SF Eel River Eastern Subbasin

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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).

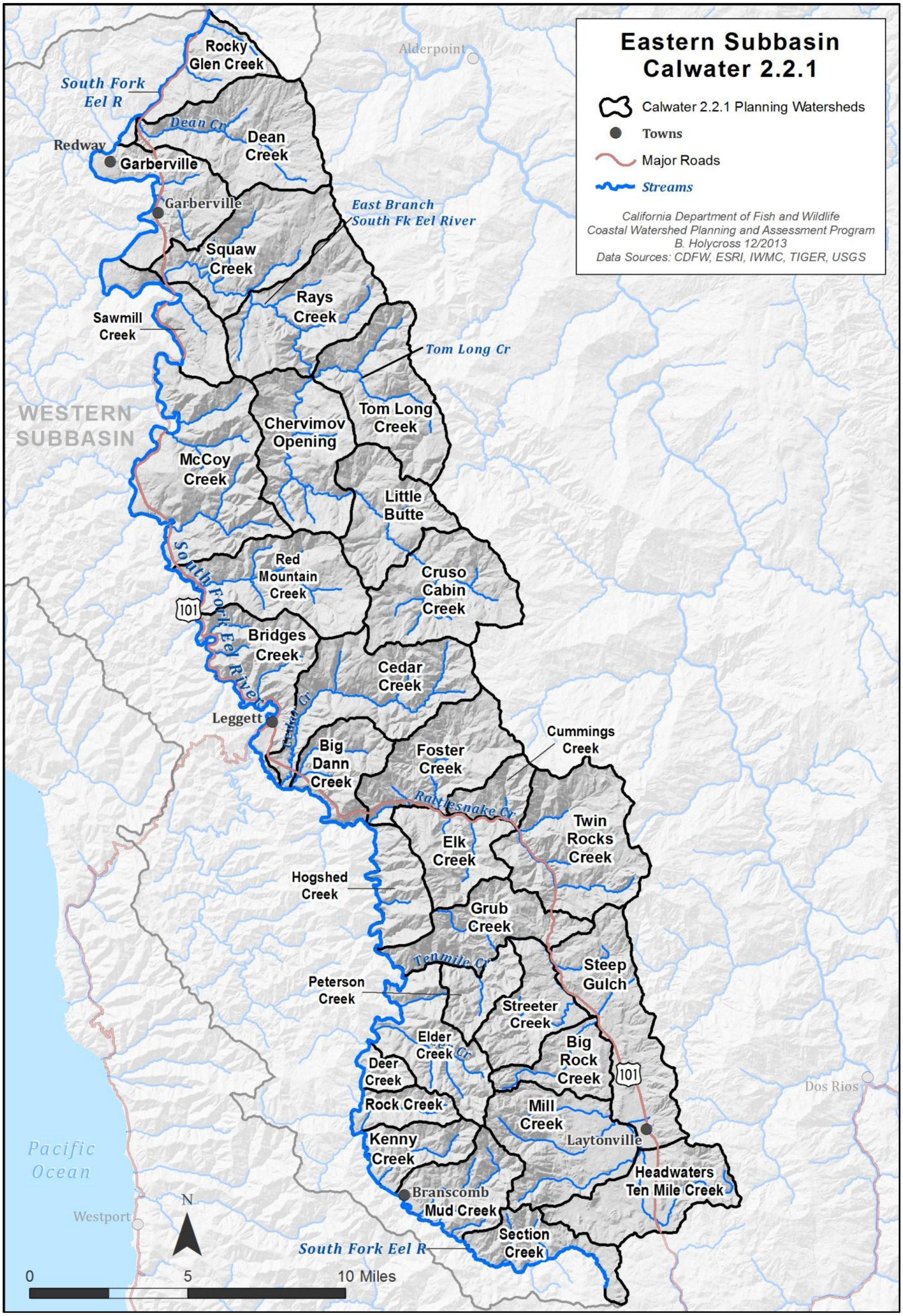

Figure 4. Map of Calwater 2.2.1 Eastern Subbasin planning subwatersheds.

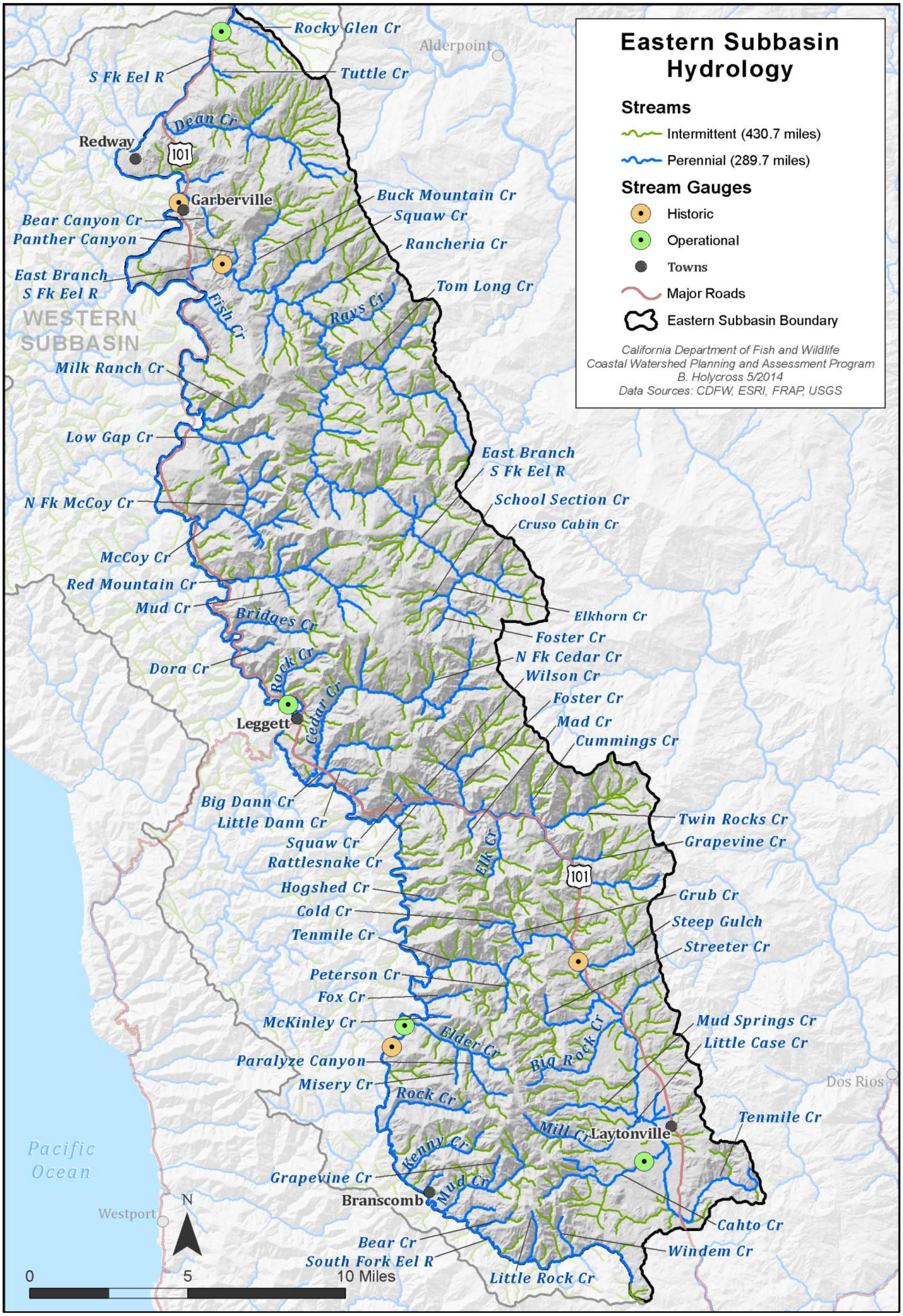

Figure 5. SF Eel River Eastern Subbasin streams.

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

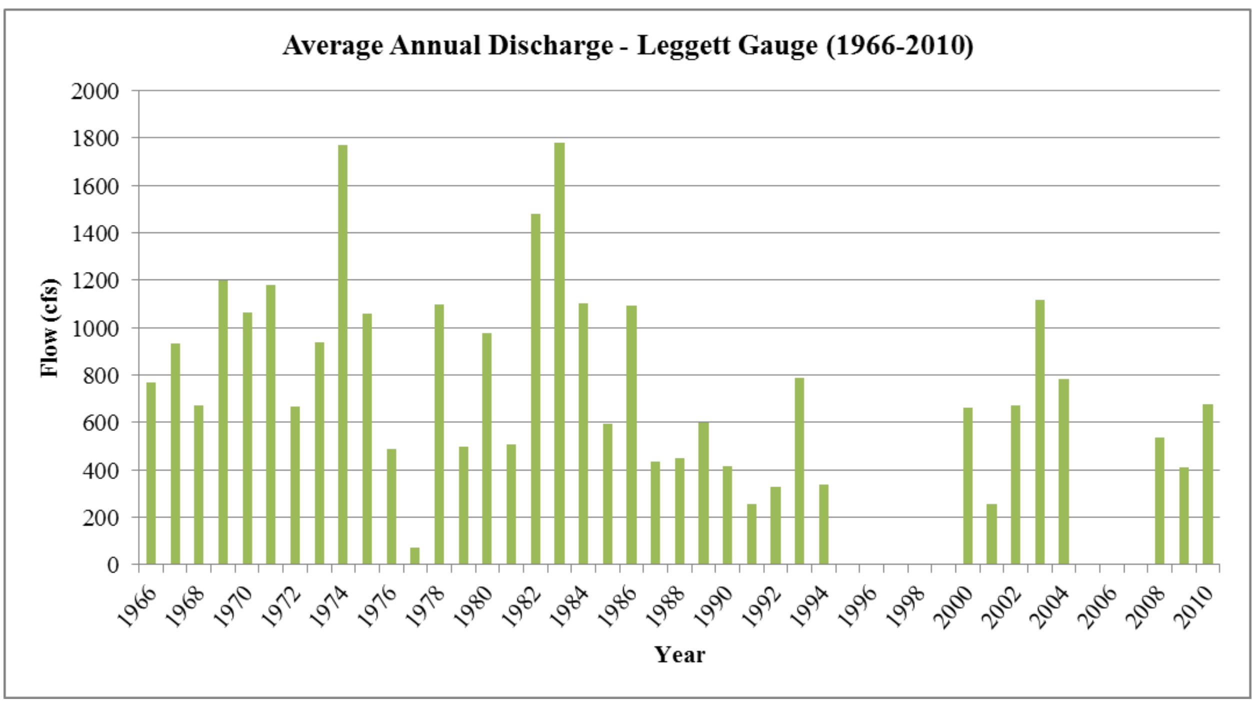

Figure 6. Average annual discharge at the Leggett gauge, located at RM 66 on the mainstem SF Eel River.

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).

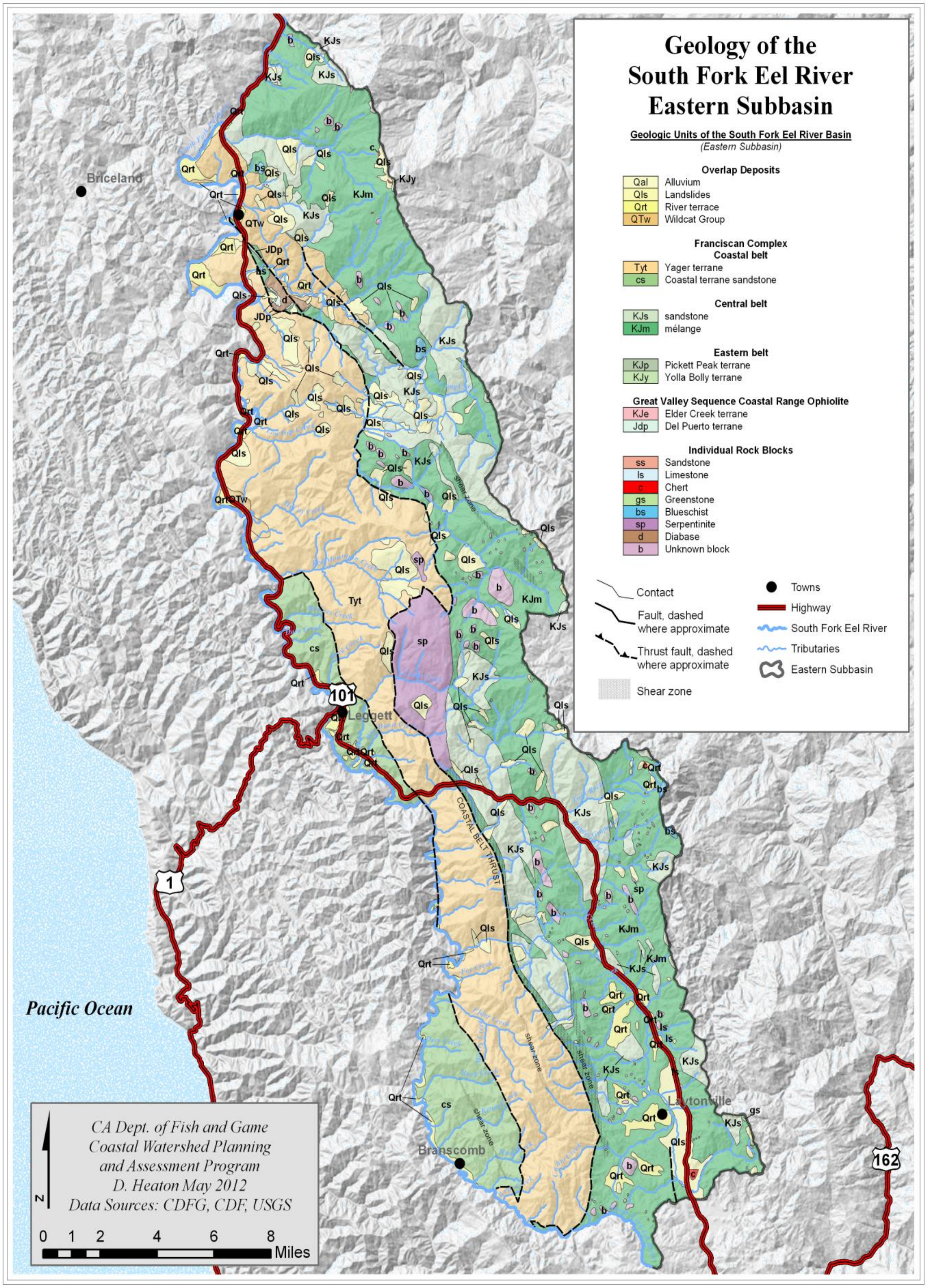

Figure 8. Geologic Map of the Eastern Subbasin

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, McLauglin 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*).

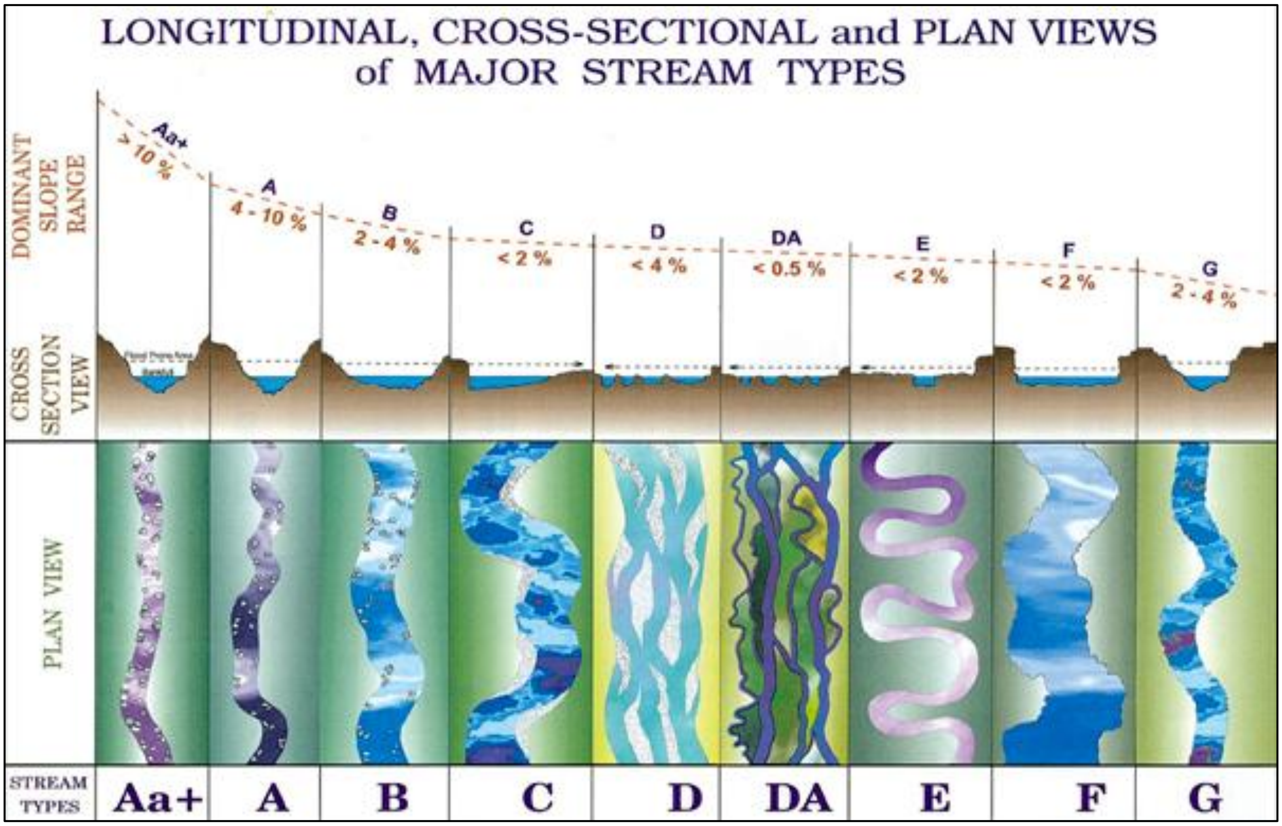

Figure 10. Illustration of channel types A-G (Rosgen 1996, courtesy of Wildland Hydrology).

