T. LaBanca, CDFW, personal communication 2012). Considering the number of outdoor and indoor operations within the watershed, this industry is having a significant effect on water flows in Eastern Subbasin tributaries. A recent trend has emerged that shows atypical low flows occurring during the late summer to early fall even during wet weather years (T. LaBanca, personal communication 2012). *Figure 28*, *Figure 29*, and *Figure 30* illustrate this potential trend using flow data from the USGS SF Eel River gauging stations near Miranda, Leggett, and Bull Creek. Daily mean discharge (in cfs) for the 2011-2014 water years was plotted along with the median daily statistic (73-year flow average for the Miranda gauge, 40-year flow average for the Leggett gauge, and 52-year flow average for the Bull Creek gauge). 2011 was considered a wet weather year, with above average rainfall throughout Northern California, and 2012 and 2013 were considered dry years, with less than normal rainfall received. *Figure 28* shows a slight decrease in low flows in September and October 2011 at Miranda compared to the 73 year average, and significantly lower discharge from July through November 2012 and July through December 2013, continuing into January 2014, when compared to the 73 year average.

*Figure 29* shows slightly lower flows in September and October 2011 and considerably lower flows in August, September, and October 2012 and 2013 compared to the 40-year average at Leggett. *Figure 30* shows much lower flows in September and October 2011 and 2012, and for nearly all of 2013, compared to the 52-year average flows recorded at the Bull Creek gauge. These atypical low flows (especially during normal water years) support the contention that water diversions by the marijuana industry are affecting streams and tributaries throughout the SF Eel River Basin by contributing to higher water temperatures, reduced streamflow at critical times for fish rearing and migration, and altering water chemistry throughout the basin.

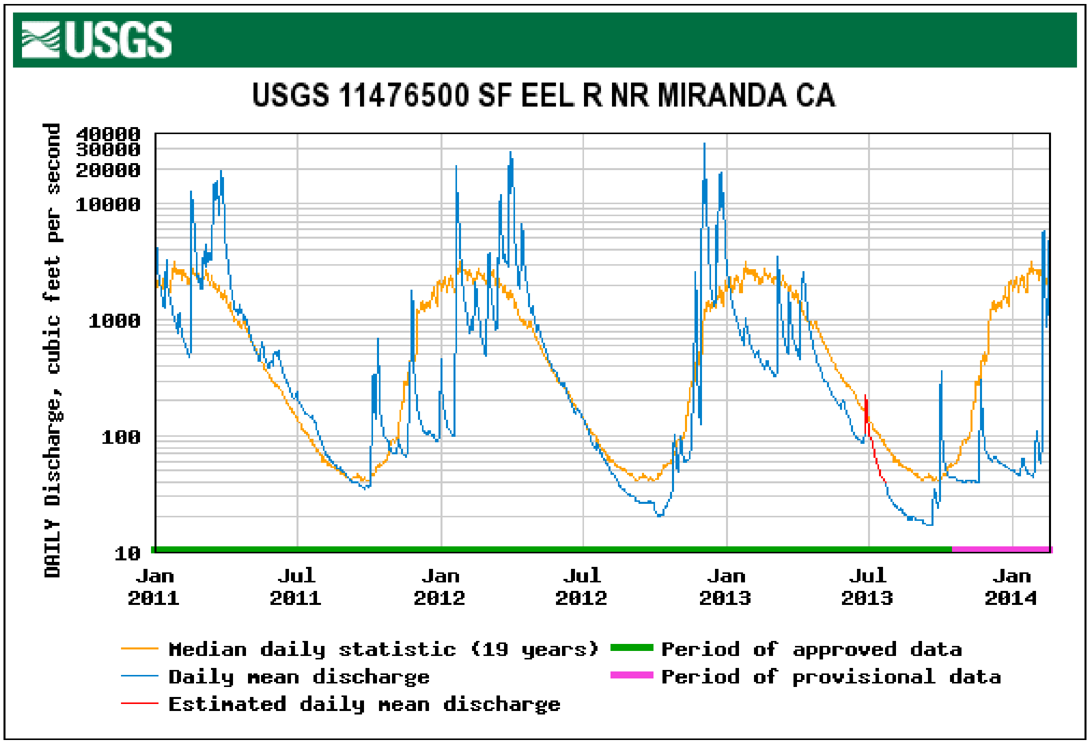



*Figure 28. USGS gauging station near Miranda showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (73-year average in cfs).*

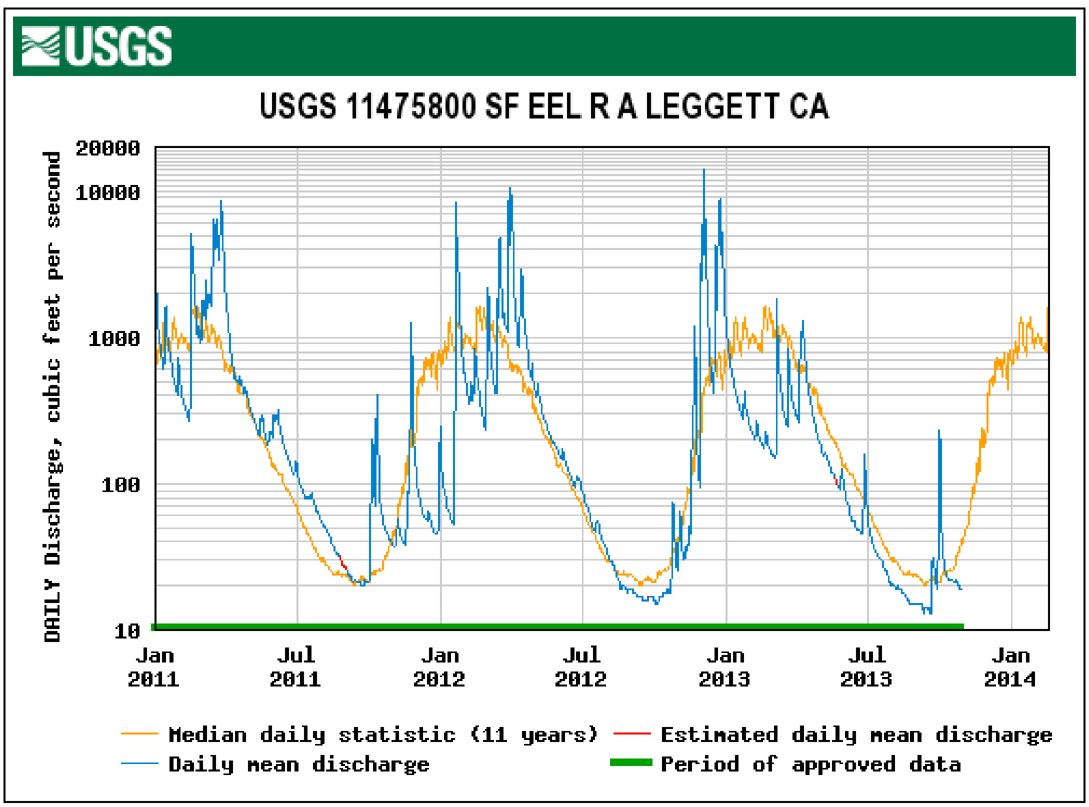



*Figure 29. USGS gauging station near Legett showing 2011 through 2014daily mean discharge (in cfs) and the mean daily statistic (40-year average in cfs).*

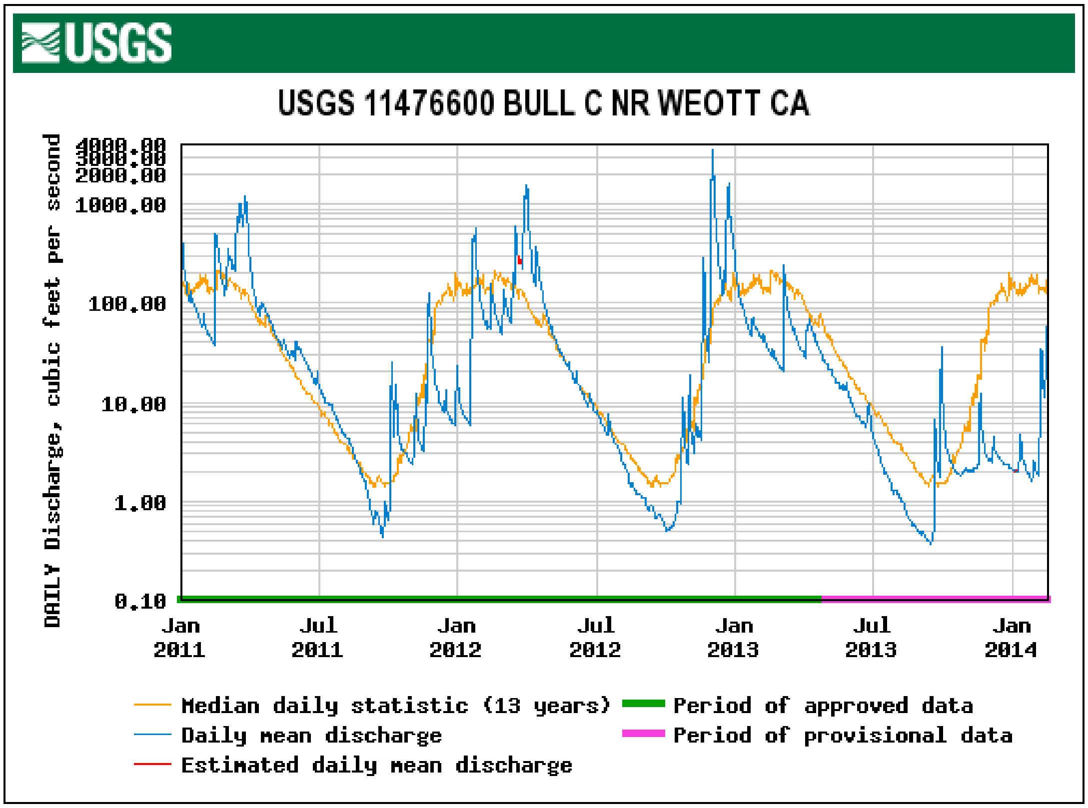



*Figure 30. USGS gauging station at Bull Creek showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (52-year average in cfs).*

Unlike permitted/licensed water diversions and other regulated land use activities such as legal timber harvesting and/or mining operations, there are no established "best management practices" or any review by agencies like CDFW and the state Water Quality Control Board on industrial marijuana grow sites. Therefore, a wide range of impacts to watercourses and their aquatic resources can be associated with these industrial marijuana agricultural operations. These impacts may include the following (CDFW 2012, T. LaBanca, personal communication 2012):

- Illegal water diversions that draw directly from the streams without screens or bypass, so juvenile fish and amphibian can be pulled from their habitat and die;
- Decreased stream flows due to illegal water diversions, leading to reduced stream depths and diminished pool habitat, possible subsurface flow in streams with excessive sediment recruitment, elevated water temperatures, and concentrated pollutants;
- A wide range of pollutants may be used (*Table 16*), including fuel, fertilizers, herbicides, pesticides, rodenticides, and construction debris. These chemicals and debris may go directly into watercourses or could leach into the soil, eventually being released into the water throughout the year;
- Human waste from camps that could also directly enter or leach into watercourses;
- Sediment from improperly constructed roads and construction around grow sites that enters watercourses throughout the rainy season; “Grow trash” such as plastic hose, construction supplies, and gardening waste left on site;
- Conversion and fragmentation of natural wildlife habitat and native ecosystems. Riparian and aquatic habitat may be disturbed or removed, grasslands and hillside habitats cleared and leveled; and
- Unpermitted timber harvests that may occur when an area is cleared for an agricultural grow operation.

*Table 16. Pollutants associated with marijuana grows and their effects on fish and wildlife (adapted from Greacen 2012)*

| Pollutant | Application | Result |
|---|---|---|
| Rodenticide | Poison is applied to garden and/or perimeter to keep rodents from harming crop. | Wild animal populations are impacted as poison travels up the food chain. Contamination of fresh stream water. |
| Insecticide | Poison is applied to garden and/or perimeter to keep insects from harming crop. | Toxic to native insects as well as fish. |
| Fungicide | Fungicide is applied to plants to keep fungus from harming crop. | Can be toxic to fish and beneficial soil invertebrates. May contain mercury. |
| Fertilizer | Fertilizer and soil amended with potent nutrients are brought to the grow and used liberally for the growing season then discarded. | Nutrients get into the streams causing problematic algal blooms. Used soil/fertilizer is washed into the streams during the rainy season which adds to the sediment load. Typically leads to a reduction of dissolved oxygen in streams. |
| Sediment | Tractor/dozer work on larger grows is implemented, often with little or no regard for good road/landscape practices in regard to site stability and erosion. | Sediment from dozer work (roads, landings, gardens) gets into streams. |
| Reduced flow | Water is taken from a nearby stream by diversion pipe or water truck and used to water crop (individual plants take 3-5 gallons/day). | Evapotranspiration releases most of the water into the atmosphere resulting in a loss of water available to the stream during the driest, hottest part of the year producing extremely low flows downstream of diversion. |

In addition, there are many pollutants in fertilizers and pesticides that may enter the stream system from grow operations, but one which poses a particular danger to salmonids is copper. Sorenson (1991, in Woody 2007) determined that copper levels below lethal concentrations have been shown to have the following potential effects on salmonids:

- Interfere with normal migration;
- Impair salmonids' sense of smell;
- Impair their ability to fight disease;
- Make breathing difficult;
- Impair their ability to sense vibrations through their lateral line canals, which interferes with their ability to avoid predators;
- Impair brain function;
- Change their blood chemistry and metabolism; and
- Modify natural hatch rates.

Additional research is necessary to determine the concentrations of copper entering the SF Eel River system, and to determine the impacts of other pollutants from pesticides and herbicides on salmonids within this system.

There are some exceptions to the poor land-use practices associated with marijuana cultivation listed above. Local residents with small scale cultivation operations seem to employ more care than larger growers who do not live on site, and may not even own the land. A more comprehensive understanding of the magnitude of the impacts of industrial operations, their effects on fish and wildlife, and consumer and grower education leading to regulation is necessary to address these problems (Weiser 2012).

Although there are no established best management practices for marijuana growing, the Northern California Farmers Guide is a community-based collaborative project that outlines concerns and solutions for many of the issues listed above. This guide is an evolving project that is designed to increase awareness of environmental issues and help cannabis growers protect the environment while growing a high quality, sustainably produced crop. For more information, go to: http://www.norcalfarmersguide.org/.

# Fish Habitat Relationship

## Fishery Resources

### Historic Distribution

Fish presence has been documented in the Eastern Subbasin by anecdotal accounts and observations made during stream surveys since 1938. Although stream survey efforts were neither specific nor standardized (and therefore limited in their evaluation of salmonid populations) until 1991 when the *California Salmonid Stream Habitat Restoration Manual (*Flosi et al. 2010) was published, these early surveys are useful in providing a perspective on the historic distribution of salmonids within the basin.

Historical salmonid documentation is available for 46 Eastern Subbasin streams. Information sources include CDFW carcass surveys, stream survey and inventory reports, electrofishing and general field notes, downstream migrant trapping data, fyke net records, and spawning stock and escapement reports (*Table 17*). Coho salmon were found in 25 of the 46 surveyed streams. Large tributaries with documented historical coho salmon presence included the East Branch SF Eel River and Tenmile Creek. Chinook salmon were documented in 12 Eastern Subbasin streams, and steelhead were found in 36 of the 46 streams surveyed, more streams than either Chinook or coho salmon. Of the 10 creeks with no documented salmonid presence, three included sightings of unidentified salmonids (*Table 17*).

*Table 17. Documented fish presence in surveys from 1934 to 2001 in the Eastern Subbasin.*

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Bear Canyon (Bear Gulch) Creek | 4/1/1968 | Electrofishing Field Note (CDFG 1968) | X (possible) | X | X | |
| | 4/30/1969 | Electrofishing Field Note (CDFG 1969) | | X | X | |
| | 7/17/1992 | Stream Inventory Report (CDFG 1992) | | X | X | |
| Bear Creek (tributary to SFER) | 8/26/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 1/15/1979 | Stream Survey (CDFG 1979) | X | | | |
| Big Dann Creek | 8/12/1968 | Stream Survey (CDFG 1968) | | | X | |
| | 9/11/1972 | Stream Survey (BLM 1972) | | | | X |
| | 7/10/1975 | Stream Survey (BLM 1975) | | | | |
| Big Rock Creek | 9/3/1969 | Stream Survey (CDFG 1969) | | X | X | |
| Bridge Creek | 7/19/1995 | Stream Inventory Report (CDFG 1995) | | | X | |
| Bridges Creek | 7/18/1968 | Stream Survey (CDFG 1968) | | X | X | |
| Cahto Creek | 10/15/1957 | Stream Survey (CDFG 1957) | | | | |
| | 9/15/1969 | Stream Survey (CDFG 1969) | | | X | |
| Cedar Creek | 7/30/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 9/3/1941 | Stream Survey (CDFG 1941) | | | | X |
| | 8/7/1968 | Stream Survey (CDFG | | | X | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | | 1968) | | | | |
| | 9/14/1972 | Stream Survey (BLM-CDFG 1972) | | | X | |
| | 7/30-8/14/1975 | Stream Survey (BLM 1975) | | | X | X |
| | 12/7/1982 - 1/11/1983 | Sapwning Stock Survey (CDFG 1983) | X | | | X |
| Cummings Creek | 8/21/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 8/1/1975 | Stream Survey (BLM 1975) | | | X | |
| Dean Creek | 8/2/1938 | Stream Survey (CDFG 1938) | | | X | |
| | 7/3/1962 | Stream Survey (CDFG 1962) | | | | X |
| | 1/24/1980 | Stream Survey (CDFG 1980) | | | | X |
| | 12/13/1982 | Spawning Stock Survey (CDFG 1982) | | | | |
| | 1990 | Downstream Migrant Trapping (CDFG 1990) | X | X | X | |
| | 1991 | Downstream Migrant Trapping (CDFG 1991) | | | X | |
| | 8/25/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| Deer Creek | 8/8/1969 | Stream Survey (CDFG 1969) | | X | X | |
| Dora Creek | 11/26/1968 | Stream Survey (CDFG 1968) | | | X | |
| East Branch SFER | 1934 | Stream Surveys (CDFG 1934) | | | X | |
| | 7/31/1938 | Stream Survey (CDFG 1938) | | | X | |
| | July, August 1961 | Field Note (CDFG 1961) | | | X | |
| | Jan-77 | Stream Survey (CDFG 1977) | | | | |
| | 1988, 1990 | Downstream Migrant Trapping (CDFG 1998, 1990) | X | | X | |
| East Branch SFER (above Buck Mountain Creek) | 1966 | Fyke Net Record (CDFG 1966) | X | X | X | |
| East Branch SFER (above Tom Long Creek to mouth) | 9/27 - 9/29/1966 | Stream Survey (CDFG 1966) | | X | X | |
| East Branch SFER (Buck Mountain Creek) | 1966 | Fyke Net Record (CDFG 1966) | X | X | X | |
| Elder Creek | 8/21/1969 | Stream Survey CDFG 1969 | | X | X | |
| | 8/21/1975 | Stream Survey BLM 1975 | | | | X |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| Elk Creek (tributary to Rattlesnake Creek) | 4/30/1959 | Intraoffice Correspondence (CDFG 1959) | | | X | |
| | 8/21/1968 | Stream Survey (CDFG 1968) | | | | |
| | 7/13/1971 | Stream Survey (CDFG 1971) | | | | |
| Elkhorn Creek | 7/31/1975 | Stream Survey (BLM 1975) | | | | |
| Fish Creek (tributary to SFER near Garberville) | 7/5/1961 | Stream Survey (CDFG 1961) | | | | X |
| Foster Creek | 8/19/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 4/10/1979 | Stream Survey (CDFG 1979) | | | | |
| | 1/21/1986 | Inspection Memorandum (CDFG 1986) | | | X | |
| Fox Creek | 8/9/1969 | Stream Survey (CDFG 1969) | | X | X | |
| Grapewine Creek | 8/26/1968 | Stream Survey (CDFG 1968) | | | X | |
| | 5/26/1976 | Stream Survey (CDFG 1976) | | | X | |
| | 10/28-29/1976 | Stream Survey (CDFG 1976) | | | X | |
| Horse Pasture Creek | 8/10/1962 | Stream Survey (CDFG 1962) | | | | X |
| Kenny Creek | 7/23/1975 | Stream Survey (BLM 1975) | | | | X |
| | 4/4/1979 | Stream Survey (CDFG 1979) | | | X | X |
| Little Dann Creek | 8/13/1968 | Stream Survey (CDFG 1968) | | | | |
| Little Rock Creek | 8/27/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 1/29 - 1/30/1979 | Stream Survey (CDFG 1979) | | | | |
| | 9/7/1996 | Electrofishing Field Form (CDFG 1996) | | | X | |
| Low Gap Creek | 1/31/1980 | Stream Survey (CDFG 1980) | | | X | X |
| McCoy Creek | 6/25/1938 | Stream Survey (CDFG 1938) | | | X | X |
| | 7/2/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 9/11/1975 | Stream Survey (BLM 1975) | | | | X |
| | 1/6/1983 | Spawning Stock Survey (CDFG 1983) | | | | |
| Milk Ranch Creek | 8/11/1938 | Stream Survey (CDFG 1938) | | X | X | |
| | 7/18/1961 | Stream Survey (CDFG 1961) | | | | X |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | 6/23/1980 | Stream Survey (CDFG 1980) | | | | X |
| Mill Creek (tributary to Tenmile) | 9/11/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 7/18/1975 | Stream Survey (BLM 1975) | | | | X |
| Misery Creek | 8/6/1975 | Field Note (BLM 1975) | | | | X |
| Mud Creek | 1/8/1969 | Field Note (CDFG 1969) | X | | | |
| | 8/13/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 7/17/1975 | Stream Survey (BLM 1975) | | | | X |
| Mud Springs Creek | 8/8/1969 | Stream Survey (CDFG 1969) | | X | X | |
| Muddy Gulch Creek | 1/23/1979 | Stream Survey (CDFG 1979) | | | | |
| Rancheria Creek | 2/19/1939 | Stream Survey (CDFG 1939) | | | X | |
| | 7/18/1962 | Stream Survey (CDFG 1962) | | | | X |
| | 9/29/1966 | Stream Survey (CDFG 1966) | | | X | |
| Rattlesnake Creek | 4/24/1939 | Stream Survey (CDFG 1939) | | | X | |
| | 8/15 - 8/27/1968 | Stream Survey (CDFG 1968) | | X | X | |
| | 10/24/1968 | Electrofishing Field Note (CDFG 1968) | | | X | |
| | 7/25/1975 | Stream Survey (BLM 1975) | | | | |
| | 12/10/1982, 1/7 and 1/14/1983 | Spawning Escapement Surveys (CDFG 1982-1983) | | | | |
| Ray's Creek | 2/19/1939 | Stream Survey (CDFG 1939) | | | X | |
| | 7/17/1961 | Stream Survey (CDFG 1961) | | | | |
| | 9/29/1966 | Stream Survey (CDFG 1966) | | | X | |
| Red Mountain Creek | 6/25/1938 | Stream Survey (CDFG 1938) | | | X | X |
| | 7/30/1938 | Stream Survey (CDFG 1938) | | | X | |
| | circa 1960 | Stream Survey (CDFG no date) | | X | X | |
| | 3/20/1967 | Stream Survey (CDFG 1967) | | | X | |
| | 7/16/1968 | Stream Survey (CDFG 1969) | | | X | |
| | 10/25/1968 | Electrofishing Field Note (CDFG 1968) | | | X | |
| | 7/16/1969 | Electrofishing Field Note (CDFG 1969) | | | X | |
| | 12/9, 12/14, | Spawning Stock Survey | X | | | |

| Stream | Date surveyed | Source | Species Present | | | |
|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Unidentified Salmonids |
| | 12/30/1982 | (CDFG 1983) | | | | |
| Rock Creek | 7/19/1968 | Stream Survey (CDFG 1968) | | | X | |
| | 8/9/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 7/20/1973 | Stream Analysis (CDFG 1973) | | | X | |
| | 1/22/1979 | Stream Survey (CDFG 1979) | X | | | |
| | 3/8/1979 | Stream Survey (CDFG 1979) | | | X | |
| | 9/29/1992 | Stream Inventory Report (CDFG 1992) | | | X | |
| Squaw Creek | 7/11/1975 | Stream Survey (BLM 1975) | | | | |
| Streeter Creek | 9/4/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 12/31/1982 | Spawning Stock Survey (CDFG 1983) | X | | | |
| | 12/14/1988 | Carcass Survey: Field Note (CDFG 1989) | X | | | |
| | 1/18/1989 | Carcass Survey: Field Note (CDFG 1989) | X | | | |
| Taylor Creek | 8/25/1969 | Stream Survey (CDFG 1969) | | X | X | |
| | 9/2/1969 | Stream Survey (CDFG 1969) | | | X | |
| | 1/16/1979 | Stream Survey (CDFG 1979) | | | | |
| | 7/21/1997 | Stream Inventory Report (CDFG 1997) | | | X | |
| Tenmile Creek | 6/9/1938 | Stream Survey (CDFG 1938) | X | | X | |
| | 5/23/1940 | Stream Survey (CDFG 1938) | | | X | |
| | 1966 | Fyke Net Record (CDFG 1966) | X | X | | |
| | 12/6/1982 - 1/21/1983 | Spawning Stock Survey (CDFG 1983) | X | | | |
| | 12/14/1988 | Carcass Survey: Field Note (CDFG 1989) | X | | | |
| | 1/18/1989 | Carcass Survey: Field Note (CDFG 1989) | X | | | |
| Tom Long Creek | 8/13/1975 | Stream Survey (BLM 1975) | | | | |
| Tuttle Creek | 7/6/1961 | Stream Survey (CDFG 1961) | | | | |
| Twin Rocks Creek | 8/26/1968 | Stream Survey (CDFG 1968) | | | X | |
| Wilson Creek | 7/14/1975 | Stream Suvey (BLM 1975) | | | | |
| Windem Creek | 1/25/1979 | Stream Survey (CDFG 1979) | | | | |

There is one long-term salmon and steelhead data set for the Eastern Subbasin, with data collected at the CDFW fish ladder at Benbow Dam, located at approximately RM 40 on the mainstem SF Eel River near Garberville. Counts were conducted between 1938 and 1975, and they show more than an 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the span of the last century (*Figure 31*). Linear regression lines for all three species at Benbow Dam show significant declines in abundance, and it is likely that salmonid populations throughout the SF Eel Basin declined similarly throughout this time period

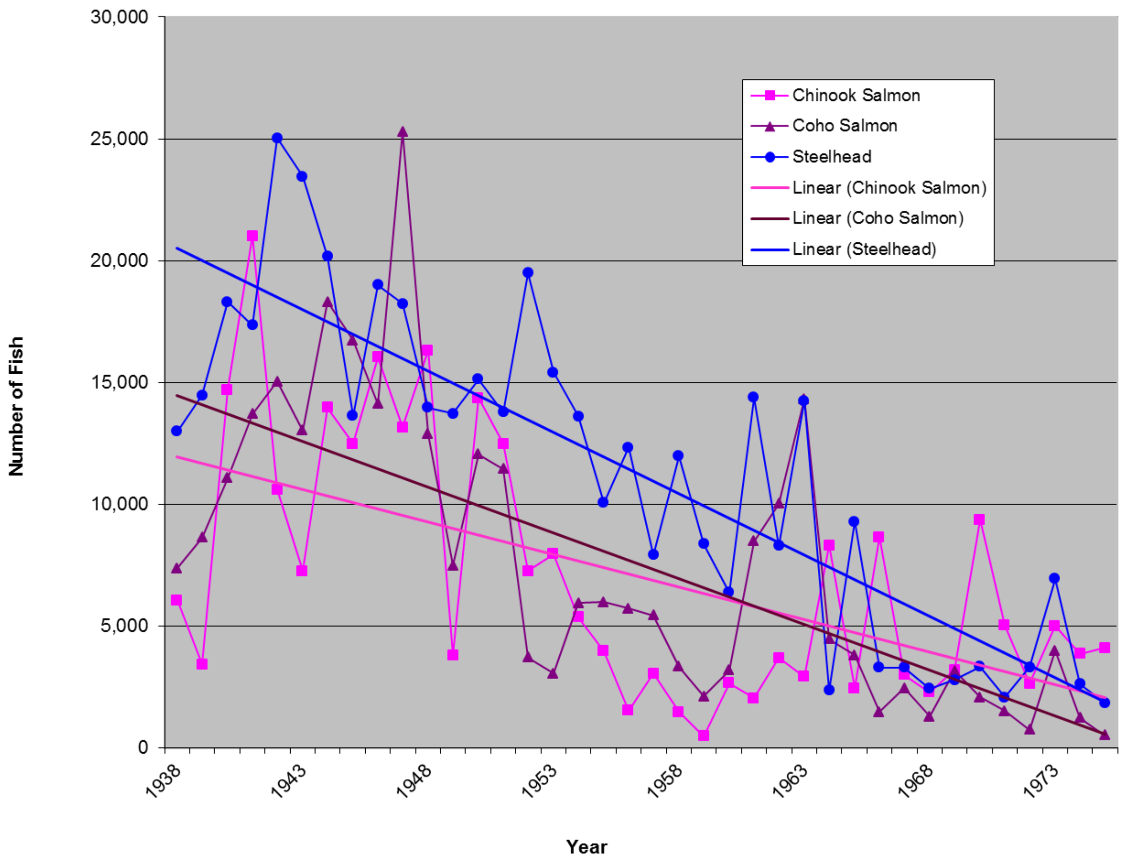



*Figure 31. Counts of migrating Chinook salmon, coho salmon, and steelhead at the Benbow Dam fish ladder between 1938 and 1975. Regression lines for all three species show declines over time.*

## Current Distribution

Current estimated Chinook salmon, coho salmon, and steelhead distributions in the SF Eel River Eastern Subbasin were based on data collected from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) and compiled by the Pacific States Marine Fisheries Commission (PSMFC). Data are available on the CalFish website at: http://www.calfish.org/Programs/ProgramIndex/AnadromousFishDistribution/tabid/184/Default.aspx.

CalFish data is observation-based, meaning that any recorded observation is collected, verified, evaluated, and applied to standard hydrography to develop a linear GIS layer. These layers are overlaid onto local watershed polygons (Calwater Planning Watersheds) to determine distribution ranges, assuming that target species can be found anywhere downstream from the observation point. Distribution layers differ slightly by species:

- Chinook distribution was developed using CDFW reports and the NOAA National Marine Fisheries Service GIS layer, which uses CDFW and PSMFC stream based routed hydrography. This layer was updated in June 2005;
- Coho salmon distribution was developed using CDFW reports and the CalFish observation-based distribution, and was

updated in June 2012;

- Steelhead distribution was developed using CDFW reports and the CalFish steelhead distribution layer, and was last updated in June 2012.

Final maps were reviewed by CDFW fishery biologists and distribution lines were added or removed where known distribution was different than gradient and observation-based information. Salmonids in the Eastern Subasin may be present in areas where they have not been documented due to a lack of data or imperfect sampling techniques.

Eastern Subbasin tributaries generally have less documented salmonid presence than Northern and Western Subbasin streams, due in part to less favorable instream conditions, reduced riparian habitat, and aspect (leading to increased solar exposure in the afternoons). The Eastern Subbasin has hotter, drier summer conditions, a higher prevalence of grassland and shrub vegetation types (resulting in reduced riparian canopy), than Northern and Western Subbasin streams. The Eastern and Northern subbasins also have and higher gradient streams compared to the Western Subbasin (Table 18).

*Table 18. Stream gradient by percentage of stream miles in SF Eel River subbasin streams.*

| Stream Gradient | Northern Subbasin | | Eastern Subbasin | | Western Subbasin | | SF Eel River Total | |
|---|---|---|---|---|---|---|---|---|
| | miles | % | miles | % | miles | % | miles | % |
| 0 - 5% | 87.133 | 29.62% | 216.404 | 31.46% | 260.110 | 53.11% | 563.647 | 38.29% |
| 5 - 10% | 43.345 | 14.73% | 105.841 | 15.38% | 90.809 | 18.54% | 239.995 | 16.31% |
| > 10% | 163.733 | 55.65% | 365.721 | 53.16% | 138.815 | 28.34% | 668.269 | 45.40% |

Steelhead trout are the most widely distributed of the three species, documented in 44 Eastern Subbasin streams. Steelhead, like other anadromous salmonids, use the mainstem and lower tributary systems in their juvenile and adult migrations, but generally prefer habitats that are located farther inland and in smaller streams than Chinook and coho salmon (Moyle et al. 2008). As stream temperature increases in tributaries, steelhead juveniles will move to faster moving water in riffles to feed, and will seek out cold water refugia at tributary confluences and seeps. As a result of these behavioral traits and possessing superior jumping abilities compared to Chinook and coho salmon, steelhead are the most widely distributed of the three species in all SF Eel River Basin streams (*Table 19*). Coho salmon have the most limited distribution, and steelhead and Chinook have been documented in a similar number of miles of tributary streams in the Eastern and Western Subbasins, but they are found in a smaller number of tributaries in the Eastern Subbasin. Recent distribution maps show coho salmon in only 17 Eastern Subbasin creeks, with most distribution limited to areas less than a mile from the confluences of larger creeks (*Figure 32*). Exceptions to this distribution pattern include the following tributaries:

- Tenmile Creek, with coho salmon presence documented more than 10 miles upstream from the confluence of the mainstem SF Eel River, and four tributaries (Grub, Big Rock, Mud Springs, and Little Case creeks) with coho salmon documented more than 1 mile upstream from the confluence with Tenmile Creek;

*Table 19. Number of tributary streams and approximate number of stream miles currently occupied by anadromous salmonids in SF Eel River Basin and subbasins.*

| Subbasin | Number of Tributaries | Total mainstem miles/tributary miles | SFER mainstem miles currently used by anadromous salmonids* | | | Number of SFER tributaries/miles currently used by anadromous salmonids | | |
|---|---|---|---|---|---|---|---|---|
| | | | Chinook | Coho | Steelhead | Chinook | Coho | Steelhead |
| **Northern** | 109 | 23 / 190 | 23 | 23 | 23 | 14 / 27 | 8 / 13 | 23 / 50 |
| **Eastern** | 167 | 82 / 360 | 80 | 79 | 80 | 27 / 82 | 17 / 25 | 44 / 130 |
| **Western** | 175 | 82 / 312 | 80 | 79 | 80 | 44 / 86 | 34 / 99 | 53 / 128 |
| ***** Mainstem SFER is dividing line between Western and Eastern subbasins; mainstem mileage is counted in both Eastern and Western Subbasin totals. | | | | | | | | |


*Figure 32. Current coho salmon, Chinook salmon, and steelhead trout distribution in SF Eel River Eastern Subbasin streams.*

- Bear Canyon, Cedar, and Kenny creeks, with coho salmon presence documented 1-5 miles upstream from the confluence with the mainstem SF Eel River.

Chinook salmon have been documented in 27 Eastern Subbasin streams (*Figure 32*). Chinook are generally found further upstream than coho salmon, and in more than three times the number of stream miles as coho salmon in Eastern Subbasin tributaries. Chinook have been observed in more streams currently than in the past, but this may be due to an increase in documentation and sampling effort rather than an increase in actual distribution in these streams.

Many of the tributaries to the SF Eel River that are located in the southern part of the basin (upstream from Tenmile Creek) are more characteristic of Western Subbasin streams. These streams have dense canopy coverage and relatively cool air and instream temperatures due to the influence of the coastal marine layer and the high levels of precipitation in the SF Eel River headwaters west of Cahto Peak. These favorable conditions are conducive to all three salmonid species distribution in this region's tributaries: Elder, Rock, Kenny, Taylor, and Bear creeks.

On the east side of Cahto Peak and Signal Peak, near Laytonville, the climate is dry and hot. Less precipitation, increased solar exposure, and reduced riparian vegetation in many streams compared to other areas in the subbasin increases stream temperatures. All three species of salmonid have been documented in Tenmile Creek, but are less widely distributed in tributaries than in Western Subbasin streams where water temperatures are cooler.

In addition to salmonid species, other native freshwater fish that have been observed in the Eastern Subbasin include rainbow trout (*Oncorhynchus mykiss*), pacific lamprey (*Lampetra tridentata*), three-spined stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (*Cottus aleuticus)* (Brown and Moyle 1997, Stillwater Sciences 2010). Invasive species inlcluding largemouth bass, green-eared sunfish, and brown bullhead, were observed following a prolonged period of drought in the 1990s in the mainstem SF Eel River near Dora Creek and in Tenmile Creek. Sacramento pikeminnow have been detected in the mainstem SF Eel River and many of its tributaries (Nakamoto and Harvey 2003). Pikeminnow abundance is increasing and their distribution is expanding due to the species' high tolerance for warm water and low flow conditions, which have become more prevalent throughout the Eastern Subbasin in recent years.

## CDFW Spawning Ground Surveys

Data on the number of spawning Chinook salmon, coho salmon, and steelhead trout have been collected in SF Eel River streams using two different approaches: index reach sampling (2002 to present) and California Coastal Salmonid Population Monitoring (CMP) program techniques (2010 to present). These methods differ in sampling frequency and intensity, and in the applicability of their conclusions, however, both provide valuable information that can be used to assess the status of salmonid populations in the basin.

### Index Reach Sampling

CDFW survey crews have collected data on the number of redds, live Chinook and coho salmon, and salmonid carcasses in 10 SF Eel River stream reaches, six of which were located in the Western Subbasin and four in the Northern Subbasin. Survey sites were not randomly selected. CDFW biologists selected index reaches based on known salmonid (primarily coho salmon) presence in areas with relatively good quality instream and riparian habitat. There were no index reaches sampled in the Eastern Subbasin.

Additional information on index reach sampling can be found in the Basin Overview, and in the Northern and Western Subbasin sections of this report.

### California Coastal Salmonid Monitoring Program (CMP)

Chinook salmon, coho salmon, and steelhead trout spawning ground surveys have been completed each year since 2010 in SF Eel River streams, as part of the CMP program. This program is designed to describe the regional status of SONCC coho salmon in coastal watersheds, including the SF Eel River (Adams et al. 2011). The CMP uses the Viable Salmonid Population (McElhaney et al. 2000) concept, with key population characteristics including: abundance, productivity, spatial structure, and diversity, to assess viability. Repeated periodic surveys were conducted on a spatially balanced random sample of stream reaches with possible coho spawning. A total of 818 surveys were completed on 151 stream reaches throughout the SF Eel River drainage between 2010 and 2014 (*Table 20*, *Figure 33*). The number of reaches sampled varied slightly by year, and sampling occurred between mid-November and early March.

CMP data were analyzed for the entire SF Eel River Basin; therefore, numbers of live fish, carcasses, redds, and redd estimates were not developed for individual subbasins.

Field crews recorded the number of spawning fish, carcasses, and redds observed in each reach, including identifying the salmonid species that constructed each redd where possible. CDFW biologists then predicted unidentified redds to species using the K-nearest neighbor algorithm (Ricker et al. in review) and estimated the total number of redds constructed across all reaches in the sample frame. Sampling methods and calculations are described in detail in Ricker et al. 2014a – 2014d.