Table 5. Surveyed channel types by percent of subbasin.

Type	%	Eastern Subbasin General Channel Types 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	6,789	A2
Eel River	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

Creek	Length (ft)	Channel Type
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.

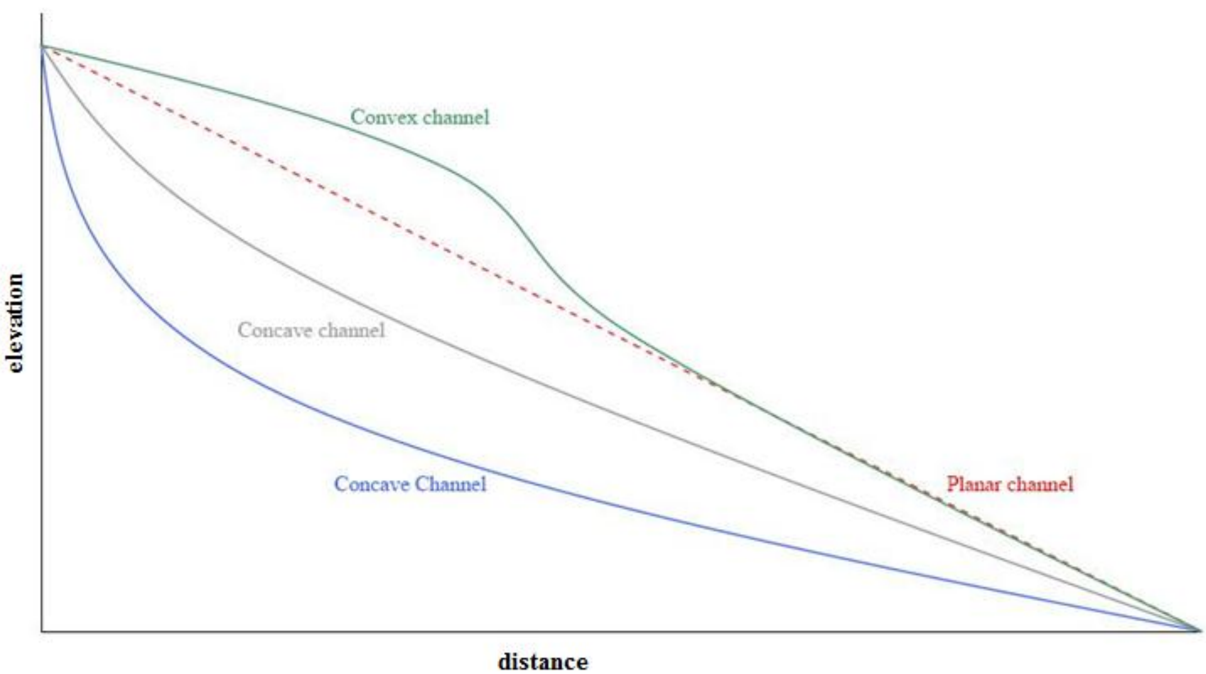

Figure 11. Basic channel profile shapes.

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

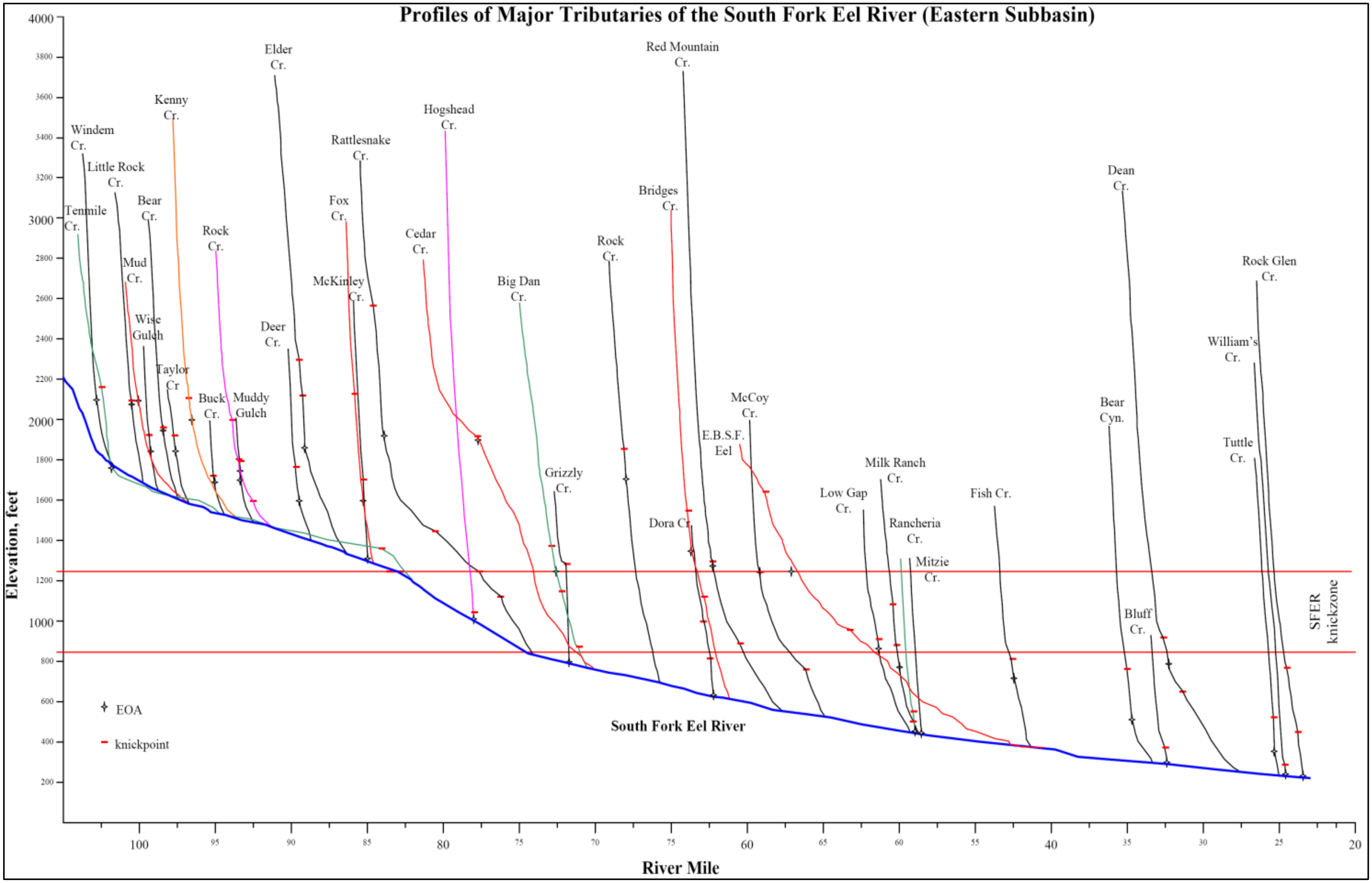

Figure 12. Longitudinal stream profiles of SF Eel River Eastern Subbasin streams.

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.

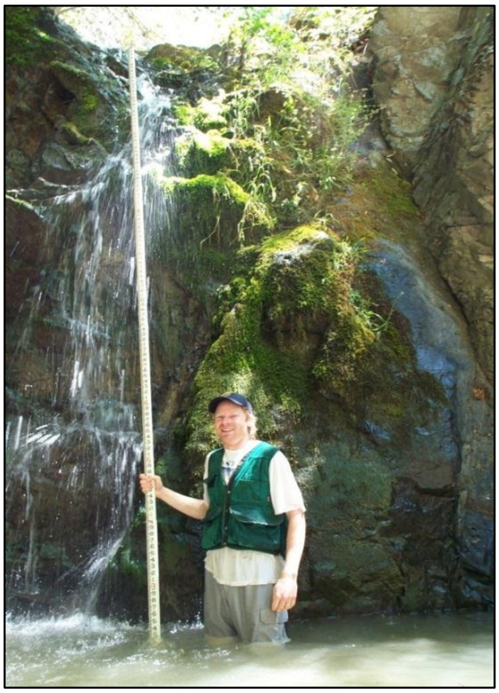

Figure 13. A waterfall that developed in response to a knickzone within the geology of the Yager Terrane on Milk Ranch Creek.

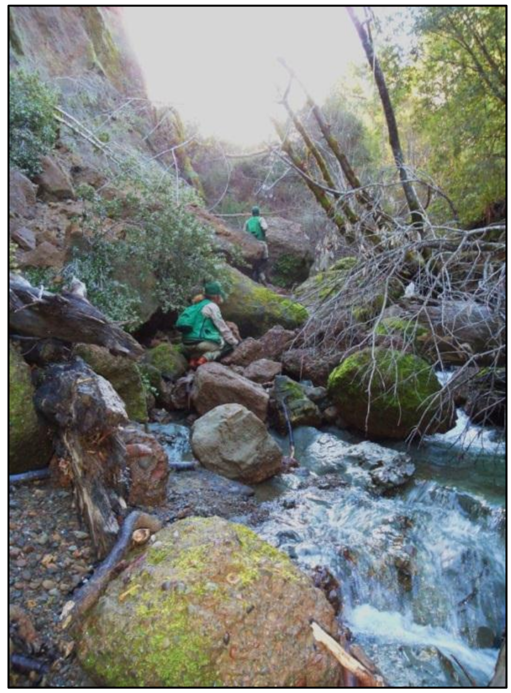

Figure 14. Tributary of Bear Canyon with steep gradient cascade boulder reach that formed in response to a knickzone within Wildcat geology.

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.

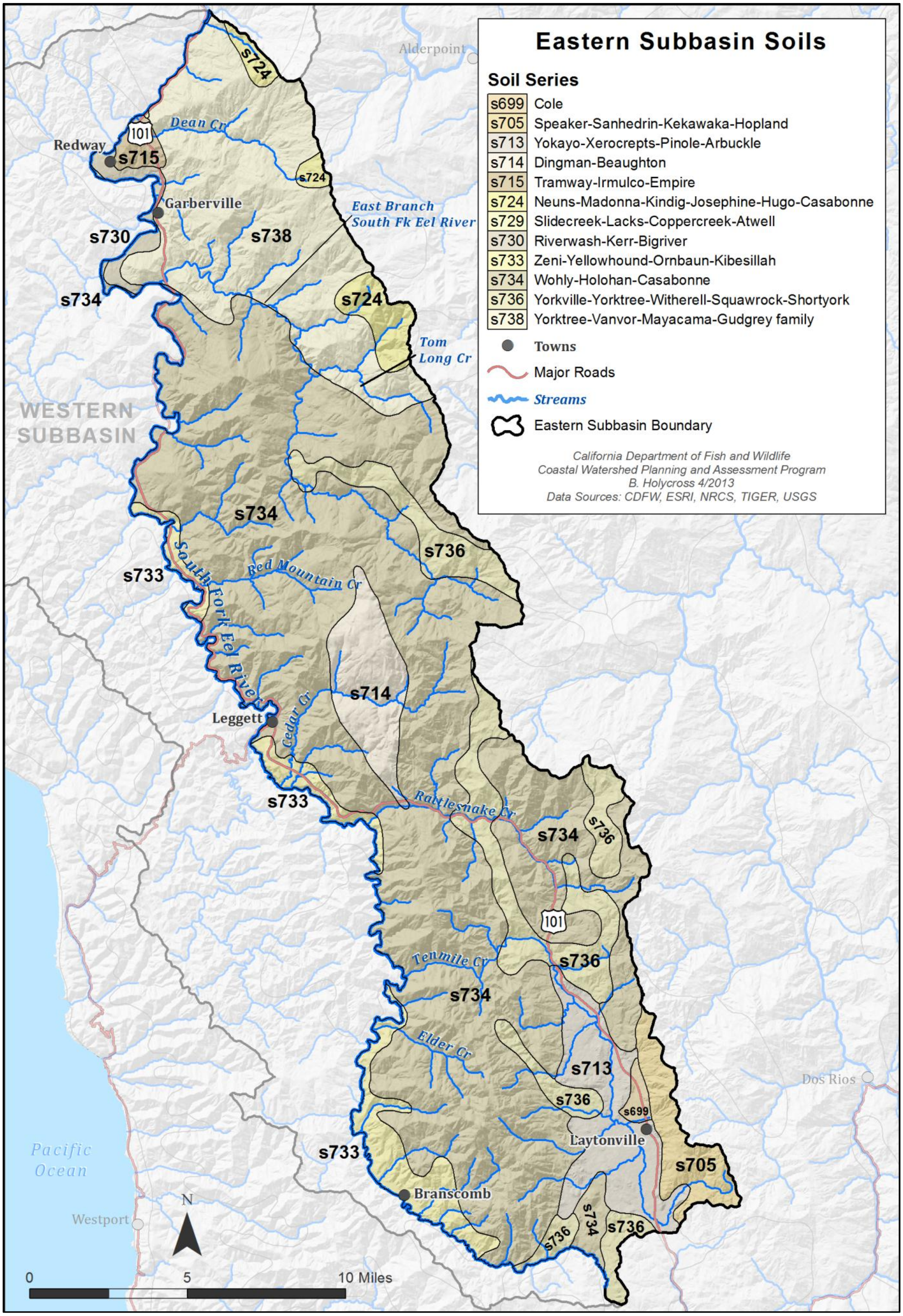

Figure 15. Eastern Subbasin soils map.

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

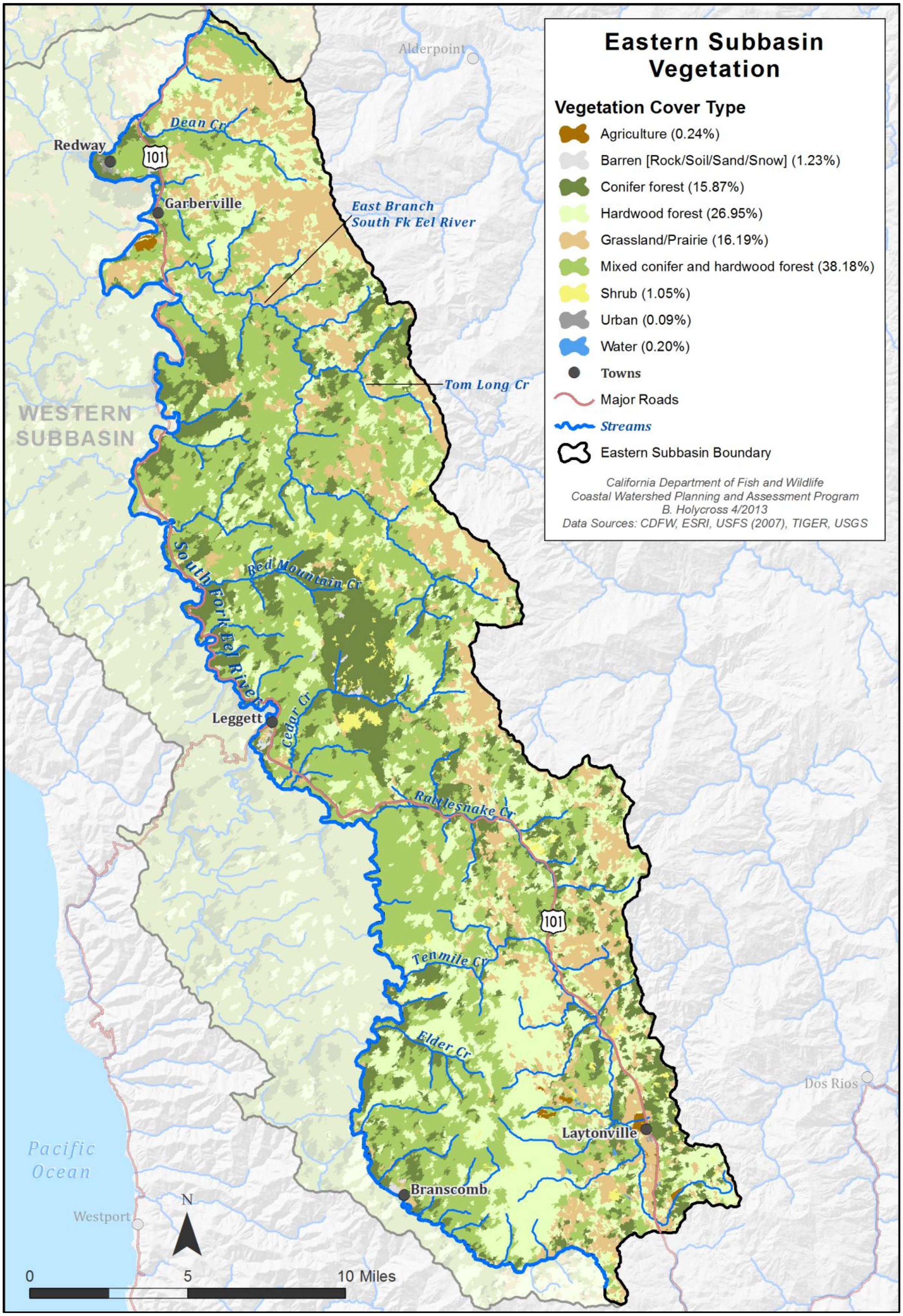

Figure 16. Eastern Subbasin vegetation map.