*Table 20. Summary of CMP regional spawning ground surveys and estimates of total salmonid redd construction in the SF Eel River (data from Ricker et al. 2014a – 2014d). UI = unidentified salmonids.*

| | **Report Year** | | | |
|---|---|---|---|---|
| | **2010** | **2011** | **2012** | **2013** |
| # of surveys | 150 | 198 | 224 | 246 |
| # of stream reaches | 31 | 42 | 39 | 39 |
| survey dates | 11/17/2010 - 3/9/2011 | 11/14/2011 - 3/12/2012 | 11/26/2012 - 2/28/2013 | 11/14/2013 - 3/25/2014 |
| # live fish | | | | |
| Chinook salmon | 93 | 63 | 106 | 17 |
| coho salmon | 39 | 293 | 33 | 178 |
| steelhead | 6 | 41 | 29 | 107 |
| UI salmonids | 44 | 142 | 41 | 24 |
| # carcasses | | | | |
| Chinook salmon | 0 | 21 | 53 | 4 |
| coho salmon | 0 | 51 | 25 | 22 |
| UI salmonids | 2 | 2 | 0 | 7 |
| # redds observed | 463 | 495 | 524 | 349 |
| # redds assigned to species | 38 | 65 | 33 | 51 |
| estimate of redds in sampling area | | | | |
| Chinook salmon* | 1316 | 569 | 1045 | 126 |
| coho salmon | 1705 | 1323 | 1346 | 905 |
| steelhead* | 160 | 431 | 148 | 736 |
| * Chinook salmon and steelhead redd estimates represent only the time period and area encompassed by the study (Ricker et al. 2014a - 2014d). | | | | |

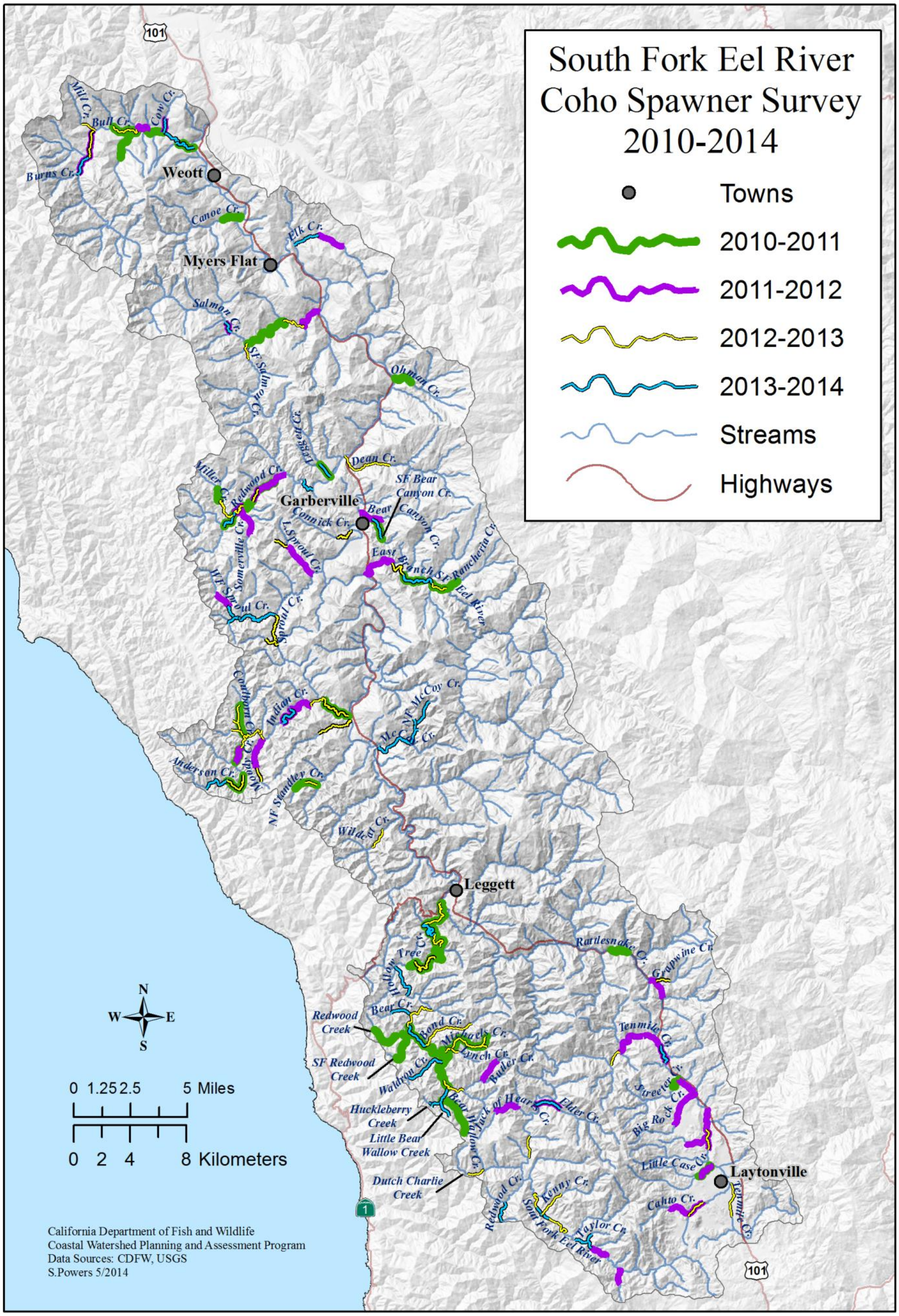



*Figure 33. Location of 2010-2014 CMP spawning reaches in the SF Eel River Basin.*

Chinook salmon and steelhead spawning is extended both spatially and temporally compared to coho salmon. The range of Chinook and steelhead extends further upstream and in more tributaries than coho salmon, and spawning occurs during different peak times and intervals than coho salmon spawning. Therefore, redd abundance estimates for Chinook salmon and steelhead apply only to the time period and physical sampling area used in the study. Redd estimates for Chinook salmon were also not particularly accurate for the first three years (A. Renger, CDFW, personal communication, 2012) due to the following limitations:

- Year 1 (2010-2011) – restricted access from landowners in selected reaches resulted in limited sampling;
- Year 2 (2011-2012) – low flow in tributaries resulted in extensive mainstem and limited tributary spawning;
- Year 3(2012-2013) – heavy rainfall in December, when most spawning occurs, limited spawning surveys (high flow and low visibility in streams).

Population estimates have not yet been developed from redd estimates because there are no redd-to-adult corrections available. These corrections are developed using life cycle monitoring stations, which are established in streams with known coho salmon presence. Essential components of a life cycle monitoring station include the following:

- A counting station for adults (e.g. a weir);
- Adult escapement surveys in areas above the counting station; and
- Outmigrant juvenile trapping using a fyke net, inclined plane, or rotary screw trap.

Counts of adults and outmigrating smolts are recorded, and these counts are used to calibrate spawning ground escapement estimates and freshwater and ocean survival. CDFW submitted a funding request in 2014 to establish a life cycle monitoring station in Sproul Creek in 2015, and information collected at this station will be used to assess the status of SONCC coho salmon in the ESU.

Data will be collected annually as part of the CMP in SF Eel River streams and at the life cycle monitoring station in order to generate more accurate salmonid population estimates, and results will be available in annual CDFW summary reports.

For additional information on the CMP, see Adams et al. (2011) or go to:
http://www.calfish.org/Programs/CaliforniaCoastalMonitoring/tabid/186/Default.aspx/.

# Habitat Overview

## Historic Conditions

Stream surveys were conducted as early 1934 in SF Eel River Eastern Subbasin streams. Beginning in the 1950s, CDFG (now CDFW) used a standard stream survey form to record data, but it was not until the early 1990s that a standard habitat inventory protocol was developed by Flosi et al. (in 1991) and is outlined in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2010). The protocol described specific data parameters, methods of data collection, and training procedures that were designed to reduce potential bias and error while collecting field data at a relatively rapid rate (Albin and Law 2006). The manual has been revised three times since 1991, and the current (4th) edition was published in 2010 and is available at:
http://www.dfg.ca.gov/fish/resources/habitatmanual.asp.

There have been two major flood events in the SF Eel River Basin: December of1955 and December of 1964. The flood crest in 1955 was 43 feet (at Weott) and in 1964 it was 46 feet (at Miranda) (CA State Parks 2012). These historic flood events, combined with land use activities (particularly timber harvest and rural residential development) have modified natural stream channels and conditions throughout the subbasin. The most notable changes have been in stream temperatures, flow regimes, and sediment input rates and volumes. These changes from historic stream conditions have resulted in reduced salmonid habitat quality and quantity.

Stream surveys were completed by CDFW on 49 streams in the Eastern Subbasin (with six reaches surveyed on the mainstem SF Eel River and five reaches surveyed on the East Branch SF Eel River), with 114 site visits documented between 1934 and 1990 (*Table 21*). Most observations in these historic stream surveys are not quantitative and have limited use in comparative analysis with current habitat inventories. However, data from these stream surveys provide a snapshot of conditions, including barriers limiting fish passage at the time of survey. Streams with relatively consistent good habitat ratings were the following: Big Dan, Cedar, Dean, Grapewine, Low Gap, Mill (near Laytonville), Rancheria, Rattlesnake, Streeter, and Tenmile Creeks, and also areas of the East Branch SF Eel River and the upper mainstem SF Eel River near Branscomb.

Historic habitat surveys included comments on possible barriers to fish passage. Log jams were abundant due the input of material from watershed slopes to streams, and gradient barriers including bedrock waterfalls and boulder runs were noted in many surveys. Intensive logging practices, road building, and the naturally fragile landscape resulted in large amounts of sediment and logging debris in Western Subbasin streams, particularly after the major flood events of 1955 and 1964. These land use practices and related input of sediment and woody debris resulted in many log jams inventoried as partial barriers and recommended for modification or removal in the "barrier comments" sections of historic stream surveys. Barrier removal can be problematic in these streams due to the large amount of sediment behind barriers that will move downstream after removal. Historically, this has been an issue in streams with limited spawning habitat; upstream barrier removal may increase movement of fine sediment loads, which further diminish spawning habitat quality and quantity of downstream gravels.

High stream temperatures were noted in the lower mainstem and in the East Branch SF Eel River in 1938. In the East Branch, temperatures above 70˚F were recorded in areas with no streamside cover. In the mainstem, water temperatures between 70 and 77˚F were recorded, and fish were only present in pools with thermal stratification. Steelhead and coho salmon production was highest in headwater areas near Branscomb, where cool air and instream temperatures are a result of shading from afternoon sun by the surrounding terrain, the influence of the coastal marine layer, and good riparian cover.

*Table 21. Habitat observations made in the SF Eel River Eastern Subbasin from 1934-1990.*

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Bear Creek | 8/26/1969 | Stream Survey (CDFG 1969) | Low velocity; lots of silt from logging activities; few, generally small pools (1' deep); good spawning areas near mouth; poor nursery conditions due to lack of water. | Six log jams recommended for removal. |
| | 1/15/1979 | Stream Survey (CDFG 1979) | Sparse canopy (deciduous and evergreen); 2% stream area good for spawning; abundant shelter. | 8' culvert may be complete barrier; recommend removal of 4 log jams |
| Bear Canyon Creek | 4/6/1981 | Stream Survey (CDFG 1981) | Good nursery habitat but poor spawning habitat due to compaction and siltation. | Six possible barriers on Bear Canyon and UT. |
| Big Dan Creek | 11/13/1937 | Fish Stocking Report Observation (CDFG 1937) | Creek runs all summer; spring-fed; well-wooded. | |
| | 8/12/1968 | Stream Survey (CDFG 1968) | Good shelter; few pools in lower section, increasing upstream; spawning areas spotty; only steelhead observed. | One mile up from Hwy 101 - 10' falls; not a total barrier. |
| | 9/11/1972 | Stream Survey (CDFG 1972) | Entire length suitable for fish; cover good; lots of silt in pools, and fines and small gravel in pool tails and low flow areas. | 0.5 - 0.75 miles upstream: 20' falls is complete barrier. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Big Dan Creek (con.) | 7/10/1975 | Stream Survey (BLM 1975) | Survey started 2 miles above confluence with SF Eel River; only resident rainbow trout observed on survey. Good shade, moderate bank erosion. | 20' rock falls downstream from start of survey is total barrier. |
| Cahto Creek | 10/15/1957 | Stream Survey (CDFG 1957) | Many small and large irrigation diversions; pools fairly large and frequent; shelter adequate in well shaded sections; high winter runoff due to extensive logging in headwaters of tributaries. | 40' high earth fill dam on the north fork above the Mast mill. West fork dam bypassed by artificial channel. |
| | 9/15/1969 | Stream Survey (CDFG 1969) | Lower 2 miles flat; vegetation is alder and oak; higher 1 mile is V shaped canyon with Douglas Fir, tan oak, and madrone; fair spawning areas; 3 miles good spawning habitat. Dark brown algal bloom present just above Branscomb road - decreases as gradient and velocity increase upstream. | 3 barriers above Branscomb Road crossing: 6' bedrock falls, 100' slide and logs, and steep gradient area. |
| Cedar Creek | 11/10/1937 | Stream Survey (CDFG 1937) | | |
| | 7/30/1938 | Stream Survey (CDFG 1938) | Good pools and shelter; good spawning areas; abundant fish food. | |
| | 3/5/1940 | Stream Survey (CDFG 1940) | Good pools and shelter; good spawning areas; abundant fish food. | No barriers seen. |
| | 9/3 - 9/4/1941 | Stream Survey (CDFG 1941) | Fair spawning areas; good pools and shelter. Large springs enter Cedar Creek all along upper and middle regions of surveyed section. Creek mouth was divided and spreading over rubble and boulders - recommend digging single channel through to SF Eel River. | |
| | 8/9 - 8/10/1946 | Stream Survey (CDFG 1946) | | |
| | 6/11/1952 | Velocity Data Form (CDFG 1952) | | |
| | 8/11 - 11/13/1960 | Velocity Data Form (CDFG 1960) | | |
| | 8/7 - 8/8/1968 | Stream Survey (CDFG 1968) | NF Cedar Creek and Cedar Creek. Good spawning and nursery areas and numerous small pools (2' deep); good shelter from boulders; good supply of aquatic invertebrates. | Pump 0.25 miles up from Hwy 101 - 4" pipe. Four debris jams but no total barriers. 7' falls 4 miles from mouth in narrow canyon could be a limiting factor. |
| | 9/14 - 9/15/1972 | Stream Survey (CDFG 1972) | Low summer flows; highly variable habitat; lots of erosion from logging filling pools. | Falls in third mile definite barrier at low flows; not at high flows. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Cedar Creek (con.) | 7/30 - 8/13/1975 | Stream Survey (BLM 1975) | Mainstem, tributary, and headwaters surveyed. Three miles of excellent habitat for anadromous fish in mainstem; severe stream bank erosion but little siltation of spawning beds; monitoring of cattle grazing and logging recommended. Very little flow in headwaters. | Remove log jam 0.4 miles above start of headwaters survey. |
| Cummings Creek | 8/21/1968 | Stream Survey (CDFG 1968) | Numerous shallow (1') pools; few deep (2.5') pools; good shade from dense bank growth; fair spawning (good in lower reaches). | 4 light log jams and one 30' falls 1 mile upstream - may be passable in winter. |
| Cummings Creek Tributary | 8/1/1975 | Stream Survey (BLM 1975) | Survey started 1 mile above Hwy 101; small but deep pools; steep (25%) gradient; uninhabitable for residents and anadromous salmonids. | |
| Dean Creek | 8/2/1938 | Stream Survey (CDFG 1938) | Excellent spawning areas; good pools and shelter; abundant fish food; stream dry at mouth. | |
| | 7/3/1962 | Field Note (CDFG 1962) | 80% of stream available for spawning; very little shelter and nursery area; pool riffle ratio 1:4; abundant food. | Roughs approximately 4 miles from mouth is natural barrier. |
| | 1/24/1980 | Stream Survey (CDFG 1980) | Suitable spawning areas continuous throughout survey area; pool riffle ratio 1:2; canopy 20% in lower, 60% in middle, and 75% in upper sections. | |
| East Branch SF Eel River | 4/17/1934 | Stream Survey (CDFG 1934) | Watershed in timber, brush, and patches of open range; many small freshet feeders; temperatures above 70 degrees F in areas with no streamside cover; very good steelhead success. | |
| | 7/31/1938 | Stream Survey (CDFG 1938) | Excellent spawning areas; good pools and shelter; good invertebrate food. | |
| | 7/18 - 8/16/1961 | Watershed description (CDFG 1961) | Stream: Lower 6 miles - good gradient, spawning gravels; pool riffle ratio approximately 1:1. Upstream: boulders, bedrock, large rubble but still limited good spawning areas; pool riffle ratio approximately 4:1. Habitat: very suitable spawning stream; numerous pools, boulders, overhanging banks - excellent shelter; steeper banks, more boulders and pools, and less exposure in upper areas for nursery hab. | 4 log jams (3 ok; one almost a barrier and should be removed); no natural complete barriers. |
| | 9/12/1975 | Stream Survey (BLM 1975) | Severe erosion on slopes. Steep gradient (>30%) prohibits anadromous fish habitation. | |
| East Branch SF Eel River (lower - from Kinsey Ranch downstream) | 9/27/1966 | Stream Survey (CDFG 1966) | Abundant spawning areas; lots of sand in gravels; heavy silt from logging during runoffs. | No barriers. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| East Branch SF Eel River (middle) | 9/29/1966 | Stream Survey (CDFG 1966) | Flows through extremely steep bedrock canyon with coastal forest cover before breaking out near Kinsey Ranch; abundant spawning areas, mostly riffle; poor to fair pool development with shallow pools and little cover; enormous slides depositing large amounts of sand and gravel (streambed filled 20-30 feet); aquatic insects scarce to moderate. | |
| East Branch SF Eel River (upper) | 9/28/1966 | Stream Survey (CDFG 1966) | Abundant spawning areas; pools shallow and lacking shelter; good pool development in upper areas; tremendous erosion and siltation in the past two years from 1964 flood and logging; large, active landslides along banks; streambed filled 20-25 feet during 1964 flood; fair invertebrate food. | No barriers. |
| East Branch SF Eel River (mouth to 10 mi upstream) | 1/1/1977 | Stream Survey (CDFG 1977) | Pool habitat scarce (10-15% habitat) and shallow (<2'); scarce shelter; few inverts; pollution from cattle is minor; winter drought flow conditions. | Partial rock barrier forms narrow chute with 3-4' cascade approximately 0.25 mi downstream from Tom Long Creek. |
| East Branch SF Eel River UT | 9/12/1975 | Stream Survey (BLM 1975) | Intermittent flow first 200 yards; few pools (5% of habitat); steep slopes with little vegetation; highly erosive slopes. | 10' rock falls in upstream reach. |
| Elder Creek | 8/22/1938 | Stream Survey (CDFG 1938) | Good pools and shelter, fair spawning areas. | Entrance to creek at SF Eel River confluence is steep rubble and boulder pitch; impassable to fish except in 4' rise in SF Eel River. Recommend rearranging boulders. |
| | 8/21/1969 | Stream Survey (CDFG 1969) | Excellent shade entire length; abundant pools up to 3-6' deep; excellent shelter (undercut boulders and dense canopy); fair to good spawning areas. | |
| | 8/21/1975 | Stream Survey (BLM 1975) | Absence of spawning material appears to limit trout production; most gravels are deposited between large rocks and are unavailable for spawning; dense shade provided by alder, fir, and bay. | Two falls located 1.7 miles above the confluence with SF Eel River; possible barriers to steelhead. |
| Elk Creek | 8/21/1968 | Stream Survey (CDFG 1968) | Numerous shallow (1.5') pools; few deep (3') pools; fair spawning areas. | 5 log jams. Two miles upstream from mouth, one total barrier: log jam creates 12' falls. Culvert at Hwy 101 may be a barrier. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Elk Creek (con.) | 7/13/1971 | Stream Survey (CDFG 1971) | 60% stream available for steelhead spawning; 40-50% canopy cover; low flow due to log jams; 80% pool habitat from mouth to forks. | Fish ladder at culvert eroding rapidly; probable velocity barrier at high flows. |
| Fish Creek | 7/5/1961 | Field Note (CDFG 1961) | 250 yards of available spawning gravel; existing spawning gravel, shelter, and nursery areas adequate. | 23 log jams surveyed; one total barrier. |
| | 3/19/1980 | Stream Survey (CDFG 1980) | Pool riffle ratio 4:1; average pool depth 1'; 30% canopy. | 10 log jams surveyed; one total barrier. |
| Grapewine Creek | 8/26/1968 | Stream Survey (CDFG 1968) | Good spawning areas; pools generally lacking; good shade. | |
| | 5/26/1976 | Stream Survey (CDFG 1976) | Scattered riparian shrub cover; minimal potential spawning area; good shelter (boulders, log debris, overhanging vegetation); | Illegally constructed dam 0.75 miles upstream from mouth (41' high - total barrier). Bedrock falls on 2 tributaries. |
| | 10/28 - 10/29/1976 | Stream Survey (CDFG 1976) | Good shelter; population estimate from mouth to dam = 3458 steelhead; excellent spawning and rearing habitat for steelhead. | |
| Grizzly Creek | 8/13/1968 | Stream Survey (CDFG 1968) | Stream not usable by migratory fish. Steep gradient, barrier at mouth, and freeway construction. | 25' falls at mouth. |
| | 7/14/1975 | Stream Survey (BLM 1975) | Small flow becomes intermittent upstream; no fish present and little fisheries development potential. | |
| Grub Creek | 9/17/1969 | Stream Survey (CDFG 1969) | Good spawning areas; lower section has many large pools (1' deep); fair shelter. Tributary with good summer flow and substantial fish population. | |
| Horse Pasture Creek | 8/10/1962 | Field Note (CDFG 1962) | Little spawning area; adequate nursery area (shelter and cover); pool riffle ratio 3:2. | |
| Little Cedar Creek | 8/7/1968 | Stream Survey (CDFG 1968) | Fair spawning areas in few sections; good shelter (boulders); resident trout but no migratory fish. | 12' falls at mouth is total barrier. |
| Little Dan Creek | 8/13/1968 | Stream Survey (CDFG 1968) | Not usable habitat for anadromous salmonids. | 30' falls at mouth - complete barrier. |
| | 9/11/1972 | Stream Survey (CDFG 1972) | Intermittent flow; does not support anadromous fish. | 50 yards above confluence with Big Dan Creek, 50-60' falls - complete barrier. |
| | 7/11/1975 | Stream Survey (BLM 1975) | Upstream survey - abundant rubble, actively eroding banks. | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Low Gap Creek | 1/31/1980 | Stream Survey (CDFG 1980) | Spawning areas continuous throughout drainage; canopy 60%; pool riffle ratio 1:2 except at mouth (continuous riffle); aquatic insects plentiful. | North Fork: 40' falls is end of anadromy; South Fork: continuous debris for 2000' is end of anadromy. |
| Mad Creek | 1938 | Supplementary Sheet (CDFG 1938) | | Stream enters Rattlesnake Creek by 75' falls; complete barrier. |
| | 8/19/1968 | Stream Survey (CDFG 1968) | | Creek unusable - 10' falls from culvert under Hwy 101. |
| McCoy Creek | 6/25/1938 | Stream Survey (CDFG 1938) | | |
| | 7/31/1941 | Stream Survey (CDFG 1941) | Very wide basin; divided channel at mouth needs improvement. | |
| | 7/2/1968 | Stream Survey (CDFG 1968) | Good spawning conditions in tributaries; fair nursery conditions; limited pools and shelter. | |
| | 9/11/1975 | Stream Survey (BLM 1975) | Small, shallow pools; very shallow riffles; low summer flows; logging operations may create serious erosion problems in the future. | |
| Milk Ranch Creek | 8/11/1938 | Stream Survey (CDFG 1938) | Good spawning areas, pools, and shelter; adequate food; abundant steelhead and coho salmon. | Log jam 100' above mouth. |
| | 7/18/1961 | Field Note (CDFG 1961) | Spawning areas limited to lower portion of stream; no canopy cover; shelter and nursery area fair; flow subsurface at mouth and 650 yards upstream during low flow times. | 13 log jams; steep gradient 0.5 miles upstream is complete barrier. |
| | 6/23/1980 | Stream Survey (CDFG 1980) | Spawning habitat not abundant; pool riffle ratio 2:1; average pool depth 3'; canopy averaged 10%; gradient 3% in lower reaches, increasing to 20%; gravel deposit 100' wide at mouth but stream was flowing at time of survey. | |
| Mill Creek (Laytonville) | 9/11/1969 | Stream Survey (CDFG 1969) | Good spawning areas entire length; good abundance of pools (1' deep); excellent shelter from undercut rocks; thick canopy cover. | 16 log jams; one large jam 2.5 miles upstream. One 4' manmade dam at mile 0.25 and one under construction at mile 2. |
| | 7/18/1975 | Stream Survey (BLM 1975) | Survey area: 2 miles N of Cahto Reservoir to Mill Creek road crossing (8 sections). Good pool formation; good spawning gravels upstream, becoming marginal downstream; numerous diversions drawing water to residences on both sides of stream. | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Misery Creek | 8/6/1975 | Stream Survey (BLM 1975) | Large amounts of high quality spawning gravel; good escape cover and ample summer flows; bank erosion in lower reaches; streams run dry 100 yards above 6' falls at confluence of forks; lower portions generally good steelhead spawning habitat. | Several log jams block fish migration into upper reaches. |
| Mud Creek | 7/20/1954 | Field Note (CDFG 1954) | Several natural mud springs approximately 2.5 miles above mouth are constantly erupting mud that flows into the stream, causing muddy condition. | |
| | 8/13/1969 | Stream Survey (CDFG 1969) | Spawning areas fair to good; most substrate too large for spawning, but pockets of good gravel exist; excellent pool structure and abundance; average pool depth 2'; good shelter and canopy (alders); visibility below springs is 1-2 inches, clear above. | 13 log jams (2 heavy); no total barriers. |
| | 7/17/1975 | Stream Survey (BLM 1975) | Heavy siltation from mud springs destroys much valuable fish habitat; high productivity in higher reaches; moderate erosion from logging and fires. | |
| | 2/3/1976 | Field Note (CDFG 1976) | Mud from springs still erupting and flowing into creek; discoloration in SF Eel River for many miles. | |
| Paralyze Canyon Creek | 8/21/1975 | Stream Survey (BLM 1975) | Low flow, shortage of deep pools, and lack of spawning areas make this stream uninhabitable for trout and salmon. | |
| Rancheria Creek | 2/19/1939 | Stream Survey (CDFG 1939) | Good pools, shelter, and invertebrate food; abundant juvenile steelhead. | |
| | 1961 | Field Note (CDFG 1962) | Good spawning habitat, shelter, and nursery habitats; little canopy; tremendous # of salmonids 1-8" in size. | Steep roughs area 1.5 miles from mouth is total barrier. |
| | 9/29/1966 | Stream Survey (CDFG 1966) | Adequate spawning areas; flows, shade, shelter, food, and temperature satisfactory; relatively large number of fish supported by short section of stream. | 75' high jumble of boulders is limit of anadromy. |
| Rattlesnake Creek | 4/24/1939 | Stream Survey (CDFG 1939) | | Number of small falls and abrupt, steep cascades impassable to adult salmonids; 3' concrete dam 500' below Farm House Inn impassable to small fish except at high water. |
| | 8/15 - 8/27/1968 | Stream Survey (CDFG 1968) | Generally good spawning areas with occasional excellent conditions; numerous 2-5' deep pools; good shelter and riparian vegetation/shade; good flow (3 cfs at mouth) decreasing to 0.5 cfs in headwaters. | Small crossing with culvert at mouth could wash out during the winter; culvert blocked by wire mesh covering. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Rattlesnake Creek (con.) | 7/25/1975 | Stream Survey (BLM 1975) | Good trout habitat; probable competition for food from western roach; marginal spawning habitat for salmon and steelhead. | 12' rock falls between subsections 2 and 3 - upper barrier to fish. |
| Ray's Creek | 2/19/1939 | Stream Survey (CDFG 1939) | Good spawning areas, pools and shelter; adequate invertebrate food. | Falls 4' high 300 yards below station. |
| | 7/17/1961 | Field Note (CDFG 1961) | Stream of no value to fish life. | Large falls, solid bedrock, and few pools near mouth make stream unavailable to salmonids. Three falls ranging from 10-40' high near mouth. |
| | 9/29/1966 | Stream Survey (CDFG 1966) | Extremely steep terrain, much of it bedrock; dense shade from canyon walls; very small areas accessible to salmonids; limited spawning areas and invertebrate food but adequate for few fish using stream; several good pools with adequate shelter. | 15' falls 700 feet above mouth is end of anadromy. |
| Red Mountain Creek | 11/10 - 11/13/1937 | Stream Survey (CDFG 1937) | Limited visibility from muddy water - source tributary above Red Mountain Auto Camp; dam with fishway above camp. | |
| | 6/25/1938 | Stream Survey (CDFG 1938) | Good spawning areas, pools, shelter, and fish food; sparse aquatic vegetation; good flow (10 cfs). | |
| | 7/30/1938 | Stream Survey (CDFG 1938) | Good spawning areas, pools, shelter, and fish food; water temp 71 degrees F. | |
| | 3/20/1967 | Stream Survey (CDFG 1967) | 80% of lower 3/4 of stream and 10% of headwaters is suitable for spawning; pool riffle ratio 1:10 in mid to lower reaches and 5:1 in headwaters; limited nursery areas and shelter; 95% of once-mature stands of alder along stream banks are dead; logging debris removal and soil stabilization needed in tributaries. | |
| | 6/16/1968 | Stream Survey (CDFG 1968) | Good spawning and nursery conditions with water maintaining good flow; pools small (less than 2' deep); extreme lack of shelter; upper tributaries littered badly by road construction; steep gradient in upper regions is problem for fish. | 2 manmade gravel dams: 0.75 miles and 2 miles from mouth; both form ponds. Log jams but no total barriers. |
| Rock Creek | 7/29/1938 | Stream Survey (CDFG 1938) | Fair spawning areas; good pools and shelter; abundant fish food. | |
| | 7/19/1968 | Stream Survey (CDFG 1968) | Very limited spawning areas; few pools in lower section (2' deep); number of pools increased and depth decreased in upstream areas; steelhead present but very limited. | Only barrier is steep gradient (400' per mile). |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Rock Creek (con.) | 8/7/1969 | Stream Survey (CDFG 1969) | Fair to good spawning areas; substrate material becomes larger further upstream; bedrock abundant throughout survey length; abundant pools (average depth 1.5') with excellent shelter; subsurface flow at mouth. | 11 log jams recorded; 2 miles up, gradient is barrier. |
| | 1/22/1979 | Stream Survey (CDFG 1979) | Pockets of spawning area; pools average 1.5' deep; abundant shelter from boulders and logs. | Series of falls at 2.5 miles is total barrier; smaller cascades downstream not total barriers but modification recommended. |
| | 3/8/1979 | Stream Survey (CDFG 1979) | Suitable spawning gravel in pockets in lower areas, decreasing to 3% of habitat in upper areas; pool depth averaged 3' in lower third and 1' in middle and upper thirds of survey; dense canopy; abundant shelter in side pools and near large rocks. | Boulder run 2 miles from mouth appears to be total barrier; another series of falls 2.5 miles from mouth is permanent total barrier. |
| Rocky (Rock) Glen Creek | 6/20-6/21/1961 | Field Note (CDFG 1961) | Pool riffle ratio 40:60; only about 100 yards available spawning habitat. | Three natural barriers - one total and two possible barriers. Total barrier 500' upstream from mouth. |
| | 4/8/1981 | Stream Survey (CDFG 1981) | Stream channel diverted into ponds near mouth, but ponds dry up and fish die. | Metal culverts 100' and 250' above mouth are complete barriers. |
| SF Eel River | 6/8, 8/15-8/17, 8/25-8/26, 9/2-9/3, 10/21/1959 | Stream Surveys (CDFG 1959) | Multiple survey locations from confluence to headwaters; high water temperatures may be limiting factor; salmonids seeking cooler water throughout survey locations (water temps 70-77 degrees F in many areas); very few fish in large pools; fish present only in pools with thermal stratification; steelhead and coho production greatest near Branscomb (good cover and cooler water); | |
| SF Eel River - near Branscomb | 12/15/1988; 1/18/1989 | Field note - carcass surveys (CDFG 1988, 1989) | Typically good; abundant spawning gravels, pools, and canopy. Woody materials lacking. Chinook and coho salmon. | |
| SF Eel River (100' above Cedar Creek) | 9/4/1941 | Stream Survey (CDFG 1941) | Good spawning areas, good pools and shelter. | |
| SF Eel River (Hollow Tree Creek bridge) | 5/22/1940 | Stream Survey (CDFG 1940) | Good spawning areas, excellent pools and shelter. | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| SF Eel River (rock shop to Mud Creek) | 1/7/1988 | Field note - carcass survey (CDFG 1988) | Abundant canopy; pool riffle ratio typically good, but long riffle stretches. Woody materials lacking. Spawning gravel fair to good - lots of fine sediment. | Several debris piles should be re-evaluated. |
| SF Eel River (mouth of Piercy Creek) | 6/25/1938 | Stream Survey (CDFG 1938) | Water temperatures too high for stocking steelhead. | Concrete dam at Reynolds Redwoods between McCoy and Red Mountain Creeks not a barrier. |
| SF Eel River (Rattlesnake Creek) | 6/26/1938 | Stream Survey (CDFG 1938) | Excellent pools and shelter; good invertebrates; fish stranded in isolated pools and small streams. | |
| SF Eel River UT (Fox Creek) | 8/22/1938 | Stream Survey (CDFG 1938) | | 2 low water barriers - one at 520 yards above mouth and one 660 yards above mouth. Temporary rubble and boulder dam; intermittent flow between barriers. |
| SF Eel River UT (Little Rock Creek) | 8/27/1969 | Stream Survey (CDFG 1969) | Few, small pools (8" deep); little canopy or cover; fair to poor spawning habitat. | Steep gradient 0.5 miles upstream is fish passage barrier. |
| SF Eel River UT (Windem Creek) | 8/28/1969 | Stream Survey (CDFG 1969) | Fair spawning areas; pools are totally lacking in this tributary; cover fair but extensive sections with no cover or shelter. Steelhead and coho YOY in fair numbers. | 8 log jams (2 moderate sized) but none are total barriers; steep gradient in upper mile of creek is barrier to fish migration. |
| Squaw Creek | 6/20/1938 | Stream Survey (CDFG 1938) | Good spawning areas. | |
| | circa 1962 | Field Note (CDFG 1962) | 3 miles of stream flows year round; 2 miles dry during summer months. Spawning habitat in lower 1.5 miles of stream (logging road destroyed lower mile); nursery habitat abundant. | One log jam (not a barrier); series of large boulders 1.5 miles upstream of mouth is barrier - no water above. |
| | 10/26/1981 | Stream Survey (CDFG 1981) | Extremely unstable banks; high gradient (12-18%); 5% canopy first 0.5 mile, then no shade; no pools for first 3700 feet, then pool riffle ratio 1:10; shallow pools (6" deep); spawning gravel in first 0.5 mile only. | 4 barriers (boulders and falls) documented. |
| Streeter Creek | 9/4/1969 | Stream Survey (CDFG 1969) | Good spawning areas, with sections of excellent habitat; few scattered pools in lower 1 1/3 miles (1.5' deep); pools more numerous in upper areas but shallower (0.75' deep); excellent nursery areas; good summer flow except for upper 0.5 mile. | 14 listed problem areas - most are light to moderate; heavy log jam with 12' fill at mile 1.25. |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Taylor Creek | 8/25/1969 | Stream Survey (CDFG 1969) | Fair spawning areas; few, small pools (8" deep); good shelter from canopy and undercut rocks; nursery conditions unfavorable due to limited flow. | 11 log jams recorded; main barrier to fish passage is steep gradient near headwaters. |
| | 9/2/1969 | Stream Survey (CDFG 1969) | No potential spawning areas observed; pools averaged 2.5 inches deep; suitable nursery areas; abundant aquatic food supply. | Numerous log jams; removal would increase area accessible to steelhead 0.25 miles currently occupied). |
| | 1/16/1979 | Stream Survey (CDFG 1979) | Very limited spawning areas; average pool depth 6"; very limited shelter; intermittent flow; little fish production potential. | 3' culvert at road crossing, 2' culvert at skid road crossing, and one diversion 0.25 miles from mouth with 1" pipe (tarp controlling diversion total block to fish). |
| Tenmile Creek | 6/9/1938 and 5/23/1940 | Stream Survey (CDFG 1938) | Excellent spawning areas, semi-exposed shading/canopy cover; fair pools and shelter. | |
| Tenmile Creek UT | 8/22/1975 | Stream Survey (BLM 1975) | Very steep (35%) gradient; numerous falls and cascades block fish passage; little vegetation on canyon walls. | Moderate erosion has caused log and rock rubble to block the stream in several places |
| Tom Long Creek | 8/13/1975 | Stream Survey (BLM 1975) | Very low flow; small pools with no fish in lower areas; pool depth and frequency increase in upstream areas; tributary dry 50 yards from confluence; moderate bank erosion but some good spawning habitat. | Removal of log jam east of tributary entrance would open up 33 square yards of spawning gravel on public land and two miles of stream habitat on private land. |
| | 10/20 - 10/22/1981 | Stream Survey (CDFG 1981) | Mainstem: 3 falls (first two not barriers); 1500' above mouth is 15' falls with log and boulder jam - probable barrier; non-existent shade canopy; steep, unstable banks. North Fork: 50% canopy; few pools; no suitable spawning and rearing habitat approximately 2000 feet from confluence. South Fork: no shade canopy; flow goes subsurface approximately 3000 feet from confluence with mainstem. | |

| Stream | Date Surveyed | Source | Habitat Comments | Barrier Comments |
|---|---|---|---|---|
| Tuttle Creek | 7/6/1961 | Stream Survey (CDFG 1961) | Pool riffle ratio 40:60; not feasible to complete restoration at Hwy 101 culvert due to lack of spawning and rearing habitat upstream. | 60 yards above mouth is Hwy 101 culvert; 25' sheer drop is total barrier to anadromous fish. About 60 yards above Hwy 101 is natural barrier (gradient and large boulders). |
| Twin Rocks Creek | 11/4/1968 | Stream Survey (CDFG 1968) | Good to fair spawning areas; numerous pools 1' deep, few 3' deep; good undercut banks and rocks; good riparian shade. | 2 very light log jams; 2 miles upstream, 40' falls on SF limits passage and gradient on NF limits passage. |
| Williams Creek | 7/6/1961 | Field Note (CDFG 1961) | Salmonid habitat only extends approximately 250' upstream from mouth.  Average stream depth 1.5 inches. | Culvert at Hwy 101; increased gradient and roughness are natural barrier 150' upstream of culvert. |

## Current Conditions

Nineteen habitat inventories were conducted by CDFW on ten creeks in the SF Eel River Eastern Subbasin between 1990 and 2010 (*Table 22*). Survey lengths ranged from 18.71 miles (Tenmile Creek 2009) to 0.3 miles (SF Bear Canyon Creek 1992).  Survey data were divided into two sampling periods (1990-1999 and 2000-2010) in order to assess changes in habitat factors and suitability of habitat for salmonids over time.

The number of reaches and the total stream length surveyed varied by stream.  Habitat typing surveys describe specific stream reaches by Rosgen channel type (see Channel Types section of this report) and sequence.  Reaches show characteristics of certain channel types for a minimum distance of 20 bankfull channel widths (Flosi et al. 2010), but are highly variable in overall length.

Some streams were surveyed in multiple years within each sampling period, and if the surveys covered the same area of stream, only the most recent survey information (from 10 streams) was used in the EMDS-based analysis.  Only habitat typing surveys completed on perennial streams were used in the analyses.  However, some perennial streams contain dry reaches during certain times of the year (usually in late summer) due to variation in annual precipitation, natural aquifer levels, and magnitude of diversion.  These dry reaches were categorized as Type 7 (Flosi et al. 2010) in habitat typing reports.

Streams that were surveyed during both time periods were often completed at different times of the year (e.g. Tenmile Creek was surveyed in September-October in 1996 but in June-July in 2009).  CDFW crews completed most surveys in July, but dates ranged from June to October (*Table 22*). Environmental conditions vary by month and year, and may influence habitat suitability values.  For example, flow is reduced between mid-July and early- to mid-September in streams throughout the Eastern Subbasin (due to limited rainfall, evapotranspiration by plants, groundwater levels, and the number and magnitude of diversions), so primary pool values and corresponding scores would most likely be lower in creeks where sampling was completed during this time interval.  Variability in rainfall received during wet and dry years may also influence flow, and therefore habitat factors and suitability values.  According to records from the USGS gauge at Leggett (RM 66), which is located within the Eastern Subbasin boundary, annual flow was very high in 1998 and 2006, and very low in 1991 and 2001 (*Figure 6*).

*Table 22. Summary of CDFW habitat inventories used in analysis for streams in the SF Eel River Eastern Subbasin, and associated target value. Averages are weighted by stream length surveyed.*

| Stream | Survey Date | Survey length (miles) | Mean Canopy Density (%) | Category 1 Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|---|
| **TARGET VALUES** | | | **>80** | **>50** | **>40** | **>100** |
| Bear Canyon Creek | June 1999 | 1.40 | 86.0 | 18.7 | 37.9 | 50.54 |
| | June 2009 | 1.44 | 86.3 | 11.0 | 27.8 | 47.4 |
| Bear Canyon Creek (SF) | June 1992 | 0.30 | 87.1 | 0 | 19.1 | 25.5 |
| | June 2009 | 0.81 | 87.6 | 41.0 | 0.7 | 19.1 |
| Big Rock Creek | July-August 1994 | 3.95 | 80.3 | 4.4 | 27.0 | 36.0 |
| | July 2009 | 3.98 | 76.7 | 36.2 | 17.3 | 27.4 |
| Cahto Creek | July 1996 | 3.97 | 83.7 | 9.0 | 44.6 | 59.4 |
| | July 2009 | 3.06 | 85.8 | 11.8 | 7.1 | 25.7 |
| Kenny Creek | July 1996 | 3.65 | 96.9 | 0 | 30.1 | 40.1 |
| | October 2005 | 2.57 | 95.5 | 2.6 | 11.6 | 15.9 |
| McCoy Creek | July 1995 | 4.19 | 88.4 | 24.1 | 48.3 | 64.4 |
| | October 2007 | 4.60 | 81.2 | 42.8 | 0.4 | 44.8 |
| Milk Ranch Creek | July 1993 | 0.80 | 40.5 | 0 | 23.2 | 30.9 |
| | July 2007 | 1.51 | 78.5 | 17.4 | 4.2 | 17.5 |
| Mud Creek (SF Eel) | August-September 1995 | 1.45 | 38.1 | 0 | 27.0 | 36.0 |
| | August 2007 | 4.25 | 88.8 | 7.3 | 6.3 | 22.3 |
| Streeter Creek | July 2009 | 0.92 | 75.8 | 58.0 | 18.5 | 32.0 |
| Tenmile Creek | September-October 1996 | 15.76 | 26.3 | 12.2 | 63.6 | 95.2 |
| | June-July 2009 | 18.71 | 51.7 | 19.7 | 38.3 | 22.0 |
| **SUBBASIN AVERAGES** | 1990-1999 | | 57.0 | 10.5 | 42.2 | 69.1 |
| | 2000-2010 | | 68.7 | 28.5 | 14.78 | 27.0 |

CWPAP staff evaluated habitat typing data using an analysis based on the Ecological Management Decision Support (EMDS) model used in previous CWPAP Watershed Assessments. Rating scores were developed from habitat typing data summarized in *Table 22* and were used in the analysis to evaluate stream reach conditions for salmonids based on water temperature, riparian vegetation, stream flow, and in channel characteristics. Additional analysis details can be found in the Analysis Appendix and in the NCWAP Methods Manual, available at: http://coastalwatersheds.ca.gov/. Calculations and conclusions in the analysis are pertinent to surveyed streams and are based on conditions existing at the time of each survey.