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

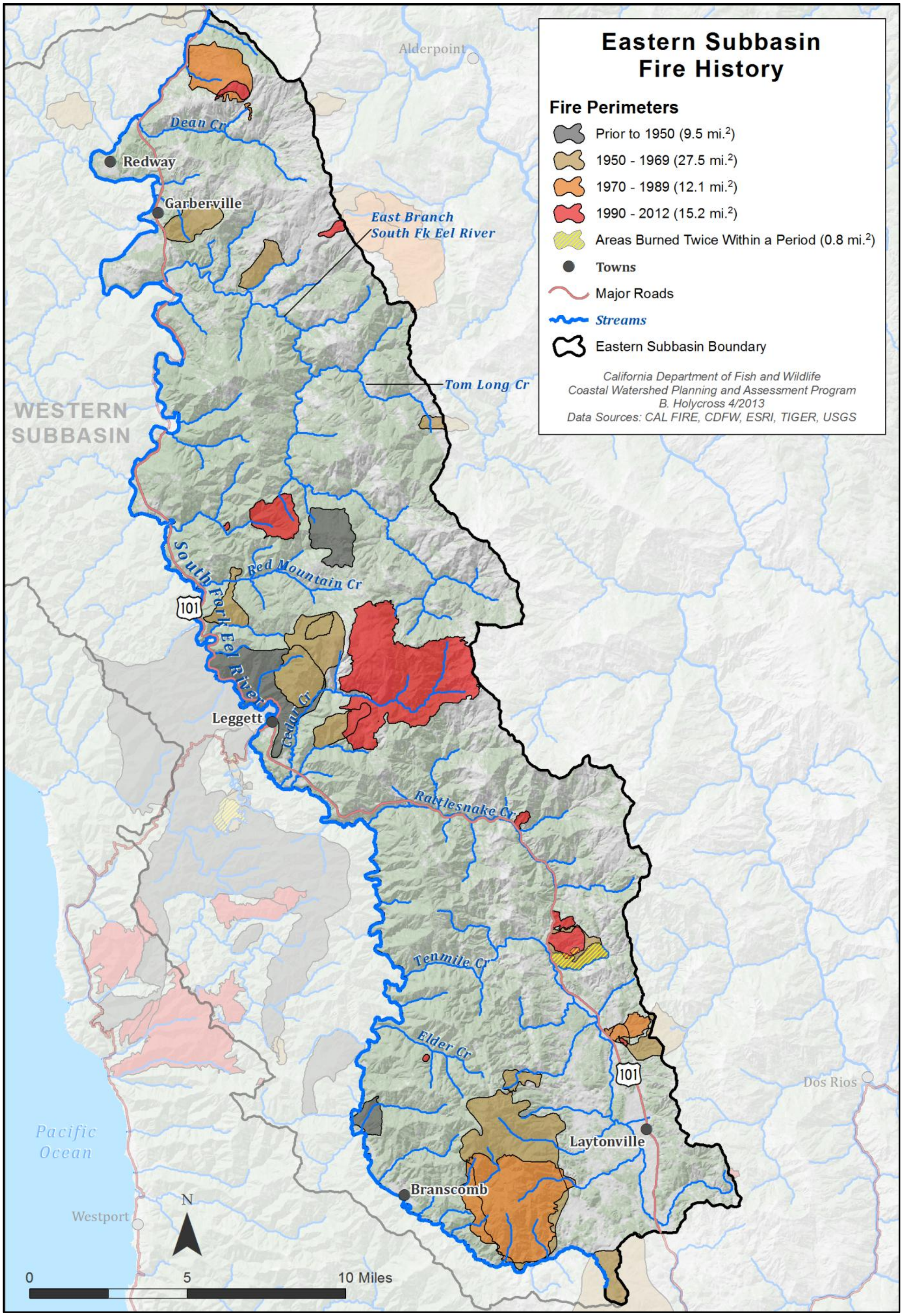

Figure 17. SF Eel River Eastern Subbasin fire history, with total square mileage burned within each time period.

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

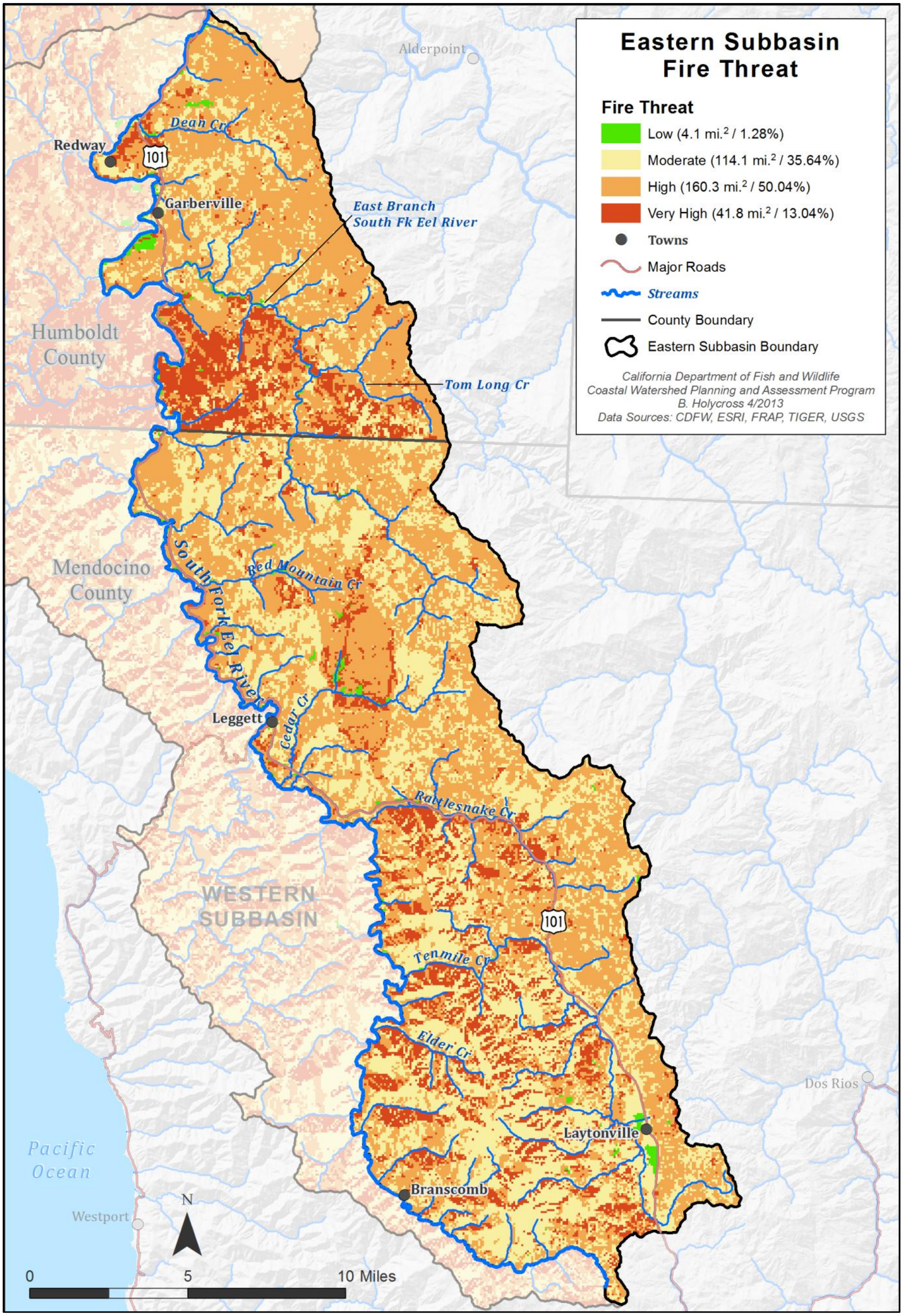

Figure 18. SF Eel River Eastern Subbasin fire threat, with percentage of total basin area in each threat category.

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.

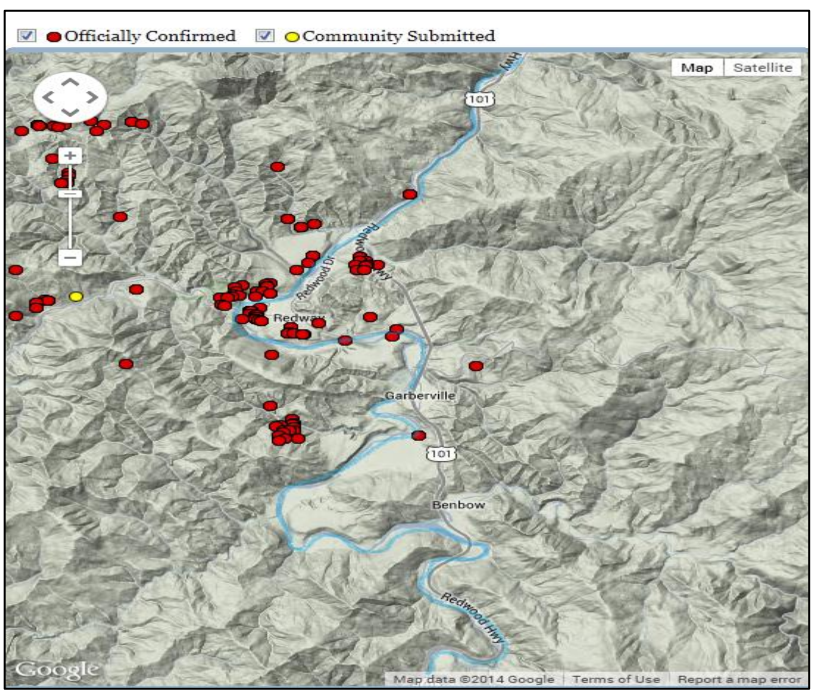

Figure 19. Confirmed (red) and reported (yellow) cases of Sudden Oak Death (SOD) in the SF Eel River Basin, from Oak Mapper website (accessed 2/27/2014).

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).

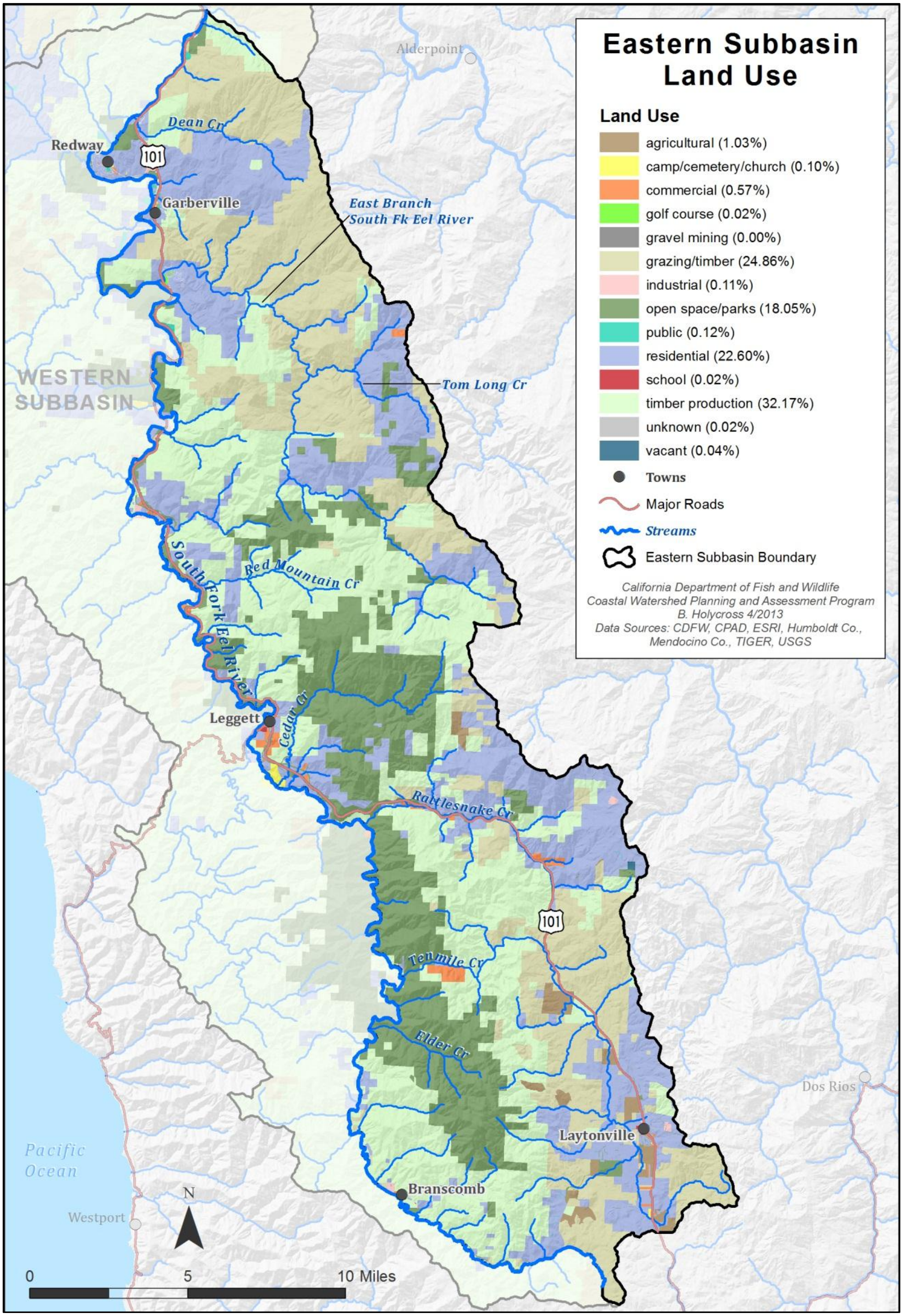

Figure 20. Land use in the Eastern Subbasin of the SF Eel River Basin.

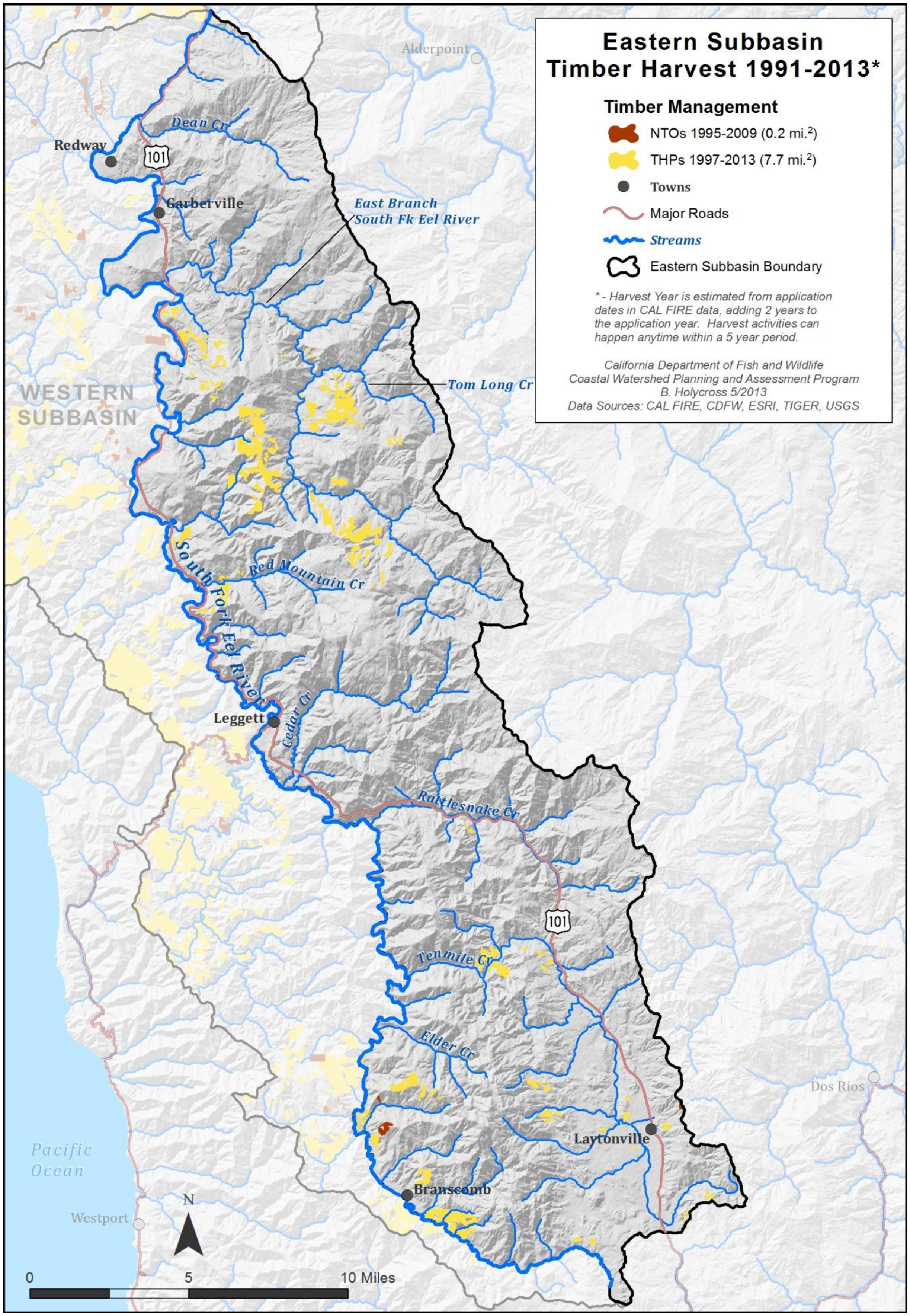

Figure 21. Timber Harvest (NTOs and THPs) between 1995 and 2012 in the SF Eel River Eastern Subbasin.

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.

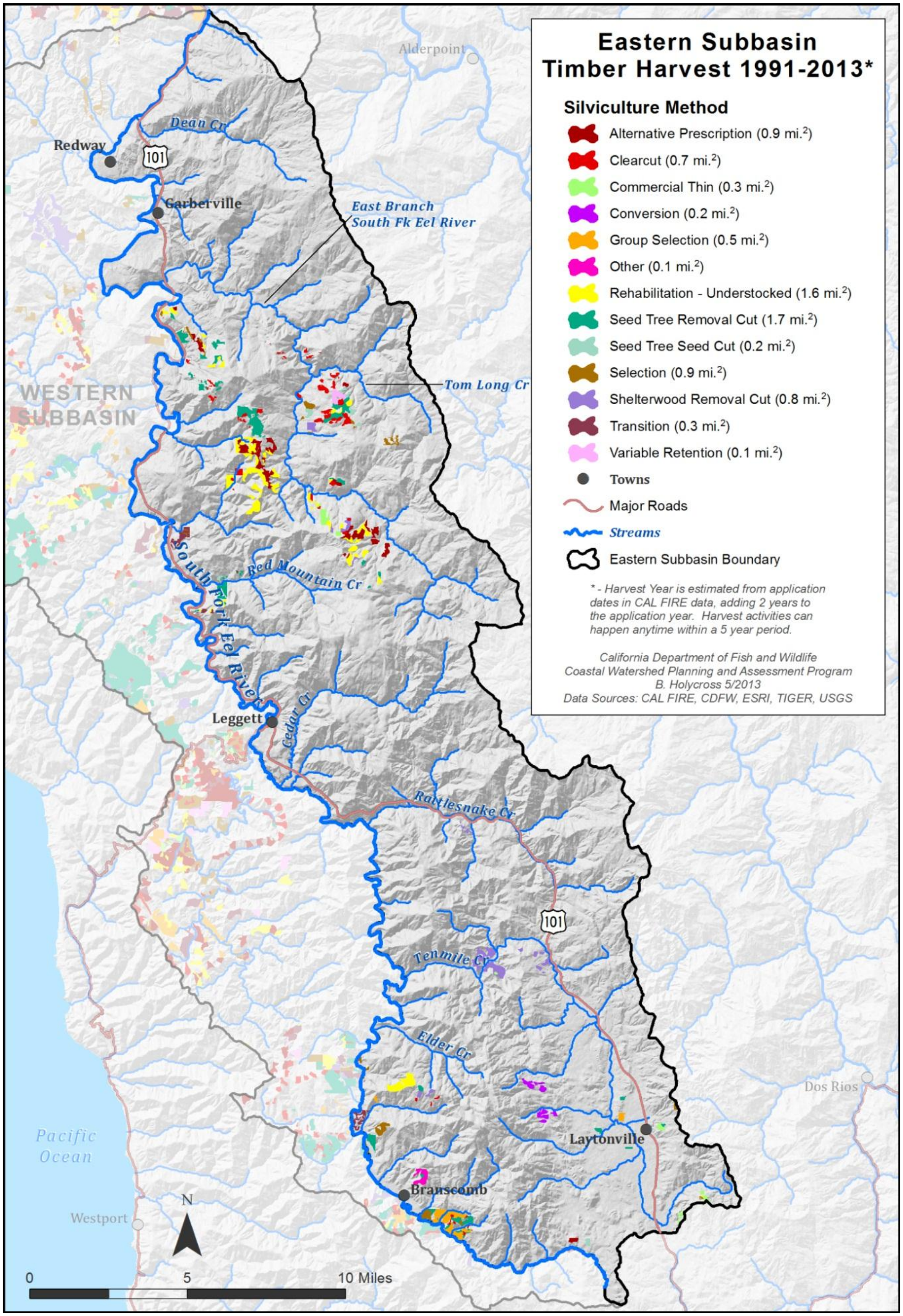

Figure 22. Timber harvest activity by silvicultural method in the SF Eel River Eastern Subbasin.

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

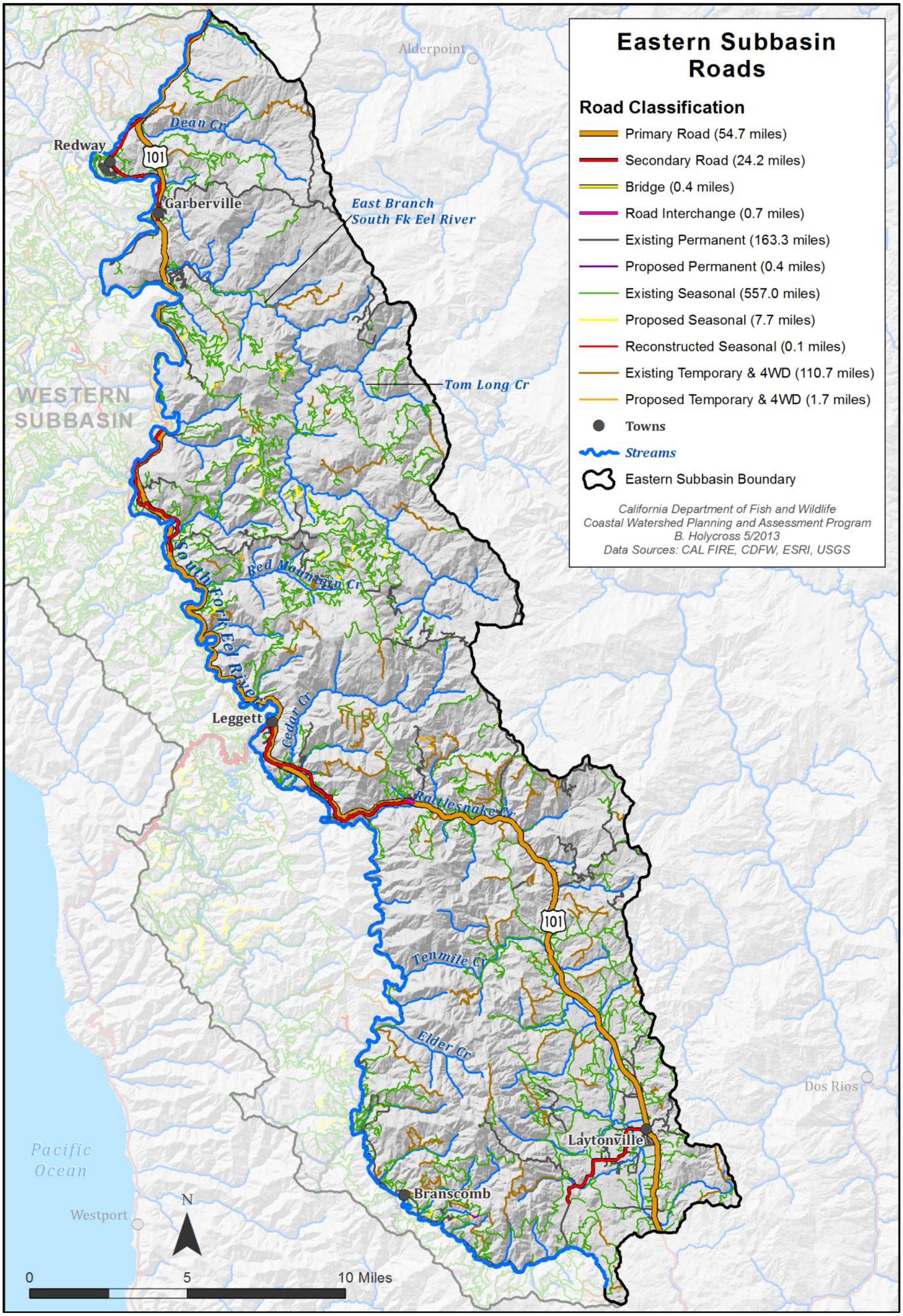

Figure 24. Roads in the SF Eel River Eastern Subbasin.

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

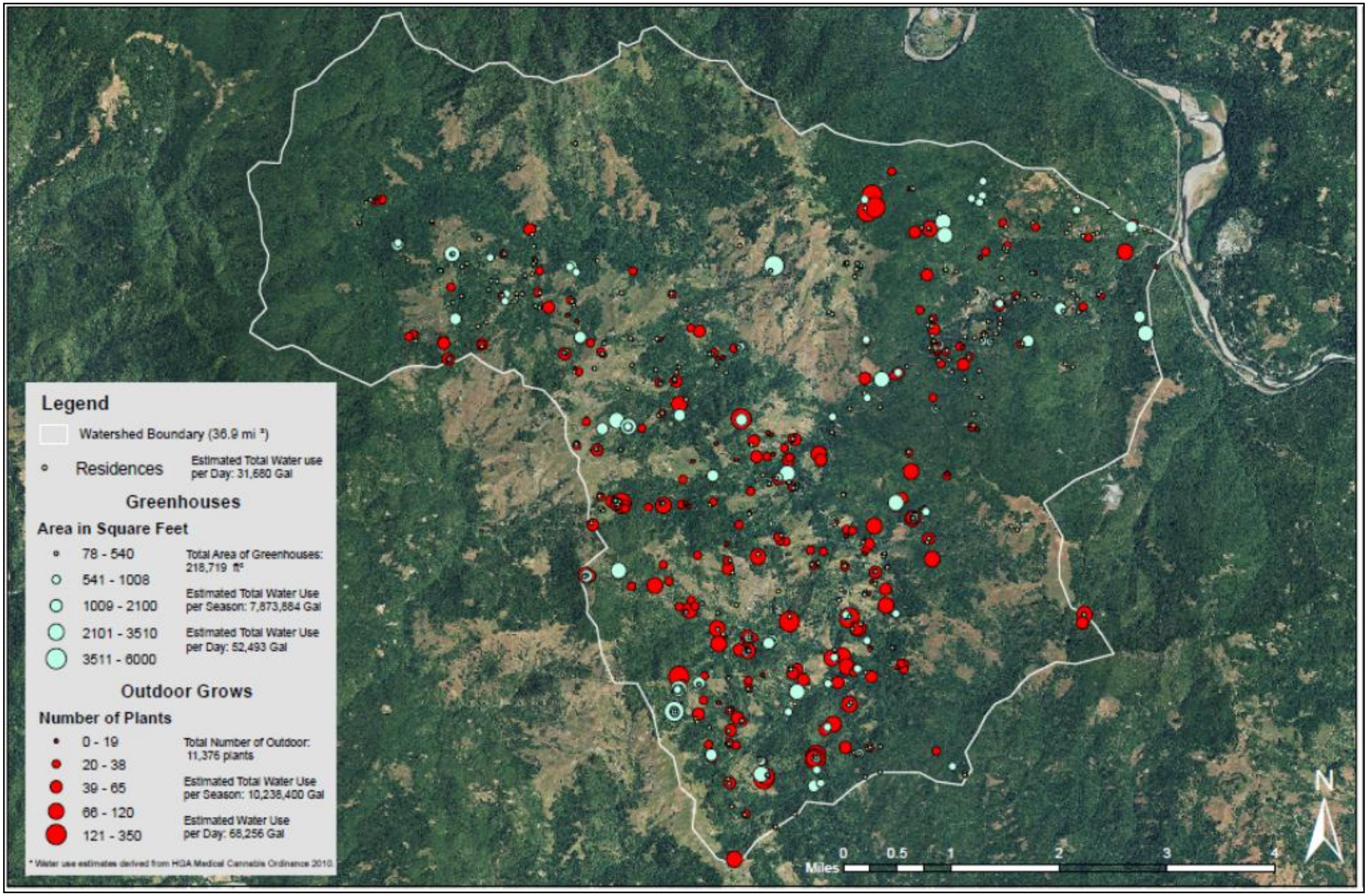

Figure 26. Marijuana cultivation operations from satellite images, with estimated total water use by grow type in Salmon Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW).

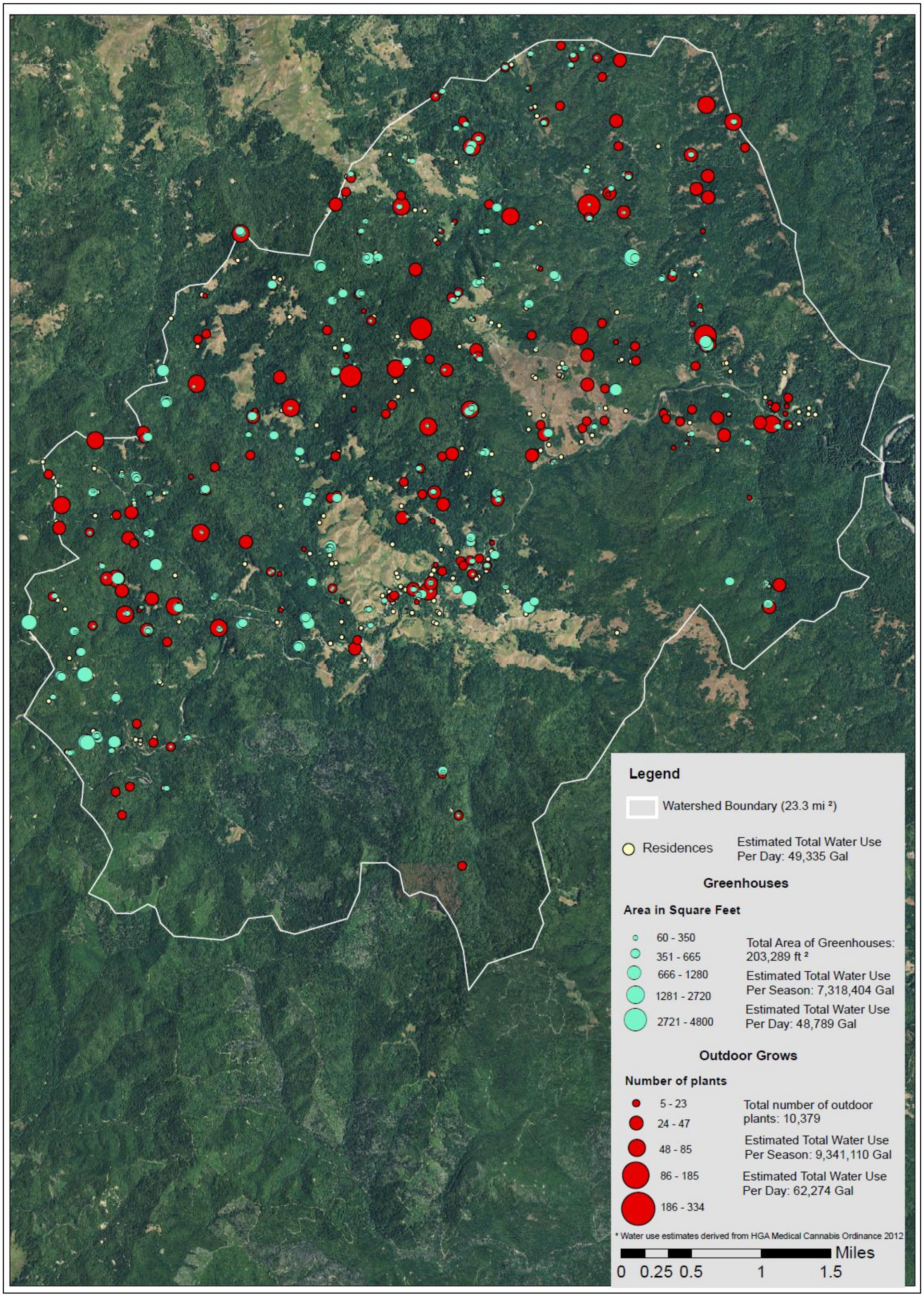

Figure 27. Marijuana cultivation operations from satellite images, with estimated total water use by grow type in Redwood Creek basin, SF Eel River (courtesy of Scott Bauer, CDFW).

(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.