Surveys completed on the same stream during both time periods may also show differences in habitat values because of changing land use practices. For example, in Cahto Creek, there has been a dramatic increase in the number and magnitude of marijuana cultivation operations in the past decade (see the Industrial Marijuana Agriculture section of this report). Increased diversions from these operations have resulted in lower flows and reduced pool depth suitability in this watershed.

Observer variability and error during habitat typing surveys may also account for changes in habitat variables over time but error and bias can be minimized through use of standards and training. Well-designed sampling schemes, comprehensive observer training, and the use of established operating protocols (e.g. the *California Salmonid Stream Habitat Restoration Manual)* will result in monitoring that effectively detects changing stream conditions (Roper et al. 2002). Because of observer and other error sources, habitat typing is best suited to detecting fundamental changes in Level I or II habitat types (Gerstein 2005), and to identify potential limiting factors for salmonids in specific watersheds for assessment purposes.

Nearly all streams were surveyed in multiple years; only Streeter Creek was surveyed in one time period. Summary values of each factor and the associated target values for these attributes are listed in *Table 22*. Average canopy density, embeddedness, and pool shelter ratings for all streams in the subbasin were below target values established by Flosi et al. (2010) during each time period. Average length of primary pools for all Eastern Subbasin streams slightly exceeded the target value of 40% in the 1990s (42.2%), but decreased to well below the target value in the 2000-2010 sampling period (16.0%). The importance of each habitat factor to salmonids, and their effect on habitat suitability will be discussed in detail in the individual factor sections of this subbasin report.

## Overall Habitat Suitability

Four factors (canopy density, pool depth, pool shelter complexity, and substrate embeddedness) were used in the EMDS-based analysis to determine overall habitat suitability using habitat typing data collected from two separate time periods: 1990 to 1999, and 2000 to 2010. Suitability scores were calculated by assessing how measured values compared to target values for each factor. Overall habitat suitability and suitability of each factor used in the analysis were calculated based on a weighted (by reach or stream length surveyed) average for Eastern Subbasin streams in each time period, and the change in suitability values between time periods was compared for streams and for individual reaches.

Suitability scores ranged between +1 and -1, and were divided into four categories:

- 1.00 - 0.50 (high suitability);
- 0.49 - 0;
- -0.01 - -0.49; and
- -0.50 - -1.00 (low suitability).

Scores were weighted by survey length, to facilitate comparison of habitats between different tributaries based on sampling effort. For a detailed discussion of the analysis framework and calculation of suitability scores, see the Analysis Appendix.

Overall suitability decreased in Eastern Subbasin streams between the 1990s and early 2000s, and were in the lowest suitability category (-0.5 - -1.0) during both sampling periods (*Table 23*). Reduced suitability in the Eastern Subbasin is primarily due to a decrease in pool shelter complexity scores between the two sampling periods, which resulted in low pool quality scores. Canopy density scores were higher than any other factor scores used in the analysis. In the analysis, canopy density (riparian vegetation score) is evaluated with an "in channel score" (a combination of pool depth, pool complexity, and substrate embeddedness factors), at the final decision node where the lower of the two scores is used to indicate the potential of the stream reach to sustain salmonid populations (see Analysis Appendix). In Eastern Subbasin streams, in channel scores were almost always lower than canopy density scores, therefore, canopy density scores were often not used as the final indicator of a stream's potential to support salmonids. Average canopy density scores were lower for data collected in the 1990s than in the 2000s, but were only lower than in channel scores three times using data collected during the 1990s and only once when using data collected between 2000 and 2010. Tenmile Creek had canopy density scores of -1 during both time periods.

*Table 23. Overall suitability and suitability by factor in SF Eel River Eastern Subbasin streams during two sampling periods: 1990-1999 and 2000-2010.*

| Sampling period | Stream miles surveyed | Overall habitat suitability score | Canopy density suitability score | Pool depth suitability score | Pool shelter suitability score | Pool quality score | Embeddedness suitability score |
|---|---|---|---|---|---|---|---|
| 1990-1999 | 35.46 | -0.56 | -0.05 | 0.52 | 0.12 | 0.16 | -0.53 |
| 2000-2010 | 41.85 | -0.71 | 0.09 | -0.58 | -0.90 | -0.76 | 0.03 |

Canopy density was generally good, except in Milk Ranch and Mud creeks in the 1990s, and in Tenmile Creek in the 1990s and early 2000s. Embeddedness was below the target value of 50% (category 1) in all but Streeter Creek. The length of primary pool habitat was generally below the target value of 40%, and pool shelter rating was below the target value in all streams during all survey years.

The influence of each factor on overall suitability and changes in specific factor scores will be discussed further in the individual factor sections of this report.

Nearly all Eastern Subbasin streams were sampled in both time periods, however the same reaches were not always sampled (e.g. Kenny Creek). Suitability in Bear Canyon, McCoy, Cahto, and Kenney Creeks decreased over time (*Figure 35*). This is due primarily to a decrease in primary pool habitat in all four creeks, accompanied by decreases in pool shelter ratings between the two time periods.

Reduced habitat suitability in Bear Canyon Creek is due numerous large landslides, five of which are described in the habitat typing report (CDFG 2009). One landslide, which is located approximately 0.3 miles upstream from the confluence of the SF Eel River, partially blocked the creek with LWD and sediment, and was a source of fine and coarse sediment input in winter 2013 (*Figure 34*).

Suitability in Bear Canyon Creek may also have decreased between the two time periods because of increased urbanization and increased marijuana cultivation activities. This small watershed is located directly to the north of the town of Garberville, and runoff from urban areas, along with pollution and illegal diversion are particularly problematic in the lower reaches of the creek.

*Figure 34. Landslide debris in Bear Canyon Creek.*

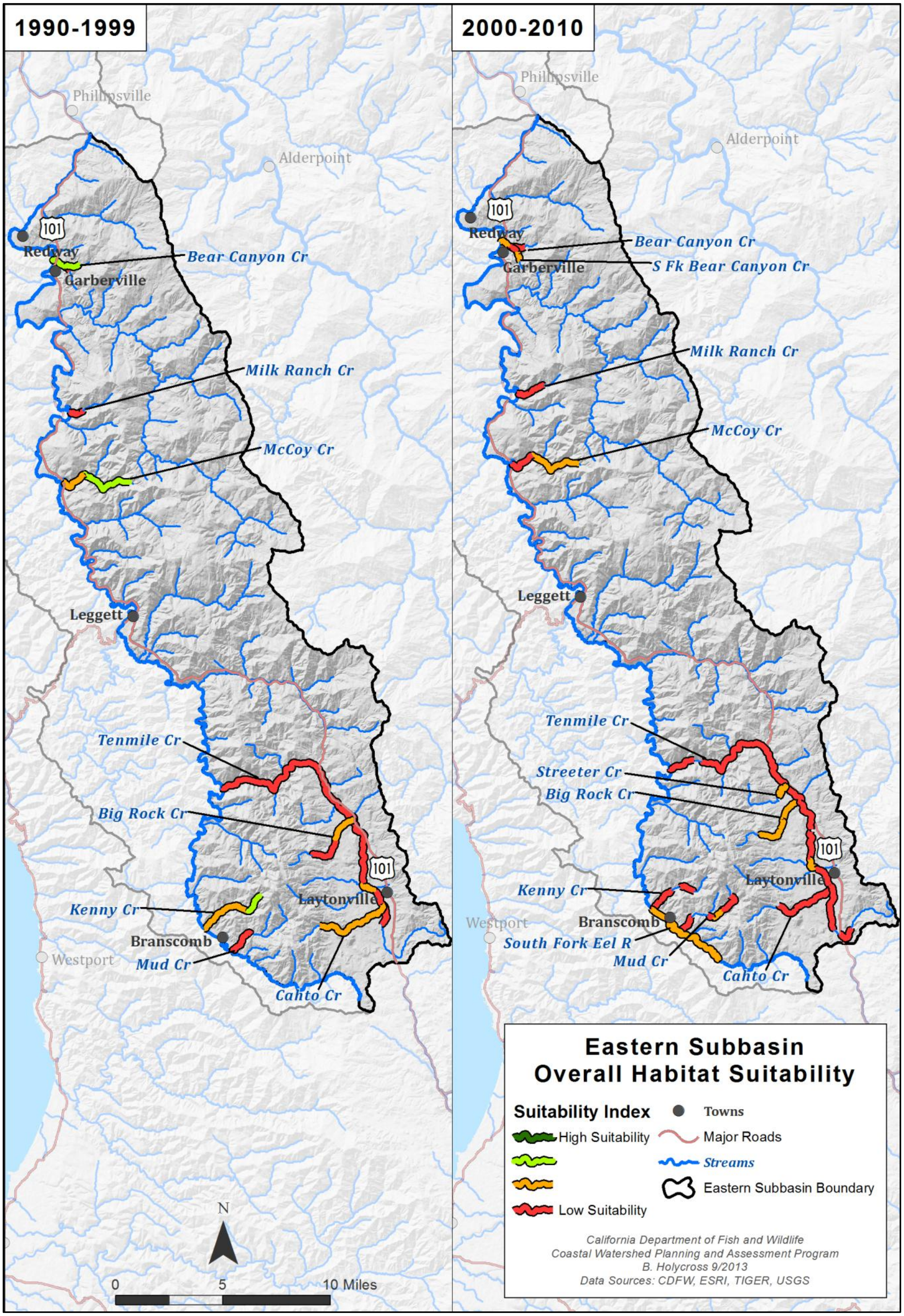



*Figure 35. Overall habitat suitability in SF Eel River Eastern Subbasin streams in two sampling periods: 1990-1999 and 2000-2010.*

## Canopy Density

Canopy density is one of the measurements estimated during CDFW habitat surveys. These measurements, which are defined as a percentage of shade canopy over the stream, provide an indication of potential recruitment of organic debris to the stream channel, are considered beneficial to macroinvertebrate populations, and are a measure of the insulating capacity of the stream and riparian areas during the 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. 2010). The CDFW recommends areas with less than 80% shade canopy as candidates for riparian improvement efforts.

Canopy density was generally best in the southwestern areas of the Eastern Subbasin, decreasing to the north and east, where vegetation on surrounding hillsides is dominated by grassland and shrub vegetation and riparian areas are less well developed (Figure 36).

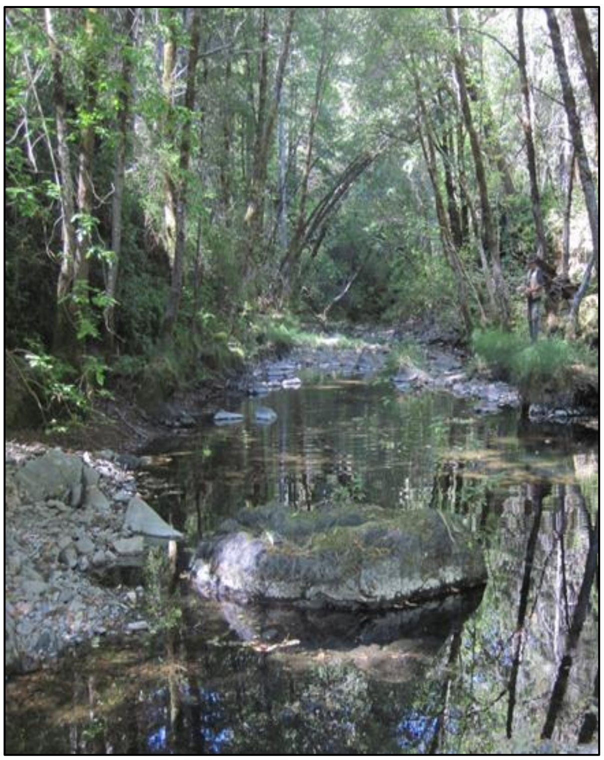
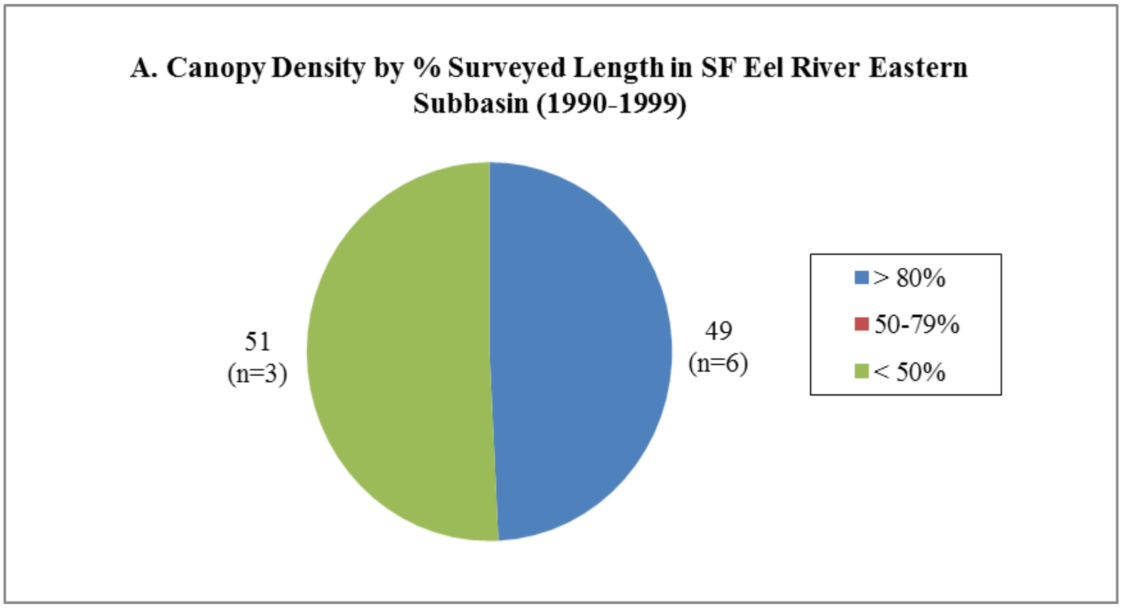


*Figure 36. Examples of streams with high canopy density (left, in the western part of the subbasin in the SF Eel River headwaters near Branscomb), and low canopy density (right, in the northeastern part of the subbasin in Dean Creek).*

Although sample sizes were small, canopy density was good in many Eastern Subbasin streams, with the percentage of surveyed stream length in the lowest category (<50%) decreasing over time from 51% to 40% of habitat surveyed (*Figure 37A*, *B*). The percentage of surveyed stream length that met target values of 80% also decreased between the 1990s and early 2000s, and the percent of habitat with 50-79% of canopy coverage increased from 0% to 20%. All surveyed habitat with less than 50% canopy cover in the 2000s (and most of the habitat in this lowest category in the 1990s), was located in Tenmile Creek. This tributary is a low gradient, wide channel, especially in the headwaters near Laytonville (Figure 38) where the stream flows mainly through areas of grassland and shrub vegetation. Most hillsides have increased solar exposure in the afternoons due to aspect, and higher air temperatures due to a lack of coastal marine layer influence than streams in other SF Eel River subbasins.



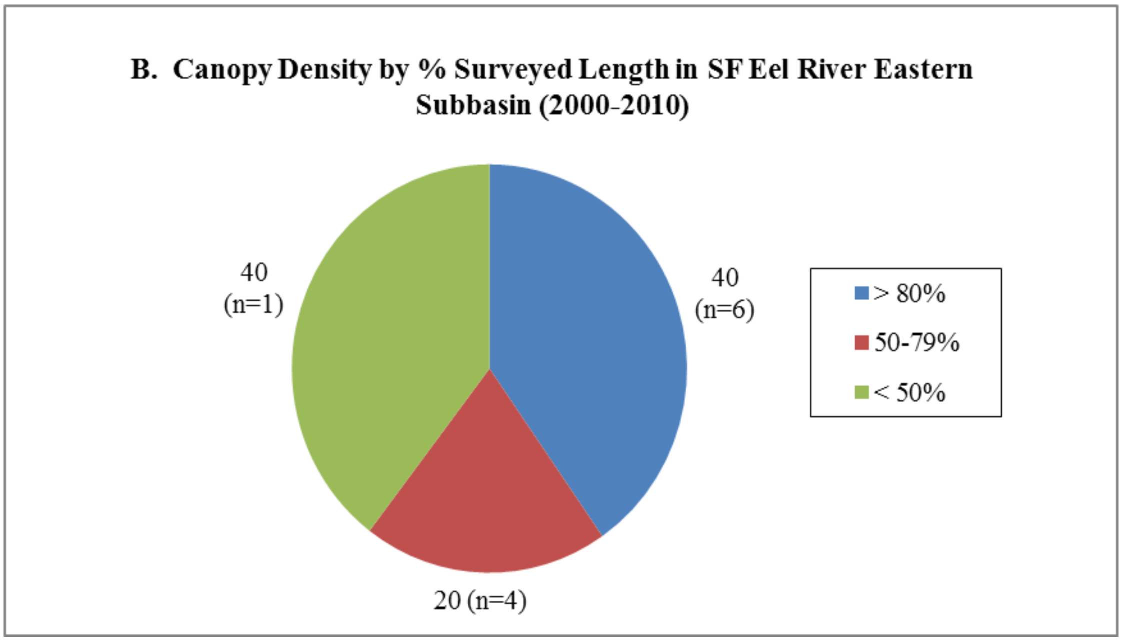




*Figure 37A,B. Canopy Density in the Eastern Subbasin, using data collected from 1990-1999 (A) and 2000-2010 (B); n = number of streams surveyed.*

*Figure 38. Tenmile Creek near Laytonville, showing wide channel with poorly developed riparian habitat.*

Canopy density suitability scores increased in some Eastern Subbasin streams between the two sampling periods, (*Figure 39*) but were still lower than those in the Northern and Western subbasins. From surveys completed between 1990 and 1999, the average canopy score for Eastern Subbasin streams was -0.05 (*Table 23*). During this sampling period, canopy density was in the lowest suitability category in Mud Creek, McCoy Creek, and most reaches surveyed in Tenmile Creek (from the confluence with Mud Springs Creek downstream to the confluence with the SF Eel River) (*Figure 39*).

From surveys completed between 2000 and 2010, the average canopy suitablility score for all streams increased slightly to 0.09. During this time period, canopy densities were in the lowest suitability category only in Tenmile Creek (from the confluence with the SF Eel River upstream to Wilson Creek, and from the confluence of Cahto Creek to approximately 4 miles upstream).

Canopy density scores increased over time in Milk Ranch Creek, the lower reach of Mud Creek, and the middle reaches of Tenmile Creek (northwest of Laytonville). Canopy density decreased over time in the lower reaches of Big Rock and Cahto Creeks, and in Tenmile Creek above Laytonville (*Figure 39*).

Riparian habitat improved over time in areas of Tenmile Creek due to riparian habitat improvement projects that have been completed since the mid-1990s. Most of these projects were done by Bioengineering Associates, and will be discussed further in the Restoration Projects section of this report.

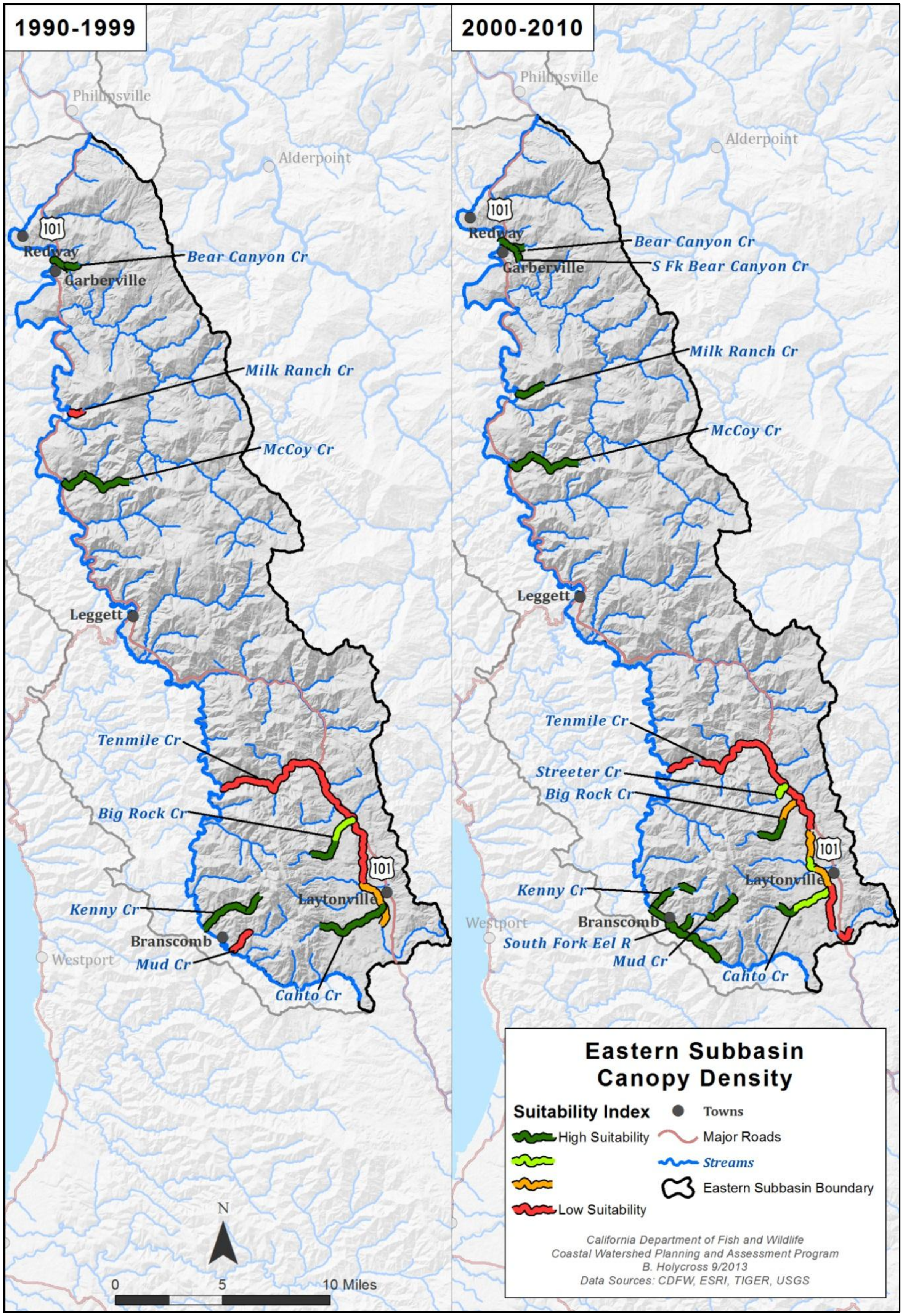



*Figure 39. Canopy density suitability for Eastern Subbasin tributaries during two sampling periods: 1990-1999 and 2000-2010.*

In addition to overall canopy density, it is important to consider the contribution of coniferous and deciduous components in the canopy. Dense deciduous riparian vegetation such as alder and maple trees provide excellent canopy closure, but do not provide the LWD recruitment potential of larger, more persistent coniferous trees (Everest and Reeves 2006). In the Eastern Subbasin, the percent contribution of canopy density from coniferous and deciduous trees was estimated visually during habitat typing surveys.

Coniferous canopy was very low (<25%) in most Eastern Subbasin streams during both sampling periods, and the percent coniferous canopy decreased over time in Bear Canyon, Cahto, and McCoy creeks (*Table 24*). Percent coniferous and deciduous vegetation increased over time in Milk Ranch, Mud, SF Bear Canyon, and Tenmile creeks. Slight increases in coniferous and deciduous canopy in Tenmile Creek are a result of restoration projects targeting riparian habitat improvement, which have been completed in almost all reaches, from the confluence with the SF Eel River to its headwaters above Laytonville.

*Table 24. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Eastern Subbasin.*

| STREAM | AVG%CONIFEROUS | AVG%DECIDUOUS | AVG%OPEN |
|---|---|---|---|
| Bear Canyon Creek 99 | 7.4 | 78.6 | 14.0 |
| Bear Canyon Creek 09 | 5.3 | 81.0 | 13.7 |
| Big Rock Creek 94 | 9.4 | 70.9 | 19.7 |
| Big Rock Creek 09 | 10.6 | 66.1 | 23.3 |
| Cahto Creek 96 | 3.3 | 80.4 | 16.3 |
| Cahto Creek 09 | 2.1 | 72.5 | 25.4 |
| Kenny Creek 96 | 11.0 | 85.9 | 3.1 |
| Kenny Creek 05 | 12.9 | 82.6 | 4.5 |
| McCoy Creek 95 | 24.9 | 63.5 | 11.6 |
| McCoy Creek 07 | 18.7 | 62.5 | 18.8 |
| Milk Ranch Creek 93 | 3.6 | 36.9 | 59.5 |
| Milk Ranch Creek 07 | 10.6 | 67.8 | 21.6 |
| Mud Creek 95 | 3.9 | 34.2 | 61.9 |
| Mud Creek 07 | 17.1 | 71.7 | 11.2 |
| South Fork Bear Canyon Creek 92 | 6.6 | 80.5 | 12.9 |
| South Fork Bear Canyon Creek 09 | 14.0 | 73.6 | 12.4 |
| Streeter Creek 09 | 3.2 | 72.6 | 24.2 |
| Tenmile Creek 96 | 0.4 | 25.9 | 73.7 |
| Tenmile Creek 09 | 5.8 | 38.2 | 56.0 |

## Pool Depth

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. Good coho salmon streams have >40% of total length in primary pool habitat. According to Flosi et al. (2010), in first and second order streams, a primary pool is described as being at least 2.5 feet deep; in third and fourth order streams, primary pool depths are 3 feet and 4 feet, respectively. Because pools are important salmonid habitat even if they are slightly shallower than the established primary pool guidelines, CWPAP staff adjusted primary pool length data for use in the analysis. This adjustment allowed 25% of the length of pool habitat in the depth category below the minimum for each stream order class to be represented in the analyses. For example, in first and second order streams, where pools ≥ 2.5 feet deep are considered primary, 25% of the length of pool habitat between 2 and 2.5 feet deep was added to the total primary pool length to obtain an adjusted percent of primary pool habitat. For third and fourth order streams, 25% of pool habitat between 2.5 and 3 feet, and 3.5 and 4 feet, respectively, was added to the primary pool length. For a complete description of pool depth categories and details of pool depth calculations, see the Analysis Appendix.

*Table 22* lists the percent length of primary pool habitat by stream in the Eastern Subbasin. Percentages ranged from 0.4% (in McCoy Creek in 2007) to 63.6% (in Tenmile Creek in 1996). The percent primary pool habitat exceeded target values of 40% in three streams: Cahto Creek (1996), McCoy Creek (1995) and Tenmile Creek (1996). All three of these tributaries were sampled again between 2000 and 2010, and percent primary pool habitat dropped well below target values in the later surveys. Overall percent primary pool habitat was 42.2% (slightly above the target value) for habitat surveys completed in the 1990s, and dropped to 14.8% for surveys conducted in the early 2000s.

The percent of primary pool habitat in first and second order streams was very low (<10%) during both sampling periods (*Figure 40*). Although the percent of surveyed length in primary pools increased over time in third order streams, all of these data (from both time periods) were collected in Tenmile Creek. Percent primary pool data would be more indicative of conditions throughout the subbasin if data were collected in other third order streams (e.g. Rattlesnake Creek and East Branch SF Eel River).

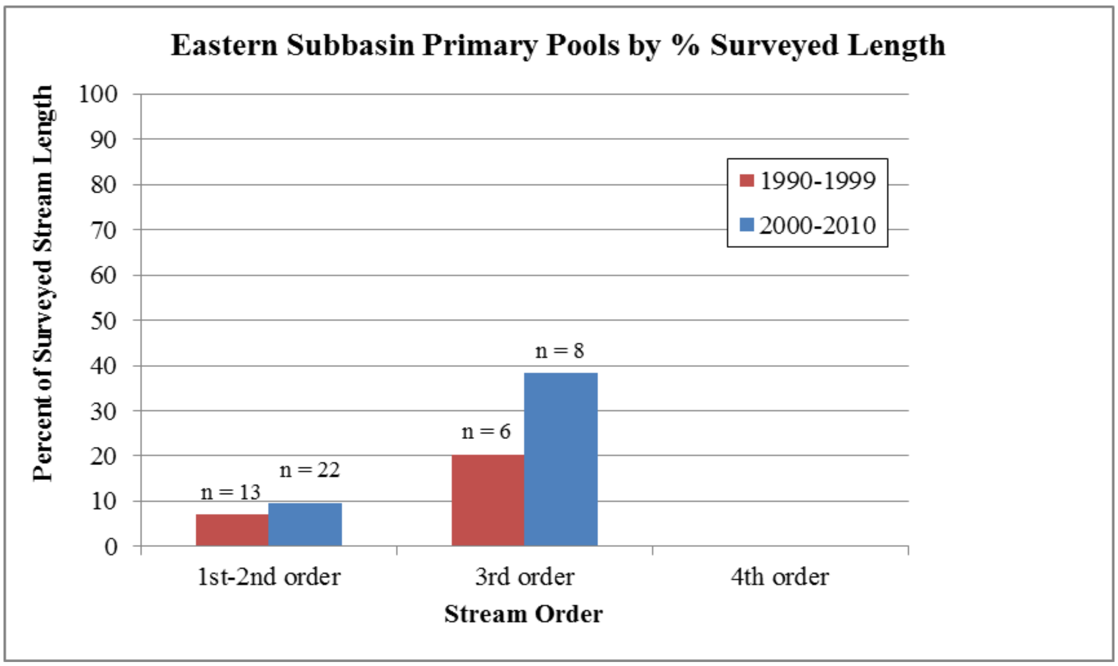



*Figure 40. Percent of surveyed habitat in primary pools in the Eastern Subbasin, using data collected from 1990-1999 and 2000-2010.*

Pool depth suitability in Eastern Subbasin streams was relatively good in the 1990s, but deteriorated over time in many streams (*Figure 41*). Conditions improved and were in the highest suitability category in the early 2000s in the middle and lower areas of Tenmile Creek, but conditions deteriorated (many from the highest to the lowest suitability category) in all other subbasin streams that were sampled during both time periods (Bear Canyon, Milk Ranch, McCoy, Big Rock, Kenny, Mud, and Cahto creeks).

Decreasing pool depth suitability is most likely due to increased sediment input. Sediment from both natural and anthropogenic sources modifies streams channels from deep, cool, and relatively stable to shallow and relatively unstable by filling in pool habitat and depositing sediment throughout the channel bed. Sedimentation rates increased dramatically in Eastern Subbasin streams following the 1955 and 1964 flood events. In their sediment source analysis, Stillwater Sciences (1999) selected one area in the Eastern Subbasin as an intensive

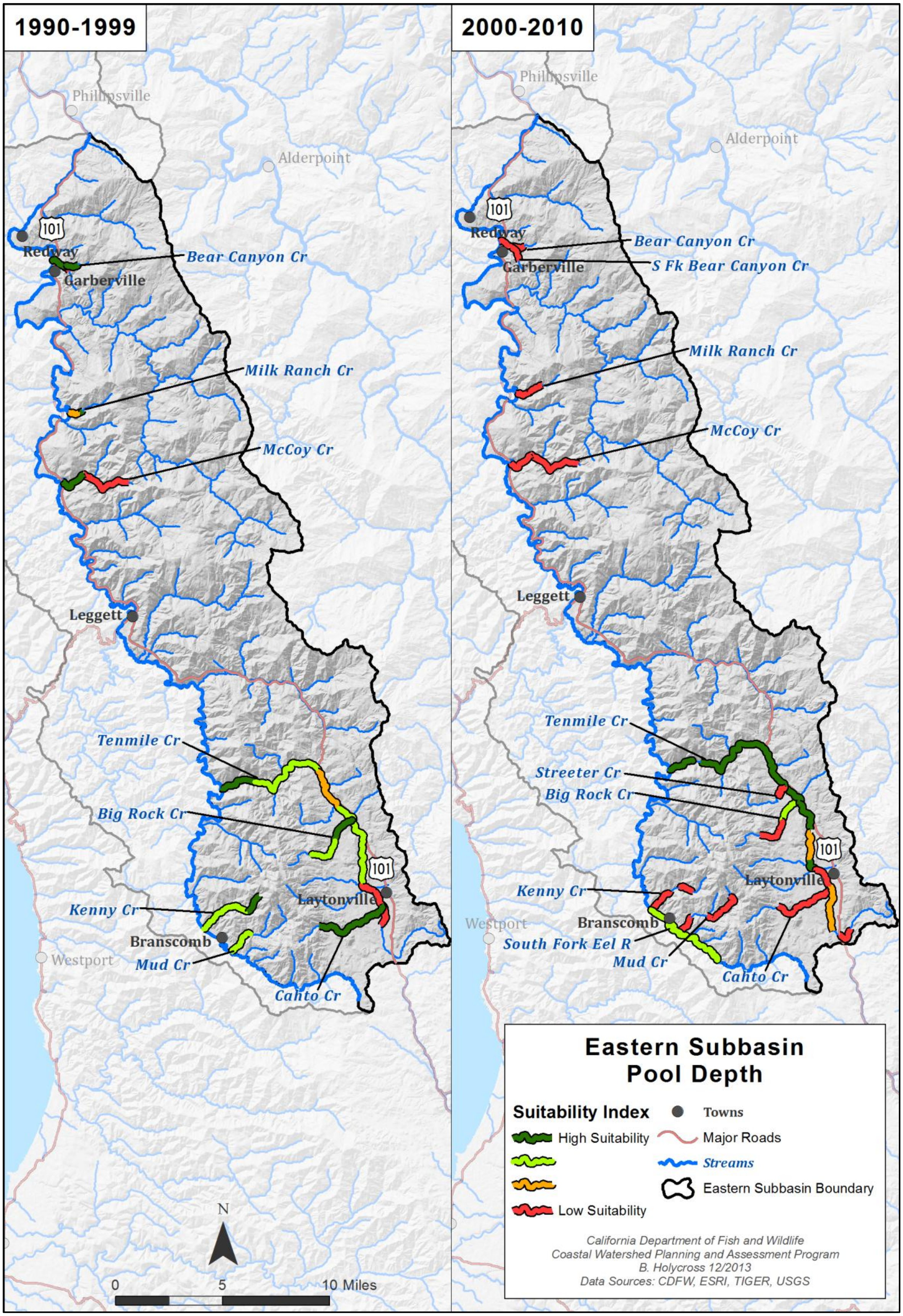



*Figure 41. Pool depth suitability in SF Eel River Eastern Subbasin streams, using data collected between 1990 and 1999, and 2000 and 2010.*

study area, Tom Long Creek, which flows into the East Branch SF Eel River at approximately RM 9. Unlike other intensive study areas in the SF Eel River Basin, the ratio of anthropogenic to natural sediment loading was relatively low, but the total sediment loading was higher (3,295 tons/square kilometer/year for 1966-1981 and 1,245 tons/square kilometer/year for 1981-1996) than in Northern and Western subbasin intensive study areas.

In the Tom Long Creek watershed, the primary source of sediment input was from earthflow toes and associated gullies, which accounted for 65% of the total loading. Deep-seated landslides contributing sediments to streams were abundant in mélange matrix, which is highly prone to erosion, and is the primary rock type in the Eastern Subbasin. The second most abundant rock type, The Yager Terrane, is usually relatively stable but is prone to large-scale landsliding in areas where it is faulted and/or sheared. Most of the Eastern Subbasin area is underlain by major faults including the Maacama Fault in the south, the Garberville Fault in the north, and the Brush Mountain Shear Zone in the center of the subbasin.

Road crossing and gully erosion was the second largest sediment source, accounting for 18% of total sediment input. Road density in this subbasin is 2.88 miles/square mile, which is relatively high and considered "at risk" when developing restoration initiatives (NMFS 1996). In addition to road density, most (60%) of the roads are seasonal roads, which were originally constructed to access and haul timber, but many are now used for residential and agricultural purposes. Existing roads in the Tom Long Creek Basin are poorly maintained, are generally insloped with inside ditches, and likely contribute to sheetwash erosion (Stillwater Sciences 1999).

Erosion from rural and logging roads includes two major components related to salmonid rearing and survival: chronic erosion of fine sediments during winter rainstorms that result in reduced survival of eggs; and catastrophic failure of roads prisms during winter storms that result in loss of rearing habitat (Downie 1995). Due to the geologic setting (steep slopes, rapid uplift, and unstable soils) in the Eastern Subbasin, seasonal road use and subsequent failures create more erosion and sediment input than those in more stable geologic locations. Restoration activities that create additional pool habitat and scour existing shallow pools while reducing sediment input from surrounding hillsides and roads are highly recommended throughout this subbasin.

## Pool Shelter

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 masses, undercut banks, bubble curtains, and submerged or overhanging vegetation in pool habitats. A standard qualitative shelter value of 0 (none), 1 (low), 2 (medium), or 3 (high) is assigned according to the complexity of the shelter. The shelter rating is calculated for each habitat unit by multiplying shelter value and percent of pool habitat covered. Thus, shelter ratings can range from 0-300, and are expressed as mean values by habitat types within a stream. Shelter ratings of 100 or less indicate that pool shelter/cover enhancement should be considered.

The average mean pool shelter rating for all Eastern Subbasin streams was 69.1 in the 1990s and 27.0 using habitat data collected between 2000 and 2010 (*Table 22*). Values ranged from a low of 15.9 in Kenny Creek in 2005, to a high of 95.2 in Tenmile Creek in 1996. None of the streams sampled in either period met target values of 100. Pool shelter type was mostly boulders (see LWD section of this report), with some aquatic vegetation and SWD in Tenmile Creek, and undercut banks as the primary shelter type in Kenny Creek. Reductions in LWD and corresponding decreases in shelter values are most likely due to the lack of LWD recruitment in these streams; Eastern Subbasin streams had the lowest percent coniferous and mixed conifer/hardwood forest habitat of all three subbasins.

Pool shelter scores were in the lowest suitability category in nearly all sampled reaches in the early 2000s (*Figure 42*). Tenmile Creek reaches showed significant decreases in suitability (from the highest to lowest scores), and other streams with decreasing shelter scores over time were Bear Canyon, McCoy, Kenny, and Cahto creeks. There were no streams in this subbasin that showed increases in pool shelter scores between the two time periods.

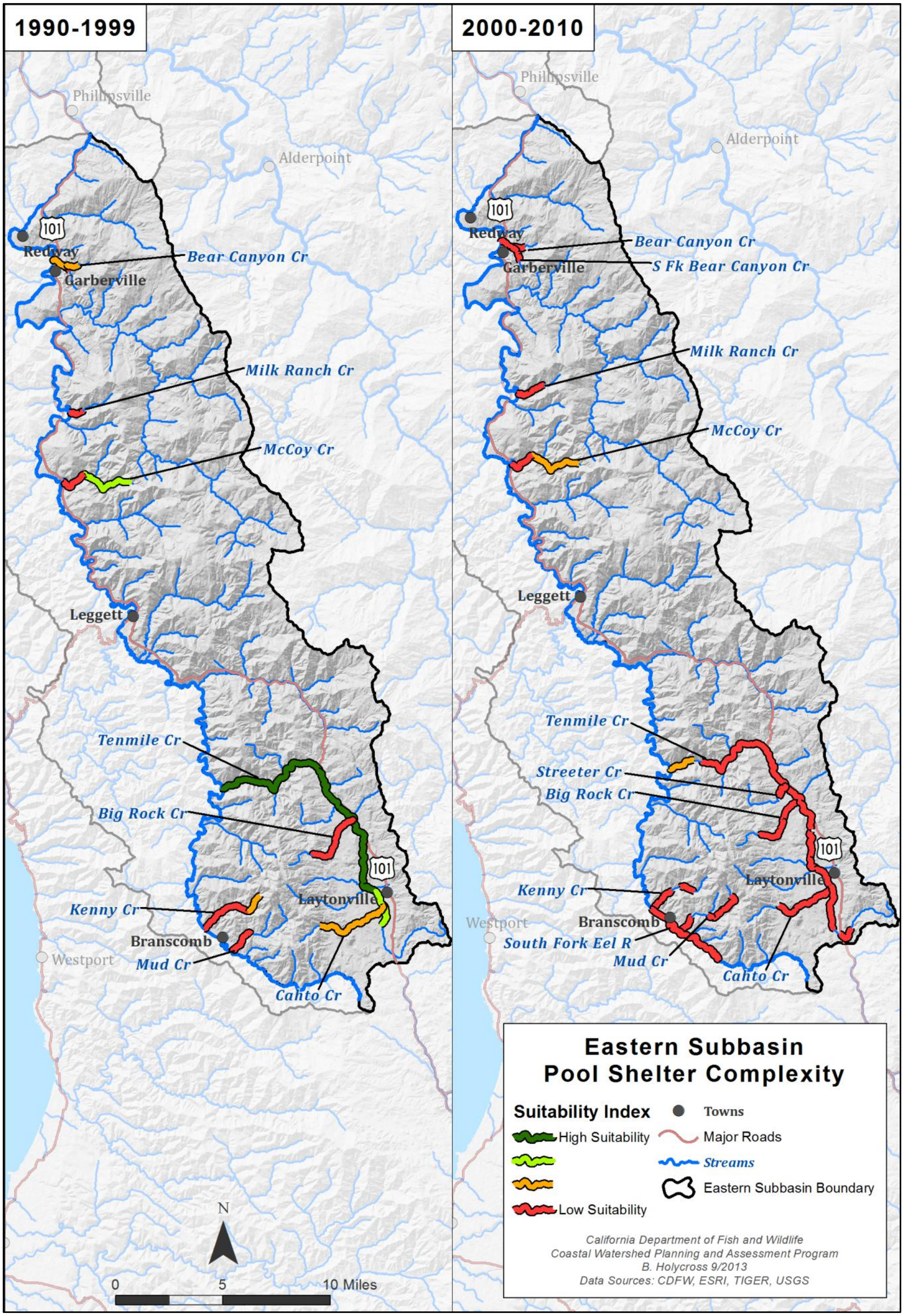



*Figure 42. Pool shelter suitability for Eastern Subbasin streams, using data collected between 1990 and 1999, and 2000 and 2010.*

Restoration projects targeting streams with particularly low pool shelter values and potential salmonid presence should be a high priority throughout the Eastern Subbasin. These projects would be particularly important in Tenmile Creek, which has documented coho salmon presence extending into tributaries near Laytonville, more than 16 miles upstream from the confluence of the mainstem SF Eel River. Because large wood recruitment is low, projects that add LWD or other forms of shelter (e.g. boulders) to streams are recommended. These projects could be combined with pool habitat creation/enhancement projects, since both primary pool habitat and pool shelter are limiting factors for salmonids in this subbasin.