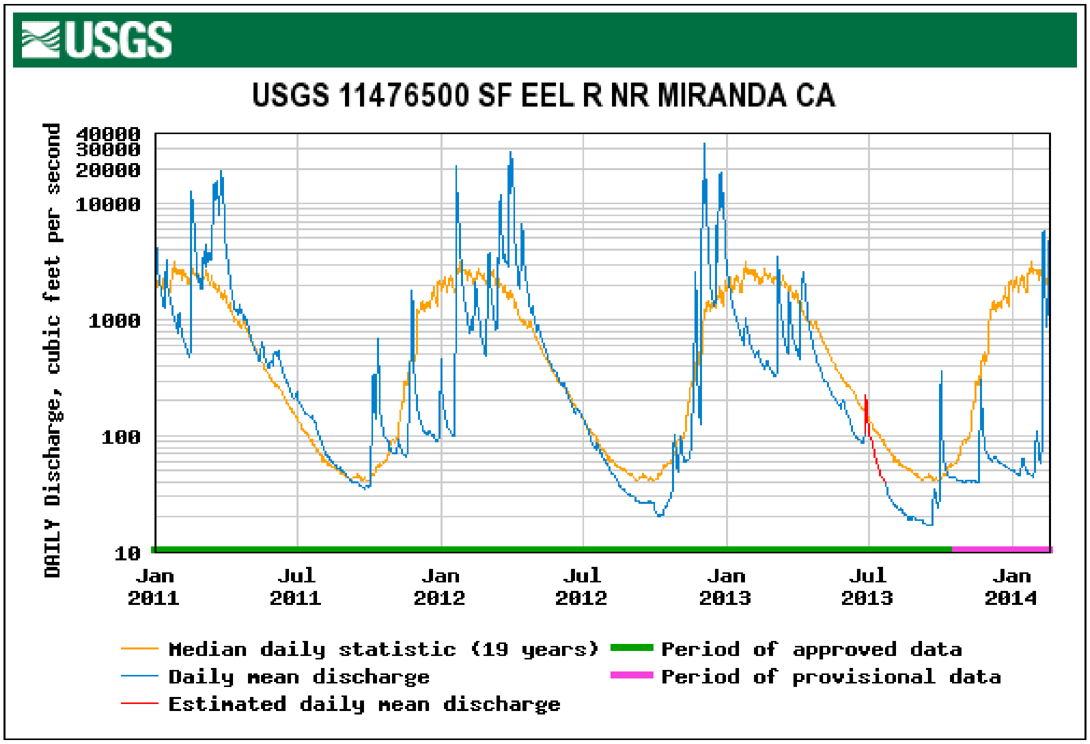

Figure 28. USGS gauging station near Miranda showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (73-year average in cfs).

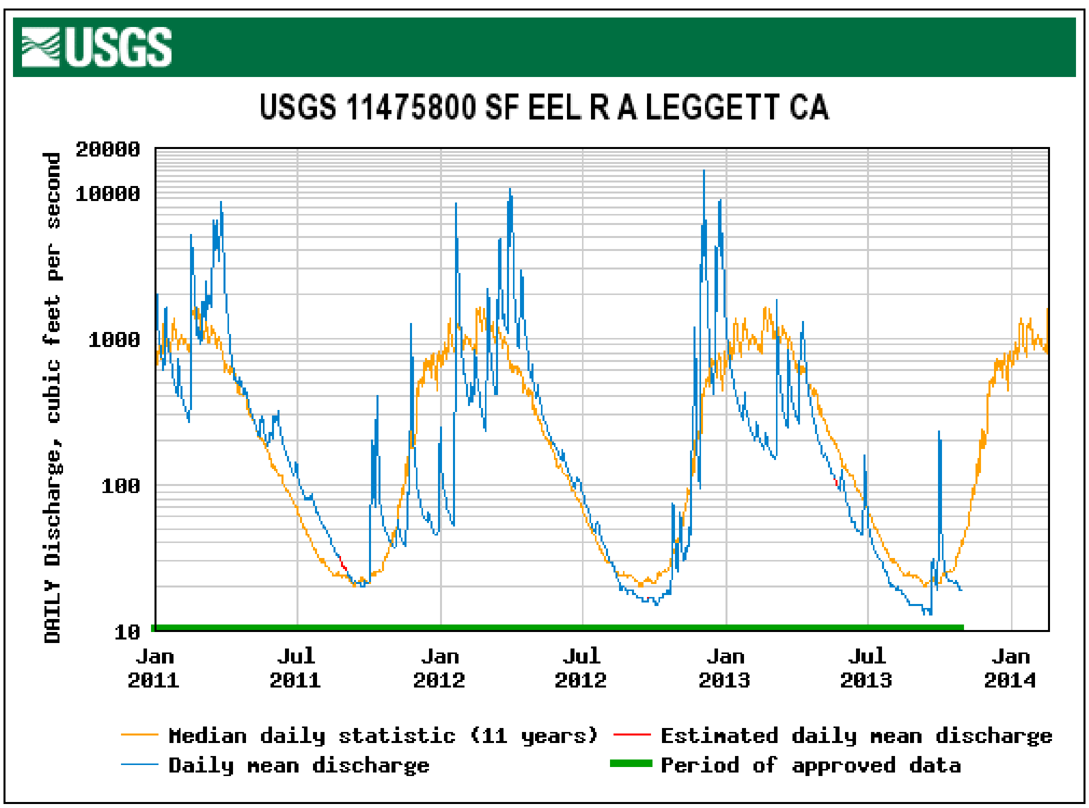

Figure 29. USGS gauging station near Legett showing 2011 through 2014daily mean discharge (in cfs) and the mean daily statistic (40-year average in cfs).

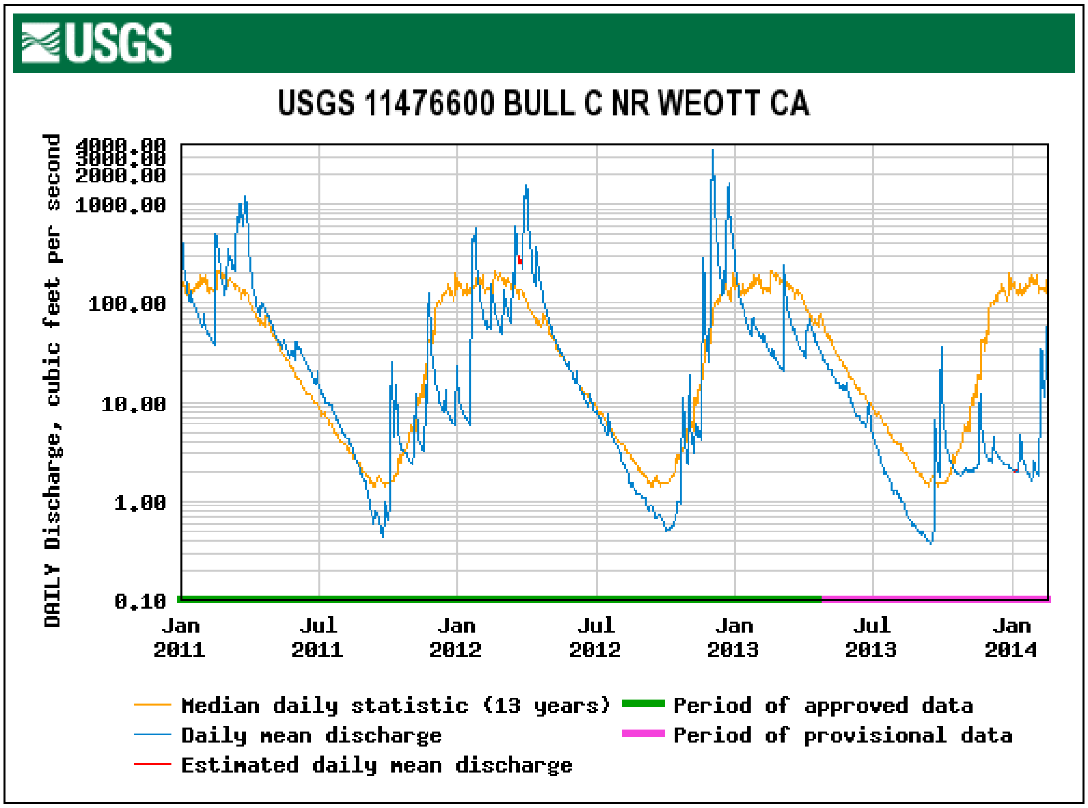

Figure 30. USGS gauging station at Bull Creek showing 2011 through 2014 daily mean discharge (in cfs) and the mean daily statistic (52-year average in cfs).

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

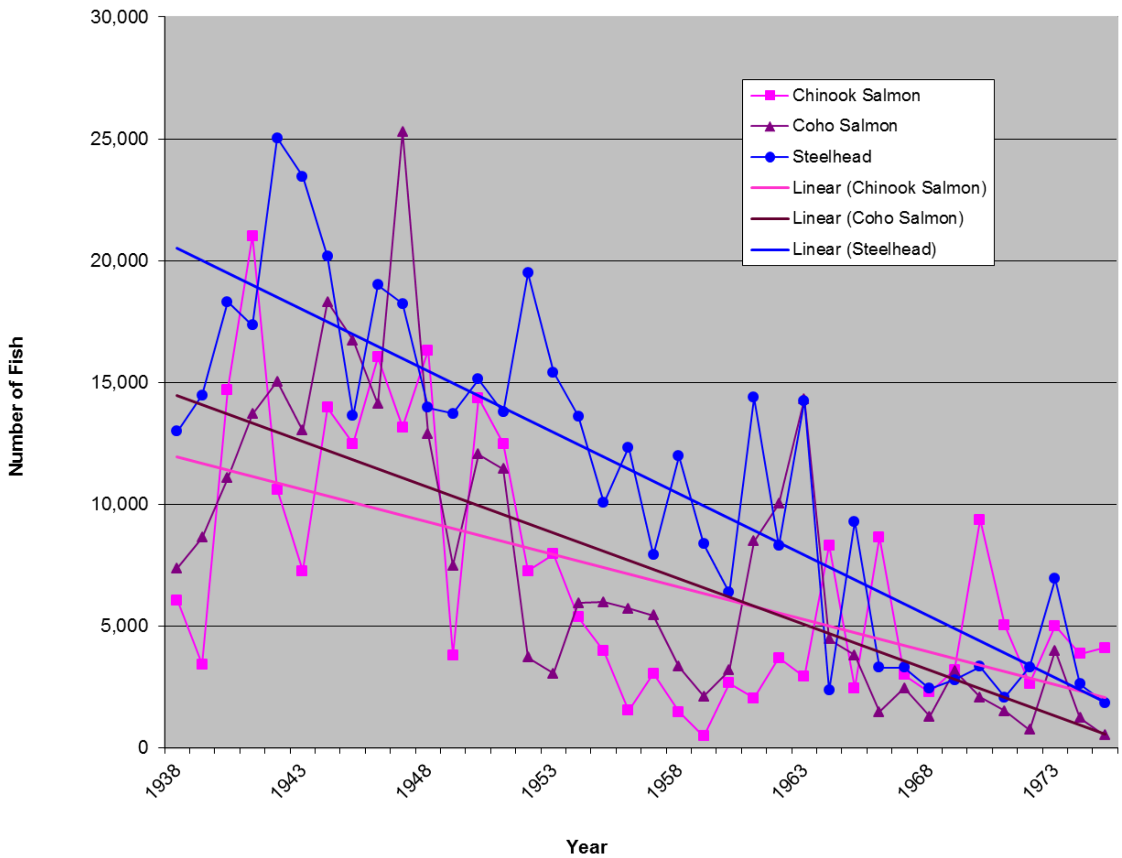

Figure 31. Counts of migrating Chinook salmon, coho salmon, and steelhead at the Benbow Dam fish ladder between 1938 and 1975. Regression lines for all three species show declines over time.

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).				

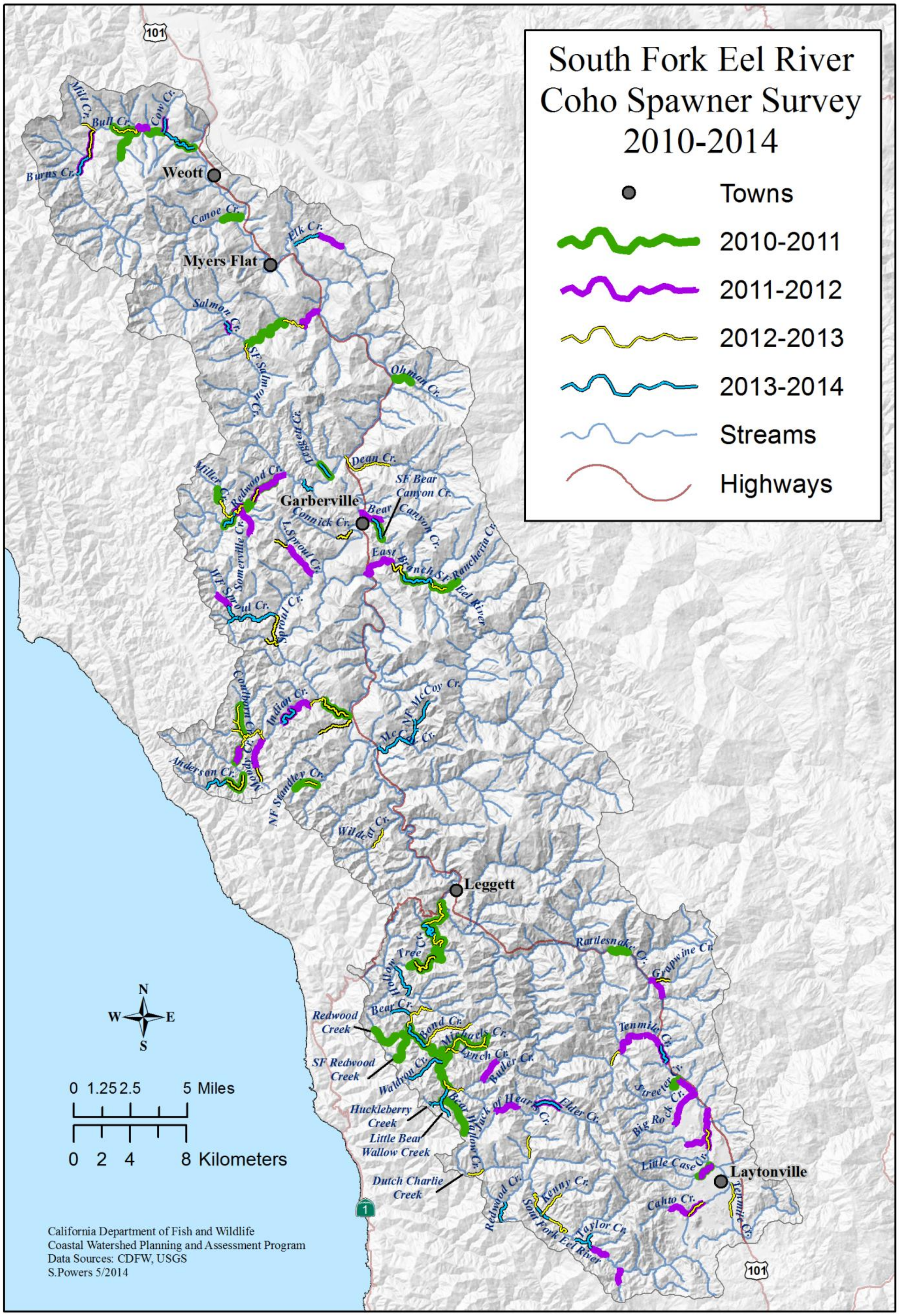

Figure 33. Location of 2010-2014 CMP spawning reaches in the SF Eel River Basin.

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.

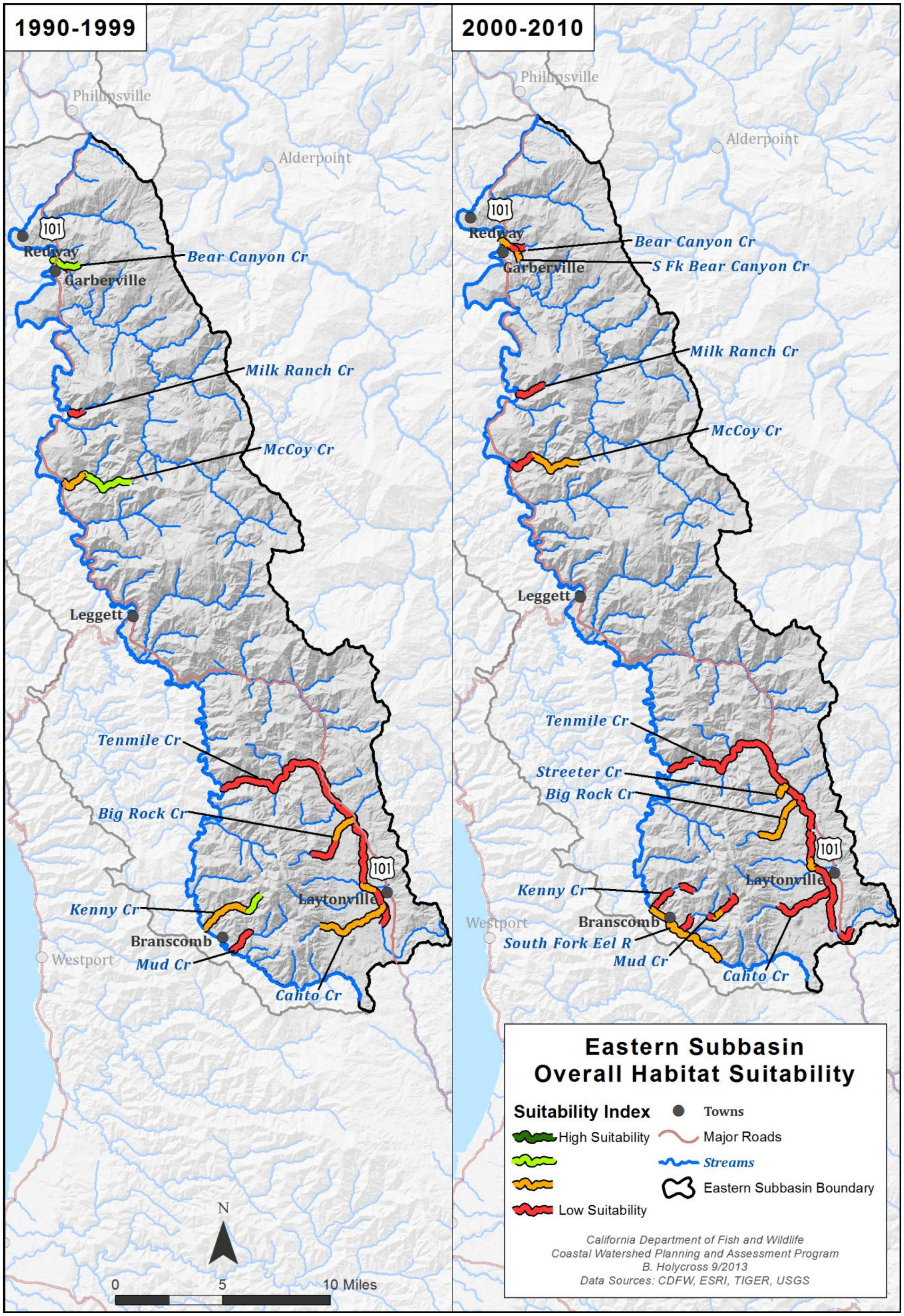

Figure 35. Overall habitat suitability in SF Eel River Eastern Subbasin streams in two sampling periods: 1990-1999 and 2000-2010.

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).

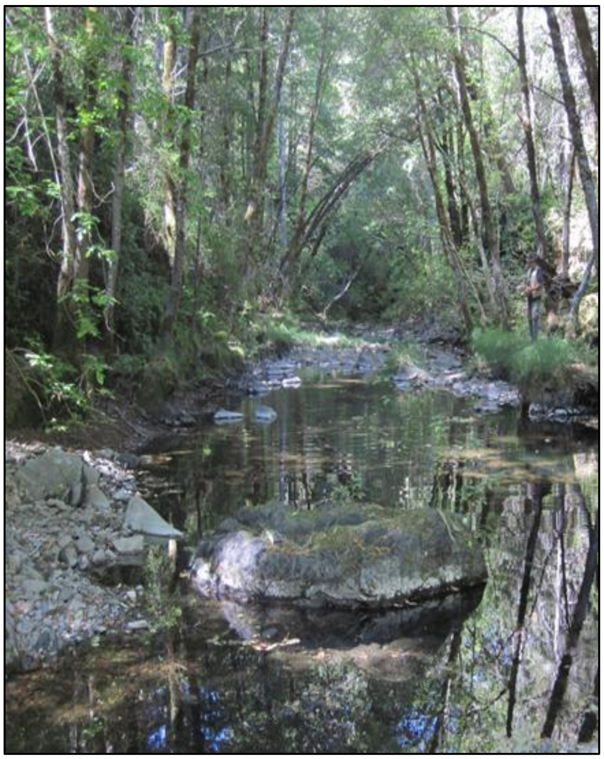

Figure 36. Examples of streams with high canopy density (left, in the western part of the subbasin in the SF Eel River headwaters near Branscomb), and low canopy density (right, in the northeastern part of the subbasin in Dean Creek).

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.

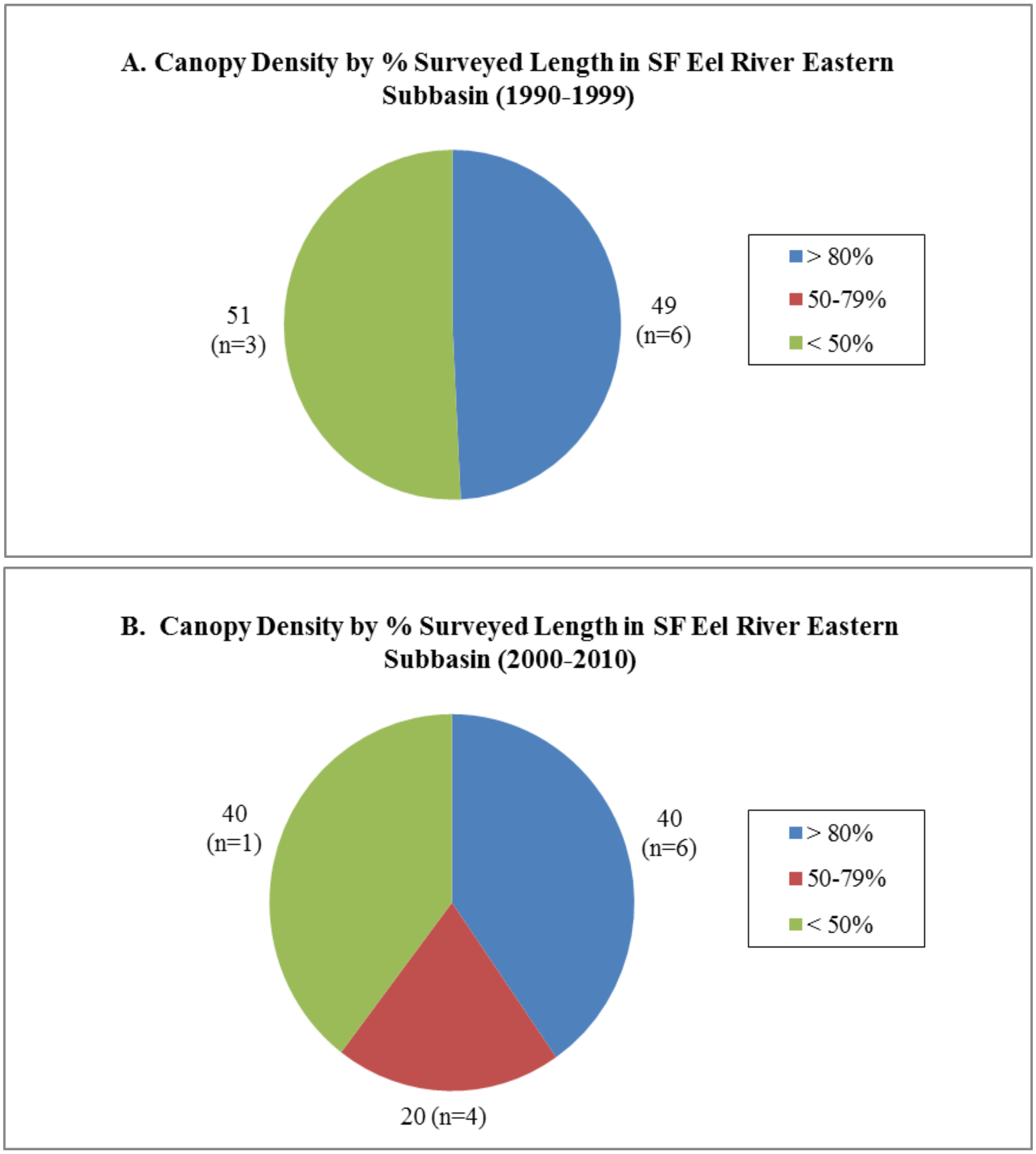

Figure 37A,B. Canopy Density in the Eastern Subbasin, using data collected from 1990-1999 (A) and 2000-2010 (B); n = number of streams surveyed.

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.

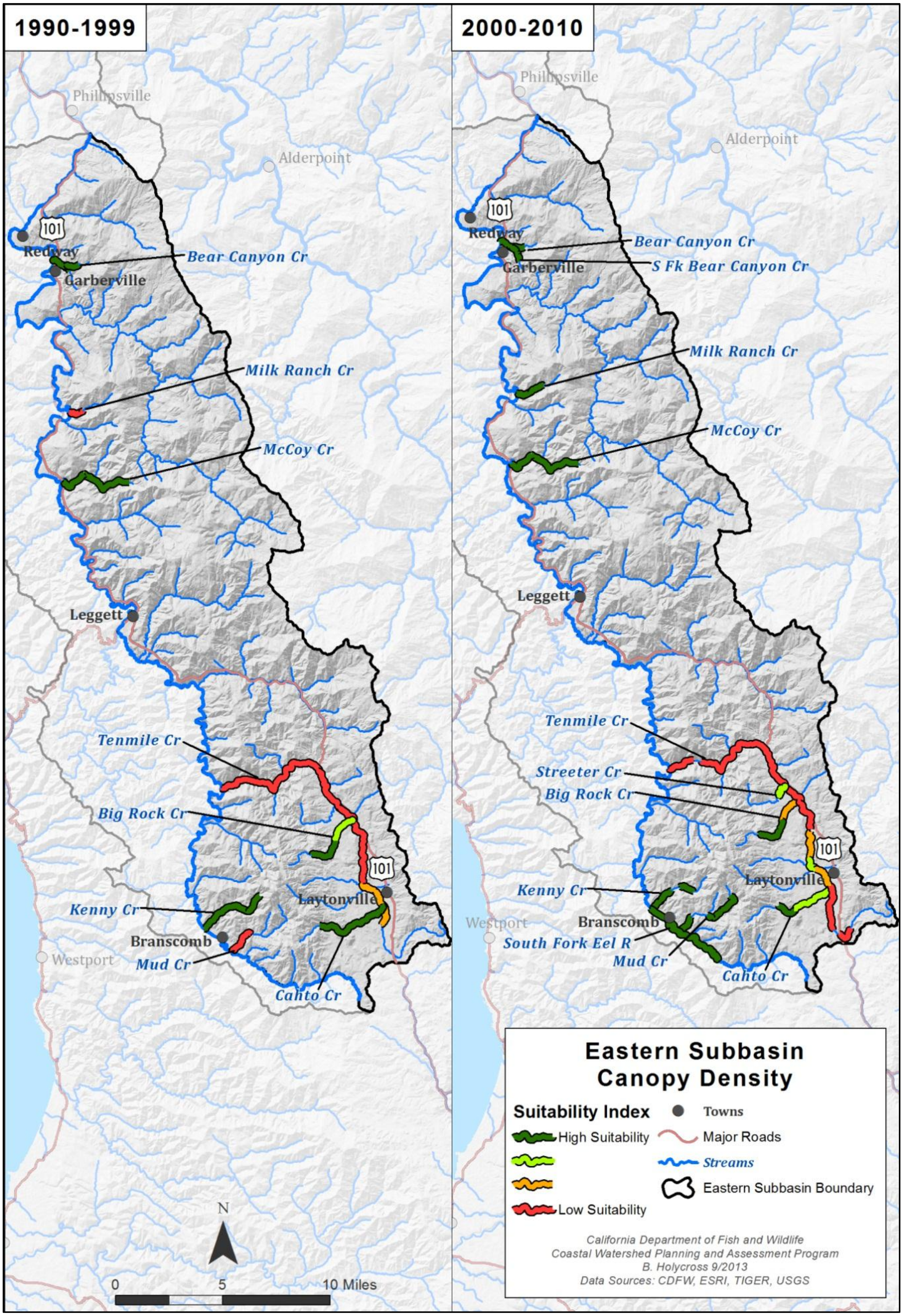

Figure 39. Canopy density suitability for Eastern Subbasin tributaries during two sampling periods: 1990-1999 and 2000-2010.

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).

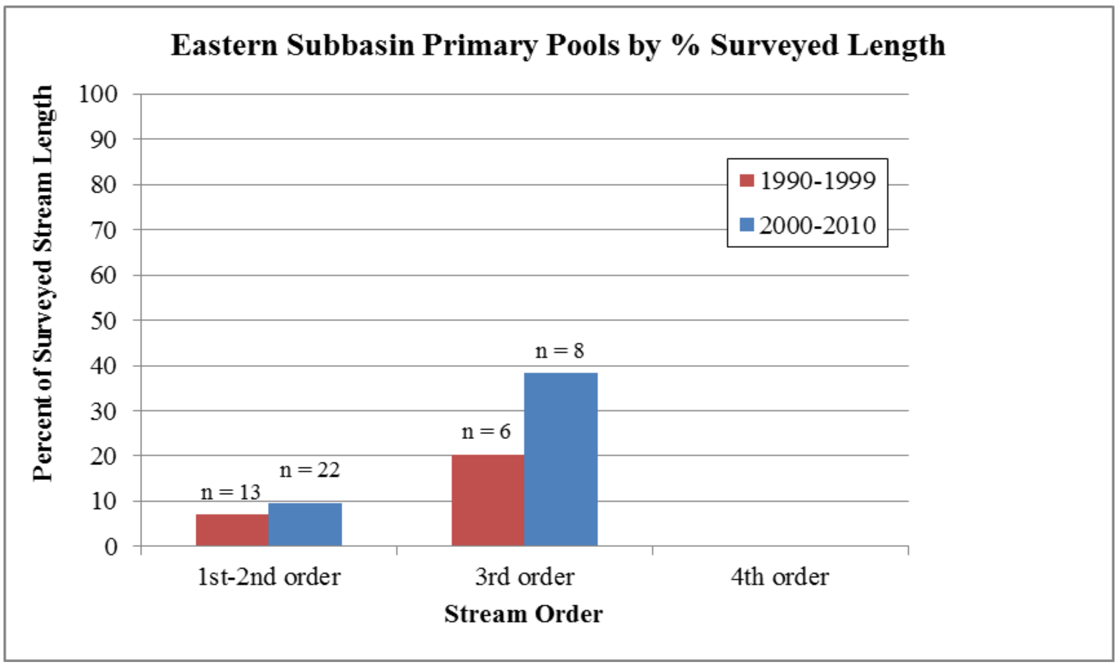

Figure 40. Percent of surveyed habitat in primary pools in the Eastern Subbasin, using data collected from 1990-1999 and 2000-2010.

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

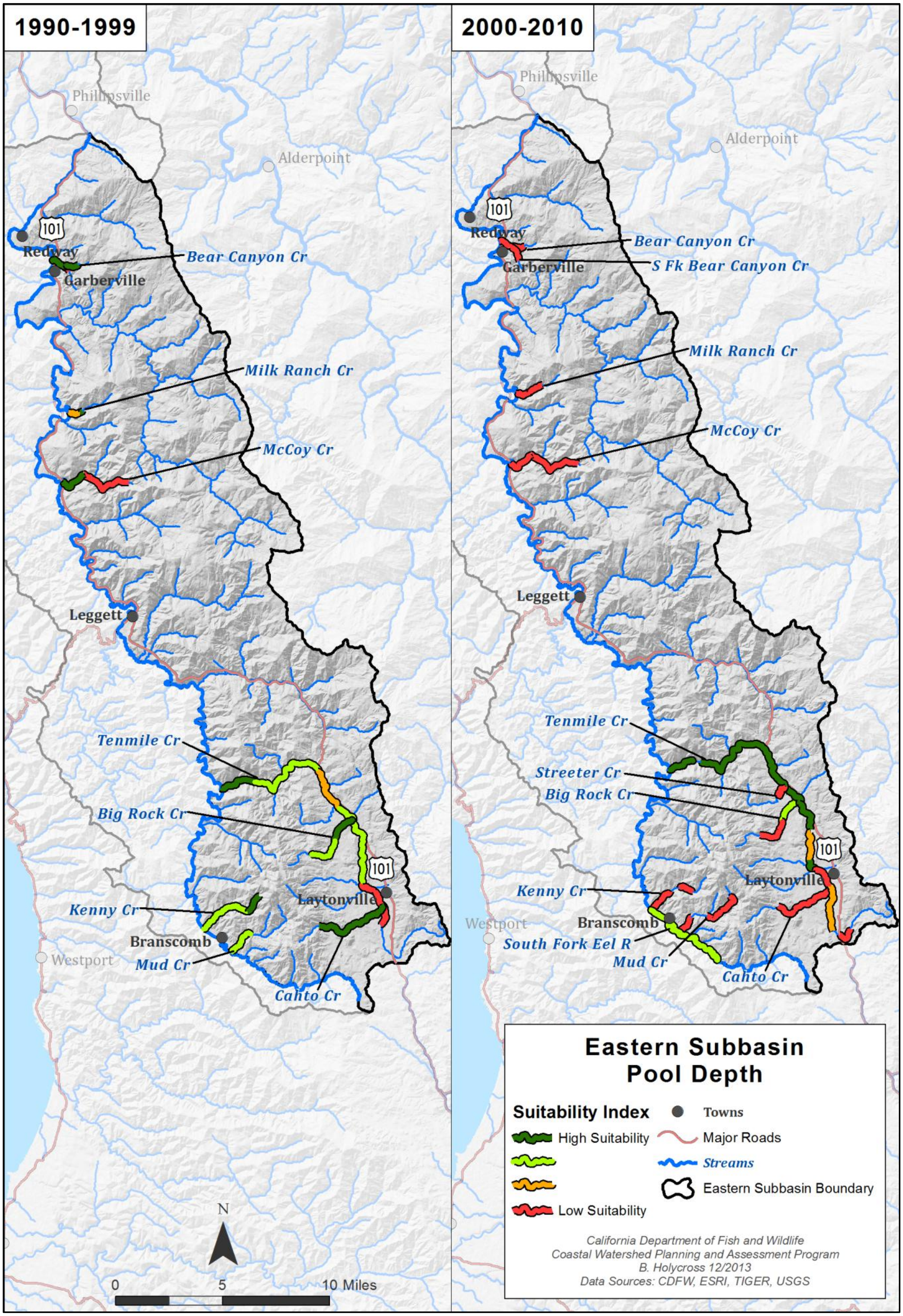

Figure 41. Pool depth suitability in SF Eel River Eastern Subbasin streams, using data collected between 1990 and 1999, and 2000 and 2010.

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.