## Substrate Embeddedness

Salmonid spawning depends heavily on the suitability of spawning gravel; fine sediments in gravels reduce spawning and incubation success. Substrate embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 cobbles are 0-25% embedded, category 2 are 26-50% embedded, category 3 are 51-75% embedded, and category 4 are 76-100% embedded. Embeddedness categories 3 and 4 are not within the fully suitable range for successful use by salmonids. Category 5 embeddedness, represented by the bars furthest to the right in *Figure 43* represent tail-outs deemed unsuitable for spawning due to inappropriate substrate like sand, bedrock, log sills, or boulders, and were not included in the suitability analysis.

Cobble embeddedness condition improved in most Eastern Subbasin streams over time, with average percent category 1 embeddedness values of 10.5% for data collected in the 1990s and 28.5% for data collected between 2000 and 2010 (*Table 22*).

While subbasin averages are a good overall indicator of embeddedness, it is valuable to consider the changes in each category type over time, since only categories 1 and 2 are suitable for salmonid spawning. The percent of pool tails surveyed in category 1 nearly tripled between the 1990s and early 2000s (*Figure 43*). Although 30% of all surveyed pool tails were in category 1 in the early 2000s, this is still less than the target value of 50% in category 1 embeddedness established by Flosi et al. (2010).

The percentage of pool tails in category 2 was nearly the same (32%-33%), the percentage in category 3 was reduced by half (from 39% to 18%), and the percentage in category 4 was slightly reduced (from 7% to 6%) between the two time periods. The percentage of pool habitat in category 5 (unsuitable for spawning) doubled between the two time periods, due to sediment input from both natural and anthropogenic sources.

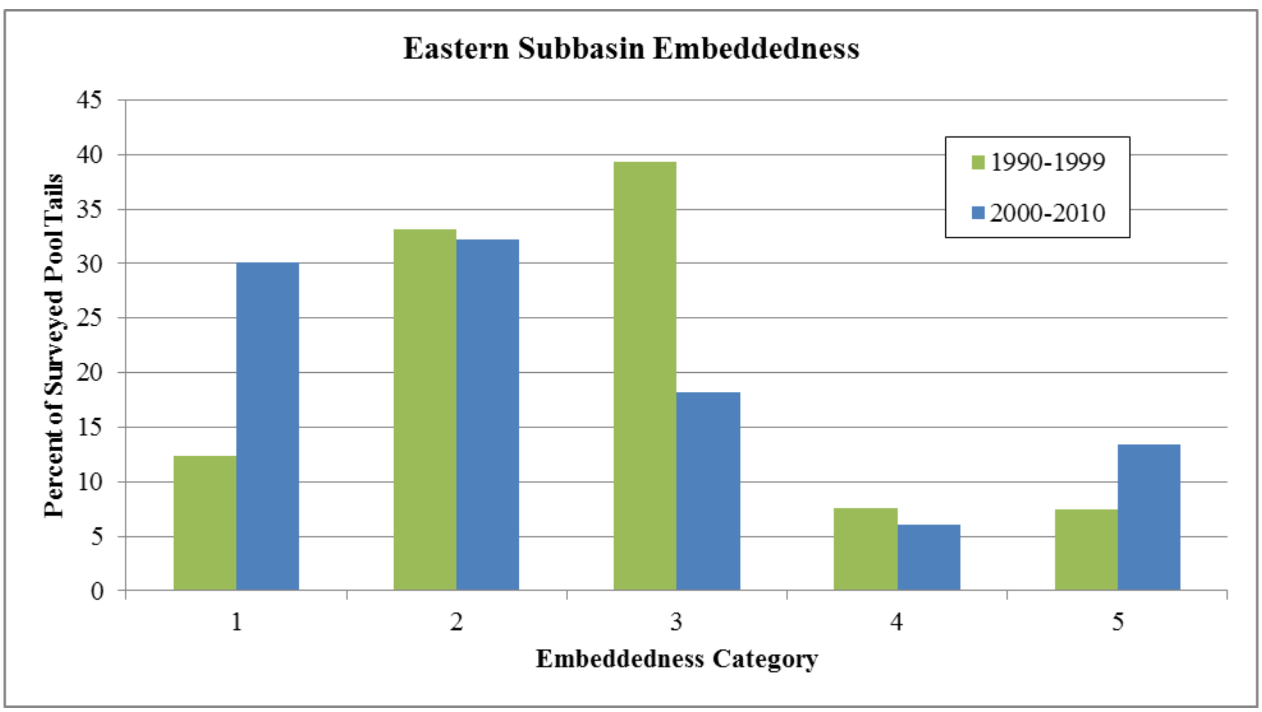



*Figure 43. Cobble Embeddedness in the Eastern Subbasin, using data collected from 1990-1999 and 2000-2010.*

The EMDS-based model used a weighted sum of embeddedness category scores to evaluate the pool tail substrate suitability for survival of eggs to emergence of fry. The percent embeddedness categories were weighted by assigning a coefficient to each category. Embeddedness category 1 was rated as fully suitable for egg survival and fry emergence and a coefficient of +1 was assigned to the percent of embeddedness scores in category 1. Embeddedness category 2 was considered uncertain and given a coefficient of 0. Embeddedness categories 3 and 4 were considered unsuitable and were assigned a coefficient of -1. Category 5 values were omitted because they are composed of impervious substrate. The values for each category were summed and evaluated in the analysis.

Embeddedness suitability increased in many Eastern Subbasin streams between the 1990s and early 2000s (*Figure 44*). Most surveyed areas were in the lowest suitability category in the 1990s, but by the early 2000s, some were in either the highest or second highest suitability category (middle Tenmile Creek and Big Rock Creek). These improvements are most likely due to sediment from historical floods moving through the system.

Upslope watershed restoration projects, including road decommissioning and upgrading projects, are designed to decrease fine sediment input and therefore decrease embeddedness. These types of projects are particularly important in this subbasin because of the relatively high road density (2.88 miles/square mile) and increased road usage for residential and agricultural purposes. Many road related restoration projects have been completed in the East Branch SF Eel River basin, but no habitat typing data has been collected in this watershed. Restoration activities and their effect on salmonid habitat in specific streams will be discussed in the Restoration Projects section of this subbasin report.

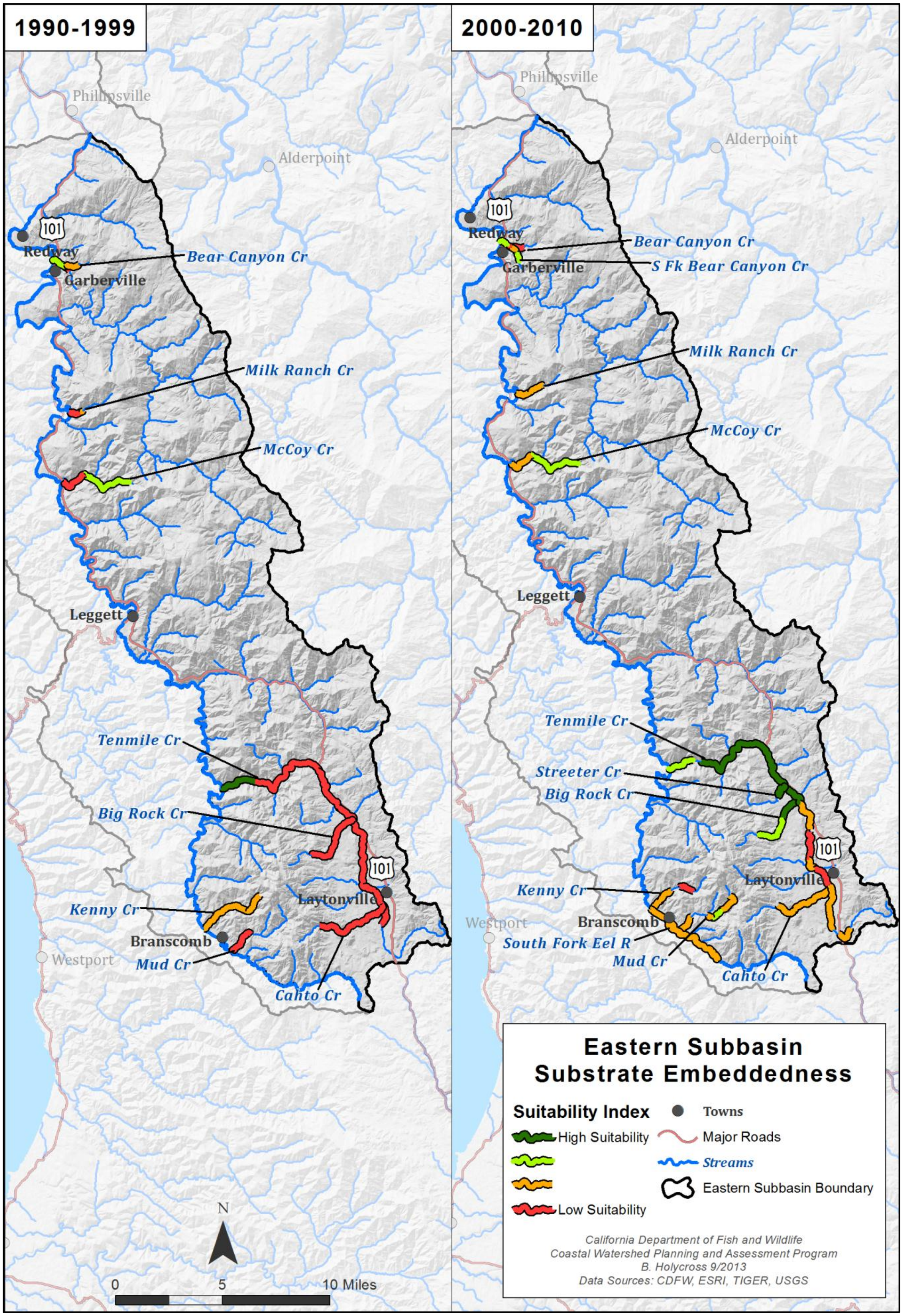



*Figure 44. Embeddedness suitability in Eastern Subbasin streams using data collected between 1990 and 1999, and 2000 and 2010.*

## LWD

Wood recruitment processes vary spatially across landscapes due to differences in forest composition and age, climate, stream size, topography, natural disturbances, and land use history (Benda and Bigelow 2011). Large wood shapes channel morphology, helps streams retain organic matter and nutrients, and provides essential cover for salmonids. It also modifies streamflow, adds habitat complexity and structure, and increases pool formation and available habitat for Chinook and coho salmon and steelhead trout at all life stages during both low and high flow times (Snohomish County Public Works 2002). Natural LWD recruitment is lower in areas where industrial timber harvest occurs (Murphy and Koski 1989, Beechie et al. 2000).

CWPAP staff did not develop reference values for frequency and volume of LWD in the EMDS-type analysis. Other models have used values derived from Bilby and Ward (1989), which are dependent on channel size. Most watersheds in the Western Subbasin did not have sufficient LWD surveys and channel size measurements for use in the analysis, but existing data were summarized to determine the frequency of LWD as the dominant shelter type and the percent shelter from LWD in pools.

Boulders were the dominant shelter type recorded in Eastern Subbasin streams during both time periods (*Table 25*). Terrestrial vegetation and undercut banks were the next most common shelter type in the 1990s, and terrestrial vegetation, root masses, and SWD were the next most common shelter types in the 2000-2010 sampling period. LWD was not documented as a pool shelter type in the 1990-1999 sampling period, and was only the dominant shelter type in one reach surveyed in the 2000-2010 sampling period, indicating that LWD is lacking in all sampled Eastern Subbasin streams. This was expected due to the relatively low percentage coniferous and hardwood forest vegetation types (which supply LWD to streams), and because of past timber harvest practices, particularly in the southern and western areas of the subbasin.

*Table 25. Dominant pool shelter type by number of reaches surveyed in Eastern Subbasin streams.*

| Dominant Shelter Type | 1990-1999 | 2000-2010 |
|---|---|---|
| Boulders | 13 | 20 |
| Root masses | 0 | 2 |
| Terrestrial vegetation | 2 | 3 |
| LWD | 0 | 1 |
| SWD | 1 | 2 |
| Aquatic vegetation | 1 | 1 |
| Undercut banks | 2 | 0 |
| Whitewater | 0 | 0 |

The average percent shelter from LWD in Eastern Subbasin streams was very low during both sampling periods, and decreased over time (*Table 26*). These low values may be due to past land management and land uses, in addition to low recruitment from vegetation types such as grassland prairie and shrub cover in watersheds throughout the basin, especially in the eastern half of the subbasin. In the 1960s and 1970s, fisheries habitat management strategies included aggressive removal of large wood (recruited from landslides, flood events, and logging debris) from channels, and historical habitat surveys identified many log jams and recommended removal in Eastern Subbasin streams. Recent restoration activities have emphasized adding large wood back into streams (Opperman et al. 2006). Average values for percent cover from LWD were extremely low (<5%), indicating the need for additional large wood as vital rearing and holding habitat components in Eastern Subbasin streams. In areas where grassland or shrub are the dominant vegetation types, large wood may need to be imported, or other types of shelter provided to enhance salmonid habitat.

*Table 26. Total length of pool habitat and average percent shelter from LWD in Eastern Subbasin streams using data collected during two time periods: 1990-1999 and 2000-2010.*

| Eastern Subbasin | Total length of pool habitat (mi) | Avg % shelter from LWD |
|---|---|---|
| 1990-1999 | 7.74 | 3.20 |
| 2000-2010 | 13.29 | 0.96 |

## Pool-Riffle Ratio

Pool-riffle ratio is a measure of the amount of habitat available to salmonids in a stream, specifically the amount of pool habitat for resting and feeding, and the amount of riffle habitat for food production and spawning. Pool-riffle sequences, ratios, and lengths are dependent on channel gradient, resistance of channel boundaries (bedrock walls and bed material), and discharge (Wohl et al. 1993). A 50:50 (1:1) ratio is usually considered optimal, but streams with a slightly lower percentage of pool habitat compared to riffle habitat (0.4:1 ratio) have also been found to support a high biomass of salmonids (Platts et al. 1983). Flosi et al. (2010) recommended that approximately 40% of anadromous salmonid stream length should be pool habitat. Streams with a high percentage of riffles and few pools are generally low in fish biomass and species diversity (Snohomish County Public Works 2002).

Although pool depth, as measured by the percentage of primary pool habitat in Eastern Subbasin streams, was below optimal levels during the most recent sampling period, the ratio of pool to riffle habitat exceeded the recommended 50:50 ratio during both time periods (*Table 27*). A pool-riffle ratio of 60:40 is generally considered to provide suitable holding area and habitat diversity for both juvenile salmonids and benthic invertebrates, which are utilized as prey items by salmonids (Johnson 1985). Aggradation from numerous active landslides and unstable geology, and sediment input from roads may have contributed to a decrease in channel complexity and less than optimal pool depths in this subbasin, and projects designed to enhance pool depths are recommended.

*Table 27. Percent pool and riffle habitat, and pool riffle ratios for Eastern Subbsin streams (from habitat typing data collected between 1990 and 1999, and 2000-2010).*

| DATE | % POOL HABITAT | % RIFFLE HABITAT | POOL:RIFFLE RATIO |
|---|---|---|---|
| 1990-1999 | 22 | 20 | 52 : 48 |
| 2000-2010 | 34 | 22 | 61 : 39 |

# Water Quality

## Water Temperature

Water temperature is one of the most important environmental influences on salmonids at all life stages, affecting physiological processes and timing of life history events (Spence et al. 1996, Carter 2005). Stressful conditions from high temperatures are cumulative and are positively correlated with both the severity and duration of exposure (Carter 2005). Elevated instream temperatures result from an increase in direct solar radiation due to the removal of riparian vegetation, channels widening and becoming shallower due to increased sedimentation, and the transport of excess heat downstream (USEPA 1999).

The Humboldt County Resource Conservation District (HCRCD), with the cooperation of 21 supporting agencies, individuals, and landowners, completed temperature monitoring and biological sampling in the Eel River Watershed, collecting data during eight field seasons from 1996-2003 (Friedrichsen 2003). They collected maximum weekly average temperature (MWAT) data in streams throughout the SF Eel River Basin, including 37 locations (26 in tributaries and 11 in the mainstem SF Eel River) in the Eastern Subbasin (*Figure 45*). Some streams (e.g. Rattlesnake and Tenmile Creek) were sampled at more than one location, and site locations are listed for each data collection point. Some large streams (Redwood and Sproul Creeks) were sampled at more than one location, and site locations are listed for each data point. Data loggers were generally deployed from June through October, and not all sites were sampled every year. Friedrichsen (2003) provided X,Y coordinates for most gauge locations, and others were digitized using HCRCD map data where available. Although not all sampling locations are included on the map, most missing data points were located in mainstem areas of larger tributaries (S. Downie, CDFW, personal communication 2013).

The CWPAP staff created suitability ranges for stream temperature based on MWATs, considering the effect of temperature on salmonid viability, growth, and habitat fitness (*Table 28*). This metric was calculated from a seven-day moving average of daily average temperatures. The maximum daily average was used to illustrate possible stressful conditions for salmonids. The instantaneous maximum temperature that may lead to salmonid mortality is ≥75°F; this temperature is potentially lethal for salmonids if cooler refuge is not available.

*Table 28. CWPAP-defined salmonid habitat quality ratings for MWATs.*

| MWAT Range | Description |
|---|---|
| 50-62°F | Good stream temperature |
| 63-65°F | Fair stream temperature |
| ≥66°F | Poor stream temperature |

Using Friedrichsen's data and these temperature ranges, 12 sites (on 10 creeks) in Eastern Subbasin tributaries and one site in the mainstem SF Eel River had good salmonid temperatures (*Table 29*). Three tributary sites (on two creeks) and one mainstem site had fair stream temperatures, and 11 tributary sites (on seven creeks) and nine mainstem sites had poor stream temperatures (*Figure 46*). Temperatures are higher in Eastern Subbasin streams than in Northern and Western subbasin streams due to a combination of reduced riparian cover, lower summer flows, warmer air temperatures due to the lack of influence of the coastal marine layer, and aspect (little afternoon shade).

Many of the sampling sites with poor stream temperatures were located in the mainstem SF Eel River, on the boundary between the Eastern and Western Subbasins (these sites are discussed in both subbasin sections). Other sites with poor stream temperatures recorded were located in the lower reaches of large tributary streams (e.g. Rattlesnake Creek, East Branch SF Eel River, and Tenmile Creek). In these areas, increased direct solar radiation from reduced riparian cover and wide channels results in warmer water temperatures than in nearby smaller tributaries. Researchers obtained a maximum daily average reading of 75˚F or greater at four sites in the Eastern Subbasin: two in the mainstem SF Eel River (near Piercy at RM 54 and near Sylvandale at RM 25), one in Tenmile Creek, and one in the East Branch SF Eel River. These temperatures exceeded the lethal temperature for salmonids if cooler refuge areas (springs and seeps) are not available nearby. Although we expect higher temperatures in mainstem SF Eel River than in tributaries, it is important to capture the duration that salmonids are exposed to these stressful or lethal temperatures, and to document the location and availability of cool water refugia areas near sites where lethal MWAT values have been recorded.

In addition to the HCRCD studies, Higgins (2013) and the Eel River Recovery Project (ERRP) employed a citizen monitoring effort in 2012 to collect water temperature data as an indicator of flow depletion in streams throughout the Eel River Basin. Higgins compared 2012 stream temperatures with data collected at similar locations by HCRCD between 1996 and 2003, and his conclusions were similar to Friedrichsen's: mainstem SF Eel River temperatures in the upper areas near Branscomb were some of the coolest mainstem conditions in the entire Eel River system, and temperatures became progressively warmer downstream. Higgins and ERRP also found temperatures in the mainstem SF Eel River near Piercy were above optimal for salmonids. Fish in these areas may seek refuge in thermally stratified pools or in localized refugia provided by surface and groundwater interactions when mainstem and tributary temperatures reach stressful or even lethal temperatures (Nielsen et al. 1994). These cool water refugia are particularly important in areas where high temperatures result in increased primary productivity (algal blooms), low dissolved oxygen concentrations, and conditions favoring invasive species such as Sacramento pikeminnow. Both spatial and temporal changes in

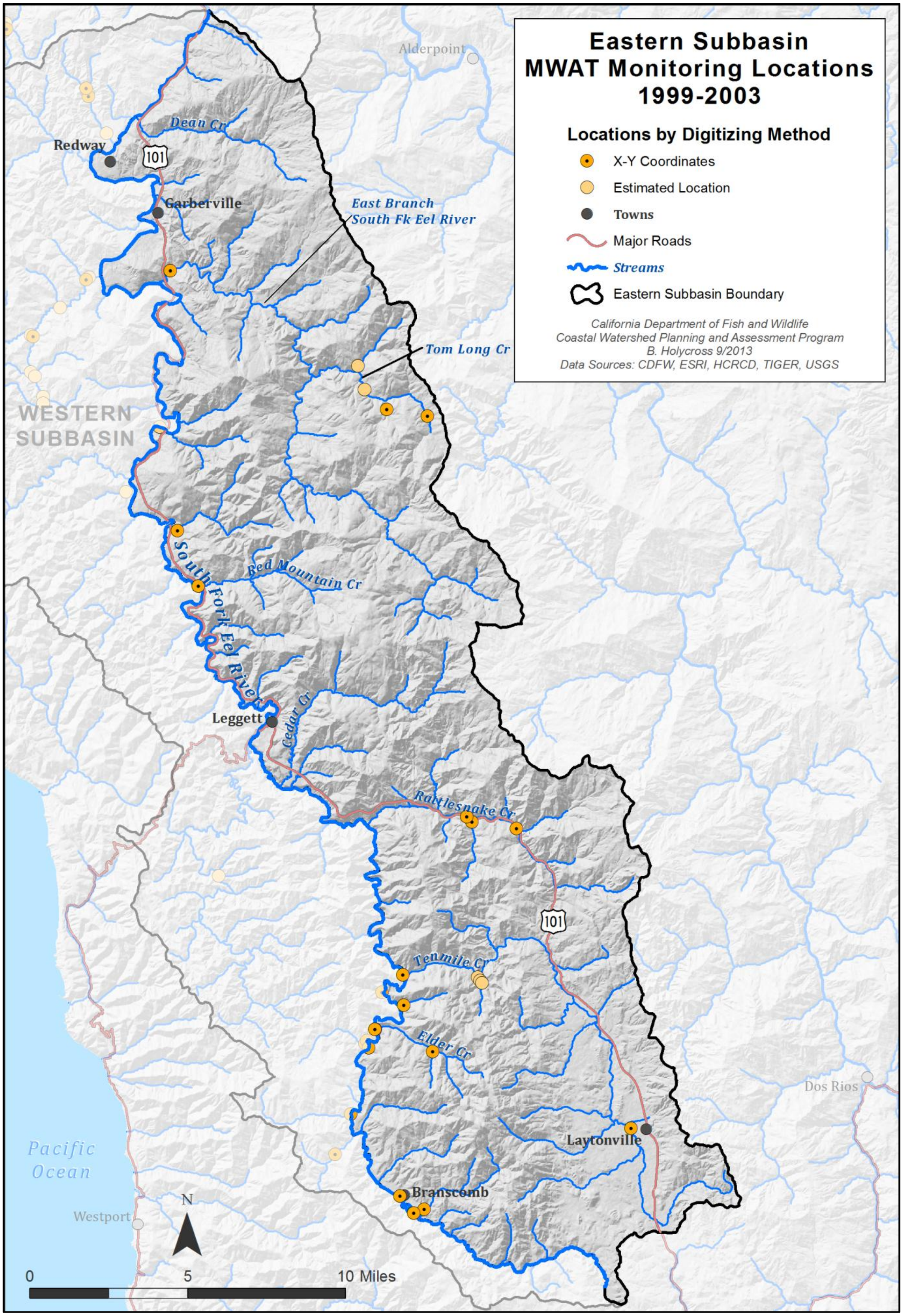



*Figure 45. Locations of temperature monitoring sites in the SF Eel River Eastern Subbasin (Friedrichsen 2003).*

*Table 29. Maximum weekly average temperatures (MWAT) and ranges collected in SF Eel River Eastern Subbasin streams from 1999-2003 (data from Friedrichsen 2003).*

| Creek | Site | MWAT Range (°F) | Average MWAT (°F) | Years of Data |
|---|---|---|---|---|
| **Good Stream Temperature (50-62 °F)** | | | | |
| Bear Creek | 8062 | 59 | 59 | 1 |
| East Branch SF Eel River | 1537 | 62 | 62 | 1 |
| Fox Creek @ Wilderness | 8052 | 62 | 62 | 1 |
| McCoy Creek | 1576 | 61-63 | 62 | 3 |
| Misery Creek (Elder Creek) | 1480 | 61 | 61 | 1 |
| Mud Creek | 1577 | 61-63 | 62 | 4 |
| Muddy Gulch | 1838 | 55 | 55 | 1 |
| Peterson Creek | 1673 | 61-62 | 61 | 2 |
| Peterson Creek | 8016 | 61-62 | 62 | 2 |
| SF Eel River @ Mud Creek | 8045 | 62 | 62 | 1 |
| Taylor Creek | 1840 | 58 | 58 | 1 |
| Tom Long Creek | 8041 | 57 | 57 | 1 |
| Tom Long Creek | 8057 | 62 | 62 | 1 |
| **Fair Stream Temperature (63-65 °F)** | | | | |
| Elder Creek (# 6) | 1461 | 62-66 | 64 | 5 |
| Elder Creek U/P Bridge | 8050 | 64 | 64 | 1 |
| SF Eel River @ Branscomb (RM 95) | 1658 | 63-66 | 64 | 5 |
| Tom and Jerry Creek | 8058 | 64 | 64 | 1 |
| **Poor Stream Temperature (≥66 °F)** | | | | |
| Elk Creek | 1542 | 67 | 67 | 1 |
| East Branch SF Eel River | 8049 | 74-75 | 75 | 2 |
| Mill Creek | 1590 | 66 | 66 | 1 |
| Rattlesnake Creek | 1610 | 71 | 71 | 1 |
| Rattlesnake Creek | 1611 | 63-67 | 66 | 4 |
| RattlesnakeCreek @ Elk | 8054 | 70 | 70 | 1 |
| Red Mountain Creek | 1621 | 68-70 | 69 | 3 |
| SF Eel River (RM 54) | 249 | 74 | 74 | 1 |
| SF Eel River (RM 84) | 9636 | 73 | 73 | 1 |
| SF Eel River (RM 86) | 9637 | 72 | 72 | 1 |
| SF Eel River (RM 51) | 241 | 73 | 73 | 1 |
| SF Eel River @ Angelo Reserve (RM 88) | 8059 | 69 | 69 | 1 |
| SF Eel River @ Piercy Creek (RM 54) | 1416 | 75 | 75 | 1 |
| SF Eel River @ Sylvandale (RM 25) | 1634 | 74-78 | 76 | 4 |
| SF Eel River Above Elder Creek (RM 90) | 1657 | 68-71 | 70 | 3 |
| SF Eel River Above Rattlesnake Creek (RM 76) | 1638 | 74 | 74 | 1 |
| Tenmile Creek (Laytonville) | 1646 | 62-69 | 66 | 5 |
| Tenmile Creek (Near SF Eel River) | 1647 | 74-76 | 76 | 5 |
| Tenmile Creek @ Peterson Creek | 1675 | 70-72 | 71 | 2 |
| Wildcat Creek (Tom Long Creek) | 8040 | 69 | 69 | 1 |

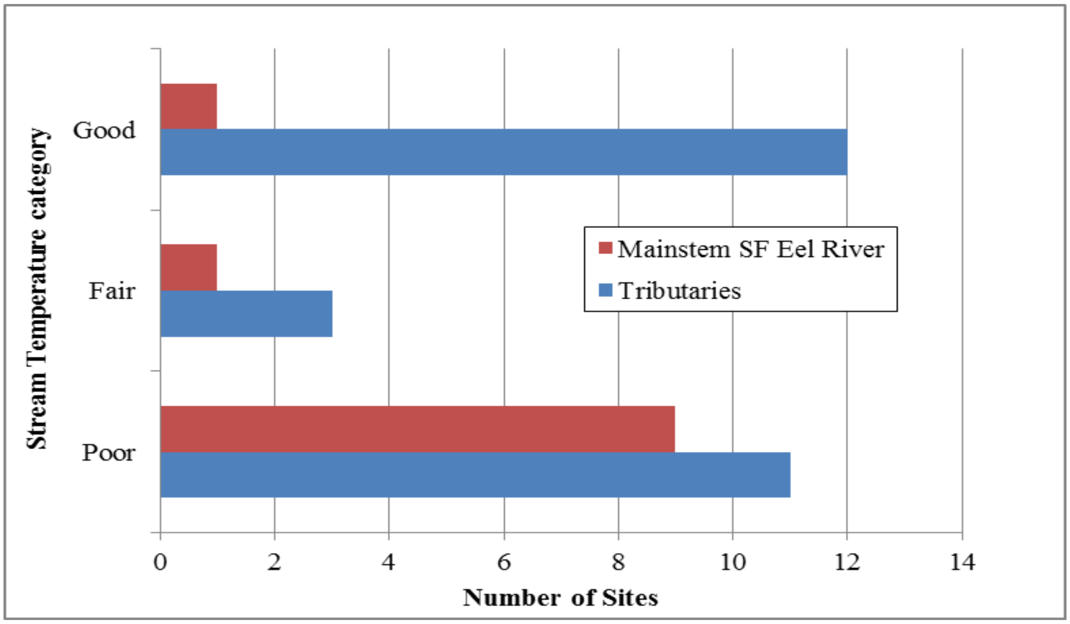



*Figure 46. Number of sites in each suitability rating category for MWATs collected from 1999-2003 (n=37; 26 tributary and 11 mianstem sites) in SF Eel River Eastern Subbasin streams (data from Friedrichsen 2003).*

stream temperatures are concerns in some Eastern Subbasin tributaries. Stressful temperature conditions caused by drawing more water out of streams both during dry years and during dry seasons each year have exposed salmonids to extremes that they would not normally encounter. These extremes are particularly problematic for fragmented populations, which are less resilient to variations in stream temperature and other habitat conditions (Poole et al. 2001).

Temperature data were also collected during the summer of 2013 by UC Berkeley graduate student Keith Bouma-Gregson. Bouma-Gregson sampled cyanotoxins, nutrients (nitrogen and phosphorous), and temperature at 7 Eel River Basin sites, including 4 in the mainstem SF Eel River: Phillipsville (RM 22), Richardson Grove (RM 49), Standish-Hickey State Recreation Area (SRA) (RM 66), and Angelo Reserve (RM 89) (*Figure 47*). Of the SF Eel River sites, daily average temperatures recorded were lowest at Angelo Reserve (64.6-74.7˚F) and warmest at Phillipsville (67.1-79.6˚F). These data are consistent with Friedrichsen's and ERRP's findings. Temperatures recorded at Richardson Grove and Standish-Hickey SRA were intermediate between the other two SF Eel River locations. Lethal temperatures (≥75˚F) were recorded on 15 days in July and August at Richardson Grove, and on 9 days in July at Standish-Hickey SRA, both of which are located within the Eastern Subbasin boundary. At the Phillipsville site, located in the mainstem SF Eel River just north of the Eastern Subbasin boundary, daily average temperatures were above lethal limits for salmonids on 27 days from mid-July to early September. There were no lethal temperatures recorded at the Angelo Reserve site (Bouma-Gregson, UC Berkeley, personal communication 2014).

Maximum weekly average temperatures are momentary high points, and both MWAT and daily average temperatures are useful for general discussion. However, in order to understand temperature conditions and their effects on salmonids, it would be more informative to capture the duration that salmonids are exposed to stressful or lethal temperatures on a reach by reach basis, and to document the availability of cool water refugia areas near locations where poor MWAT values have been recorded. There are studies in development to address flow and temperature concerns in other parts of the SF Eel River Basin (e.g. Redwood Creek, near Redway (SRF 2013)), but additional studies are necessary in streams with documented salmonid presence, particularly in tributaries to larger creeks and in locations further upstream in tributaries sampled by Friedrichsen et al., ERRP, and Bouma-Gregson. Studies addressing temperatures during low flow periods are especially important to determine how low flow and diversion are affecting temperatures in tributaries, and the effects of these changes on salmonids throughout the subbasin.

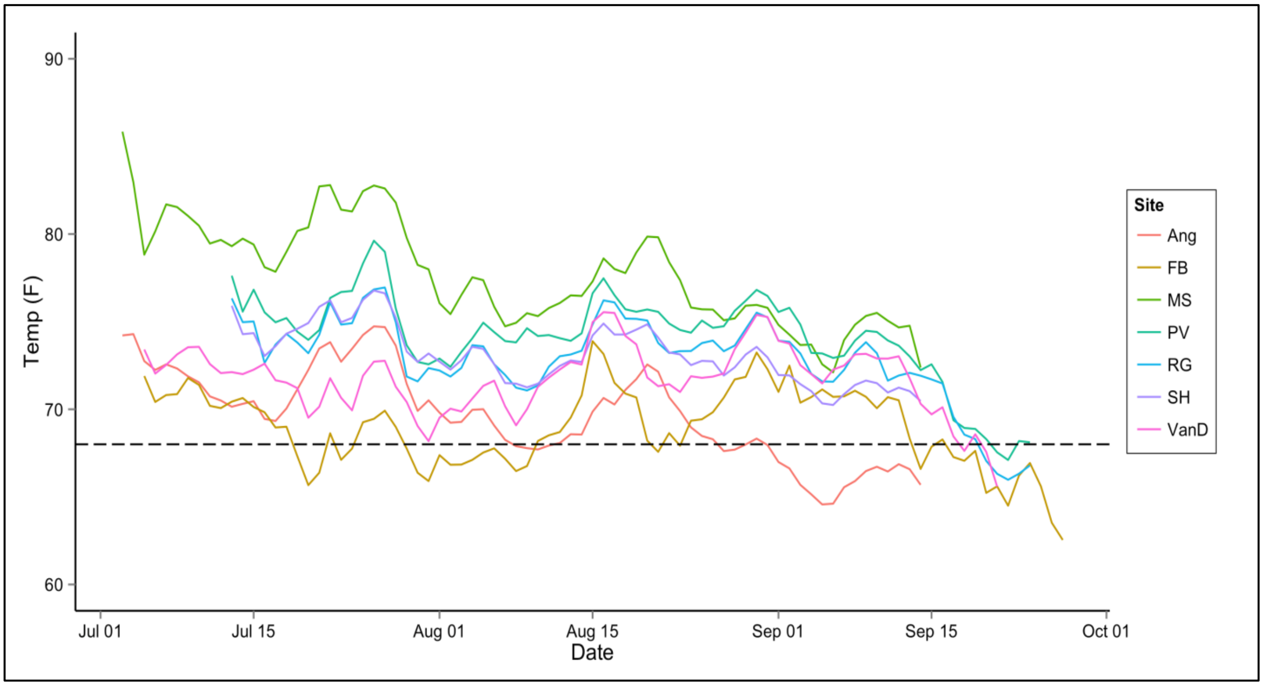



*Figure 47. Daily average temperatures (degrees F) from July 3 through September 24, 2013, recorded at 7 sampling locations in the Eel River Basin. Data and graph provided by Keith Bouma-Gregson (UC Berkeley, 2014). Ang = Angelo Reserve; FB = Fernbridge; MS = Mainstem Outlet Creek; PV = Phillipsville; RG = Richardson Grove; SH = Standish-Hickey SRA; VanD = Van Duzen River.*

## Flow

There are four sources of stream flow in a natural watershed:

- **Groundwater flow** into the channel provides base flow. In perennial streams, the water table is at the height of the stream surface;
- **Interflow** from the soil moisture zone;
- **Direct channel precipitation** at the surface; and
- **Surface runoff** as overland flow (Ritter 2013).

Instream flow is typically measured in cubic feet per second (cfs), and is a measure of how fast the water is moving through a cross-section of the stream. Flow velocity is directly related to the hydraulic radius and channel slope, and inversely related to channel roughness in a stream (Ritter 2013).

River morphology (width, depth, slope, and channel pattern) changes in response to the supply of sediment and water from the surrounding watershed (Pitlick and Wilcock 2001). In Eastern Subbasin streams, increased deposition and aggradation from high sediment input rates affect flow, particularly during summer months when natural flow sources are significantly reduced and diversion rates are high. These low flows and the predominance of sediment result in streams with subsurface flow during late summer and early fall months, which decreases the quantity and quality of salmonid habitat in many streams by reducing stream depth and available pool habitat, elevating water temperatures, and concentrating pollutants.

The USGS monitors flow at two locations in the Eastern Subbasin: the mainstem SF Eel River near Leggett (RM 66, on the boundary line between the Eastern and Western subbasins), and Elder Creek (RM 88, near Branscomb) (*Figure 48*, *Figure 49*). The Elder Creek gauge is located approximately 1600 feet upstream from the confluence of the SF Eel River. Records from these gauges show a recently emerging pattern of atypical low flows (compared to the historic running average) occurring during the late summer to early fall months even during wet weather years.

As the cross sectional area in a stream increases, the discharge also increases. The mainstem SF Eel River is much larger than Elder Creek, and the scale of discharge (Y axis) ranges from 10-20,000 cfs for the SF Eel River at Leggett, and ranges from 0.1 to 600 cfs for the much smaller Elder Creek. These low flows may be caused by reduced winter precipitation compared to historical averages in Elder Creek, which is not affected by diversions. Further downstream in the mainstem SF Eel River at Leggett, low flows may be caused by reduced rainfall and by an increase in both the number of diversions and the quantity of water diverted from subbasin streams and tributaries for agricultural and domestic uses.

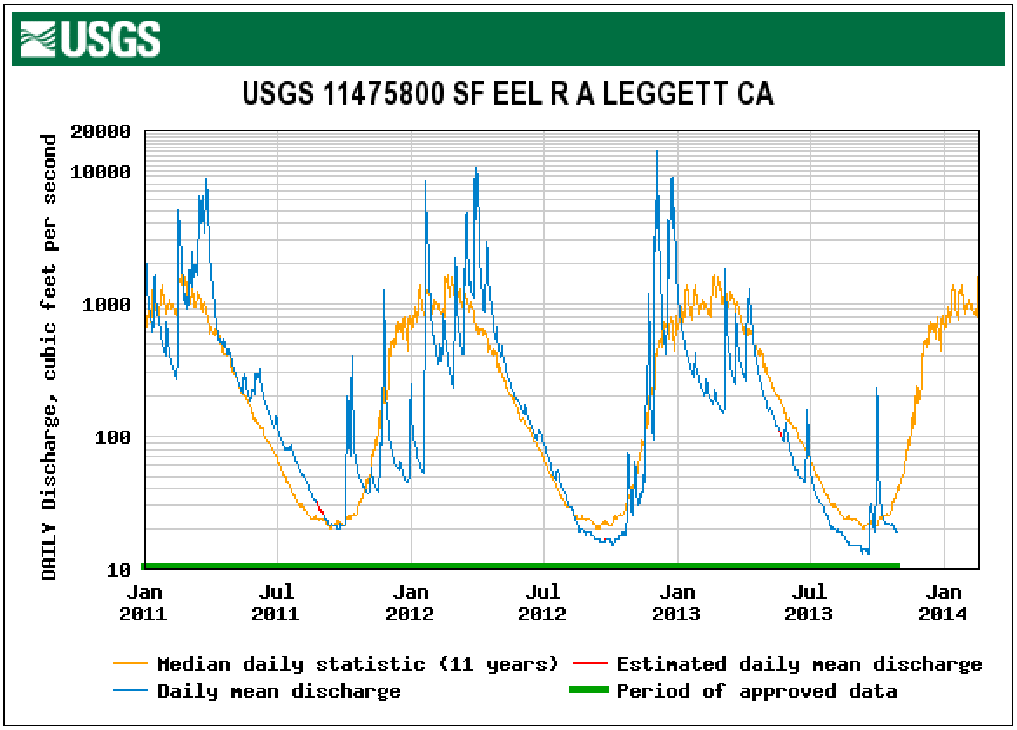



*Figure 48. Daily mean discharge (in cfs) and mean daily discharge (40-year average in cfs) for USGS gauging station at SF Eel River near Leggett, showing 2011-2014 data.*

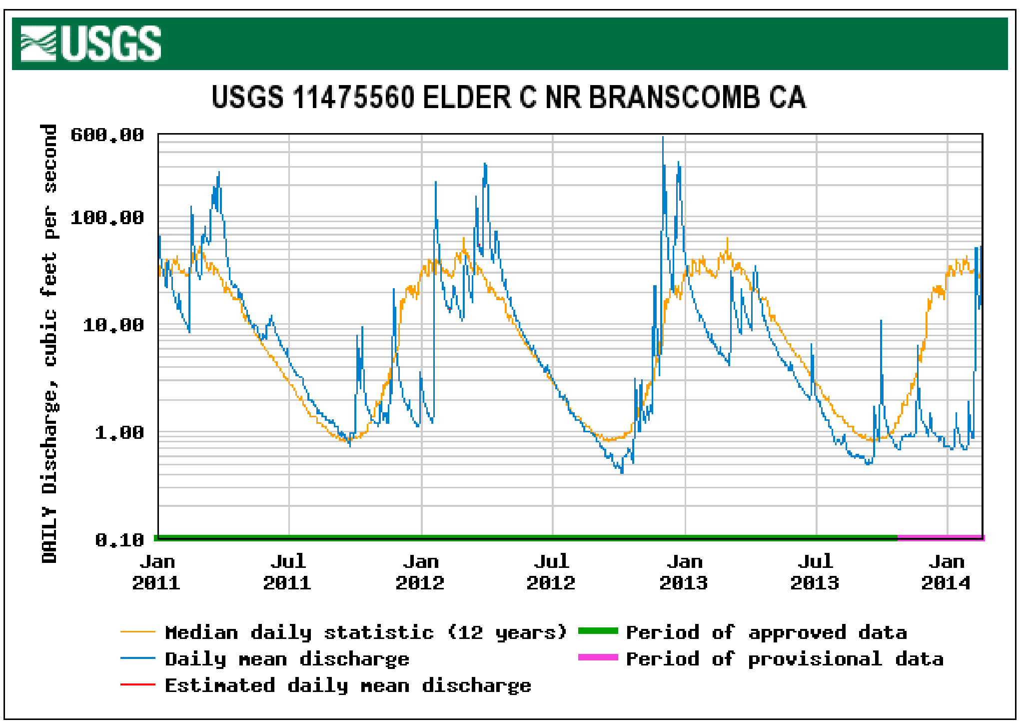



*Figure 49. Daily mean discharge (in cfs) and mean daily discharge (45-year average in cfs) for USGS gauging station at Elder Creek, showing 2011-2014 data.*

### Recent Low Flow Studies

In response to the limited rainfall in the winter and spring of 2012-2013 and concern over extremely low flow conditions that were being reported/observed in the SF Eel River Basin, CWPAP staff conducted a brief low flow study in August and September, 2013. The staff collected information at six mainstem SF Eel River sites and in 37 tributaries with known coho distribution. The purpose of the study was to document extremely low flow conditions and its potential impacts on juvenile salmonids (stress, mortality, etc.) while comparing conditions in streams that are heavily diverted (due to marijuana cultivation and residential use) with those those that are not heavily diverted. In streams that were not affected by diversion (n = 15) and in streams that were not heavily diverted (n = 21), flows were typical of those seen in very low water years. In heavily diverted streams, conditions ranged from dry or isolated pools only in some streams, to connected streams with very low flow in others.

Three of the streams that were affected extensively by diversion were located in the Eastern Subbasin: Tenmile Creek, Cahto Creek, and the East Branch SF Eel River. Of these three, Cahto Creek was dry (*Figure 50*) and Tenmile Creek had only isolated pools in the headwaters near Laytonville.

*Figure 50. Dry creekbed in Cahto Creek on September 13, 2013. Photo taken ±1.25 miles upstream from confluence with Tenmile Creek.*

### Water Diversion

The effects of low flow, diversions, and warm water temperatures on salmonids are major concerns in streams throughout the Eastern Subbasin. In 2013, the Salmonid Restoration Federation (SRF) and Humboldt State University (HSU) initiated a study to determine the feasibility of implementing a voluntary water conservation and storage program in Redwood Creek in the Western Subbasin. Although this study area was located in a different subbasin, findings and recommendations most likely apply in Eastern Subbasin streams with similar land use patterns and diversion pressure from agricultural and domestic sources.

SRF's study was based on Sanctuary Forest's water storage tank and forbearance program, where participating landowners store water in tanks and stop all diversion during low flow times. These actions have increased flows and improved fish habitat and water quality in tributary streams in the Mattole River Basin. SRF determined that there are landowners in the SF Eel River Basin who are willing to take part in a voluntary water conservation program, but there are some obstacles. Tank installation requires a financial commitment, including the purchase of a new tank and additional property taxes when water storage is installed, which are currently financial disincentives for residents interested in participating in the water storage program. Several local non-profit agencies are currently investigating options for a new tax policy to provide financial incentives for residents interested in installing water tanks. Water rights are also problematic in the watershed: many landowners currently divert water for domestic and agricultural purposes, but only two residents in the Redwood Creek watershed have established water rights (SRF 2013). SRF, in cooperation with several local non-profit agencies, established a public forum to educate residents about water rights and compliance issues so that they can legally divert and store water.

This study emphasizes the need for specific information on water diversions and flow, and it is an example of successful community involvement in fisheries habitat monitoring and restoration efforts. Similar voluntary conservation programs could be applied in the future in Eastern Subbasin watersheds, particularly in areas where there are substantial quantities of water diverted for marijuana cultivation and residential uses.

In January 2014, Governor Brown declared a drought State of Emergency in California and directed state officials to take all necessary actions to prepare for water shortages. In March 2014, CDFW and the SWRCB announced that they would expedite the permitting and approval of storage tanks for landowners who currently divert water from rivers and streams in the Northern and Bay Delta regions of CA (CDFW regions 1 and 3). This action, which came under the State Water Board's Small Domestic Use (SDU) registration program, will relieve pressure for in-stream diversions during the drier months when fish need it most. This action was a direct result of suggestions made by local communities, SRF, Mattole River Sanctuary Forest, and Trout Unlimited (CDFW 2014).

## Water Chemistry

### Sediment

Sediment affects salmonids both directly and indirectly by modifying aquatic habitat. Coarse sediment, fine sediment, and suspended sediment may adversely affect adult and juvenile salmonids by altering channel structure and affecting production.

In 1999, the SF Eel Basin was listed by the USEPA as an impaired water body for sediment. In the TMDL analysis (USEPA 1999), the USEPA interpreted water quality standards, calculated existing sediment loads, set loading capacities, and established load allocations. The most significant sources of sediment found in the watershed included roads, timber harvest related activities, and natural sources. In order to interpret water quality standards and to determine the amount of sediment that will not adversely affect salmonids, USEPA developed a set of indicators: percent fines, turbidity, V star (V*), and the thalweg profile. Stillwater Sciences (1999) then completed a sediment source analysis, which was used to set TMDL loading capacity and allocations for the SF Eel River Basin. TMDL allocations were developed to assess the maximum allowable amount of sediment received by a stream while still meeting water quality requirements (*Table 30*).

*Table 30. USEPA sediment indicators and targets for the SF Eel River Basin (USEPA 1999).*

| Indicator | Target | Purpose |
|---|---|---|
| Substrate composition – percent fines | <14%<0.85 mm | 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 | Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities |
| Residual pool filling (V*) | <0.10 | Estimate of sediment filling of pools from disturbance |
| Thalweg profile | Increasing variation from the mean | Estimate of improving habitat complexity & availability |

The USEPA and Stillwater Sciences did not subdivide the SF Eel River Basin into subbasins, so estimates and recommendations were developed for the entire basin. The USEPA calculated that existing sediment loading was approximately two times the natural rate, or for every ton/square kilometer/year of natural sediment, there was one ton/square kilometer/year of human-induced sediment (USEPA 1999). Stillwater Sciences (1999) found that sediment loading is variable, and roads are the largest anthropogenic contributors of fine sediment to streams throughout the basin.

The total sediment load was calculated to be 704 tons/square kilometer/year or 1.9 tons/square kilometer/day on a 15 year running average (*Table 31*). The ratio of human-induced sediment is approximately 1:1, but slightly more sediment is from natural sources (54% of total) than from anthropogenic sources (46% of total). Earthflows are the primary source of natural sediment, and roads are the primary source of anthropogenic sediment in the basin.

The loading capacity, or the amount of pollution that a stream can assimilate and still meet water quality standards, was set for all stream reaches in the basin based on a 1:4 ratio of human to natural sediment.

*Table 31. Basinwide estimates of sediment sources for the SF Eel River Basin from 1981-1996 (USEPA 1999).*

| Sediment Source | Total sediment input (tons/year) | Unit area sediment input (tons/square kilometer/year) | Fraction of total |
|---|---|---|---|
| Natural Sediment Sources | | | |
| Earthflow toes and associated gullies | 478800 | 269 | 38% |
| Shallow landslides | 132500 | 74 | 11% |
| Soil creep | 62980 | 35 | 5% |
| **Subtotal** | **674280** | **378** | **54%** |
| Anthropogenic Sources | | | |
| Shallow landslides, roads and harvest | 216200 | 121 | 17% |
| Skid trail erosion | 21534 | 12 | 2% |
| Road surface erosion | 67512 | 38 | 5% |
| Road crossing failures and gullying | 276500 | 155 | 22% |
| **Subtotal** | **581746** | **326** | **46%** |
| **Total** | **1256026** | **704** | **100%** |

Using this ratio, the allowable human-induced loading capacity would be 95 tons/square kilometer/year, and the TMDL for the basin would be 473 tons/square kilometer/year. Considerable erosion control measures will be required to meet the TMDL and loading capacity. For example, in order to meet the target ratio, road sediment would need to be reduced from current levels by 80%. Sediment from landslides would then require a 55% reduction in input levels.

In their South Fork Eel TMDL Sediment Source Analysis, Stillwater Sciences (1999) studied sediment sources and rates of input in three SF Eel River drainages in order to develop estimates and recommendations for the entire SF Eel River Basin. One of the watersheds selected for intensive study was Tom Long Creek (total area 13 square miles), located southeast of the town of Benbow in the Eastern Subbasin. Stillwater Sciences compared sediment sources and input in two time periods: 1966-1981 and 1981-1996. The Tom Long Creek watershed differed in land use and vegetation from other study area basins in the Northern (Bull Creek) and Western (Sproul Creek) subbasins in geology, geography, and land use. Land uses around Tom Long Creek consist primarily of residential, with some grazing, small-scale timber harvesting, and open space/parks; most land in the basin is privately owned (Stillwater Sciences 1999). Sediment input was higher between 1966 and 1981 averaged (3,295 tons/square kilometer/year) than between 1981 and 1996 (1,245 tons/square kilometer/year), and both of these amounts were larger than those documented in other study areas in the SF Eel River Basin (Stillwater Sciences 1999). Earthflow toes and associated gullies were the primary sediment sources in the Tom Long Creek basin (accounting for 65% of the total loading), followed by road crossing and gully erosion (18%). Sediment yield was dependent on local geology; mélange areas had significantly higher yields than Coastal Belt areas. These observations are consistent with Mackey and Roering (2011), who found that slow-moving earthflows, occurring mainly in mélange lithology, were the primary erosion processes in the Eel River Basin. Roads in the Tom Long Creek Basin are poorly maintained, are generally insloped with inside ditches, and likely contribute to sheetwash erosion. Basin residents noted that many road crossing failures occurred in the early 1980s, particularly during the wet winter of 1982-1983 (Stillwater Sciences 1999). These road crossing failures provide substantial sediment input to streams in this watershed.

In the Water Quality Control Plan for the North Coast Region, NCRWQB established SF Eel River basin-wide regulations that turbidity should not be increased more than 20 percent above naturally occurring background levels (NCRWQCB 2011). Additional prohibitions are included for erosion sources such as logging operations, roads, and constructions projects, so that organic material (including soil, bark, slash, sawdust, and other earthen material) from these operations is not directly or indirectly discharged into streams in quantities sufficient to harm fish and wildlife.

Road decommissioning, or the removal and stabilization of unwanted roads to a natural state, is an effective management technique used to reduce sediment input in watersheds with high road densities. McCaffery et al. (2007) found that watersheds with decommissioned roads had lower percentages of fine sediment in streams than those with roads in use. Many CDFW Fisheries Restoration Grant Program (FRGP) projects that have been completed in upslope areas in the Eastern Subbasin include road decommissioning and erosion control measures.

Pacific Watershed Associates (PWA) completed an evaluation of CDFW road decommissioning protocols and guidelines used on more than 51 miles of road in Northern California between 1998 and 2003 (PWA 2005). They determined that at decommissioned stream crossing sites:

- Sediment delivery was approximately 5% of the original pre-treatment fill volume;
- Unexcavated fill was the most common problem; and
- Protocols were effective but were not being uniformly followed at stream crossing sites.

At landslide sites and road drainages, PWA determined that protocols were effective and were being followed, but protocols for “other” sites were vague and ineffective. When done properly, road decommissioning projects resulted in decreased fine sediment input at most treated sites. Although PWA did not look at specific road decommissioning sites in the Eastern Subbasin, their findings are important to consider given the high road density and the potential to significantly reduce the amount of sediement input from legacy and failing roads. Other sediment reduction projects completed in the subbasin (see Fish Restoration Programs section) will also contribute to a reduction in overall sediment input, and will be monitored over time.

Unique to the Eastern Subbasin, two streams (Mud Creek and Mud Springs Creek) in the southern part of the subbasin receive constant sediment input from natural mud springs (*Figure 51 A, B*). Mud Creek has higher levels of suspended sediment and more limited fish presence than Mud Springs Creek.

*Figure 51 A, B. Natural mud springs (photo taken in 1954) (above (A)) and mud suspended in waters of Mud Creek downstream from mud springs near confluence with SF Eel River (below (B)).*

## Nutrients

Low to moderate concentrations of nutrients (primarily nitrogen and phosphorous) are essential to the health of streams. However, high nutrient levels may lead to eutrophication, which decreases water clarity, reduces dissolved oxygen concentrations, and may lead to blue-green algae blooms, all of which are harmful to aquatic invertebrates and salmonids. UC Berkeley graduate student Keith Bouma-Gregson sampled nitrogen and phosphorous concentrations at seven Eel River Basin sites while collecting cyanotoxin and temperature data in the summer of 2013. Three of these sites were located in the mainstem SF Eel River, on the Eastern Subbasin boundary line: at Richardson Grove (RM 49), Standish-Hickey SRA (RM 66), and Angelo Reserve (RM 89). Bouma-Gregson is currently analyzing data and developing conclusions on the relationship between blue-green algae blooms, toxins, temperatures, nutrient levels, and blue-green algae and green algae associations in SF Eel River streams (K. Bouma-Gregson, UC Berkeley, personal communication 2014).

## Aquatic Invertebrates

Aquatic macroinvertebrates are the primary food source for salmonids, and can be used as indicators of stream health because they are directly affected by physical, chemical and biological stream conditions. They may also show effects of habitat loss and short- and long-term pollution events that may not be detected in traditional water quality assessments (USEPA 1997). High instream temperatures, reduced flow, and increased sediment input may result in decreased macroinvertebrate assemblages and abundance, and populations may be further reduced in watersheds where land use activities have intensified these conditions (Cover et al. 2006).

In 1996, Friedrichsen (1998) sampled macroinvertebrate communities throughout the Eel River Basin. Sampling locations were selected by Scott Downie (CDFW) and reviewed by the project's technical advisory committee. Seven of the sampling sites were located within the SF Eel River Basin boundary, with three locations in the Eastern Subbasin (Tenmile Creek, Cedar Creek, and East Branch SF Eel River). Five metrics (explained in detail by Plafkin et al. 1989) of macroinvertebrate assemblages and community structure were used to assess stream condition:

- The Simpson Index (diversity of taxa and evenness of the community);
- Modified Hilsenhoff Index (tolerance values and number of organisms per taxa divided by the total number of invertebrates in the sample);
- EPT Index (number of species of Ephemeroptera, Plecoptera (*Figure 52*), and Trichoptera (mayflies, stoneflies, and caddisflies));
- Percent Dominant Taxa (the total number of organisms in the sample divided by the number of invertebrates in the most abundant taxa); and
- Richness Index (total number of taxa).


*Figure 52. Stonefly (Plecoptera) larva (photo courtesy of Joyce Gross, UC Berkeley).*

These metrics may indicate if the stream is healthy or impaired, and can be used to determine how invertebrate assemblages respond to human and natural disturbances. Friedrichsen (1998) found that when all metric results were considered, streams with high summer temperatures (e.g. East Branch SF Eel River) had declining scores from spring to fall, possibly due to high water temperatures. The most abundant taxa in the East Branch SF Eel River were adapted to warm water and were grazers, which thrive in streams with low canopy density and abundant algal growth. Invertebrate populations in Redwood Creek (near Branscomb) in the Western Subbasin were among the healthiest in the SF Eel River Basin. These invertebrate communities had good evenness, and a higher level of representation of taxa associated with cooler summer water temperatures. Other SF Eel River headwater streams located in the Eastern Subbasin that are not heavily impacted by diversion for residential and agricultural uses that have similar instream conditions as Redwood Creek are Fox, Elder, Rock, Kenny, Taylor, Bear, and Little Rock creeks.

Many streams in the Eastern Subbasin are heavily diverted, particularly in areas where residential land use is high and water is diverted for illegal marijuana cultivation. In addition to reduced instream flow, water entering the stream near grow operations may be polluted with fertilizers, diesel fuel, rodenticides, human waste, and fine sediment, affecting water quality and, therefore, instream invertebrate communities. More information is necessary to determine invertebrate species tolerance levels for increasing pollution levels and elevated water temperatures, to assess the effects of increased diversions on aquatic invertebrate populations, and to determine how changes in invertebrate populations affect salmonid populations.

Food web ecology and aquatic invertebrates that support salmonids have been studied at Angelo Coast Range Reserve near Branscomb, as part of the Eel River Critical Zone Observatory (https://criticalzone.org/images/national/associated-files/Eel/EelRiverCZO_Project_Description.pdf). Scientists and students from UC Berkeley have monitored low flow food web dynamics and explored links between the mainstem SF Eel River and food webs in 12 tributary streams in the headwaters, including Elder Creek. For more information, and a list of publications, go to: http://angelo.berkeley.edu/angelo/

## Blue-Green Algae Blooms

Blue-green algae (cyanobacteria) are naturally occurring photosynthetic bacteria present in warm, slow-moving surface waters during temperate months in the late summer and early fall. Some forms of blue-green algae produce harmful toxins which may attack the liver (hepatotoxins) or the nervous system (neurotoxins). These toxins are released into the environment when cells rupture or die, and may be concentrated during algal blooms (Hoehn and Long 2008, Blaha 2009). The relationship between the timing of blooms and the concentration of cyanotoxins in the water column is currently unknown (K. Bouma-Gregson, UC Berkeley, personal communication 2014).

Cyanobacteria occur naturally throughout the SF Eel River, in the water column, living within the cell walls of diatoms, growing directly on the substrate, and growing on certain types of filamentous green algae such as *Cladophora*.

Rapid accumulations of cyanobacteria cells, or algal blooms, occur during warm summer months, under optimal conditions including elevated stream temperatures, high levels of nutrients (phosphorous and nitrogen, and the ratio of the two), increased periods of sunlight, and low flow. Human activities such as inadequate sewage treatment, or activities that result in increased agricultural and sediment input, lead to excessive fertilization (eutrophication) in water bodies. Eutrophication creates favorable conditions for blue-green algae blooms (WHO 2009) and decreased water clarity and reduced dissolved oxygen levels in streams (Trout Unlimited 2013).

Measures to prevent blooms should be designed to control anthropogenic influences that promote blooms, such as the leaching and runoff of excess nutrients. Management practices for nutrient input, specifically nitrogen and phosphorus, should be designed to reduce loadings from both point and nonpoint sources, including water treatment discharges, agricultural runoff, and stormwater runoff (USEPA 2012). This is especially important in Eastern Subbasin drainages where nutrients, sediment, and/or pollutants are entering streams from large marijuana cultivation operations (e.g. Tenmile Creek, Cahto Creek, and the East Branch SF Eel River). Nutrients enter streams directly in runoff from operations, and in areas where spent soil is illegally dumped adjacent to rivers and streams (Times-Standard 2012).

The Humboldt County Department of Health and Human Services (HCDHHS) recently issued warnings notifying recreational users of the SF Eel River to avoid exposure to neurotoxins and liver toxins found in blue-green algae in the river (HCDHHS, Division of Environmental Health, 2011). The County provided the following recommendations for homeowners and land managers to reduce conditions favoring the spread of blue-green algae:

- Minimize the use of water, fertilizers, and pesticides;
- Recycle or dispose of spent soil that has been used for intensive growing – it may still contain high levels of phosphorous and nitrogen;
- Operate and maintain your septic system properly; have the system pumped every 3-4

years;
- Encourage the growth of native plants on riverbanks and shorelines to prevent erosion and filter water, with no fertilizers or pesticides required;
- Keep livestock out of surface waters and prevent surface runoff from agricultural areas; and
- Prevent sediment from roads, construction projects, and logging operations from entering streams.

In recent years, blue-green algae blooms have become more common in the mainstem SF Eel River during the late summer, when flows are at a minimum and air temperatures are high (>100˚F). These conditions are prevalent in the middle mainstem areas of SF Eel River in the Eastern Subbasin. The ERRP is currently collecting information on algal blooms, flows, pollutants, and temperatures throughout the Eel River Basin, and are currently developing recommendations to improve ecological conditions and reduce pollution. Bouma-Gregson obtained weekly average concentrations of dissolved cyanotoxins, nitrogen, and phosphorous at seven sites in the Eel River Basin from July-September, 2013 (for a description of sampling locations, see the Temperature section of this subbasin report). The sites with the highest concentrations of toxins were located in the SF Eel River, though cyanobacteria were present at all sites except Fernbridge. *Anabaena* and *Phormidium*, two genera of cyanobacteria that produce cyanotoxins, were frequently observed at all of the monitoring sites except Fernbridge (Bouma-Gregson, UC Berkeley, personal communication, 2014).

In the Eastern Subbasin, cyanobacteria blooms have been reported only in the mainstem SF Eel River. However, it is likely that they have occurred in larger tributaries such as the East Branch SF Eel River, in the late summer and early fall, when flow is at a minimum and air and stream temperatures are high (*Figure 53*). Additional studies targeting Eastern Subbasin tributaries are necessary to address the following issues: specific locations of blue-green algae blooms; the relationship between blue-green algae and green algae; levels of nutrients and pollutants present; current sources of nutrient input; and ways to reduce the input of these and other harmful substances in order to improve salmonid habitat.

*Figure 53. Algae in East Branch SF Eel River during low flow (8/27/2013).*

## Fish Passage Barriers

Barriers to fish passage occur on all natural streams, and are usually gradient or flow barriers near the headwaters. Barriers that occur downstream and limit the naturally occurring range and distribution of salmonids can be classified according to the cause of the barrier (natural or anthropogenic), the barrier's lifespan (temporary or permanent), and the barrier's effectiveness (partial or total). Natural barriers include gradient, landslide, and log debris accumulations (LDA); manmade barriers include culverts and dams. All types of barriers fragment the habitat available to different life stages of salmonids by reducing access to stream reaches that are used as migratory corridors, and spawning and rearing habitat.

Several fish passage barrier issues have been identified in the Eastern Subbasin. Most of the barriers are gradient barriers (n = 28), followed by culvert barriers (12 partial and 15 total) (*Figure 54*). Six "Other" barriers were mostly lack of landowner permission and access issues, but also included one instance of the end of anadromy due to orange bacteria from bank to bank as far upstream as surveyors could see in Cahto Creek in 2009.

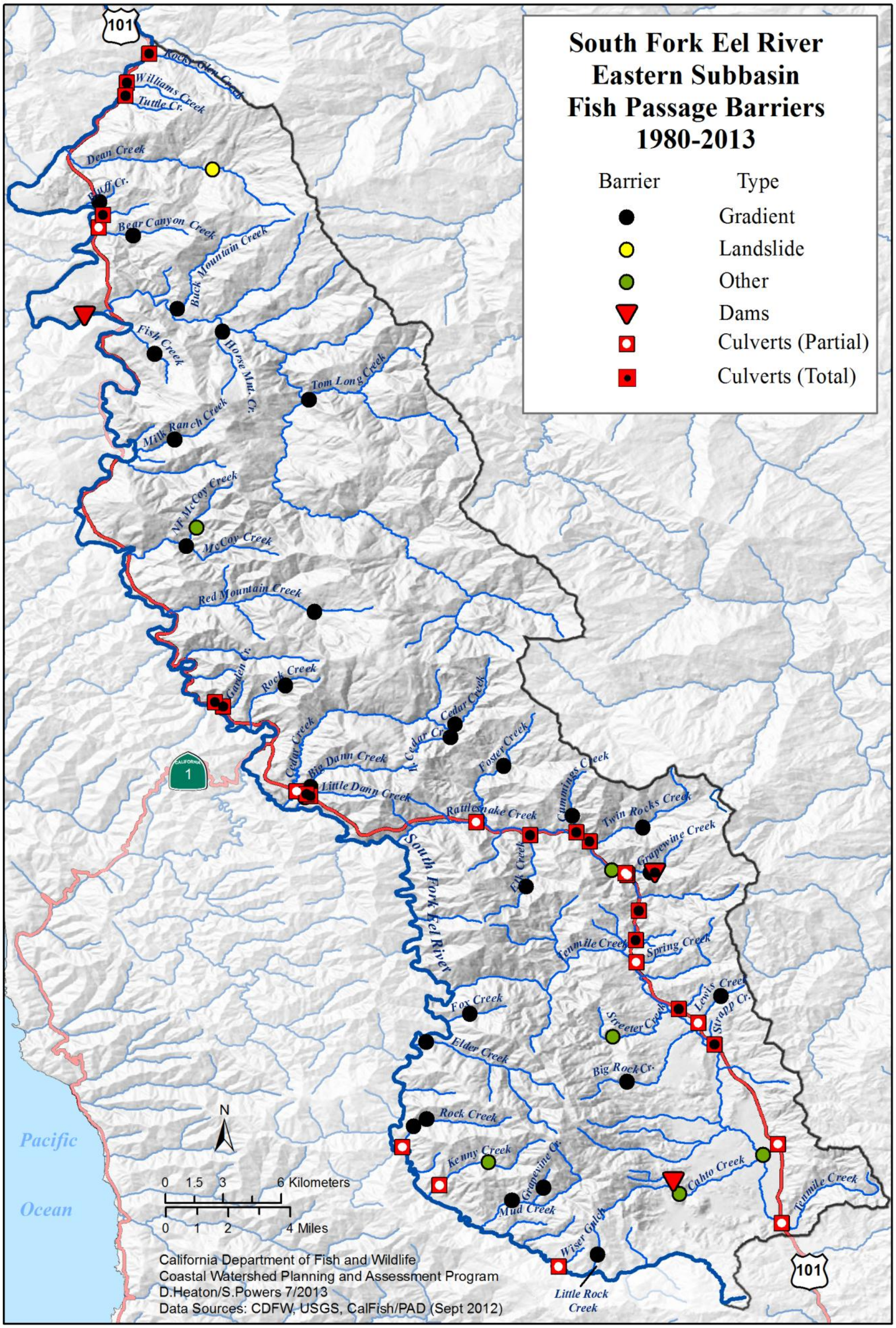



*Figure 54. Fish passage barriers in the SF Eel River Eastern Subbasin.*

Improper culvert placement where roads and streams cross can limit or eliminate fish passage (Gucinski et al. 2001). Highway 101, the only primary road in the subbasin, runs along the SF Eel River for the full length of the subbasin, with a secondary frontage road following the highway for most of its length. Many smaller roads, some permanent and some seasonal, connect Highway 101 with headwater areas in most of the larger watersheds. Many roads cross streams multiple times, and at each crossing, passage issues are a possibility. Twenty four culvert barriers (9 partial and 15 total) are located along the Highway 101 corridor, near the mainstem SF Eel River, and along Rattlesnake and Tenmile Creeks (*Figure 55*). There are three partial culvert barriers on roads not located along the Highway 101 corridor, located on Wise Gulch, and Rock and Kenny creeks in the headwaters of the SF Eel River near Branscomb.

*Figure 55. Partial culvert barrier where Highway 101 crosses Rattlesnake Creek in the Eastern Subbasin.*

There are two dams in the Eastern Subbasin, one of which is considered a total barrier (Grapevine Creek) and one is currently unassessed (unnamed tributary to Cahto Creek). Benbow Dam was identified by CalFish (2012) and included on the barrier map for reference, however, the flashboards are no longer installed each summer to impound water, and it is not considered a barrier to fish passage at this time (S. Downie, CDFW, personal communication 2014).

Gradient barriers formed by boulders or bedrock are found throughout Eastern Subbasin streams (*Figure 54*). Most of the gradient barriers mapped in this subbasin were waterfalls, which are considered extreme examples of gradient barriers. The largest waterfall barrier (22’) in the subbasin is located on Fish Creek, and other streams contain smaller waterfalls that are large enough to act as total barriers. Height or vertical drop of falls, plunge pool area and depth, and the jumping ability of each species must be considered when determining whether a waterfall is a barrier to fish passage (Powers and Orsborn 1985). Other types of gradient barriers were boulder runs and series of cascades.

Log jams, referred to in this report as LDAs, in streams can also become fish passage barriers. These are noted in CDFW stream inventories. LDAs are usually temporary barriers, because they shift or break apart during large flow events, but some trap sediment and additional material so that they may persist for decades as total barriers. Stream inventories in the Eastern Subbasin documented no total LDA barriers, although many large debris jams were noted in stream surveys, especially following historic flood events. Restoration activities in the past concentrated on removing wood jams, including those that were complete, partial, or potential barriers. These actions, combined with intensive industrial timber harvest activities, resulted in a lack of large wood in streams. Current restoration projects concentrate on adding large wood back into streams to scour pool habitat and provide cover for adult and juvenile salmonids.

# Habitat Conclusions

## Overall Suitability

CWPAP staff assessed changes in Eastern Subbasin salmonid habitat using historic data collected on surveys from 1938-1990, and stream habitat typing survey data collected from 1990-1999 and 2000-2010. Data from older surveys, collected prior to the establishment of a stream survey protocol (Flosi et al. 2010), provided a snapshot of the conditions at the time of each survey. Terms such as excellent, good, fair, and poor were based on the judgment of the biologist or scientific aid who conducted the survey. The results of these historic stream surveys were qualitative and were not used in comparative analyses with quantitative data provided by habitat inventory surveys collected beginning in the 1990s. However, the two data sets were compared to show general trends.

In historic surveys (1934-1990), spawning habitat, invertebrate food, and shelter were good in Cedar, Grapewine, Rancheria, and Red Mountain creeks. High water temperatures were noted in Red Mountain Creek and in the mainstem and East Branch SF Eel River. Low summer flows were also mentioned in many Eastern Subbasin stream reports. Diversions were a concern and were noted beginning in the 1950s in Cahto, Mill, and Taylor creeks. Log jams and waterfalls were the most common barrier type, and many of the waterfalls were considered total barriers to fish passage.

Using recently collected (1990-2010) habitat typing data from Eastern Subbasin streams, canopy density suitability was generally good except in Tenmile, Milk Ranch, Mud, and Cahto creeks (*Table 32*). Canopy density suitability did not change in most streams between the two time periods, except for slight decreases in Cahto Creek and substantial increases in Milk Ranch and Mud creeks.

Overall canopy density measurements do not take into account differences between smaller, younger riparian vegetation and the larger microclimate controls that are provided by old-growth forest canopy conditions. CWPAP staff considered the contribution of coniferous and deciduous components in the canopy, and found that the average percent of coniferous and deciduous vegetation increased slightly in Milk Ranch, Mud, SF Bear Canyon, and Tenmile creeks over time.

Primary pool length decreased dramatically in nearly all Eastern Subbasin streams surveyed, and was in the lowest suitability category for nearly all streams during the 2000-2010 sampling period. Tenmile Creek was the only stream surveyed that showed improvement in the length of primary pool habitat over time.

Pool shelter was in the lowest suitability category in most Eastern Subbasin streams during both time periods. Pool shelter values were only suitable in Tenmile Creek in 1996. Both pool habitat and pool shelter are likely limiting factors in Eastern Subbasin streams.

Cobble embeddedness suitability increased slightly in most Eastern Subbasin streams over time, but was only in the highest category in Streeter Creek in 2009. This improvement is most likely due to changes in timber harvest regulations, road decommissioning, numerous restoration and instream habitat improvement projects completed in this basin, and sediment from historic floods moving through the system. Although embeddedness suitability scores increased in many streams, average values were still below target values during both sampling periods.

Summer water temperature measurements showed that there were more Eastern Subbasin sites with poor stream temperatures than good or fair sites. Temperatures were good for salmonids in the mainstem SF Eel River and tributaries above Branscomb (RM 95), but were stressful for salmonids at downstream sites and in larger tributaries. Lethal temperatures were recorded in the mainstem SF Eel River at Piercy (RM 54) and Sylvandale (RM 25), and in the East Branch SF Eel River and lower Tenmile Creek. These streams are wide channels with little riparian canopy cover and increased direct solar radiation, resulting in higher stream temperatures than smaller, shaded streams. Stream temperatures are also higher in tributaries where water is diverted for residential use and marijuana cultivation operations. Water temperature is likely a limiting factor for salmonids in surveyed streams in this subbasin, and cold water seeps where springs or tributaries enter the mainstem may provide important refugia areas with cooler water for salmonids during late summer months.

Sediment loading in the Eastern Subbasin is extremely high, and primary input sources include natural landslides and earthflows, road erosion and failure, and logging related erosion from skid trails and road construction. This subbasin has a high density of roads, and road decommissioning projects have resulted in decreased fine sediment input at most treated sites, however, considerable erosion control measures will be required to meet the established TMDL and loading capacity. Sediment loading and turbidity conditions may be limiting factors for salmonid production.

*Table 32. EMDS-based Anadromous Reach Condition Model suitability results for factors in Eastern Subbasin streams.*

| Stream | Survey Year | Mean Canopy Density (%) | Pool Tail Cobble Embeddedness (%) | Length of Primary Pools (%) | Pool Shelter Rating |
|---|---|---|---|---|---|
| Bear Canyon Creek | 1999 | ++ | + | ++ | - |
| | 2009 | ++ | - | -- | -- |
| SF Bear Canyon Creek | 1992 | ++ | -- | -- | -- |
| | 2009 | ++ | + | -- | -- |
| Big Rock Creek | 1994 | ++ | -- | + | -- |
| | 2009 | ++ | + | -- | -- |
| Cahto Creek | 1996 | ++ | -- | ++ | - |
| | 2009 | + | - | -- | -- |
| Kenny Creek | 1996 | ++ | - | ++ | -- |
| | 2005 | ++ | - | -- | -- |
| McCoy Creek | 1995 | ++ | - | ++ | - |
| | 2007 | ++ | + | -- | -- |
| Milk Ranch Creek | 1993 | -- | -- | - | -- |
| | 2007 | ++ | - | -- | -- |
| Mud Creek (SF Eel) | 1995 | -- | -- | + | -- |
| | 2007 | ++ | - | -- | -- |
| Streeter Creek | 2009 | + | ++ | -- | -- |
| Tenmile Creek | 1996 | -- | -- | - | ++ |
| | 2009 | -- | + | ++ | -- |
| **Key: ++ = Highest Suitability -- = Lowest Suitability** | | | | | |

## Restoration Projects

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 CDFW's Fisheries Restoration Grants Program (FRGP) projects and other projects with which CDFW has been involved. The CHRP data is available through CalFish (www.calfish.org) and includes some projects from agencies and programs outside of CDFW. In addition, the Natural Resources Project Inventory (NRPI), available through the University of California, Davis (www.ice.ucdavis.edu/nrpi/), contains information on projects from the CHRPD and other sources. Information presented here includes projects from both of these databases, but are not comprehensive of all restoration projects completed in the Eastern Subbasin.

There have been 64 restoration projects, totaling more than 3 million dollars in funding, completed in the Eastern Subbasin from 1982 to the present (*Table* 33). The most common type of project has been upslope watershed restoration, followed by

*Table 33. Northern Subbasin restoration project type and funding (1982 to 2013).*

| | Eastern Subbasin | |
|---|---|---|
| **Project Type** | **# of Projects** | **Total Project Funding** |
| Bank Stabilization | 11 | $644,168 |
| Cooperative Rearing | 2 | $55,853 |
| Fish Passage Improvements | 6 | $461,906 |
| Instream Habitat Improvement | 6 | $367,613 |
| Land Acquisition | 0 | $0 |
| Monitoring | 1 | $17,887 |
| Other * | 10 | $386,608 |
| Riparian Habitat Improvement | 8 | $238,013 |
| Upslope Watershed Restoration | 14 | $1,299,181 |
| Watershed Evaluation, Assessment & Planning | 6 | $150,113 |
| **Total** | **64** | **$3,621,341** |
| * "Other" includes education/outreach, training, capacity building and public involvement. | | |

bank stabilization. The highest level of funding, more than one third of the overall funding, has been allocated to upslope watershed restoration.

Most Eastern Subbasin upslope watershed restoration projects have been completed in the East Branch SF Eel River, and many are part of the Reed Mountain sediment assessment/planning and road stormproofing (Figure 56). Upslope restoration projects have also been completed in Mud and Kenny creeks in the SF Eel River headwaters near Branscomb. Bank stabilization projects have been completed in Tenmile Creek, and in the East Branch SF Eel River and its tributaries. Riparian habitat improvement projects have been completed in Tenmile Creek and in the middle to lower mainstem SF Eel River.

Additional information on specific projects can be found on CalFish (www.calfish.org) or on the Natural Resources Project Inventory online database (www.ice.ucdavis.edu/nrpi/).

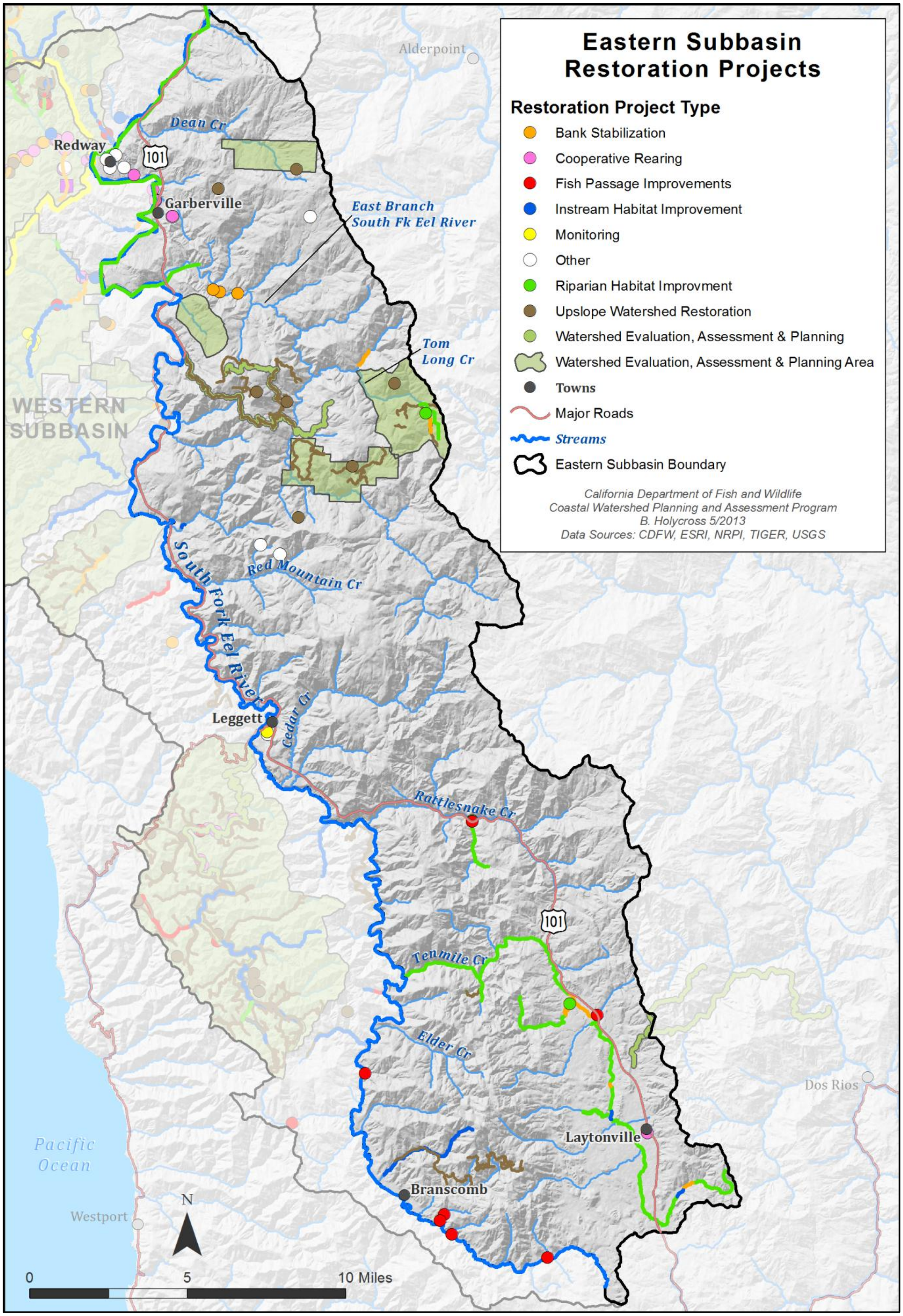



*Figure 56. SF Eel River Eastern Subbasin restoration projects.*

# Integrated Analysis

## Analysis of Tributary Recommendations

In addition to presenting habitat condition data, all CDFW stream inventories provide a list of recommendations that address those conditions that did not reach target values (see the Fish Habitat section of this subbasin report). In the Eastern Subbasin, 46 inventories on 33 streams were completed, and recommendations for each were selected and ranked by a CDFW biologist (*Table 34*). The first recommendation in every CDFW stream inventory report is that the stream "should be managed as an anadromous, natural production stream". Because this recommendation is the same for every stream, and because it does not address specific issues, with associated target values, it was not included in the tributary recommendation analysis. The tributary recommendation process is described in more detail in the Synthesis section of the Basin Profile.