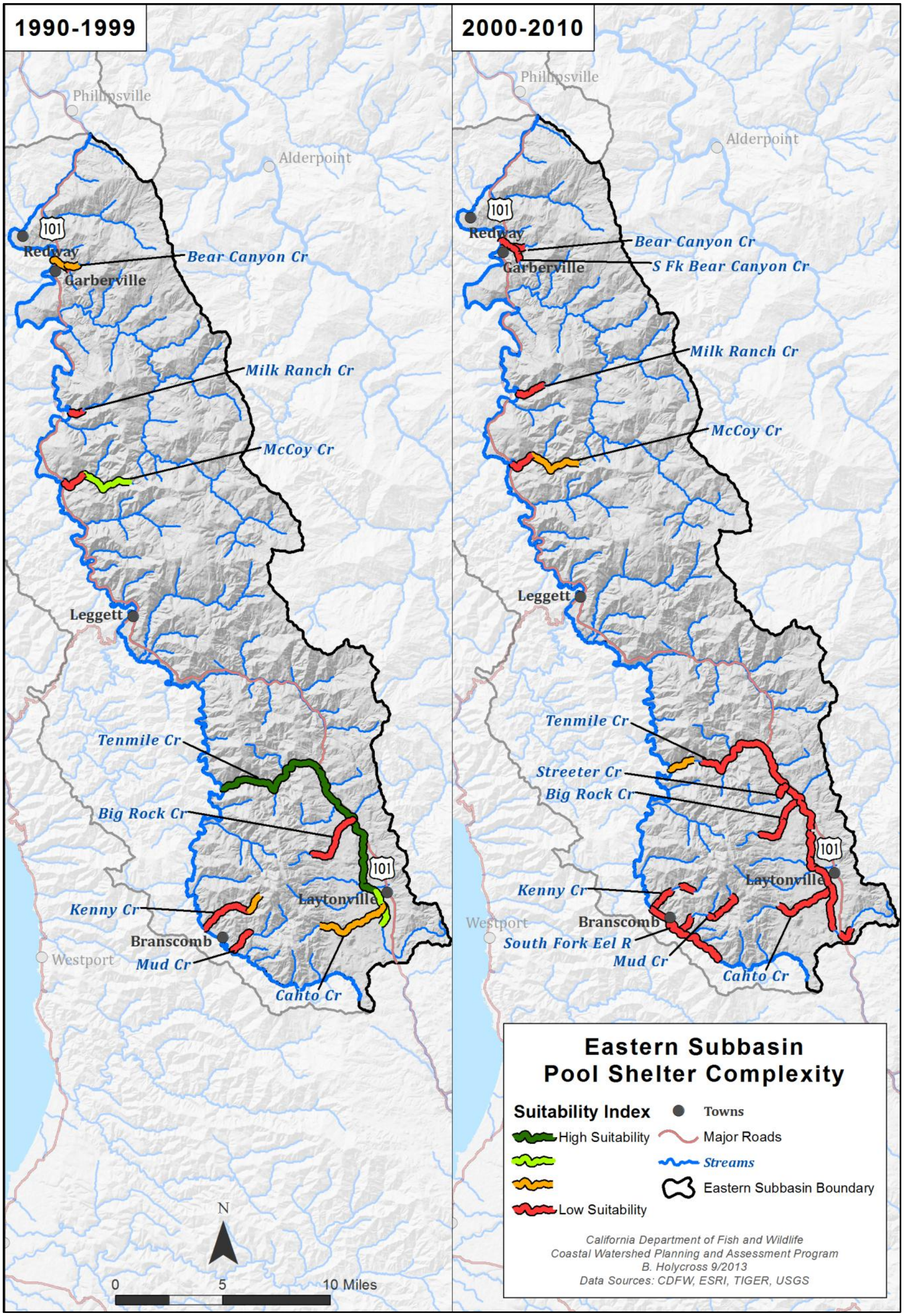

Figure 42. Pool shelter suitability for Eastern Subbasin streams, using data collected between 1990 and 1999, and 2000 and 2010.

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.

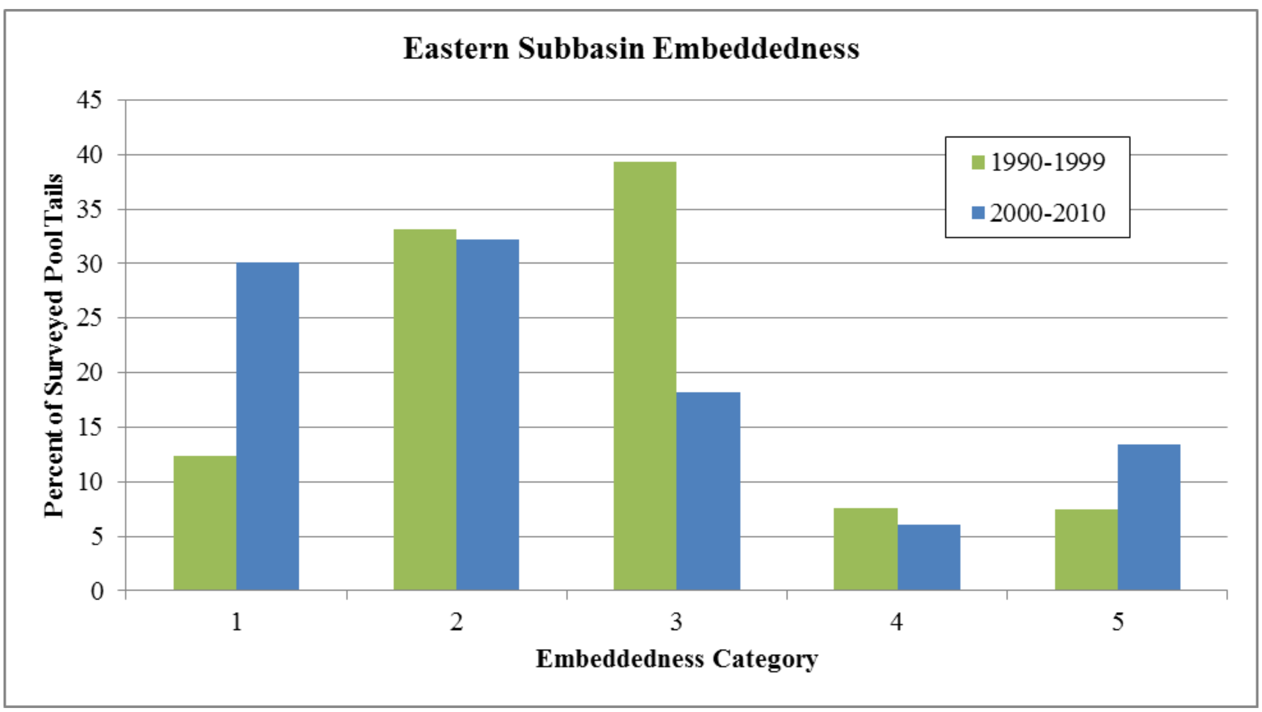

Figure 43. Cobble Embeddedness in the Eastern Subbasin, using data collected from 1990-1999 and 2000-2010.

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.

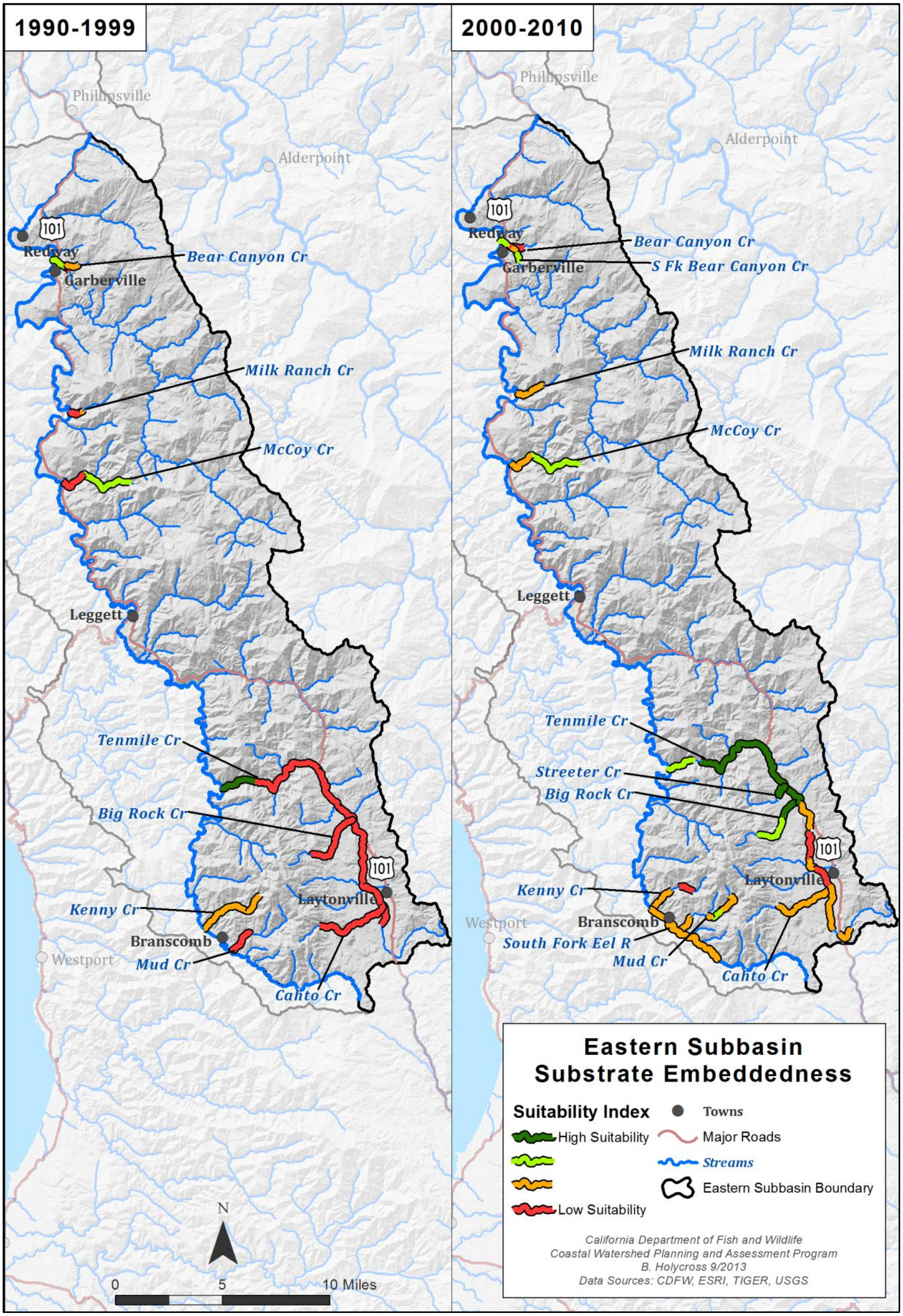

Figure 44. Embeddedness suitability in Eastern Subbasin streams using data collected between 1990 and 1999, and 2000 and 2010.

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

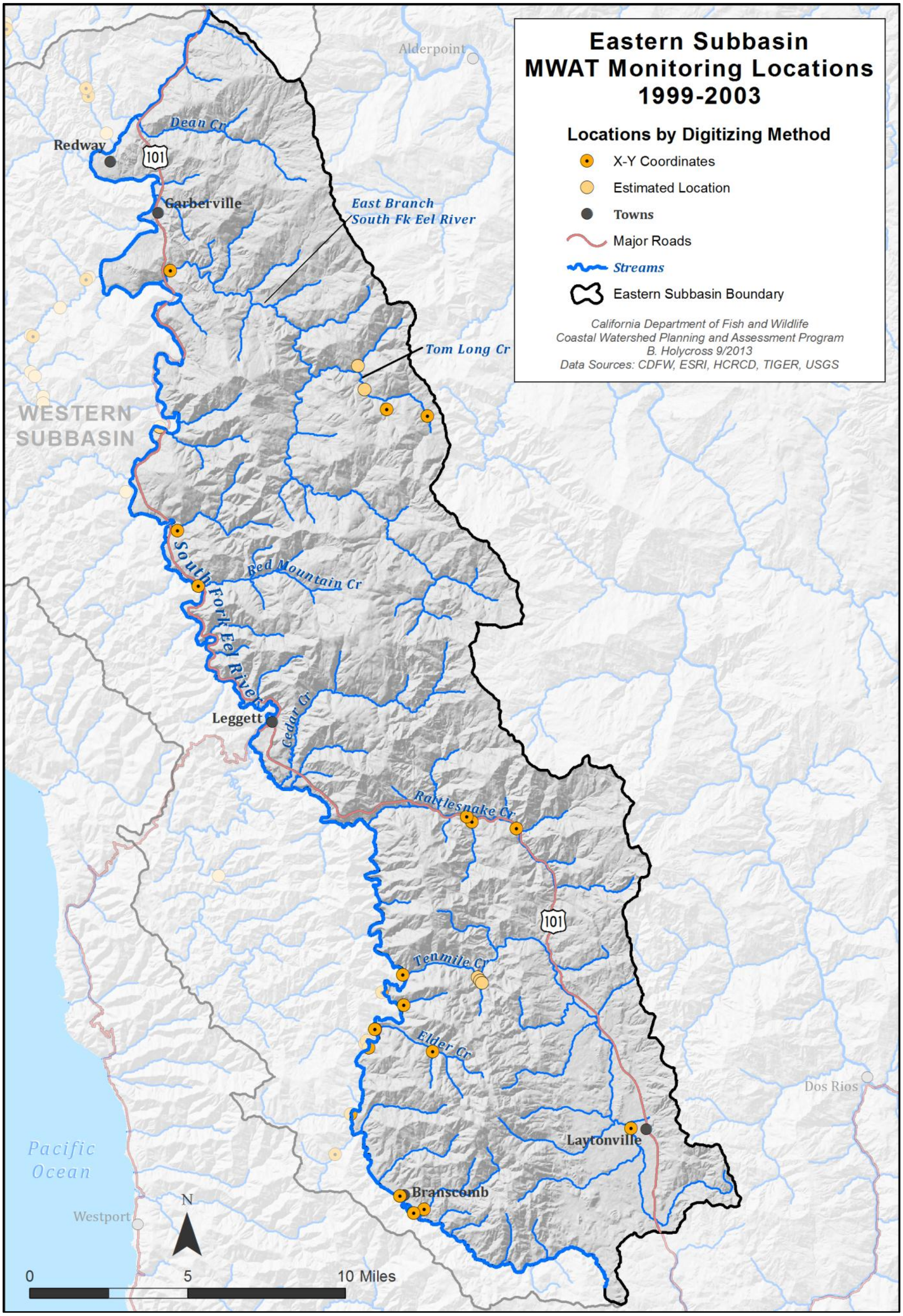

Figure 45. Locations of temperature monitoring sites in the SF Eel River Eastern Subbasin (Friedrichsen 2003).

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

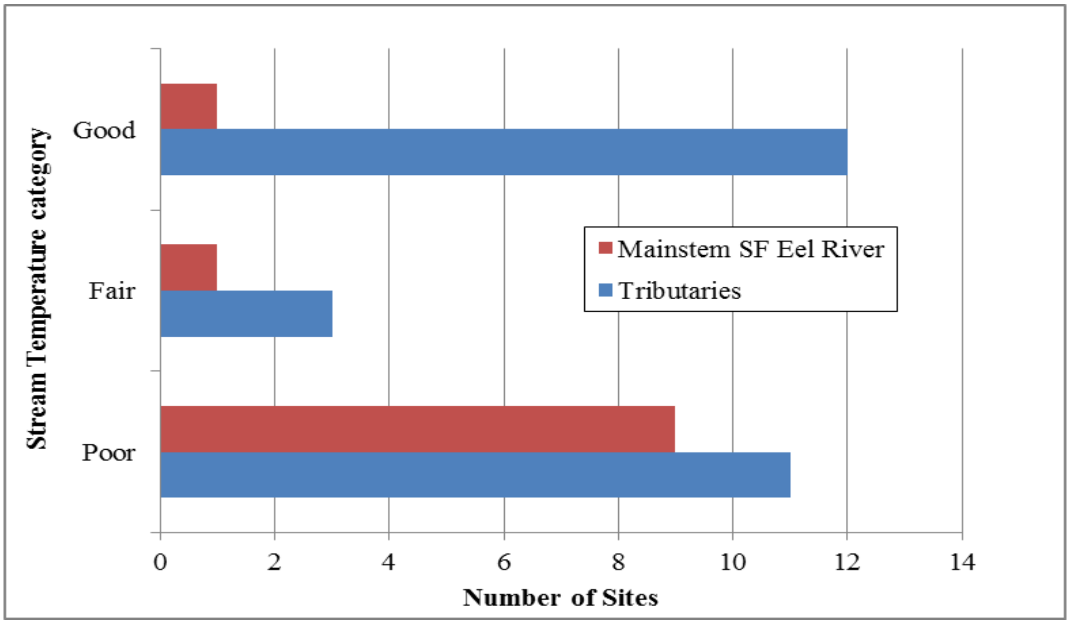

Figure 46. Number of sites in each suitability rating category for MWATs collected from 1999-2003 (n=37; 26 tributary and 11 mianstem sites) in SF Eel River Eastern Subbasin streams (data from Friedrichsen 2003).

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.