In order to compare tributary recommendations within the subbasin, the recommendations of each stream were collapsed into five target issue categories (*Table 35*). The top three recommendations for 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 Eastern Subbasin is instream habitat.

However, comparing recommendation categories in the subbasin by number of tributaries can be confounded by the differences in the length surveyed in each tributary. Therefore, the number of stream miles within the subbasin assigned to various recommendation categories was calculated (*Figure 57*). By examining recommendation categories by number of stream miles, the most important target issue was riparian/water temperature, followed by instream habitat and erosion/sediment as the most important issues. Because of the high number of recommendations dealing with these target issues, high priority should be given to restoration projects that emphasize riparian habitat improvement that will lead to cooler stream temperatures. Projects designed to increase the quality of instream habitat (by providing shelter and deep pool habitat), and those that address road improvement, decommissioning, and bank stabilization to decrease sediment input should also be considered high priority in the Eastern Subbasin.

*Table 34. Occurrence of stream habitat inventory recommendations for streams of the Eastern Subbasin.*

| **Stream** | **Survey Length (miles)** | **Bank** | **Roads** | **Canopy** | **Temp** (A=study required) | **Pool** | **Cover** | **Spawning Gravel** | **LDA** | **Livestock** | **Fish Passage** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bear Canyon Creek (1992) | 1.3 | 4 | 5 | | A1 | 2 | 3 | | | | |
| Bear Canyon Creek (1999) | 1.4 | | | 4 | A1 | 2 | 3 | | | | |
| Bear Canyon Creek (2009) | 1.4 | | 4 | | A1 | 2 | 3 | | | | |
| Bear Canyon Creek, SF (1999) | 0.3 | | | | A1 | | | | | | |
| Bear Canyon Creek, SF (2009) | 0.8 | | | | A1 | | 2 | | | | |
| Big Rock Creek (1994) | 3.9 | 2 | 3 | 4 | A1 | 5 | 6 | | | | |
| Big Rock Creek (2009) | 4 | 3 | | 4 | A1 | | 2 | | | | |
| Bridges Creek (1994) | 3.1 | 1 | 2 | 6 | | 5 | 4 | | 3 | | |
| Cahto Creek (1996) | 4 | | 5 | | A1 | 2 | 3 | | | 4 | |
| Cahto Creek (2009) | 3.1 | 3 | 4 | 5 | A1 | | 2 | | | | |

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cedar Creek (1993) | 10.5 | 3 | | 2 | A1 | 7 | 4 | 5 | | | 6 |
| Cummings Creek (1993) | 0.8 | 4 | 5 | | A3 | 1 | 2 | | | | 6 |
| Dean Creek (1992) | 5.7 | 4 | 5 | 3 | A1 | 7 | 6 | | | | |
| East Branch SF Eel River (1993) | 20.8 | | 5 | 2 | A1 | 3 | 4 | | | 6 | |
| Elder Creek (1992) | 1.6 | | 3 | | | 1 | 2 | 4 | | | 5 |
| Elk Creek (Rattlesnake Creek) (1993) | 2.4 | 4 | 5 | | A1 | 2 | 3 | | | | 6 |
| Fish Creek (Benbow) (1994) | 1.3 | 5 | 6 | 2 | A1 | 3 | 4 | | 7 | | 8 |
| Foster Creek (1993) | 3.2 | 5 | 6 | 2 | A1 | 3 | 4 | | | | |
| Fox Creek (1992) | 0.7 | | | | | 3 | 4 | | 1 | | 2 |
| Grapevine Creek (1997) | 0.7 | | 5 | | A3 | 2 | 1 | 4 | | | |
| Grapewine Creek (1993) | 0.8 | 1 | | | A4 | 2 | 3 | | | | |
| Kenny Creek (1996) | 3.6 | | 2 | | A1 | 4 | 3 | | | | |
| Kenny Creek (2005) | 2.6 | 4 | 5 | 6 | A1 | 2 | 3 | 7 | 8 | 9 | |
| Lewis Creek (1994) | 1.3 | 4 | 5 | | A1,8 | | | | | | |
| Little Rock Creek (1996) | 0.8 | 4 | | | A3 | 2 | 1 | 5 | | | |
| Low Gap Creek (Piercy) (1993) | 1.9 | 4 | 5 | 6 | A2 | 1 | 3 | 8 | 7 | | |
| McCoy Creek (1995) | 4.2 | 3 | 4 | | | 1 | 2 | | 5 | | |
| McCoy Creek (2007) | 4.6 | 3 | 4 | | A5 | 1 | 2 | | | | |
| McCoy Creek, NF (1995) | 0.8 | | | 4 | A1 | 2 | 3 | | | | |
| Milk Ranch (1993) | 0.8 | | | 4 | A1 | 2 | 3 | | | | |
| Milk Ranch (2007) | 1.5 | 4 | 5 | | A1 | 2 | 3 | | | | |
| Mud Creek (1996) | 3.9 | | | | A1 | 2 | 3 | | | 4 | |
| Mud Creek (2007) | 4.3 | 4 | 5 | | A6 | 1 | 2 | 3 | | | |
| Rattlesnake Creek (1993) | 8.6 | 4 | 5 | 6 | A1 | 2 | 3 | | | | |
| Red Mountain Creek (1997) | 4.4 | 4 | | 5 | A1 | 2 | 3 | | | | |
| Rock Creek (1992) | 2.5 | 3 | 4 | | | 1 | 2 | | | | |
| SF Eel Headwaters (1996) | 9 | 1 | 2 | | A7 | 5 | 3 | | 6 | 4 | |
| SF Eel Headwaters (2007) | 5.4 | | | | A2 | | 1 | | | | |

| Stream | Survey Length (miles) | Bank | Roads | Canopy | Temp (A=study required) | Pool | Cover | Spawning Gravel | LDA | Livestock | Fish Passage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Streeter Creek (1994) | 3.2 | 3 | 4 | 2 | A1 | 6 | 7 | | | 5 | |
| Streeter Creek (2009) | 0.9 | 3 | | 4 | A1 | | 2 | | | | |
| Taylor Creek (1997) | 1 | | 4 | | A1 | 2 | 3 | | | | |
| Tenmile Creek (1996) | 15.8 | 3 | 4 | 2 | A1 | 5 | 6 | | | | |
| Tenmile Creek (2009) | 18.7 | 3 | | 4 | A1 | | 2 | | | | |
| Tom Long Creek (1993) | 4.1 | 2 | 1 | 4 | A3 | 6 | 7 | | | | 5 |
| Twin Rocks (1993) | 2 | 3 | | | | 1 | 2 | | | | |
| Windem Creek (1996) | 0.7 | 4 | 5 | | A1 | 2 | 3 | 6 | | | |

**Canopy** = shade canopy is below target values; **Bank** = stream banks are failing and yielding fine sediment into the stream; **Roads** = fine sediment is entering the stream from the road system; **Temp** = summer water temperatures seem to be above optimum for salmon and steelhead; **Pool** = pools are below target values in quantity and/or quality; **Cover** = escape cover is below target values; **Spawning Gravel** = spawning gravel is deficient in quality and/or quantity; **LDA** = large debris accumulations are retaining large amounts of gravel and could need modification; **Livestock** = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; **Fish Passage** = there are barriers to fish migration in the stream.

*Table 35. Top three ranking recommendation categories by number of tributaries in the Eastern Subbasin.*

| Target Issue | Related Table Categories | Count |
|---|---|---|
| Erosion / Sediment | Bank / Roads | 22 |
| Riparian / Water Temp | Canopy / Temp | 43 |
| Instream Habitat | Pool / Cover | 62 |
| Gravel / Substrate | Spawning Gravel / LDA | 3 |
| Other | Livestock / Barrier | 1 |

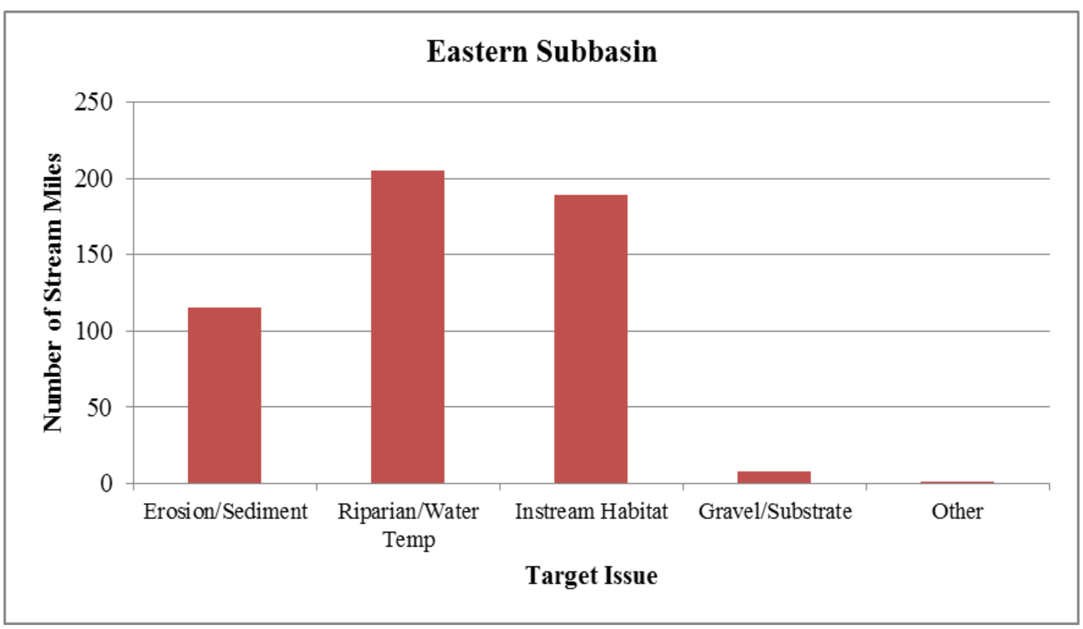



*Figure 57. Recommendation target issues by stream miles for the Eastern Subbasin.*

## Refugia Areas

The interdisciplinary team identified and characterized refugia habitat in the Eastern Subbasin using 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 salmonid refugia productivity. The team also used results from information processed by the EMDS-based analysis at the stream reach scale.

A total of 31 Eastern Subbasin streams were designated as salmonid refugia areas and were rated into one of the four refugia categories. Refugia categories were defined as:

- **High Quality** – relatively undisturbed habitat, with the range and variability of conditions necessary to support species diversity and natural salmonid production;
- **High Potential** – diminished but good quality habitat with salmonids present, currently managed to protect natural resources with the possibility to become high quality refugia;
- **Medium Potential** – degraded or fragmented instream and riparian habitat, with salmonids present but reduced densities and age class representation. Habitat may improve with modified management practices and restoration efforts;
- **Low Quality** – highly impaired riparian and instream habitat with few salmonids (species, life stages, and year classes). Current management practices and conditions have significantly altered the natural ecosystem and major changes are required to improve habitat.

The most complete data available in the Eastern Subbasin were for tributaries surveyed by CDFW. However, many of these tributaries were still lacking data for some factors considered. Two of the larger streams, East Branch SF Eel River and Tenmile Creek, were divided into two sections because of significant differences in conditions and salmonid use in upper and lower areas.

Eastern Subbasin streams were generally medium potential and low quality due primarily to lack of canopy, warm water temperatures, and unstable geology (*Figure 58*). Only one stream in the subbasin was rated high quality: Elder Creek in the headwaters near Branscomb. This stream is located entirely within the boundaries of the Angelo Coast Range Reserve, administered by UC Berkeley as a site for research, education, and public service. Low instream temperatures, good canopy cover, undiverted flow, and minimal road mileage in the watershed, combined with a relatively cool climate influenced by the coastal marine layer, make this excellent salmonid habitat (*Figure 59*).

Three streams were rated high potential refugia: McCoy Creek, Cedar Creek, and the upper mainstem SF Eel River (beginning at RM 92). Cedar Creek flows primarily through land managed by the USBLM (the Red Mountain Unit), and the dominant vegetation cover type is coniferous forest. This stream contains excellent steelhead habitat, and was chosen as the site of the Cedar Creek hatchery, which operated from 1949-1964. The upper mainstem SF Eel River provides good salmonid habitat due to cool instream and air temperatures (because of the influence of the coastal marine layer), topography that includes many steep walled canyons and narrow valleys, and fewer diversions than in other areas within the Eastern Subbasin.

Six streams in the subbasin were rated low quality: Dean Creek, lower East Branch SF Eel River, Fish Creek, Cummings Creek, Mud Creek, and Cahto Creek were classified as low quality refugia. Most of these creeks are located in residential areas and are heavily diverted. Instream habitat is characterized by high stream temperatures, poor canopy cover, low flow, high sedimentation rates, and poor water quality.

Twenty one streams in the Eastern Subbasin were rated medium potential refugia. Several specific issues include the following:

- East Branch SF Eel River above Tom Long Creek (± RM 9) – an excellent steelhead stream with cool water temperatures, but there are low flow issues due in part to diversions;
- Bridges Creek – the possibility of completing restoration projects is low due to restricted access;
- Rattlesnake Creek – there are passage issues at numerous culverts. Good flow below Elk Creek, with some areas of good canopy cover;
- Elk Creek – the culvert under Highway 101 crossing is a total barrier. Flow is a problem due to intense diversion pressure.

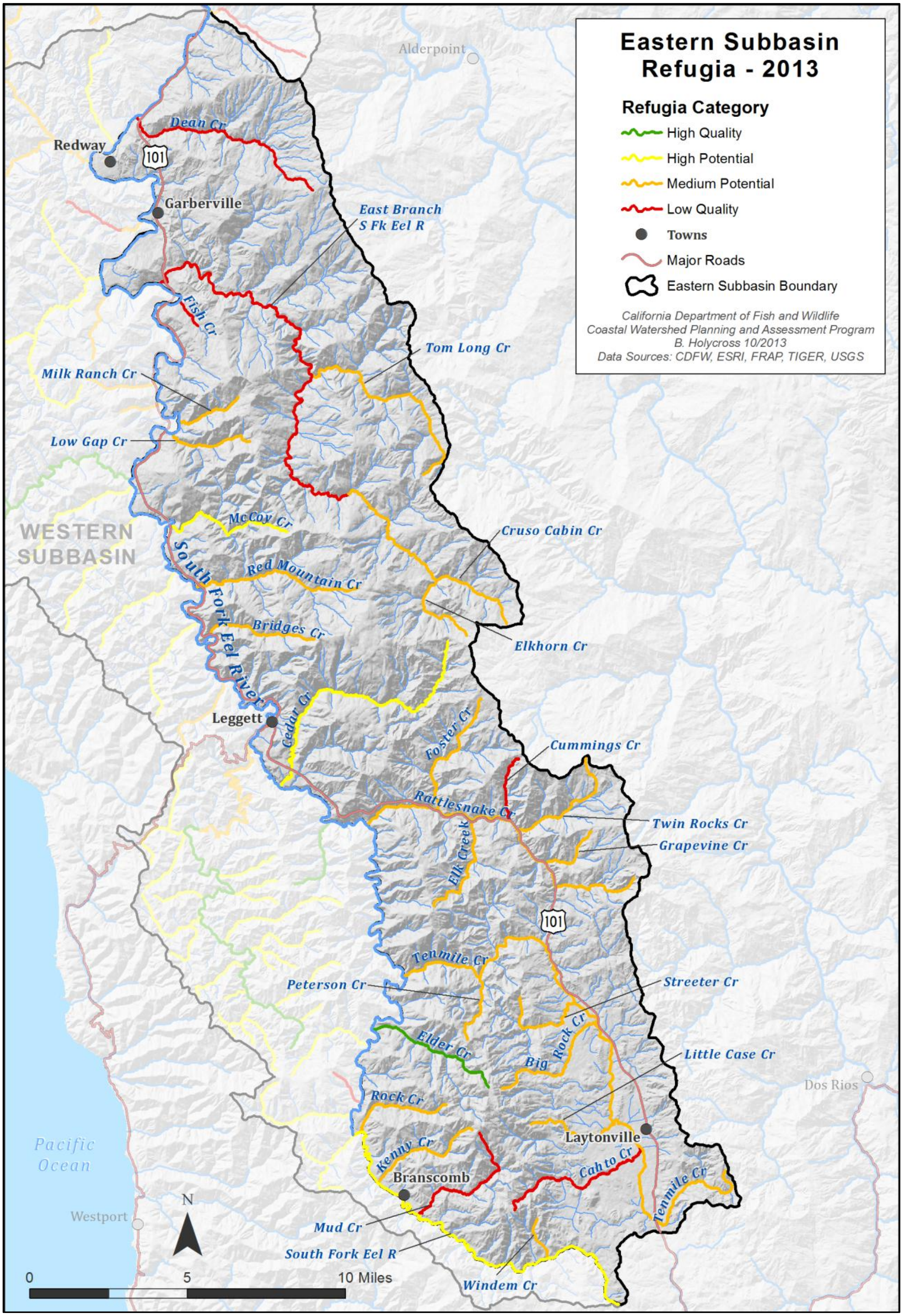



*Figure 58. Refugia ratings in SF Eel River Eastern Subbasin streams.*

*Figure 59. High quality refugia habitat in Elder Creek, part of the Angelo Coast Range Reserve in the SF Eel River headwaters near Branscomb.*

## Key Subbasin Issues

- Altered flow regimes, particularly during low flow periods in late summer, resulting from reduced winter precipitation and an increase in the number and magnitude of diversions;
- High instream temperatures in many streams, with above lethal temperatures recorded in the late summer in Tenmile Creek, the East Branch SF Eel River, and the middle and lower mainstem SF Eel River;
- High levels of fine sediment input related to high road density and erosion from landslides, construction waste, and ground disturbance on unstable soils;
- Low percent canopy density and poor quality pool habitat (depth, shelter, and cobble embeddedness) in most surveyed Eastern Subbasin streams;
- High gradient streams with natural (primarily waterfalls) or anthropogenic (culverts) barriers limiting anadromy;
- Addition of fertilizers, pollutants, and sediment to streams from marijuana cultivation operations in watersheds with high residential land use;
- Sacramento pikeminnow documented in mainstem SF Eel River and in some Eastern Subbasin tributaries.

## Responses to Assessment Questions

**What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Eastern Subbasin?**

*Findings and Conclusions:*

- The Eastern Subbasin supports populations of Chinook salmon, coho salmon, and steelhead trout;
- Using data from one long term data set for salmonid populations in the SF Eel River Basin (Benbow Dam counts occurring from 1938-1975), trend lines for Chinook salmon, coho salmon, and steelhead trout abundance all show significant decreases throughout the sampling duration. These trends are most likely similar for salmonid populations throughout Eastern Subbasin streams;
- Populations of all three salmonids appeared to decline abruptly following the 1955 and 1964 floods;
- Current salmonid populations are not only less abundant, but they are less widely distributed than they were historically:
    - Historical and anecdotal accounts in 46 Eastern Subbasin streams dating back to the late 1930s indicate the presence of presence of Chinook salmon in 12 tributaries (26% of streams sampled), coho salmon in 25 tributaries (54% of streams sampled), and steelhead trout in 36 tributaries (78% of streams sampled) in the Eastern Subbasin;
    - Current salmonid distribution, based on data collected for 167 Eastern Subbasin streams from a variety of sources (CDFW, USFS, tribal fisheries monitoring, university research, local watershed stewardship programs, and additional fisheries stakeholders) indicate the presence of Chinook salmon in 27 tributaries (16% of streams), coho salmon in 17 tributaries (10% of streams), and steelhead trout in 44 tributaries (26% of streams) in the Eastern Subbasin;
- Historically and currently, steelhead trout have been found in more tributaries and in areas further upstream than both Chinook and coho salmon. This is due to their preference for habitats that are located farther inland, in smaller streams than Chinook and coho salmon (Moyle et al. 2008), their ability to tolerate a broader range of instream conditions, and their comparatively superior jumping abilities;
- Eastern Subbasin streams have higher gradients than most Northern and Western subbasin streams, but steelhead are able to access high quality habitat in upper areas in many tributaries (e.g. Tom Long, Cruso Cabin, and Cedar creeks);
- Non-native Sacramento pikeminnow have been documented in most surveys beginning in the late 1990s and are now common in areas of the mainstem SF Eel River and in lower reaches of many tributaries. Pikeminnow compete with and prey upon juvenile salmonids, and are adapted to withstand warmer water temperatures than native salmonids.

**What are the current salmonid habitat conditions in the Eastern Subbasin? How do these conditions compare to desired conditions?**

*Findings and Conclusions:*

**<u>Flow and Water Quality:</u>**

- Instream flow in many streams has been reduced through unpermitted diversion for residential uses and marijuana cultivation, particularly in areas where land use is primarily residential (e.g. near Garberville, Redway, and Laytonville). Reduced flow (compared to historical averages) has been documented in Eastern Subbasin streams during the late summer and early fall;
- Low summer flows result in dry or intermittent reaches on streams, which may be stressful to salmonids and lead to juvenile mortality;
- The recent increase in industrial marijuana cultivation coupled with several drought years has led to increased development or reliance on groundwater wells, which will only further exacerbate low flow conditions in the summer and early fall;

- Water diversion by industrial timber companies for road dust/sediment control has been estimated at 2,000-4,000 gallons/mile/day between May 15th and October 15th. The amount of water used may be substantial at a time when stream flow is already low, particularly in areas with multiple users with high water demand;
- Water quality is reduced by input of fine sediments from roads throughout the subbasin, primarily seasonal roads that were originally used to access or haul timber. Many of these roads are now also used to access residential areas in newly developed locations or where larger parcels have been subdivided;
- Water quality is also reduced by marijuana cultivation operations, which may input of fertilizers, pesticides, rodenticides, diesel fuel from generators, and sediment from improperly constructed roads, and clearing and construction activities at grow sites;
- Increased turbidity is stressful to salmonids, especially during the rainy winter months. High levels of turbidity occur during salmon and steelhead spawning season.

**Erosion/Sediment:**

- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing and feeding habitat for salmonids. High sediment input from natural and anthropogenic sources have resulted in low suitability pool habitat and reduced water quality in Eastern Subbasin streams;
- Road density is relatively high (2.88 miles/square mile) in the Eastern Subbasin, which is the lowest density of all three SF Eel River subbasins but is still high enough to negatively affect the ecosystem and aquatic species by reducing water quality and increasing watershed degradation (Carnefix and Frissell 2009). Legacy logging roads and the use of substandard logging roads for hauling timber and for residential purposes are a significant source of sediment input to streams throughout the subbasin;
- Pacific Watershed Associates (2001) stated that the most important element necessary for long term restoration of salmon and steelhead habitat in the East Branch of the SF Eel River is the reduction of accelerated erosion and sediment delivery to the stream system. Upgrading and decommissioning existing roads were the primary recommended treatments;
- Soils in the Eastern Subbasin are prone to erosion, and landslides and streambank failures contribute fine sediments to streams throughout the subbasin;
- Two streams in the southern part of the subbasin, Mud Creek and Mud Springs Creek, receive constant fine sediment input from natural mud springs near Cahto Peak, but Mud Springs Creek has substantially less suspended sediment than Mud Creek, which appears milky throughout the year;
- During the historic flood events of 1955 and 1964, very large quantities of sediment entered Eastern Subbasin streams, and legacy effects of the sediment input are still influencing these streams;
- Increased fine sediment in stream gravel has been linked to decreased fry emergence, decreased juvenile densities, reduced diversity and abundance of invertebrates, loss of winter carrying capacity, and increased predation (Gucinski et al. 2001).

**Riparian Condition/Water Temperature:**

- Canopy density met or exceeded target values (>80%) in more than half of the streams sampled in the Eastern Subbasin in the 1990s and early 2000s, however, values were significantly below target values in Tenmile Creek during both sampling periods.
- In the 1990s, 51% of the stream length surveyed had canopy densities below 50% and only 49% met target values of 80% or greater. Coniferous canopy cover was relatively low (< 50%) in most streams, and was less than 10% in Bond Creek, Hollow Tree Creek, Michaels Creek, and an unnamed tributary to Durphy Creek;
- In the early 2000s, 40% of the stream length surveyed had less than 50% canopy density, 20% had canopy densities of 50-79%, and 40% of surveyed stream length met target values of 80% or greater;
- Canopy density suitability improved or stayed the same over time in most Eastern Subbasin streams, but decreased in areas of Cahto and Big Rock creeks. In the early 2000s, suitability scores were in the lowest category in upper and lower Tenmile Creek, and in the second lowest suitability category

in the middle reaches of Tenmile Creek and the lower reach of Big Rock Creek;
- Coniferous canopy was very low (<25%) in most Eastern Subbasin streams during both sampling periods. The percent coniferous canopy decreased over time in Bear Canyon, Cahto, and McCoy creeks, and increased over time in Milk Ranch, Mud, SF Bear Canyon, and Tenmile creeks;
- Water temperature data collected by HCRCD (between 1996-2003), and ERRP (in 2012) indicated poor (≥66ºF) instream temperatures at 11 tributary sites and 9 mainstem SF Eel River sites; fair (63-65˚F) instream temperatures at three tributary and one mainstem sites; and good instream temperatures (50-62˚F) recorded at 12 tributary and one mainstem locations in Eastern Subbasin streams. There were four sites where lethal (≥75ºF) conditions were recorded: two in the mainstem SF Eel River near Piercy (RM 54) and Sylvandale (RM 25), one in Tenmile Creek, and one in the East Branch SF Eel River;
- Bouma-Gregson (UC Berkeley) recorded average daily temperatures above lethal levels (≥75˚F) on 15 days between July and August 2013 in the mainstem SF Eel River at Richardson Grove (RM 49), and on nine days in July 2013 at Standish-Hickey State Recreation Area (RM 66);
- High temperatures in Eastern Subbasin streams are a result of a combination of reduced riparian cover, lower summer flows, warmer air temperatures due to the lack of influence of the coastal marine layer, and aspect (little afternoon shade).

**Instream Habitat:**

- Three Eastern Subbasin streams met the >40% target value for pool depth when sampled between 1990 and 1999: Cahto Creek (1996; 45% primary pool habitat), McCoy Creek (1995; 48% primary pool habitat), and Tenmile Creek (1996; 64% primary pool habitat). All three of these tributaries were sampled again between 2000 and 2010, and percent primary pool habitat dropped well below target values. The remaining 7 streams surveyed did not meet target values for primary pool habitat, and values ranged from a high of 38% in Tenmile Creek in 2009 to a low of 0.4% in McCoy Creek in 2007;
- Quality pool structure is lacking in Eastern Subbasin streams. The average mean pool shelter rating was 69.1 in the 1990s and 27.0 using habitat data collected between 2000 and 2010. These values are well below the target pool shelter value of 100 for salmonids. Pool shelter decreased in both rating value and suitability between the 1990s and early 2000s;
- Boulders were the dominant pool shelter type during both sampling periods. Using habitat data collected in the 1990s, other shelter types were terrestrial vegetation and undercut banks; in the early 2000s, other shelter types were terrestrial vegetation, root masses, and SWD. LWD was not documented as a pool shelter type in the 1990-1999 sampling period, and was only the dominant shelter type in one reach surveyed between 2000 and 2010, indicating that LWD is lacking in all sampled Eastern Subbasin streams;
- Although pool depths were generally shallow, pool-riffle ratios were above optimal ratios (1:1) in Eastern Subbasin streams during both sampling periods, and the percentage of pool habitat relative to riffle habitat increased slightly in recent years (2000-2010) compared to percentages recorded on surveys in the 1990s. In the 2000s, the pool riffle ratio was 61:39, which is generally considered to provide suitable holding area and habitat diversity for both juvenile salmonids and benthic invertebrates;
- More than 50% of the total stream mileage in Eastern Subbasin tributaries is >10% gradient. Many ends of anadromy occur at boulder roughs or waterfall barriers.

**Gravel/Substrate:**

- Cobble embeddedness conditions improved in all Eastern Subbasin streams over time, with average category 1 embeddedness values of 10.5% for data collected in the 1990s and 28.5% for data collected between 2000 and 2010. Although embeddedness values increased, they were still below target values (>50% category 1) during both time periods;
- The percent of pool tails surveyed in cobble embeddedness category 1 nearly tripled between the 1990s and early 2000s. The percent of pool tails in category 2 stayed nearly the same, and the

percent of pool tails in embeddedness category 3 was reduced by more than 50% between the two time periods. Only categories 1 and 2 are suitable for salmonid spawning;

- Low substrate embeddedness suitability for salmonids in Eastern Subbasin streams in the 1990s was due to extensive sediment input from highly erosive soils, active landslides, roads, and historical flood events. Suitability scores increased as a result of sediment from historic floods moving through the system, and restoration projects including road decommissioning and bank stabilization. Most of these restoration projects have been completed as part of the East Branch SF Eel /Reed Mountain Watershed Restoration Implementation Project.

**Refugia Areas:**

- Salmonid habitat conditions were generally rated as medium potential refugia (21 of 31 rated stream areas), meaning that most Eastern Subbasin streams have degraded or fragmented instream and riparian habitat, with salmonids present but reduced densities and age class representation. Salmonid habitat may improve with modified management practices and restoration efforts;
- Elder Creek was the only Eastern Subbasin stream rated as high quality refugia habitat. This creek is part of the University of California Natural Reserve system, and the habitat is relatively undisturbed, with conditions necessary to support species diversity and natural production;
- Three streams were rated high potential refugia: McCoy Creek, Cedar Creek, and the upper mainstem SF Eel River (beginning at RM 92). Cedar Creek flows primarily through land managed by the USBLM (the Red Mountain unit), and this stream contains excellent steelhead habitat. The upper mainstem SF Eel River provides good salmonid habitat due to cool instream and air temperatures, topography that includes many steep walled canyons and narrow valleys, and fewer diversions than in other areas within the Eastern Subbasin;
- Six tributaries were rated low quality: Dean Creek, lower East Branch SF Eel River, Fish Creek, Cummings Creek, Mud Creek, and Cahto Creek. Most of these creeks are located in residential areas and are heavily diverted. Instream habitat is characterized by high stream temperatures, poor canopy cover, low flow, high sedimentation rates, and poor water quality. Current conditions and management practices have modified the natural environment extensively, and major changes are required to improve habitat conditions in these areas.

**Barriers and Other Concerns:**

- Both natural barriers (landslides, gradient, and LDA) and anthropogenic barriers (culverts and dams) were mapped using information from stream inventories, field reconnaissance, and the CalFish Passage Assessment Database;
- Most of the barriers identified were gradient barriers (n = 28), followed by culvert barriers (12 partial and 15 total);
- The most common type of gradient barriers in Eastern Subbasin streams were waterfalls, and the largest waterfall (22') documented by CDFW crews is located on Fish Creek;
- Most culvert barriers, both total and partial, were located at road crossings along the mainstem SF Eel River, Rattlesnake Creek, and Tenmile Creek, where Highway 101 and smaller roads leading into individual basins cross tributary streams. Three culverts that are partial barriers to fish passage are located in the headwaters of the SF Eel River, where Branscomb Road crosses Rock Creek, Kenny Creek, and Wise Gulch;
- There are two dams in the Eastern Subbasin, one of which is considered a total barrier (Grapevine Creek) and one is currently unassessed (unnamed tributary to Cahto Creek);
- Benbow Dam, located on the mainstem SF Eel River at RM 40, is not currently a barrier to fish passage, but it has been in the past (when flashboards were installed each summer to form a recreational dam) and it is currently being considered for removal.

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

*Findings and Conclusions:*

- Natural erosion rates in the Eastern Subbasin are high due to the following conditions:
  - All rock types in the SF Eel River Basin are considered lithologically soft, prone to erosion, and sensitive to land use. The major rock type underlying the Eastern Subbasin is the mélange of the Central Belt of the Franciscan Complex, which is weak and highly unstable, and behaves more like an extremely viscous liquid than solid bedrock. It creates a hummocky, rolling landscape that is highly prone to mass movement and erosion, especially when saturated with water from frequent rainfall events;
  - The Eastern Subbasin is located in one of the most seismically active regions in North America, and fault movement can result in uplift or subsidence of the local landscape, increasing the potential for erosion or deposition;
- Floods periodically occur due to high winter precipitation levels and high runoff rates;
- During the rainy season, heavily silted water flows from steep upstream terrain, downstream to lower reaches, increasing turbidity and sediment levels in many subbasin streams;
- The predominant vegetation type is mixed conifer and hardwood forest, found mostly in the central and western sections covering 38% of the total subbasin area. The percentage of forest cover is substantially lower, and the percentage of grassland and shrub habitat is much greater in the Eastern compared to the Northern and Western subbasins;
- The average percent deciduous canopy was greater than coniferous canopy in all surveyed streams, but the percent coniferous canopy increased slightly between the late 1990s (6%) and early 2000s (9%).

**How has land use affected these natural processes?**

*Findings and Conclusions:*

***Changes in basin due to land use:***

- The primary land use in the Eastern Subbasin is industrial timber harvest, which occurs in 32% of the total subbasin area. There is less harvest activity now than in the past, and newer forest practices and management actions (including road decommissioning) have prioritized habitat preservation and fisheries habitat management;
- Nonindustrial timber harvesting and grazing occurs on 25% of the subbasin area, and 23% of the subbasin area is used for residential purposes. There has been a substantial increase in the number of marijuana cultivation operations in these residential areas. Many operations divert substantial quantities of water from tributaries, and significantly reduce water quality by adding fertilizers, pesticides, rodenticides, diesel fuel, and fine sediment from improperly constructed and unmaintained roads and clearings;
- Road density is relatively high in this subbasin (2.88 miles/square mile). Most roads were originally built to access and haul timber, but many are now also used to access marijuana cultivation sites and residences, especially in areas where large parcels have been subdivided into smaller lots;
- Sediment input from land use activities, primarily roads and timber harvest, is particularly problematic in this subbasin due to highly erodible soils and active landslides.

***Possible effects seen in stream conditions:***

<u>Instream habitat conditions for salmonids poor in some streams:</u>

- Low summer flows are exacerbated by diversions, which may result in dry or intermittent reaches on streams, which are stressful to salmonids;
- In addition to low flows, water quality (temperature, pollution, turbidity) decreases in areas with high levels of instream diversion and input of fertilizers, chemicals, sediment, and waste from grow operations, resulting in decreased habitat suitability for salmonids;
- Average canopy density, pool shelter, and embeddedness values did not meet target values in surveyed Eastern Subbasin streams (n = 10) during most surveys. The percent primary pool habitat

in Tenmile, Cahto, and McCoy creeks was above target values during surveys in 1995 and 1996, but when these streams were surveyed in 2007 and 2009, primary pool habitat values had decreased to well below target values;
- Excessive sediment in stream channels has resulted in an overall loss of spawning, rearing, and feeding habitat for salmonids. Sediment input from both natural (landslides and streambank erosion) and anthropogenic (timber harvest and road failures and/or degradation) sources are high, with correspondingly high turbidity levels which are stressful for salmonids. Substrate embeddedness values increased over time in most surveyed reaches, but were still below target values during both time periods;
- Boulders were the dominant shelter type in pools, followed by terrestrial vegetation. Average percent shelter from LWD was less than 5% for data collected during both sampling periods.

<u>Expansion of residential areas and marijuana cultivation operations is a concern:</u>

- Nearly one quarter (23%) of the land in the subbasin is in the residential land use category;
- Many of these residential areas support large marijuana cultivation operations, which rely on illegal and unpermitted water diversions (often during the hottest, driest time of the year, when natural streamflow is lowest);
- These operations divert millions of gallons of water during each growing season from SF Eel River watersheds, and may be contributing to a trend of atypical low flows occurring in late summer and early fall months, even in wet weather years;
- Most residences and grow operations use seasonal or temporary roads to access property. These roads were originally built to access and haul timber, are poorly maintained, and are not designed for the current level of traffic and intensive use. Erosion and road crossing failures associated with these substandard roads are a significant source of fine sediment input to Eastern Subbasin streams;
- Marijuana cultivation operations are often constructed using illegal and unpermitted grading techniques, which result in additional sediment input to nearby streams;
- Once established, many grow operations are sources of fertilizers, pesticides, herbicides, rodenticides, and other pollutants that enter streams directly (in runoff from hillsides) or indirectly (through groundwater), reducing water quality in streams throughout the subbasin;
- Industrial marijuana cultivation expansion combined with several drought years has led to the increased development of or reliance on groundwater wells, which will only further exacerbate low flow conditions in the summer and early fall;
- Marijuana cultivation operations are increasing in both magnitude and number throughout the Eastern Subbasin, and enforcement of environmental policies and infractions has been challenging due to safety concerns, limited funding, and a lack of laws and regulations related to these activities.

<u>Erosion related to timber harvest on unstable soils is a concern:</u>

- Industrial timber harvest occurred in most areas in the subbasin prior to the 1960s, and continues to be the primary land use in nearly one third of the subbasin. Sediment enters the streams from timber harvest activities and road related input, including both chronic erosion of fine sediments and catastrophic failure of roads prisms during winter storms;
- Timber harvest, while less of an issue than in the past, still occurred in many Eastern Subbasin streams between 1997 and 2013. THPs were concentrated in areas between Garberville and Leggett, and south of Rattlesnake Creek. Erosion related to timber harvest is a concern in logged watersheds due to highly erosive soils, active tectonics contributing to unstable slopes, and heavy rains received during winter months;
- Logging roads, which are often also used for residential purposes, are significant sources of fine sediment input to streams;
- Timber harvest impacts were magnified by the 1955 and 1964 floods, and sediment pulses from historic land use practices and floods are still moving through Eastern Subbasin streams;
- Central Belt Mélange is the dominant rock type in the Eastern Subbasin; it is considered highly unstable and is prone to erosion and mass movement, especially when disturbed by land use

practices such as logging, road construction/use, and residential development.

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

*Findings and Conclusions:*

Based on available information for this subbasin, it appears that salmonid populations are limited by:

- Low summer flows;
- High summer water temperatures;
- High levels of fine sediments in streams;
- Loss of habitat area and complexity;
- High gradient streams, with many waterfall barriers limiting anadromy;
- Shortage of areas with suitable spawning gravel in tributaries;
- Restricted access from culverts at road crossings; and
- Competition with Sacramento pikeminnow.

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

- Most habitat recommendations from surveys conducted in Eastern Subbasin streams targeted instream habitat, including pool and cover categories. Most other recommendations targeted riparian habitat/water temperatures (canopy and temperature) and erosion/sediment (related to streambanks and roads);
- To increase canopy cover consider replanting of native species, like willow, alder, redwood and Douglas-Fir in areas with little or no native vegetation;
- Riparian restoration projects like those completed in Tenmile Creek by Bioengineering Associates could be completed in other Eastern Subbasin tributaries. Native riparian trees, grasses, and forbs were planted, tree protectors installed, and drip irrigation systems were set up and maintained to provide water to young plants during dry periods;
- Ensure that water diversions used for domestic or irrigation purposes bypass sufficient flows to maintain all fishery resource needs;
- Support ongoing efforts by timber harvest review agencies to quantify water usage by industrial timber companies for road dust abatement/sediment control, and support actions designed to encourage efficient use of water;
- Support and expand projects designed to address solutions to low flow during the late summer months by reducing the number and magnitude of diversions (e.g. SRF's water conservation project in Redwood Creek in the Western Subbasin could be expanded to include Eastern Subbasin watersheds with primarily residential land use). Public outreach is needed to increase awareness of land use practices and their impacts on the basin's natural resources;
- Identify areas where marijuana cultivation is occurring and quantify environmental effects at sites, including illegal diversions (especially during low flow times), input of pesticides and other pollutants, and sediment loading from these practices. Enforce existing regulations and develop new environmental regulations to target these activities;
- Monitor streams near land development activities and existing rural residential areas for turbidity, pollution, and drainage issues;
- To restore salmonid habitat in the Eastern Subbasin, accelerated erosion and sediment delivery to streams must be reduced. Bank stabilization and upslope watershed restoration projects, including road decommissioning and rehabilitation, should be given high priority;
- Road decommissioning projects are important in this subbasin due to the relatively high road density and increased use of legacy logging roads for residential and other purposes;
- In the Reed Mountain area southeast of Benbow, road decommissioning projects were completed from 2003-2005 as part of Pacific Watershed Association's Erosion Assessment and Erosion Prevention and Planning Project. An upslope erosion inventory similar to the one done in the Reed

Mountain area should be completed in high and medium potential refugia streams in order to identify and map stream bank and road-related sediment sources. Sites should be prioritized, improved, and monitored following project completion;

- Restoration activities that will create additional pool habitat and scour existing shallow pools, while reducing sediment input from roads, are highly recommended throughout this subbasin;
- Wood recruitment is low in most Eastern Subbasin streams, and projects that add LWD to streams are recommended. These projects could be combined with pool habitat creation/enhancement projects, since both primary pool habitat and pool shelter are limiting factors for salmonids in this subbasin;
- Continue to conduct biological sampling through the CMP to determine salmonid population abundance and diversity;
- Consistently collect water quality data, including temperature, dissolved oxygen, and water chemistry throughout the year for several years in order to accurately characterize conditions. Support programs and organizations such as SRF and ERRP that develop studies to monitor the flow, temperature, diversion, and water quality of streams throughout the subbasin, particularly in developed areas.

## Subbasin Conclusions

The Eastern Subbasin is the largest of the three SF Eel River subbasins, covering an area of 320 square miles, or nearly one half (47%) of the total basin area. This subbasin includes the SF Eel River mainstem and the drainage area on the east side of the mainstem between the confluence of Ohman Creek (RM 23) to the headwaters southeast of Laytonville (RM 105). Streams in this subbasin contain runs of Chinook and coho salmon, and steelhead trout. Current salmonid populations are considerably smaller and less well distributed compared to their historic range.

The Eastern Subbasin is characterized by hotter, drier summer conditions and a higher prevalence of grassland and shrub vegetation types (resulting in reduced riparian canopy) than the Northern and Western subbasins. Most Eastern Subbasin streams have less suitable instream conditions for salmonids, reduced riparian habitat, more miles of stream with high gradient (>10%), and aspects that increase solar exposure in the afternoons compared to streams in the Northern and Western subbasins. Some tributaries in the headwaters area (upstream from the confluence of Tenmile Creek, ± RM 82) are similar in habitat and environmental conditions to Western Subbasin tributaries. These areas are influenced by the coastal marine layer, and vegetation type is dominated by conifer and hardwood forest with well-developed riparian habitat, resulting in cool air and stream temperatures. The only stream in the subbasin rated high quality in the refugia analysis was Elder Creek (RM 88), which is located in this area and is managed as part of the University of California natural reserve system.

The fishery resources in the Eastern Subbasin have been adversely affected by land use and resource development. Historically, streams provided important spawning and juvenile rearing grounds that enabled salmon and steelhead populations to thrive. Currently, nearly one third of the land is used for industrial timber harvest, approximately one quarter is used for nonindustrial timber harvest/grazing, and one quarter is used for residential purposes. Most industrial timber harvest occurs in the western half of the subbasin, and grazing/nonindustrial timber occurs in the eastern half. Residential development is concentrated around larger towns including Laytonville, Garberville, and Redway, but is also the dominant land use in areas east of Rattlesnake Creek and in the upper East Branch SF Eel River.

Road density in the Eastern Subbasin is the lowest of all SF Eel River subbasins (2.88 miles/square mile), but is still high enough to negatively affect the ecosystem and aquatic species by decreasing water quality and increasing watershed degradation (Carnefix and Frissell 2009). More than 60% of all roads in the subbasin are temporary roads that were originally built to access and haul timber. Many roads are still utilized for these purposes, but some are also used to access residential areas, especially where large parcels have been subdivided. Road surface erosion, road crossing failures and gullies, skid trails, and landslides from roads are the primary anthropogenic sources of sediment input in Eastern

Subbasin streams. Roads that are no longer used or those that were improperly constructed should be targeted for decommissioning and/or upgrading in order to reduce fine sediment input and associated turbidity, thereby improving salmonid habitat in tributaries throughout the subbasin. There have been more upslope watershed restoration (primarily road decommissioning) projects completed, and more funding dedicated to this type of project than any other in the Eastern Subbasin. Numerous agencies and private groups, including the USBLM, Mendocino Resource Conservation District, Trout Unlimited, Pacific Watershed Associates, Bioengineering Associates, Eel River Watershed Improvement Group, and Jack Monschke Watershed Management, have completed erosion control, road decommissioning, and road upgrading projects in the subbasin since 1982.

Reduced streamflow has dramatically affected salmonids in the subbasin at all life stages. Low flows are particularly problematic during the dry summer months, when there is an increase in the number and volume of diversions (for residential and agricultural uses, and for dust abatement/sediment control on industrial timber company lands), combined with longer dry periods (less precipitation) in the winter and early spring. Low flows are especially apparent in residential areas of the subbasin, where water is diverted for marijuana cultivation operations. These operations have increased dramatically in both number and magnitude in recent years. In 2012, CDFW Environmental Scientist Scott Bauer identified 549 grows with a total of 18,500 plants estimated to be associated with these operations in Redwood Creek, and 567 grows totaling 20,000 plants in Salmon Creek in the SF Eel River Basin. These grow operations consumed between 16.5 and 18 million gallons of water in one growing season (Easthouse 2013), much of which was diverted from nearby tributaries. Although these watersheds are not within Eastern Subbasin boundaries, marijuana cultivation activity is widespread in many areas of the subbasin, and similar environmental impacts from grow operations are concerns throughout the SF Eel River Basin. Industrial marijuana cultivation expansion coupled with several drought years has led to the increased development or reliance on groundwater wells, which will only further exacerbate low flow conditions in the summer and early fall.

Many marijuana cultivation operations also reduce water quality in streams throughout the subbasin by discharging pollutants including pesticides, herbicides, rodenticides, and diesel fuel into streams. Fine sediment input has also increased because of illegal or improperly constructed access roads and/or clearing crop locations, and some unpermitted timber harvest has occurred where land has been cleared at grow sites. These impacts have been increasing while enforcement has been challenging due to safety concerns, limited funding, and a lack of personnel. Law enforcement and other agency officials are limited to targeting only the most egregious offenders, but future actions and regulations must address the detrimental environmental impacts of all large-scale illegal marijuana cultivation operations in the subbasin.

Large historic flood events resulted in increased sedimentation and in-filling in Eastern Subbasin streams. Natural landsliding, unstable geology, timber harvest, land subdivision activities, and road erosion and failures have contributed large amounts of fine sediment, and the result has been an overall reduction in channel area in these streams over time. Large quantities of sediment fills in pool habitat, reduces the depth of existing pools, and increases embeddedness of substrate, resulting in a corresponding decrease in available salmonid spawning and rearing habitat. Although streams are designed to move sediment through the system naturally, low gradient streams in the Eastern Subbasin streams often do not have sufficient flow to flush out the quantities of sediment. Many higher gradient streams in the Eastern Subbasin are more effective at moving sediment through the system, but do not support populations of salmonids due to access issues in streams with gradients that are greater than accepted gradient barrier thresholds (4% for Chinook salmon, 6% for coho salmon, and 10% for steelhead trout).

CDFW crews collected habitat typing data in 10 Eastern Subbasin streams during two time periods (1990-1999 and 2000-2010), and CWPAP staff analyzed data to determine changes in habitat suitability for salmonids over time. Although average values of canopy density and cobble embeddedness increased between time periods, they were still well below target values during both time periods. Primary pool length and pool shelter values also decreased over time, and were below target values during most time periods. Average primary pool length in the 1990s was slightly greater than the target value of 40% (due to high values in Tenmile Creek), but decreased to 16% in the early 2000s. Overall habitat suitability scores were in the lowest category during both time periods. In the most recent time period (2000-2010), only canopy density and embeddedness scores were positive. Canopy density suitability increases are most likely due to instream habitat restoration projects completed in Tenmile Creek and its tributaries, and because of management practices that promote the growth and recovery of riparian areas since historic damage from floods, timber harvest, grazing, and agricultural practices.

CDFW currently conducts spawning ground surveys annually as part of the CMP on a select percentage of habitat in Eastern Subbasin streams; surveys include live fish or redd counts and carcass counts. A life cycle monitoring station will be established (most likely in Sproul Creek in the Western Subbasin) in the future to record counts of adults and outmigrating smolts. These counts will be used to calibrate spawning ground escapement estimates and freshwater and ocean survival, which will then be used to assess the status of CC Chinook and SONCC coho salmon in this ESU.

Diminishing runs of salmon and to a lesser extent steelhead in SF Eel River Basin streams are susceptible to being reduced to remnant populations. Regulations addressing environmental impacts and their effect on salmonids in the basin have primarily addressed timber harvest practices (and associated impacts from legacy and new roads) and ranching activities, and these rules and guidelines have resulted in decreased riparian impacts, decreased sedimentation from roads, and improved instream conditions in many areas of the basin. However, many regulations designed to help protect salmonid stocks, water resources, and stream habitats in the subbasin have not provided sufficient protection since the recent rapid expansion of marijuana cultivation operations, especially in areas dominated by residential land use. Reductions in water quality and quantity (primarily from unregulated diversion) may be detrimental to salmonids and their habitat in this subbasin, especially considering recent late summer low flow patterns and reduced natural precipitation levels. Management and enforcement actions to date have not been on large enough spatial or temporal scales to provide significant improvements to the overall habitat condition and ecosystem function necessary to restore salmonid populations to desirable numbers or ranges in Eastern Subbasin streams.

A cooperative approach with concerted effort is necessary to address diversion, stream temperature, and water quality (fine sediment and pollution) issues in order to improve and expand spawning and rearing habitat for salmonids, and to increase overall ecosystem health in streams throughout the Eastern Subbasin. Additional monitoring efforts, including CMP coho salmon spawner surveys and calibration of escapement estimates will be an important step in understanding population trends of SF Eel River salmonids. Continued prioritization and completion of restoration projects designed to reduce sediment input in Eastern Subbasin streams, and actions and regulations designed to slow environmental damage from marijuana cultivation operations, are some of the most critical management activities required in order to improve habitat conditions and ecosystem function necessary to restore salmonid populations in the subbasin.

*Juvenile Chinook salmon (photo courtesy of Teri Moore, CDFW).*

# Appendix A: Glossary of Terms

**ACCRETION:** Process in which new land is added onto the continental margin at a convergent plate boundary.

**AGGRADATION:** The geologic process in which stream beds, floodplains, and the bottoms of other water bodies are raised in elevation by the deposition of material eroded and transported from other areas. It is the opposite of degradation.

**ALEVIN:** The life stage of salmonids that occurs after eggs have hatched but before young emerge from the gravel nests where they have incubated. Alevin still have yolk sacs attached to provide them with nutrition within the nest.

**ALLUVIUM:** A general term for all deposits resulting directly or indirectly from the sediment transport of streams, thus including the sediments laid down in riverbeds, floodplains, lakes, fans and estuaries.

**ALLUVIAL** *adj*. Relating to, found in, or composed of alluvium.

**ANADROMOUS:** Fish that leave freshwater and migrate to the ocean to mature then return to freshwater to spawn. Salmon, steelhead and shad are examples.

**ANTHROPOGENIC:** Caused by humans.

**ARCINFO:** ESRI (Environmental Systems Research Institute) proprietary software, which provides a complete GIS data creation, update, query, mapping, and analysis system.

**AERIAL:** Having to do with or done by aircraft. Aerial photographs are taken from aircraft equipped with cameras.

**ATHABASKAN:** A group of related North American Indian languages including the Apachean languages, languages of Alaska, northwest Canada, and coastal Oregon and California. The Athabaskan languages formerly spoken in the northern third of Mendocino and the southern half of Humboldt counties in northwestern California fall into three broad groups of closely related dialects: Hupa-Chilula, Mattole-Bear River, and Eel River (including Cahto and the Kuneste (from koneest'ee', person) dialects: Lassik, Nongatl, Sinkyone, Wailaki).

**BANKFULL DISCHARGE:** The discharge corresponding to the stage at which the floodplain of a particular stream reach begins to be flooded; the point at which bank overflow begins.

**BANKFULL WIDTH:** The width of the channel at the point at which overbank flooding begins.

**BASIN:** see watershed.

**BED SUBSTRATE:** The materials composing the bottom of a stream.

**BENTHIC:** The collection of organisms living on or in sea, river or lake bottoms.

**BOULDER:** Stream substrate particle larger than 10 inches (256 millimeters) in diameter.

**CALWATER:** A set of standardized watershed boundaries for California nested into larger previously standardized watersheds and meeting standardized delineation criteria.

**CANOPY:** The overhead branches and leaves of streamside vegetation.

**CANOPY COVER:** The vegetation that projects over the stream.

**CANOPY DENSITY:** The percentage of the stream covered by the canopy of plants, sometimes expressed by species.

**CENTROID:** The center of water mass of a flowing stream at any location. This location usually correlates well with the thalweg, or deepest portion of the stream. Sampling in the centroid is intended to provide a reasonably representative sample of the main stream.

**CHANNEL:** A natural or artificial waterway of perceptible extent that periodically or continuously contains moving water. It has a definite bed and banks, which serve to confine the water.

**COAST RANGE:** A string of mountain ranges along the Pacific Coast of North America from Southeastern Alaska to lower California.

**COBBLE:** Stream substrate particles between 2.5 and 10 inches (64 and 256 millimeters) in diameter.

**COLLUVIUM:** A general term for loose deposits of soil and rock moved by gravity; e.g. talus.

**CONIFEROUS:** Any of various mostly needle-leaved or scale-leaved, chiefly evergreen, cone-bearing gymnospermous trees or shrubs such as pines, spruces, and firs.

**CONSUMPTIVE USE OF WATER:** Occurs when water is taken from a stream and not returned.

**COVER:** Anything that provides protection from predators or ameliorates adverse conditions of streamflow and/or seasonal changes in metabolic costs. May be instream cover, turbulence, and/or overhead cover, and may be for the purpose of escape, feeding, hiding, or resting.

**CWPAP:** Coastal Watershed Planning and Assessment Program (known as the North Coast Watershed Assessment Program (NCWAP) prior to 2003).

**DEBRIS:** Material scattered about or accumulated by either natural processes or human influences.

**DEBRIS JAM:** Log jam. Accumulation of logs and other organic debris.

**DEBRIS LOADING:** The quantity of debris located within a specific reach of stream channel, due to natural processes or human activities.

**DECIDUOUS:** A plant (usually a tree or shrub) that sheds its leaves at the end of the growing season.

**DEGRADATION:** The geologic process in which stream beds and floodplains are lowered in elevation by the removal of material. It is the opposite of aggradation.

**DEMOGRAPHY:** The study of the characteristics of populations, such as size, growth, density, distribution, and vital statistics.

**DEPOSITION:** The settlement or accumulation of material out of the water column and onto the streambed. Occurs when the energy of flowing water is unable to support the load of suspended sediment.

**DEPTH:** The vertical distance from the water surface to the streambed.

**DISCHARGE:** Volume of water flowing in a given stream at a given place and within a given period of time, usually expressed as cubic meters per second ($m^3$/sec), or cubic feet per second (cfs).

**DISSOLVED OXYGEN (DO):** The concentration of oxygen dissolved in water, expressed in mg/l or as percent saturation, where saturation is the maximum amount of oxygen that can theoretically be dissolved in water at a given altitude and temperature.

**DIVERSION:** A temporal removal of surface flow from the channel.

**ECOTONE:** A transition area between two distinct habitats that contains species from each area, as well as organisms unique to it.

**EMBEDDEDNESS:** The degree that larger particles (boulders, rubble, or gravel) are surrounded or covered by fine sediment. Usually measured in classes according to percentage of coverage of larger particles by fine sediments.

**ECOLOGICAL MANAGEMENT DECISION SUPPORT (EMDS):** An application framework for knowledge-based decision support of ecological landscape analysis at any geographic scale.

**EMBRYO:** An organism in its early stages of development, especially before it has reached a distinctively recognizable form.

**ENDANGERED SPECIES:** Any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man.

**EROSION:** The group of natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface.

**EROSIONAL** *adj*. Relating to natural processes by which material is worn away from the earth’s surface.

**ESTUARY:** A water passage where the tide meets a river current.

**EXTIRPATION:** To destroy totally; exterminate.

**EXTINCTION:** The death of an entire species.

**FILL:** a) the localized deposition of material eroded and transported from other areas, resulting in a change in the bed elevation. This is the opposite of scour; b) the deliberate placement of (generally) inorganic materials in a stream, usually along the bank.

**FINE SEDIMENT:** The fine-grained particles in stream banks and substrate. Those are defined by diameter, varying downward from 0.24 inch (6 millimeters).

**FISH HABITAT:** The aquatic environment and the immediately surrounding terrestrial environment that, combined, afford the necessary biological and physical support systems required by fish species during various life history stages.

**FLATWATERS:** In relation to a stream, low velocity pool or run habitat.

**FLOOD:** Any flow that exceeds the bankfull capacity of a stream or channel and flows out of the floodplain; greater than bankfull discharge.

**FLOODPLAIN:** The area bordering a stream over which water spreads when the stream overflows its banks at flood stages.

**FLOW:** a) the movement of a stream of water and/or other mobile substances from place to place; b) the movement of water, and the moving water itself; c) the volume of water passing a given point per unit of time. Discharge.

**FLUVIAL:** Relating to or produced by a river or the action of a river. Situated in or near a river or stream.

**FLUVIALGEOMORPHOLOGY:** The study of landforms constructed by flowing water viewed in a geologic context.

**FRESHETS:** A sudden rise or overflowing of a small stream as a result of heavy rains or rapidly melting snow.

**FRY:** Small fish, especially young, recently hatched fish.

**GENETIC DRIFT:** The random change of the occurrence of a particular gene in a population.

**GEOGRAPHIC INFORMATION SYSTEM (GIS):** A computer system for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data related to positions on the Earth's surface. Typically, a GIS is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature (e.g. roads). Each feature is linked to a position on the graphical image of a map.

**GEOMORPHOLOGY:** The study of surface forms on the earth and the processes by which these develop.

**GRADIENT:** The slope of a streambed or hillside. For streams, gradient is quantified as the vertical distance of descent over the horizontal distance the stream travels.

**GRAVEL:** Substrate particle size between 0.08 and 2.5 inches (2 and 64 millimeters) in diameter.

**GRILSE:** see jack.

**GULLY:** A deep ditch or channel cut in the earth by running water after a prolonged downpour.

**HABITAT:** The place where a population lives and its surroundings, both living and nonliving; includes the provision of life requirements such as food and shelter.

**HABITAT CONSERVATION PLAN:** A document that describes how an agency or landowner will manage their activities to reduce effects on vulnerable species. An HCP discusses the applicant's proposed activities and describes the steps that will be taken to avoid, minimize, or mitigate the take of species that are covered by the plan.

**HABITAT TYPE:** A land or aquatic unit, consisting of an aggregation of habitats having equivalent structure, function, and responses to disturbance.

**HATCH BOX:** An apparatus in which environmental conditions, such as temperature and sediment, can be controlled, used for hatching eggs artificially.

**HEADWARD EROSION**: Fluvial erosion in an upslope (upstream) direction that elongates and/or exacerbates an erosional feature such as a rill or gully.

**HETEROZYGOSITY:** The presence of different alleles at one or more loci on homologous chromosomes.

**HIERARCHY:** A series of ordered groupings of people or things within a system.

**HYDROGRAPH:** A graph showing, for a given point on a stream, the discharge, stage, velocity, or other property of water with respect to time.

**HYDROLOGY:** The science of water, its properties, phenomena, and distribution over the earth's surface.

**HYDROGRAPHIC UNIT:** A watershed designation at the level below Hydrologic Region and above Hydrologic Sub-Area.

**HYPOTHESIS:** A tentative explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation.

**INBREEDING:** The breeding of related individuals within an isolated or a closed group of organisms.

**INBREEDING DEPRESSION:** The exposure of individuals in a population to the effects of deleterious recessive genes through matings between close relatives.

**INCUBATION:** Maintaining something at the most favorable temperature for its development.

**INSTREAM COVER:** Areas of shelter in a stream channel that provide aquatic organisms protection from predators or competitors and/or a place in which to rest and conserve energy due to a reduction in the force of the current.

**INTERMITTENT STREAM:** A stream in contact with the ground water table that flows only at certain times of the year when the ground water table is high and/or when it receives water from springs or from some surface source such as melting snow in mountainous areas. It ceases to flow above the streambed when losses from evaporation or seepage exceed the available stream flow. Seasonal.

**JACK:** An immature male salmonid (usually two-year old) that returns to freshwater to spawn. Also known as grilse.

**KNOWLEDGE BASE:** An organized body of knowledge that provides a formal logical specification for the interpretation of information.

**LAGOON:** A shallow body of water, especially one separated from a sea by sandbars or coral reefs.

**LIMITING FACTOR:** Environmental factor that limits the growth or activities of an organism or that restricts the size of a population or its geographical range.

**LARGE WOODY DEBRIS (LWD):** A large piece of relatively stable woody material having a diameter greater than 12 inches (30 centimeters) and a length greater than 6 feet (2 meters) that intrudes into the stream channel. Large organic debris.

**MACROINVERTEBRATE:** An invertebrate animal (animal without a backbone) large enough to be seen without magnification.

**MAINSTEM:** The principal, largest, or dominating stream or channel of any given area or drainage system.

**MASS WASTING:** The downslope movement of soil or rock material under the influence of gravity.

**MELANGE:** A matrix of tectonically sheared rock material containing mappable bodies of rock-blocks of all sizes, both exotic and native.

**MIGRATION:** The periodic passage from one region to another for feeding or breeding.

**NCWAP:** North Coast Watershed Assessment Program, now known as the Coastal Watershed Planning and Assessment Program (CWPAP).

**NETWEAVER:** A knowledge-based development system. A meta database that provides a specification for interpreting information.

**NUTRIENT:** A nourishing substance; food. The term *nutrient* is loosely used to describe a compound that is necessary for metabolism.

**ONCORHYNCHUS:** A genus of the family salmonidae (salmons and trouts). They are named for their hooked (onco) nose (rhynchus).

**ORGANIC DEBRIS:** Debris consisting of plant or animal material.

**ORTHOPHOTOQUADS:** A combined aerial photo and planimetric quad map (with no indication of contour) without image displacements and distortions.

**PERMANENT STREAM:** A stream that flows continuously throughout the year. Perennial. pH: A measure of the hydrogen ion activity in a solution, expressed as the negative $\log_{10}$ of hydrogen ion concentration on a scale of 0 (highly acidic) to 14 (highly basic) with a pH of 7 being neutral.

**PLATE TECTONICS:** A theory in which the earth's crust is divided into mobile plates which are in constant motion causing earthquake faults, volcanic eruptions, and uplift of mountain ranges.

**PHOTOGRAMMETRY:** The process of making maps or scale drawings from photographs, especially aerial photographs.

**PRODUCTIVITY:** a) Rate of new tissue formation or energy utilization by one or more organisms; b) Capacity or ability of an environmental unit to produce organic material; c) The ability of a population to recruit new members by reproduction.

**RAVEL:** The movement of individual particles down a slope as a result of wetting and drying, freezing and thawing, or mechanical disturbance, causing surface erosion.

**REDD:** A spawning nest made by a fish, especially a salmon or trout.

**REFERENCE CONDITIONS:** Minimally impaired conditions that provide an estimate of natural variability in biological condition and habitat quality.

**RIFFLE:** A shallow area extending across a streambed, over which water rushes quickly and is broken into waves by obstructions under the water.

**RILL:** An erosion channel that typically forms where rainfall and surface runoff is concentrated on slopes. If the channel is larger than one square foot in size, it is called a gully.

**RIPARIAN:** Pertaining to anything connected with or immediately adjacent to the banks of a stream or other body of water.

**RIPARIAN AREA:** The area between a stream or other body of water and the adjacent upland identified by soil characteristics and distinctive vegetation. It includes wetlands and those portions of floodplains and valley bottoms that support riparian vegetation.

**RIPARIAN VEGETATION:** Vegetation growing on or near the banks of a stream or other body of water on soils that exhibit some wetness characteristics during some portion of the growing season.

**RUBBLE:** Stream substrate particles between 2.5 and 10 inches (64 and 256 millimeters) in diameter.

**SALMONID:** Fish of the family *Salmonidae*, including salmon, trout, chars, whitefish, ciscoes, and graylings.

**SCOUR:** The localized removal of material from the stream bed by flowing water. This is the opposite of fill.

**SEDIMENT:** Fragmented material that originates from weathering of rocks and decomposition of organic material that is transported by, suspended in, and eventually deposited by water or air, or is accumulated in beds by other natural phenomena.

**SERAL STAGES:** The series of relatively transitory plant communities that develop during ecological succession from bare ground to the climax stage.

**SHEAR:** A deformation resulting from stresses that cause contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact.

**SHEAR ZONE:** A geographically narrow zone of rock that has been intensely deformed due to tectonic shear strain.

**SILVICULTURE:** The care and cultivation of forest trees; forestry.

**SMOLT:** Juvenile salmonid one or more years old that has undergone physiological changes to cope with a marine environment, the seaward migration stage of an anadromous salmonid.

**SMOLTIFICATION:** The physiological change adapting young anadromous salmonids for survival in saltwater.

**SPAWNING:** To produce or deposit eggs.

**STADIA RODS:** Graduated rods observed through a telescopic instrument while surveying to determine distances and elevation.

**STAGE:** The elevation of a water surface above or below an established datum or reference.

**STRATH:** a) An extensive terrace-like remnant of a broad valley floor that has undergone dissection; b) a broad valley floor representing a local base level, usually covered by a veneer of alluvium.

**STREAM:** (includes creeks and rivers): A body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life. This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation.

**STREAM BANK:** The portion of the channel cross section that restricts lateral movement of water at normal water levels. The bank often has a gradient steeper than 45 degrees and exhibits a distinct break in slope from the stream bottom. An obvious change in substrate may be a reliable delineation of the bank.

**STREAM CLASSIFICATION:** Various systems of grouping or identifying streams possessing similar features according to geomorphic structure (e.g. gradient, water source, spring, and creek), associated biota (e.g. trout zone) or other characteristics.

**STREAM CORRIDOR:** A stream corridor is usually defined by geomorphic formation, with the corridor occupying the continuous low profile of the valley. The corridor contains a perennial, intermittent, or ephemeral stream and adjacent vegetative fringe.

**STREAM REACH:** A section of a stream between two points.

**SUBSTRATE:** The material (silt, sand, gravel, cobble, etc.) that forms a stream or lakebed.

**SUBWATERSHED:** One of the smaller watersheds that combine to form a larger watershed.

**TAKE:** to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

**TERRACE:** A former floodplain of the stream channel with sediment deposited when the stream was flowing at a higher level (or conversely when the landscape was at a lower altitude); typically forming a relatively level bench along a valley side adjacent to a recent floodplain.

**TERRAIN:** A tract or region of the earth’s surface considered as a physical feature, an ecological environment, or a site of some planned activity of man.

**TERRANE:** A fault bounded area that is stratigraphically distinct from the surrounding geology in depositional history and or tectonic emplacement. The term is used in a general sense and does not imply a specific rock unit.

**THALWEG:** The lineal extent of the highest flow velocity within a stream generally represented by a line connecting the lowest or deepest points along a streambed.

**THREATENED SPECIES:** Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

**TOPOGRAPHY:** The general configuration of a land surface, including its relief and the position of its natural and man-made features.

**TOPOLOGY:** The analytical, detailed study of minor landforms, requiring fairly large scales of mapping.

**TRIBUTARY:** A stream feeding, joining, or flowing into a larger stream. Feeder stream, side stream.

**UNDERCUT BANK:** A bank that has had its base cut away by the water action along man-made and natural overhangs in the stream.

**VELOCITY:** The time rate of motion; the distance traveled divided by the time required to travel that distance.

**V*:** Measures of percent sediment filling of a stream pool with deposits such as silt, sand, and gravel compared to the total volume.

**WATER RIGHT:** The right to draw water from a particular source, such as a lake, irrigation canal, or stream. Often used in the plural.

**WATERSHED ASSESSMENT:** An interdisciplinary process of information collection and analysis that characterizes current watershed conditions at a course scale.

**WATERSHED:** Total land area draining to any point in a stream, as measured on a map, aerial photograph or other horizontal plane. Also called catchment area, watershed, and basin.

**WATERSHED MANAGEMENT AREA (WMA):** In the context of the North Coast Regional Water Quality Control Board's Watershed Management Initiative, this represents a grouping of smaller watersheds into a larger area for identifying and addressing water quality problems, e.g., the Humboldt WMA includes all watersheds draining to the ocean or bays north of the Eel River to and including Redwood Creek.

**WEIR:** A barrier constructed across a stream to divert fish into a trap.

**WETLAND:** An area subjected to periodic inundation, usually with soil and vegetative characteristics that separate it from adjoining non-inundated areas.

**WILDLIFE CORRIDOR:** Linear spaces that connect the various areas of an animal's habitat, links between feeding, watering, resting, and breeding places.

# List of Abbreviations

**BLM** Bureau of Land Management

**CalEPA** California Environmental Protection Agency

**Caltrans** California Department of Transportation

**CCD** Census County Division

**CDF** California Department of Forestry and Fire Protection

**CEQA** California Environmental Quality Act

**CESA** California Endangered Species Act

**CFS** Cubic Feet per Second

**DAU** Detailed Analysis Unit

**CDFG** California Department of Fish and Game

**DOC/CGS** California Department of Conservation-California Geological Survey

**DWR** California Department of Water Resources

**EMDS** Ecological Management Decision Support

**EPA** Environmental Protection Agency

**EPIC** Environmental Protection Information Center

**ESA** Federal Endangered Species Act

**ESU** Evolutionarily Significant Units

**FPA** Z'Berg-Nejedly Forest Practice Act

**FPR** California Forest Practice Rules

**GIS** Geographic Information System

**HA** Hydrologic Area

**HCP** Habitat Conservation Plan

**HR** North Coast Hydrologic Region

**HSA** Hydrologic Sub-area

**HU** Hydrologic Unit

**IFR** Institute for Fisheries Resources

**KRIS** Klamath Resource Information System

**KRNCA** King Range National Conservation Area

**LFA** Limiting Factor Analysis

**LWD** Large Woody Debris

**MOU** Memorandum of Understanding

**MRC** Mattole Restoration Council

**MSG** Mattole Salmon Group

**MTJ** Mendocino Triple Junction

**MWAT** Maximum Weekly Average Temperature

**NCRWQCB** North Coast Regional Water Quality Control Board

**NCWAP** North Coast Watershed Assessment Program

**NEPA** National Environmental Policy Act

**NPDES** National Pollution Discharge Elimination System

**NMFS** National Marine Fisheries Service

**PALCO** Pacific Lumber Company

**PSA** Planning Sub Area

**PWS** Planning Watershed

**RM** River Mile

**SPEWS** Super Planning Watershed

**SRP** Scientific Review Panel

**SWRCB** California State Water Resources Control Board

**TMDL** Total Maximum Daily Load

**TPZ** Timber Production Zone

**USFS** United States Forest Service

**USGS** United States Geologic Survey

**WMA** Watershed Management Area

**WQO** Water Quality Objectives

# Appendix B: SF Eel River Bibliography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# Appendix C: Ecological Management Decision Support (EMDS) Model

## Table of Contents



## Table of Figures

# Ecological Management Decision Support (EMDS)-Based Analysis

## I. The Ecological Management Decision Support (EMDS) Model

### Introduction

The North Coast Watershed Assessment Program (NCWAP, now known as the Coastal Watershed Planning and Assessment Program (CWPAP)), selected the Ecological Management Decision Support (EMDS) (Reynolds 1999) analysis framework to evaluate and synthesize information on selected watershed and stream conditions that are important to salmonids during the freshwater phases of their life history. Only freshwater factors were considered; factors related to marine habitat and fishing were excluded from the analysis. EMDS uses linguistically based models, which are frequently employed in engineering and the applied sciences to validate expert opinion. This type of approach is one of several that CWPAP used to aid in identifying habitat factors that affect the production of salmonids in California's North Coast Watersheds (see limiting factors discussion in the Assessment Report). This appendix describes the general workings of EMDS, how EMDS relates to the analysis used in current CWPAP watershed assessments, and details of other factors being developed by CWPAP. For additional information on EMDS and its use in previous assessments, see the EMDS Appendix, available at: http://coastalwatersheds.ca.gov/AboutAssessment/AssessmentTools/tabid/259/Default.aspx.

NCWAP scientists constructed "knowledge base" models to identify and evaluate environmental factors (e.g., watershed geology, stream sediment loading, stream temperature, land use activities, etc.) which taken together shape anadromous salmonid habitat. Based upon these models, our analysis evaluated available data to provide insight into the conditions of streams and watersheds for salmonids in the region. The synthesis provided was then compared to more direct measures of salmonid production - i.e., the number of salmonids recently found in streams. The EMDS based analysis offers a number of benefits for the assessment work that CWPAP is conducting, and also has some known limitations. Both the advantages and drawbacks of the EMDS model are presented in this appendix.

Our use of the EMDS based model outputs is tentative. A scientific peer review process conducted in April of 2002 indicated that substantial changes to NCWAP's EMDS modeling approach were needed. At the time of the production of this report, CWPAP staff had implemented some, but not all of these recommendations. Therefore, we used model outputs with caution. CWPAP will continue to work to refine and improve the model and subsequent analysis, based on peer review.

### Background

#### Details of the EMDS Software

EMDS (Reynolds 1999), was developed by Dr. Keith Reynolds at the USDA-Forest Service, Pacific Northwest Research Station. It employs a linked set of software that includes MS Excel, NetWeaver, the EMDS ArcView Add-in, and ArcView™. Microsoft Excel is a commonly used program for data storage and analysis. NetWeaver (http://rules-of-thumb.com/), developed at Pennsylvania State University, helps scientists build graphics of models (knowledge base networks) that specify how various environmental factors will be incorporated into an overall stream or watershed assessment. These networks resemble branching tree-like flow charts, graphically show the logic and assumptions used in the assessment, and are used in conjunction with environmental data stored in a Geographic Information System (ArcView™) to perform the assessments and display the results on maps. This combination of Excel/NetWeaver/EMDS/ArcView software is currently being used for watershed and stream reach assessment within the federal lands included in the Northwest Forest Plan

(NWFP) (Lanigan et al. 2012). Because EMDS version 4.2 was not compatible with current ArcMap 10 (ArcView) software, CWPAP staff created a program in Visual Basic to analyze specific instream habitat data for 4 factors: canopy density, pool depth, pool shelter, and cobble embeddedness. Our analysis used similar logic, factors, and assumptions, but a more simplified model framework compared to the EMDS analysis used in previous NCWAP and CWPAP watershed assessments. Habitat suitability maps were designed by importing model output data into ArcMap 10, and the analysis was referred to throughout the assessment report as an "EMDS based analysis".

NCWAP staff began developing EMDS knowledge base models at a three-day workshop in June of 2001, organized by the University of California, Berkeley. In addition to the NCWAP staff, model developer Dr. Keith Reynolds and several outside scientists also participated. As a starting point, NCWAP used an EMDS knowledge base model developed by the NWFP for use in coastal Oregon. Based upon the workshop, subsequent discussions among NCWAP staff and scientists, examination of the literature, and consideration of California conditions, NCWAP scientists then developed preliminary versions of the EMDS models.

The initial NCWAP models were reviewed over 2 days in April 2002 by an independent nine-member science panel, which provided a number of suggestions for model improvements. According to these suggestions, NCWAP scientists revised their EMDS models, and a description of these models is presented below.

## The Knowledge Base Networks

For California's north coast watersheds, the NCWAP team constructed five knowledge base networks reflecting the best available scientific studies and information on how various environmental factors combine to affect anadromous fish on the north coast. All five models were designed to address current conditions (in-stream and watershed) for salmonids, and to reflect a fish's perspective of overall habitat conditions:

1) The Stream Reach model (*Figure 1* and *Table 1*) addresses conditions for salmon on individual stream reaches and is based largely on data collected under the Department of Fish and Wildlife's stream survey protocols;
2) The Sediment Production model evaluates the magnitude of various sediment sources in the basin according to whether they are natural or management related;
3) The Water Quality model offers a means of assessing characteristics of the in-stream water (flow and temperature) in relation to fish;
4) The Fish Habitat Quality model incorporates the Stream Reach model results in combination with data on accessibility to spawning fish and a synoptic view of the condition of riparian vegetation for shade and large woody debris;
5) The Fish Food Availability model has not yet been constructed, but will evaluate the watershed based upon conditions for producing food sources for anadromous salmonids.

The only model currently used in CWPAP assessments is the Stream Reach Condition model, and discussion in this appendix will be limited to this model. For a complete description of the other models, and a discussion of their development, limitations, and applications, see the EMDS Appendix (http://coastalwatersheds.ca.gov/AboutAssessment/AssessmentTools/tabid/259/Default.aspx).

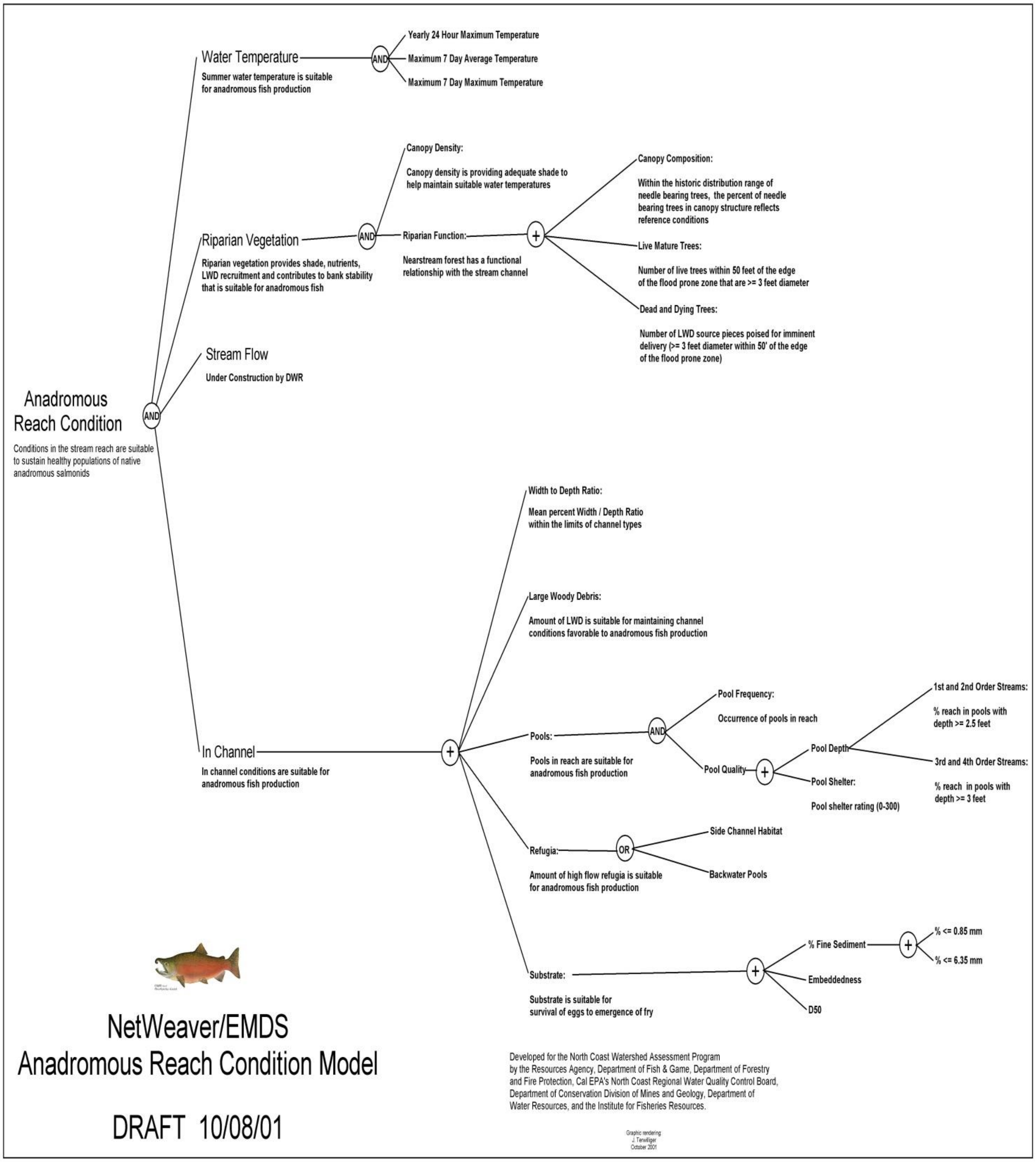


*Figure 1. NCWAP EMDS Anadromous Reach Condition Model.*

*Table 1. Reference Curve Metrics for EMDS Stream Reach Condition Model.*

| Stream Reach Condition Factor | Definition and Reference Curve Metrics |
|---|---|
| **Water Temperature** | |
| Summer MWAT | • Maximum 7-day average summer water temperature.<br>• <45° F fully unsuitable, 50-60° F fully suitable, >68° F fully unsuitable.<br>• Water temperature was not included in current EMDS evaluation. |
| **Riparian Function** | |
| Canopy Density ***** | • Average percent of the thalweg within a stream reach influenced by tree canopy.<br>• <50% fully unsuitable, ≥85% fully suitable. |
| Seral Stage | Under development |
| Vegetation Type | Under development |
| **Stream Flow** | Under development |
| **In-Channel Conditions** | |
| Pool Depth ***** | • Percent of stream reach with pools of a maximum depth of 2.5, 3, and 4 feet deep for first and second, third, and fourth order streams respectively.<br>• ≤20% fully unsuitable, 30 – 55% fully suitable, ≥90% fully unsuitable. |
| Pool Shelter Complexity ***** | • Relative measure of quantity and composition of large woody debris, root wads, boulders, undercut banks, bubble curtain, overhanging and instream vegetation.<br>• ≤30 fully unsuitable, ≥100 - 300 fully suitable. |
| Pool frequency | Under development |
| Substrate Embeddedness ***** | • Pool tail embeddedness is a measure of the percent of small cobbles (2.5" to 5" in diameter) buried in fine sediments.<br>• EMDS calculates categorical embeddedness data to produce evaluation scores between –1 and 1. The proposition is fully true if evaluation sores are 0.8 or greater and -0.8 evaluate to fully false. |
| Percent fines in substrate <0.85mm (dry weight) | • Percent of fine sized particles <0.85 mm collected from McNeil type samples.<br>• <10% fully suitable, > 15% fully unsuitable.<br>• There was not enough of percent fines data to use Percent fines in EMDS evaluations. |
| Percent fines in substrate < 6.4 mm | • Percent of fine sized particles <6.4 mm collected from McNeil type samples.<br>• <15% fully suitable, >30% fully unsuitable.<br>• There was not enough of percent fines data to use Percent fines in EMDS evaluations. |
| Large Woody debris | • The reference values for frequency and volume is derived from Bilby and Ward (1989) and is dependent on channel size.<br>• Most watersheds do not have sufficient LWD surveys for use in EMDS. |
| Refugia Habitat | • Refugia is composed of backwater pools and side channel habitats and deep pools (>4 feet deep).<br>• Not implemented at this time. |
| Pool to Riffle Ratio | Under development |
| Width to Depth Ratio | Under development |
| ***** indicates factors currently used in analysis. | |

*Figure 2* shows the NCWAP EMDS model parameters in relation to work done by Ziemer and Reid (1997), and is a modification of Ziemer and Reid's figure titled "The Shape of the Problem". The original figure was used to show the complex linkages among natural and human-related phenomena which combine to affect salmonids in freshwater streams. Here it is redrawn to show more of the flow of various factors (from top to bottom), with annotation of the parameters that were included in NCWAP EMDS models. Graphics such as these help to conceptualize the interrelationships of the problems facing salmonids, and serve as a basis for building models that reflect these complex systems.

In creating the EMDS models listed above, NCWAP scientists used a "top-down" approach. For example, the Stream Reach Condition model began with the proposition: *The overall condition of the stream reach is suitable for maintaining healthy populations of native coho salmon, Chinook salmon, and steelhead trout*. A knowledge base (network) model was then designed to evaluate the "truth" of that proposition, based upon data from each stream reach. The model design and contents reflected the specific information NCWAP scientists believed was needed, and the manner in which data should be combined, to test the proposition.

In evaluating stream reach conditions for salmonids, the model uses data on several environmental factors. The first branching of the knowledge base network (*Figure 3*) shows that information on in-channel condition, stream flow, riparian vegetation and water temperature are all used as inputs in the stream reach condition model. In turn, each of the four branches is progressively broken down into more basic data components that contribute to it (not shown). The process is repeated until the knowledge base network incorporates all information believed to be important to the evaluation.

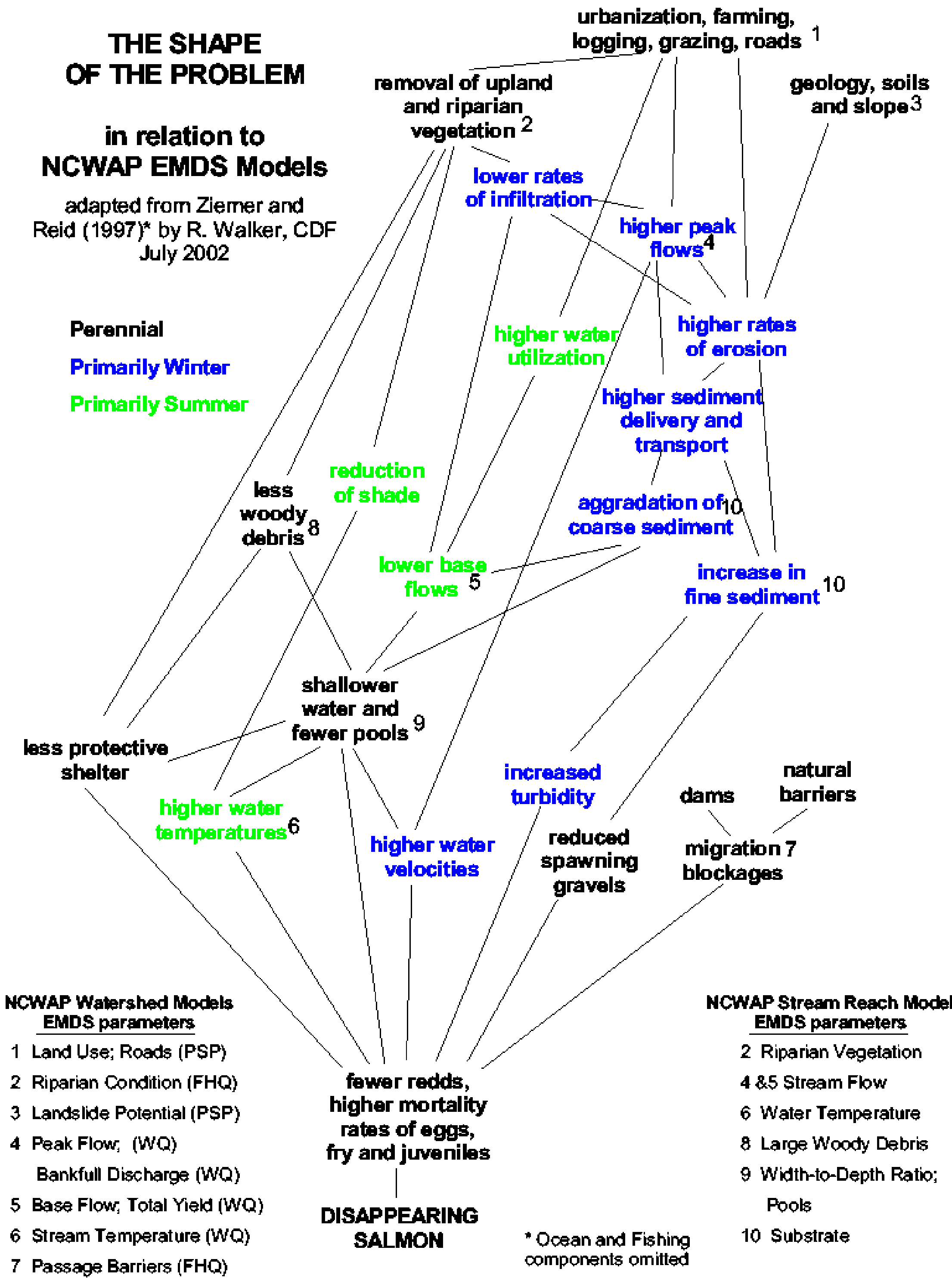


*Figure 2. Modified from Figure 1 of Ziemer and Reid (1997) "The Shape of the Problem" to show the relationship between EMDS model parameters and the conceptual diagram of problems facing salmon in north coast California freshwater streams. Abbreviations used for watershed models above are: PSP – Potential Sediment Production model; FHQ – Fish Habitat Quality model; WQ – Water Quality model. Figure from NCWAP (2002).*

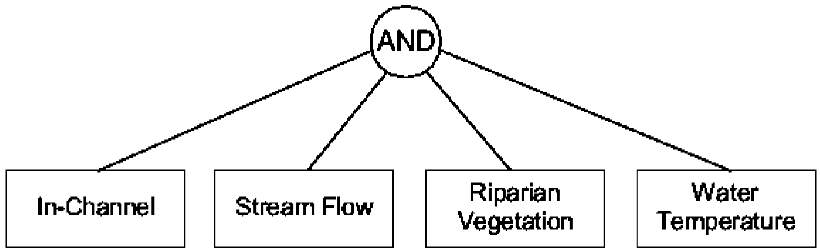


*Figure 3. EMDS Stream Reach Knowledge Base Network. EMDS uses knowledge base networks to assess the condition of watershed factors affecting native salmonids.*

Although model construction is typically done top-down, models are run in EMDS from the "bottom up". That is, data on the stream reach is entered at the lowest branches of the network tree (the "leaves"), and is combined progressively with other information as it proceeds up the network. Decision nodes are intersections in the model networks where two or more factors are combined before passing the resultant information on up the network. For example, the "AND" at the decision node in Figure 3 means that the lowest value of the four general factors coming in to the model at that point is taken to indicate the potential of the stream reach to sustain salmon populations.

EMDS models assess the degree of truth (or falsehood) of each model proposition. Each proposition is evaluated relative to simple graphs called "reference curves" that determine its degree of truth/falsehood, according to the data's implications for salmon. *Figure 4* shows an example reference curve for the proposition "*the stream temperature is suitable for salmon*". The horizontal axis shows temperature in degrees Fahrenheit, while the vertical axis is labeled "Truth Value" and ranges from –1 to +1. The line shows what are fully unsuitable temperatures (-1), fully suitable temperatures (+1) and those that are in-between (> -1 and <+1). In this way, a similar numeric relationship is required for all propositions evaluated in the models.

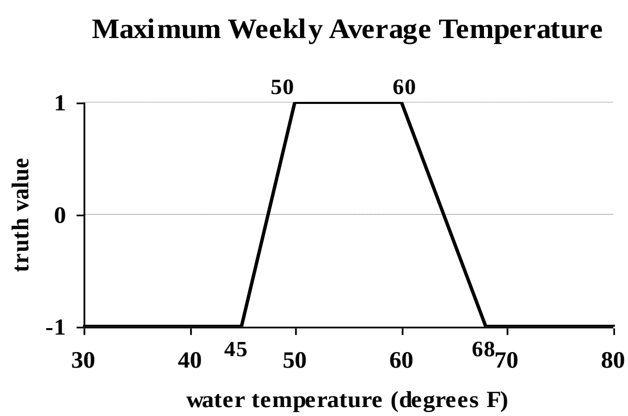


*Figure 4. EMDS Reference Curve. EMDS uses this type of reference curve in conjunction with data specific to a stream reach. This example curve evaluates the proposition that the stream's water temperature is suitable for salmonids. Break points can be set for specific species, life stage, or season of the year. Curves are dependent upon the availability of data.*

Proposition evaluations do not always result in simple "true" vs. "false" assessments – a strength of EMDS is its capability to determine degrees of truth or falsehood, or in effect, the degree to which the proposition is supported in the model by the evidence. For each evaluated proposition in the network, the result is a number between –1 and +1. The number relates to the degree to which the data support or refute the proposition. In all cases a value of +1 means that the proposition is "completely true", and –1 implies that it is "completely false", with in-between values indicating "degrees of truth" (i.e., values approaching +1 being closer to true and those approaching –1 converging on untrue). A zero value means that the proposition cannot be evaluated based upon the data available. Breakpoints (where the slope of the reference curve changes) in the *Figure 4* example occur at 45, 50, 60 and 68 degrees Fahrenheit. For the Stream Reach model, NCWAP fisheries biologists determined these temperatures by reviewing relevant scientific literature.

For many NCWAP parameters, particularly those related to upland geology and management activities, little or no scientific literature was available to assist in determining breakpoints. Because of this, NCWAP used a more empirically-based approach for breakpoints. Specifically, for each evaluated parameter, the mean and standard deviation were computed for all planning watersheds in a basin. Breakpoints were then selected to rank each planning watershed for that parameter in relation to all others in the basin. NCWAP staff used a simple linear approximation of the standardized cumulative distribution function, with the 10$^{th}$ and 90$^{th}$ percentiles serving as the low and high breakpoints (*Figure 5*).

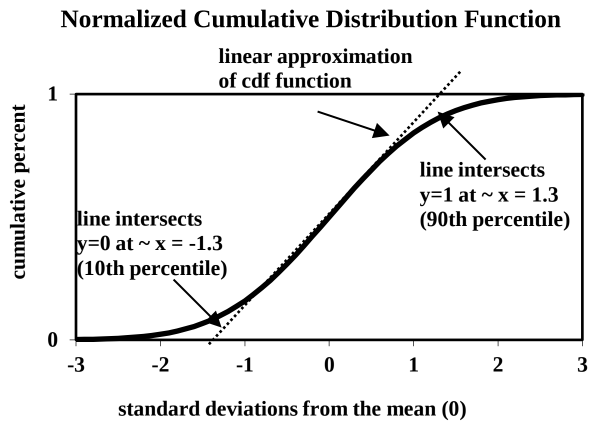


*Figure 5. Using the 10$^{th}$ and 90$^{th}$ percentiles as breakpoints (as with Land Use) is a linear approximation of the central part of the normalized cumulative distribution function*

The science review panel recommended that this method developed by NCWAP scientists be changed. They advised to use a set of reference watersheds from the region, compute the distributions of land use and other parameters from those watersheds to determine breakpoints. At this point CWPAP staff have not had the resources to select the reference watersheds, nor to process the data for them. This issue will be addressed in future watershed assessments and the breakpoints adjusted as information from reference watersheds becomes available.

NCWAP map legends used a seven-class system for depicting the EMDS suitability-values, but CWPAP staff reduced the number of suitability classes to four in order to more simply and effectively describe the suitability of instream habitat for salmonids. Stream or reach habitat with values at or near +1 are classified as “high suitability”, and those habitats with values at or near –1 are classified as “low suitability”. Between the high suitability and low suitability classes, there are two categories of intermediate suitability which are unlabeled in the figure legends.

In EMDS, the data that are fed into the knowledge base models come from GIS layers stored and displayed in ArcView. In our analysis, we imported suitability values into attribute tables and created data layers for graphical representation of suitability by stream and reach in ArcMap.

## Advantages Offered by EMDS Based Analysis

The EMDS type analysis offers a number of advantages for use by CWPAP. Instead of being a hidden “black box”, each model has an open and intuitively understandable structure. The explicit nature of the model networks facilitates open communication among agency personnel and with the general public through simple graphics and easily understood flow diagrams. The models can be easily modified to incorporate alternative assumptions about the conditions of specific environmental factors (e.g., stream water temperature) required for suitable salmonid habitat.

Using ESRI GIS software, CWPAP mapped the factors affecting fish habitat and showed how they varied across a basin. Models provided a consistent and repeatable approach to evaluating watershed conditions for fish, and maps from supporting levels of the model showed specific factors that taken together determined the overall watershed condition. This latter feature can help identify what is most limiting to salmonids, and thus assist with prioritization of restoration projects or modification of land use practices.

Another feature of the system is the ease of running alternative scenarios. Scientists and others can test the sensitivity of the assessments to different assumptions about the environmental factors and how they interact, through changing the knowledge-based network and breakpoints. "What-if" scenarios can be run by changing the shapes of reference curves (e.g., *Figure 4*), or by changing the way the data are combined and synthesized in the network.

Analysis tools can be applied at any scale, from reach specific to watershed-wide. The spatial scale can be set according to the spatial domain of the data selected for use and issue(s) of concern. Alternatively, through additional network development, smaller scale analyses (i.e., subwatersheds) can be aggregated into larger hydrologic units. With sufficient sampling and data, analyses can be done on single or multiple stream reaches.

CWPAP did not use the EMDS based analysis exclusively for watershed synthesis. The program used various other approaches for further exploration of fish-environment relationships.

## Management Applications of Watershed Synthesis Results

EMDS based analysis results can be applied at the basin scale to assess current watershed status. Maps depicting those factors that may be the largest impediments, as well as those areas where conditions are very good, can help guide protection and restoration strategies. The model can also help assess the cost-effectiveness of different restoration strategies. By running sensitivity analyses on the effects of changing different habitat conditions, it can help decision makers determine how much effort is needed to significantly improve a given factor in a watershed and whether the investment is cost-effective.

At the project planning level, EMDS based model results can help landowners, watershed groups and others select the appropriate types of restoration projects and locations (i.e., planning watersheds or larger) that can best contribute to recovery. Agencies will also use the information when reviewing projects on a watershed basis.

The main benefit of using this type of system to perform limiting factors analyses is flexibility, and through explicit logic, easily communicated graphics, and repeatable results, it provides insights into the relative importance of the constraints limiting salmonids in North Coast watersheds. CWPAP will use these analyses not only to assess conditions for fish in the watersheds and to help prioritize restoration efforts, but also to facilitate an improved understanding of the complex relationships among environmental factors, human activities, and overall habitat quality for native salmon and trout.

## Limitations of the EMDS Model and Data Inputs

At the time of the production of this report, we have not been able to implement all of the recommendations made by our peer reviewers. Therefore, current model outputs should be used with caution. CWPAP will continue to work to refine and improve the EMDS model, based on the peer review.

While EMDS based syntheses are important tools for watershed assessment, they do not by themselves yield a course of action for restoration and land management. Analysis results require interpretation, and how they are employed depends upon other important issues, such as social and economic concerns. In addition to the accuracy of the expert opinion and knowledge base system constructed, the currency and completeness of the data available for a stream or watershed will strongly influence the degree of confidence in the results. External validation of the model using fish population data and other information should be done where possible.

One disadvantage of linguistically based models such as EMDS is that they do not provide results with readily quantifiable levels of error. However, CWPAP staff are developing methods of determining levels of confidence in the analysis results, based upon data quality and overall weight given to each parameter in the model.

CWPAP will use the EMDS framework only as an indicative model, evaluating the quality of watershed or instream conditions based on available data and the model structure. It is not intended to provide highly definitive answers, such as those from a statistically-based process model. It does provide a reasonable first approximation of conditions through a robust information synthesis approach; however, specific outputs need to be considered and interpreted in combination with other information sources and an understanding of the inherent limitations of the model and its data inputs. It also should be clearly noted that this analysis does not assess the marine phase of the salmonid lifecycle, nor does it consider fishing pressures.

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# II.The Stream Reach Condition Model: An Explanation of Model Parameters and Data Sources

## Introduction

The stream reach knowledge base uses all available data for a stream reach to test the proposition: *Conditions in the stream reach are suitable to sustain healthy populations of anadromous salmonids*.

The stream reach knowledge base is composed of four logic networks relating to environmental factors that affect anadromous salmonid habitat conditions: 1) Water Temperature; 2) Riparian Vegetation Function; 3) Stream Flow; and 4) In Channel Conditions (*Figure 1*). The overall Stream Reach Condition is determined by combining the four evaluations through the "AND" logic node. This evaluates to "true" (+1) when all the network evaluations are "true", "false" (-1) if any of the four network evaluations is "false", or a numerical value between +1 and –1, showing the degree to which the above proposition is "true".

A complete summary of the Stream Reach Condition knowledge base used in the model is presented below. For each parameter in the model, its proposition, definition and explanation are presented. The CWPAP model used data from four factors: canopy density, pool depth, pool shelter complexity, and cobble embeddedness. Other factors are included in the parameter and data source discussion but have not yet been implemented due to lack of data and/or undeveloped reference curve metrics.

## Model Parameters and Data Sources

### Water Temperature (not yet implemented)

<u>Proposition:</u>

Summer water temperature is suitable sustain healthy populations of anadromous salmonids.

<u>Definition:</u>

Water temperature at the reach level is evaluated by comparing the 7-Day Maximum Average Temperature (7DMAT) collected from instream monitoring sites to the experimentally and empirically based Maximum Weekly Average Temperature (MWAT) for summer rearing juvenile anadromous salmonids. Additional metrics will provide a broader based evaluation including:

1) Yearly 24 hour maximum temperature
2) Maximum weekly maximum temperature

The Maximum Weekly Average Temperature (MWAT) is a calculated value based on experimental and empirical data, and is defined as the upper temperature limit recommended for a specific salmonid life stage (Armour 1991). The MWAT is essentially the upper temperature that fish can withstand for long durations and still maintain healthy populations (Sullivan et al. 2000). The experimental calculation for the MWAT is:

$$MWAT = OT + \frac{UUILT - OT}{3}$$

- **OT = Optimal Temperature** reported for a particular species and life stage. In the CWPAP analysis, summer juvenile rearing is used.

- **UUILT = Upper Ultimate Incipient Lethal Temperature** is the highest temperature at which tolerance does not increase with increasing acclimation temperatures.

Explanation:

The 7DMAT measured from continuous temperature recorders is compared to reference values derived from experimentally and empirically determined MWATs for anadromous salmonids. The NCWAP team used one MWAT value across all streams rather than attempting a site specific or species specific approach. Reference values for the MWAT were selected from a synthesis of relevant studies, including those reviewed by Stillwater Sciences (1997):

> "Stein et al. (1972) reported that growth rates in juvenile coho salmon slow considerably at 18˚C, and Bell (1973) reported that growth of juvenile coho ceases at 20.3˚C. Decreases in swimming speed may occur at temperatures over 20˚C (Griffiths and Alderdice 1972). Empirical studies by Hines and Ambrose (2000) determined that the number of days a site exceeded an MWAT of 17.6˚C (63.7˚F) was one of the most influential variables predicting coho presence and absence".

Welsh et al. (2001) suggested that an MWAT greater than 16.7˚C (62.0˚F) may preclude the presence of coho salmon in the Mattole River.

Data Sources:

Measurements from field observations.

Reference Values:

The proposition for water temperature is fully true if MWAT values are between 50 and 60˚F, and are fully false below 45˚F and above 68˚F (*Figure 6*).

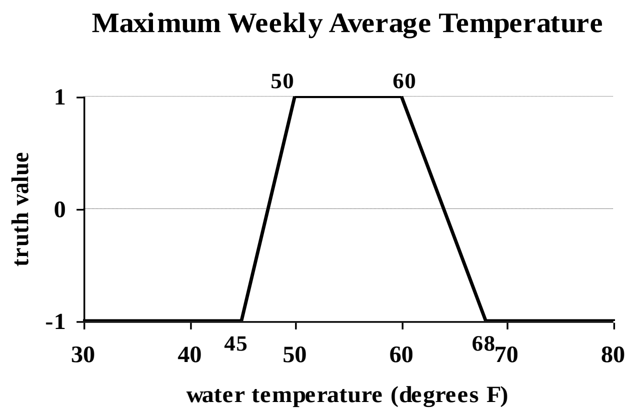


*Figure 6. Breakpoints for MWAT truth values.*

## Riparian Vegetation

Proposition:

Current riparian vegetation provides sufficient shade, nutrients, large woody debris recruitment, and contributes to bank stability to maintain healthy populations of anadromous salmonids.

Definition:

The riparian vegetation assessment consists of an evaluation of canopy density, which shades the stream channel, and an evaluation of the near-stream forest's ability to provide LWD and nutrients to the stream channel. Seral stage and species composition is still under construction; only canopy density data used was used to assess riparian vegetation in the analysis.

The Riparian Vegetation Function network is composed of an evaluation of:

1) Canopy Density
and the mean value of the evaluation of:
2) Canopy Species Composition
3) Live Mature Trees
4) Imminent Source of Large Woody Debris.

## *Canopy Density*

Proposition:

Canopy density is provides adequate shade to help maintain suitable water temperature and nutrient input to maintain healthy anadromous salmonid populations.

Definition:

Canopy density is the percent of stream influenced by tree canopy measured with a spherical densiometer from the center of a stream habitat unit.

Explanation:

Shade from streamside canopy helps to reduce stream water temperatures, especially during summer months. This parameter measures the adequacy of the vegetation in performing this important role.

The California Department of Fish and Game's Salmonid Stream Habitat Restoration Manual recommends, in general, that revegetation projects should be considered when canopy density is less than 80% (Flosi et al. 2010). Everest and Reeves (2006) reported that in westside forests the amount of solar radiation reaching the stream channel is approximately 1 - 3% of the total incoming radiation for small streams and 10 -25% for mid-order (3rd to 4rth order) streams.

Data Sources:

Measurements from field observations collected during DFW stream surveys.

Reference Values:

The proposition for Canopy Density is fully true if field observations are 85 percent or above and fully false if field observations are below 50 percent (*Figure 7*).

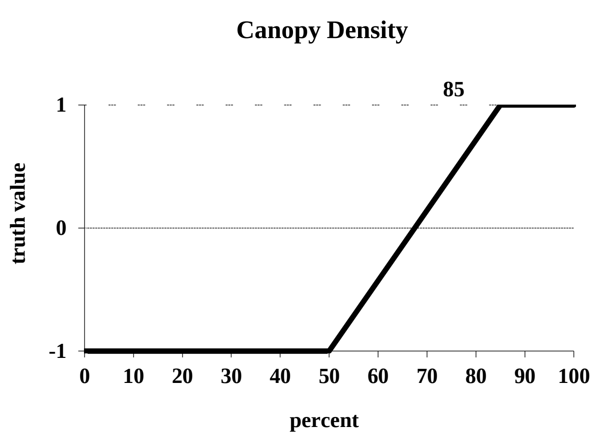


*Figure 7. Breakpoints for Canopy Density*

## *Riparian Function*

### Canopy Species Composition (not used in analysis)

Proposition:

The canopy species composition is within the range of historic species distribution and is suitable to maintain healthy anadromous salmonid populations. This factor is not yet implemented in the model.

Definition:

The similarity of species and life forms between the current vegetation and that which existed prior to Euro-American colonization.

Explanation:

The species composition of riparian vegetation can indicate recent historical events that have occurred in and near the stream reach. Some areas currently dominated by broad-leafed trees were dominated in the past by conifers. This can indicate that disturbances have occurred in the watershed, which resulted in this change in species composition. Also, conifers tend to provide more cooling in their shade than broad-leaf trees.

Data Sources:

Measurements from field observations.

Reference Values:

The proposition is fully true if the observed canopy species composition has a high degree of similarity to the pre-Euro-American range of species composition and fully false if it has a low similarity.

### Live Mature Trees (not yet implemented)

Proposition:

The number of live trees three feet or greater in diameter at breast height within a riparian buffer zone is sufficient to maintain conditions needed to support healthy anadromous salmonid populations. Reference values have not been developed for this factor.

### Imminent Source of Large Woody Debris (LWD) (not yet implemented)

Proposition:

The number of LWD sources poised for imminent delivery to the stream channel is suitable to maintain channel conditions suitable to support anadromous salmonid populations. Reference values have not been developed for this factor.

## Stream Flow (not yet implemented)

Proposition:

The stream flow regime is suitable to sustain healthy populations of anadromous salmonids. This subnetwork of the Stream Reach model is being developed by the Department of Water Resources and was not included in the Stream Reach Condition Model.

## In-channel Conditions

Proposition:

In-channel conditions are suitable to support healthy anadromous salmonid populations.

Definition:

In-channel conditions are determined by the mean truth value returned by the evaluation of 5 networks:

1. Large Woody Debris
2. Width to Depth Ratio
3. Pool Habitat
4. Winter Habitat
5. Substrate Composition.

### *Width-to-Depth Ratio (not yet implemented)*

Proposition:

The Width-to-Depth Ratio of the stream reach is suitable for sustaining healthy populations of anadromous salmonids. Reference value curves have not been developed for this factor.

### *Large Woody Debris (not yet implemented)*

Proposition:

The amount of in channel Large Woody Debris (LWD) is suitable for maintaining channel conditions to support healthy populations of anadromous salmonids.

Definition:

The target reference values for LWD frequency and volume is derived from Bilby and Ward's (1989) channel-width dependent regression for unmanaged streams in western Washington. The relationships between channel width and number of pieces (Bilby and Ward 1989) and "key" pieces of LWD (Fox 1994) are presented in the Pacific Lumber Company Habitat Conservation Plan, Aquatic Properly Functioning Condition Matrix (work in progress 1997).

Explanation:

Large woody debris is important to stream ecosystems because it exerts considerable control over channel morphology, particularly in the development of pools (Keller et al. 1995). Petersen and Quinn (1992) noted that LWD is associated with the majority of pools in forested streams, and there is a direct correlation between the amount of LWD present and the pool volume, pool depth and percentage of pool area in streams. Stillwater Sciences' Preliminary Draft Report (1997) suggested that LWD and its associated rearing habitat may be the most important limiting factors for coho salmon populations in coastal Mendocino County streams. The North Coast Regional Water Quality Control Board, in cooperation with the California Department of Forestry (Knopp 1993), stated that LWD benefits all life stages of salmonids by:

- creating holding pools used by adults during migration;
- retaining spawning gravels;
- creating slack water areas where juveniles can feed on drift;
- providing essential cover from predators and freshets (Murphy and Meehan 1991); and
- increasing the frequency and diversity of pool types (Bilby and Ward, 1991).

Juvenile salmonids, especially coho salmon, appear to prefer habitats with deep (>45 cm), slow (<15cm/s) areas in or near instream cover or roots, logs, and flooded brush (Bustard and Narver 1975), especially during freshets (Tschaplinski and Hartman 1983). Shirvell (1990) found that 99% of all coho salmon fry were observed in areas downstream of natural or artificial rootwads, during artificially created drought, normal, and flood stream flows.

Data Sources:

Measurements from LWD field surveys.

Reference Values:

Not yet developed.

### *Pool Habitat*

Proposition:

The pool frequency, pool depth, and pool complexity observed in the stream reach is suitable to support healthy populations of anadromous salmonids.

Definition:

The Pool Habitat sub-network evaluation is composed from evaluations of:

1) Pool Frequency, and
2) Pool Quality:
   a) Pool Depth
   b) Pool Shelter Complexity

### Pool Frequency (not yet implemented)

Proposition:

The number of pools observed during stream surveys is within the suitable frequency range for the channel type, gradient, bankfull width, and channel confinement of the stream reach.

Definition:

The number of pools observed per unit length of stream reach.

Explanation:

Not yet implemented.

Reference Values:

The proposition is fully true if the observed pool frequency has a high degree of similarity to the expected frequency range and fully false if it has a low similarity.

### Pool Quality

The pool quality network is composed of an evaluation of pool depth and pool shelter complexity rating.

#### *Pool Depth*

Proposition:

The percent by stream reach length in primary pools is suitable to support healthy anadromous salmonids.

Definition:

Primary pools have a maximum depth of 2.5 feet or greater in first and second order streams, a maximum depth of 3 feet or greater for third order streams, and a maximum depth of 4 feet or greater in fourth order streams.

Explanation:

The percent by stream reach of adequately deep pools or primary pools is determined according to stream order. For this analysis, stream order is determined from streams displayed as solid blue lines on 1:24,000 USGS topo maps. The percent reach of primary pools is calculated by: length of primary pool habitat / stream reach length.

Data Sources:

Measurements from field observations collected during DFW stream surveys.

Reference Values:

The proposition for the Pool Depth evaluation is fully true if 33 to 55 percent of the reach is in primary pools and fully false if there is less than 20 percent or more than 85 percent primary pool habitat (*Figure 8*).

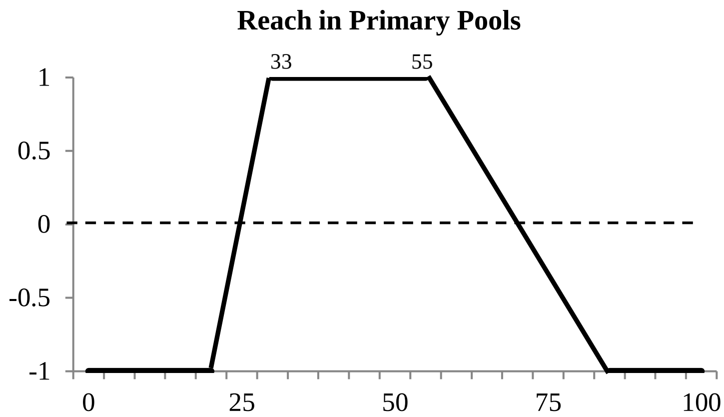


*Figure 8. Breakpoints for Pool Depth.*

### *Pool Shelter Complexity*

Proposition:

The average pool shelter complexity is suitable to support anadromous salmonids.

Definition:

A DFG field procedure rates pool habitat shelter complexity (Flosi et al. 2010). The pool shelter rating is a relative measure of the quantity and composition of LWD, root wads, boulders, undercut banks, bubble curtain, and submersed or overhanging vegetation that serves as instream habitat, creates areas of diverse velocity, provides protection from predation, and separates territorial units to reduce density related competition. The rating does not consider factors related to changes in discharge, such as water depth.

Data Sources:

Measurements from field observations collected during DFW stream surveys.

Reference Values:

The proposition for the Pool Shelter Complexity evaluation is fully true if the pool shelter rating is 100 or greater and fully false if the pool shelter rating is 30 or less (*Figure 9*).

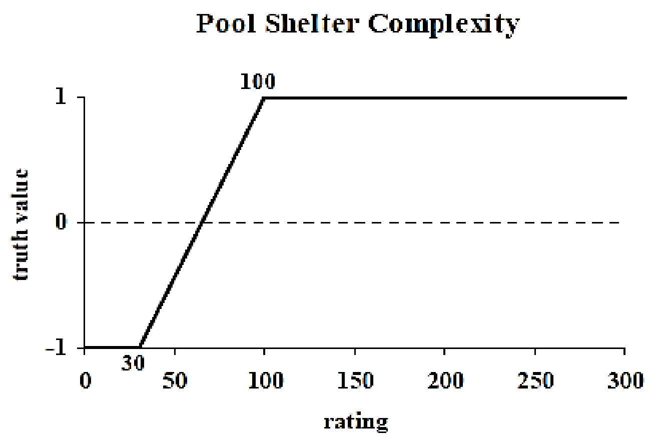


*Figure 9. Breakpoints for Pool Shelter Complexity.*

### *Refugia Habitat (not yet implemented)*

Proposition:

The amount of backwater pools, deep pools and side channel habitats is suitable (especially as winter refuge) to support healthy anadromous salmonid populations.

Definition:

Refugia for this evaluation are composed of backwater pools, side channel habitat, and deep pools (>4 feet deep) identified from DFW's stream habitat surveys.

Explanation:

The majority of juvenile coho salmon in coastal streams appear to overwinter in deep pools, backwater habitats, or alcoves within the stream channel that have substantial amounts of cover in the form of woody debris and/or provide shelter from high winter flows (Bustard and Narver 1975, Scarlett and Cederholm 1984, Brown and Hartman 1988, Bell 2001). Swimming ability decreases with temperature and as water temperature falls below 9˚C, juvenile coho salmon become less active (Bustard and Narver 1975, Nieraeth 2010) and require rearing habitat that provides shelter during high winter flows.

Data Sources:

Measurements from field observations collected during DFW stream surveys.

Reference Values:

The proposition for the Refugia Habitat evaluation is fully true if 10 percent of the stream reach is side channel or backwater pool habitat and fully false if there is no such habitat in the stream reach (*Figure 10*).

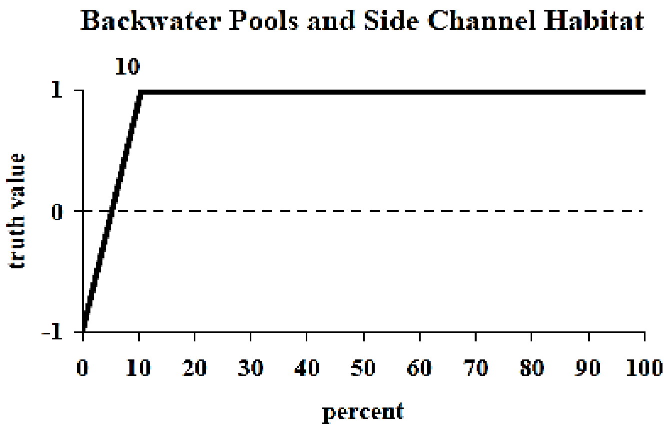


*Figure 10. Breakpoints for percentage in backwater pools and side channel habitat.*

### *Substrate Composition*

#### Pool Tail Embeddedness

Proposition:

The pool tail substrate provides suitable spawning material and promotes survival of salmonid eggs to emergence of fry.

Definition:

Pool tail embeddedness is a measure of the percent of small cobbles (2.5” to 5” in diameter) buried in fine sediments. Percent cobble embeddedness is determined at pool tail-outs where spawning is likely to occur. Average embeddedness values are placed into one of five embeddedness categories:

- 1 = 0 to 25%
- 2 = 26 to 50%
- 3 = 51 to 75%
- 4 = 76 to 100%
- 5 = unsuitable for spawning (impervious)

Explanation:

The EMDS based model used a weighted sum of embeddedness category scores to evaluate the pool tail substrate suitability for survival of eggs to emergence of fry. The percent embeddedness categories are weighted by assigning a coefficient to each category. The model rates embeddedness category 1 as fully suitable for egg survival and fry emergence and assigns a coefficient of +1 to the percent of embeddedness scores in category 1. Embeddedness category 2 is considered uncertain and given a coefficient of 0. Embeddedness categories 3 and 4 are considered unsuitable and are assigned a coefficient of -1. Category 5 values are omitted because they are composed of impervious substrate such as boulders, bedrock, or log sills. The values for each category are summed and evaluated in the analysis.

Data Sources:

Measurements from field observations collected during DFW stream surveys.

Reference Values:

A summary score of ≤ -0.8 is considered fully unsuitable and a score of ≥ 0.8 is fully suitable (*Figure 11*).

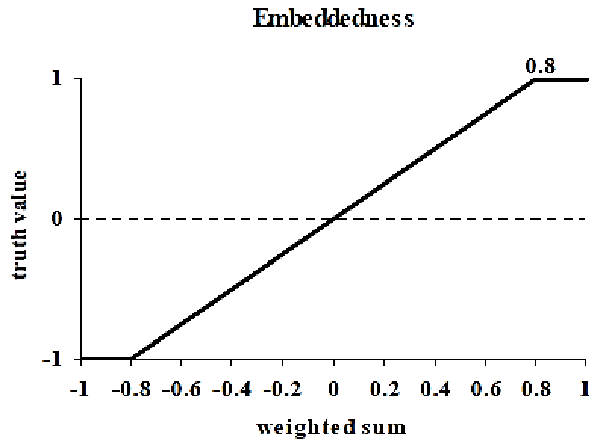


*Figure 11. Breakpoints for embeddedness.*

## Percent Fine Sediment (not yet implemented)

Explanation:

Substrate composition is used as a suitability measure of pool tail sediments for survival of eggs to the emergence of fry. Sedimentation resulting from land use activities is recognized as a fundamental cause of salmonid habitat degradation (FEMAT 1993). Excessive accumulations of fine sediments reduce water flow (permeability) through gravels in redds. The percent of fine sediments is higher in watersheds where the geology, soils, precipitation or topography create conditions favorable for erosional processes (Duncan and Ward 1985). Fine sediments are typically more abundant where land use activities such as road building or land clearing expose soil to erosion and increase mass wasting (Cederholm and Reid 1987; Swanson et al 1987; Hicks et al 1991).

McHenry et al. (1994) found that when fine sediments (<0.85mm) exceeded 13% (dry weight) salmonid survival dropped drastically. Bjornn and Reiser (1991) showed that salmonid embryo survival dropped considerably when the percentage of substrate particles smaller than 6.35 mm exceeded 30 percent.

Data Sources:

Substrate samples collected from instream sites.

Reference Values:

Reference values curves for Percent Fine Sediment are presented in *Figure 12* and *Figure 13*.

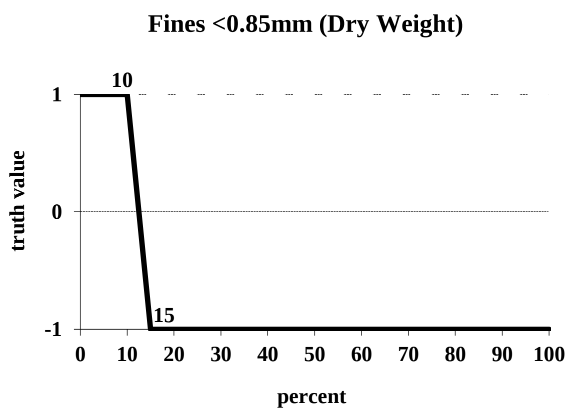


*Figure 12. Breakpoints for Percent Dry Weight of Fine Sediments <0.85mm*

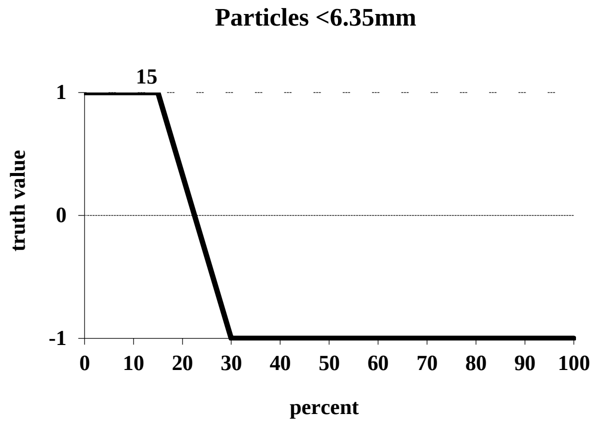


*Figure 13. Breakpoints for Percent of Sediments <6.35mm*

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