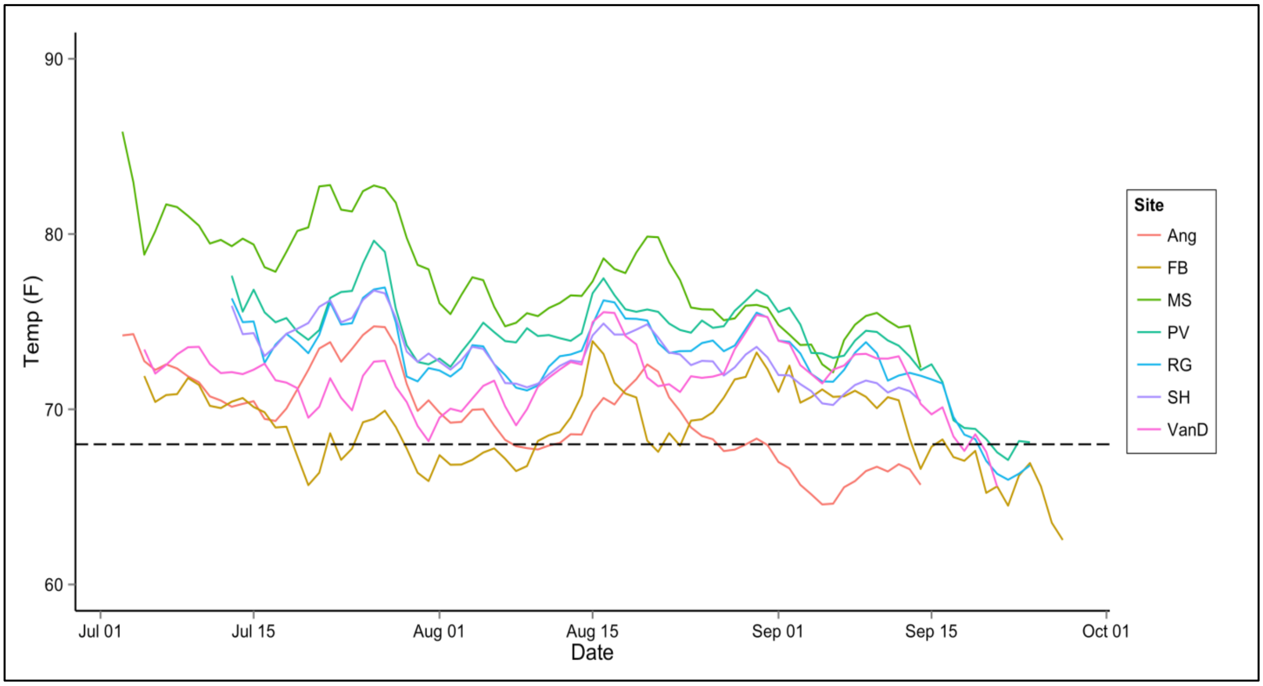

Figure 47. Daily average temperatures (degrees F) from July 3 through September 24, 2013, recorded at 7 sampling locations in the Eel River Basin. Data and graph provided by Keith Bouma-Gregson (UC Berkeley, 2014). Ang = Angelo Reserve; FB = Fernbridge; MS = Mainstem Outlet Creek; PV = Phillipsville; 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.

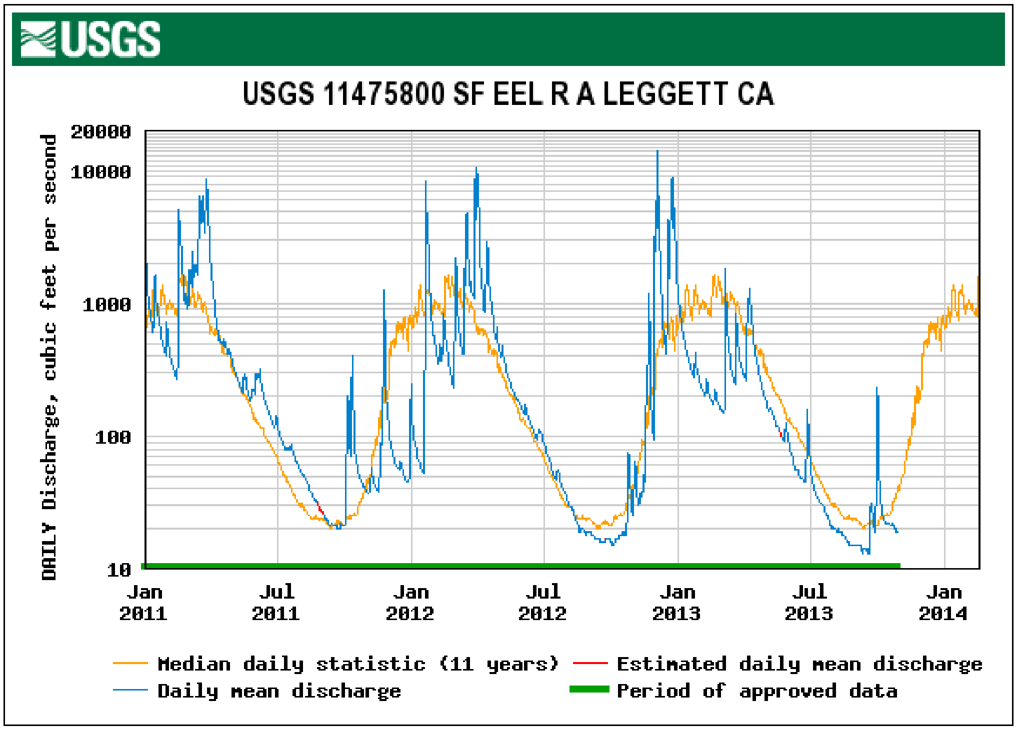

Figure 48. Daily mean discharge (in cfs) and mean daily discharge (40-year average in cfs) for USGS gauging station at SF Eel River near Leggett, showing 2011-2014 data.

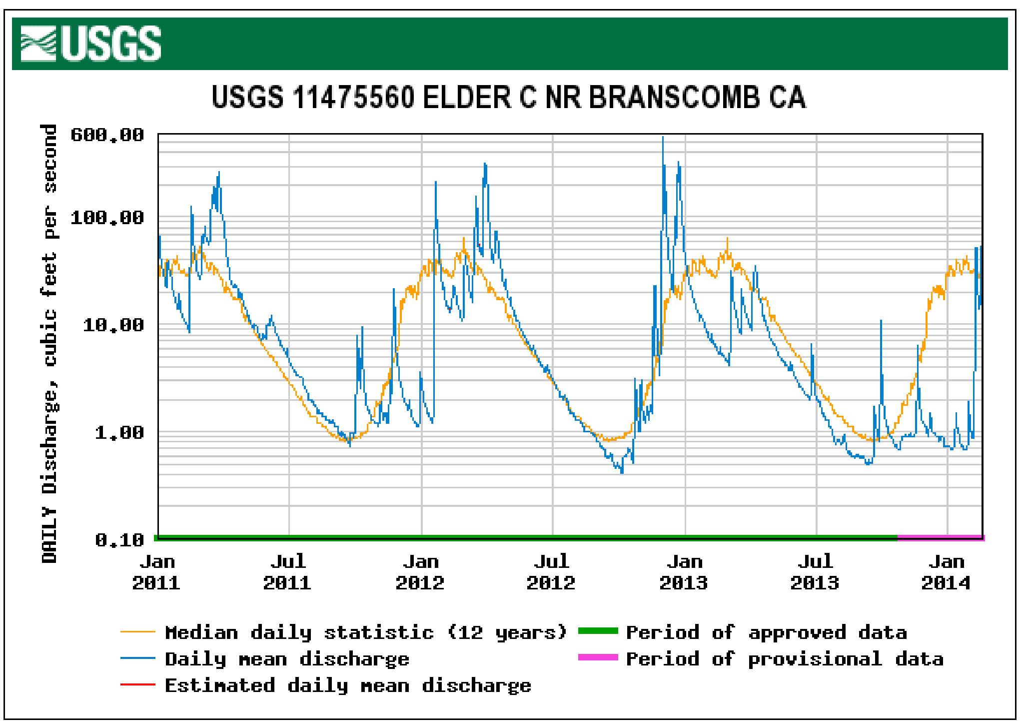

Figure 49. Daily mean discharge (in cfs) and mean daily discharge (45-year average in cfs) for USGS gauging station at Elder Creek, showing 2011-2014 data.

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.

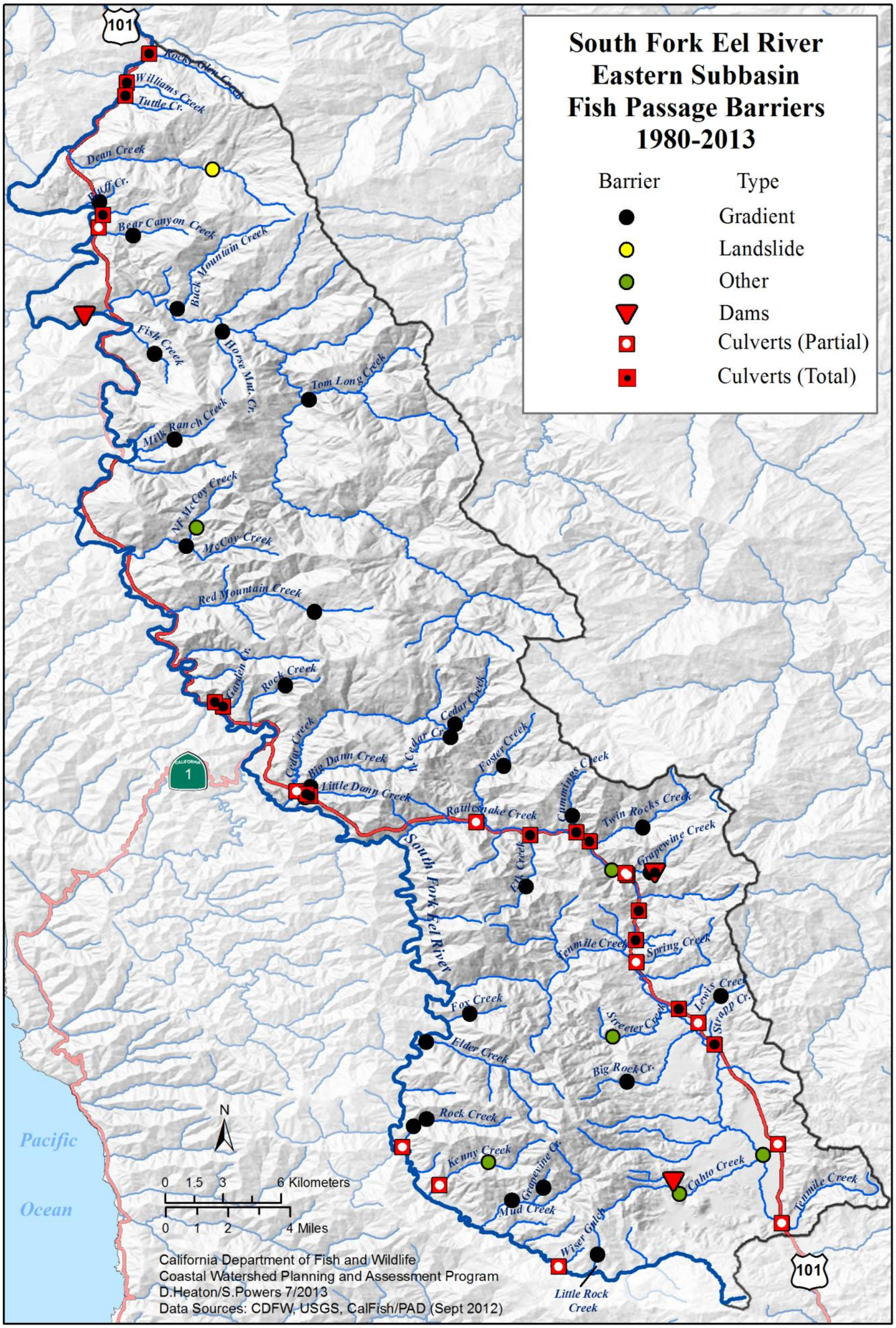

Figure 54. Fish passage barriers in the SF Eel River Eastern Subbasin.

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/).

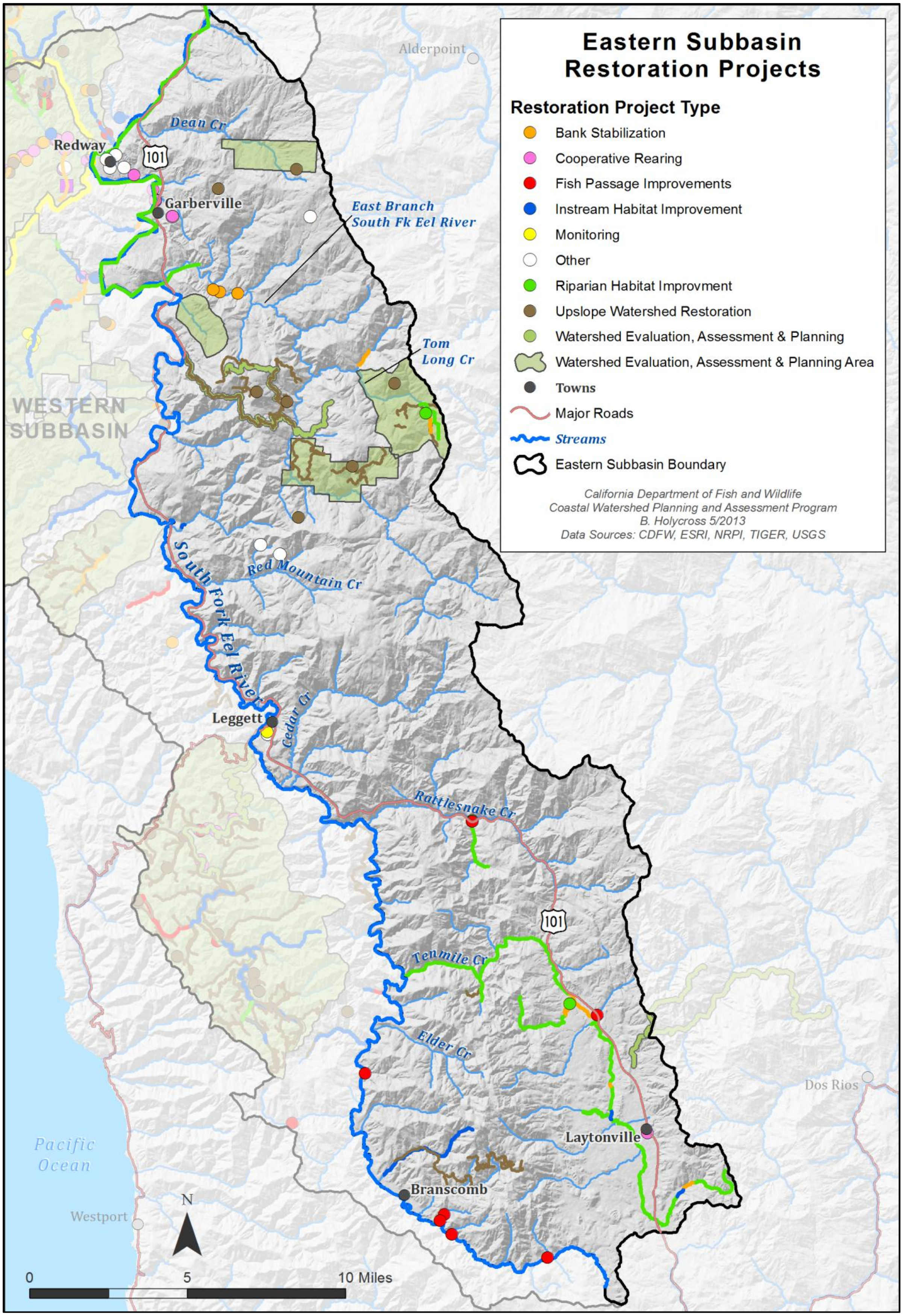

Figure 56. SF Eel River Eastern Subbasin restoration projects.

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

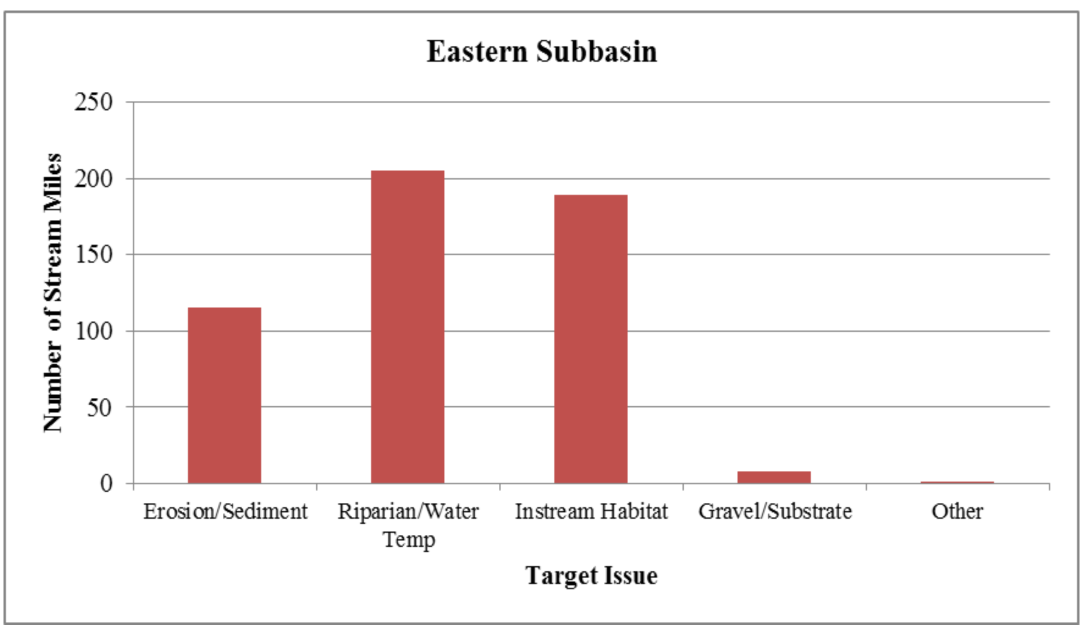

Figure 57. Recommendation target issues by stream miles for the Eastern Subbasin.

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.

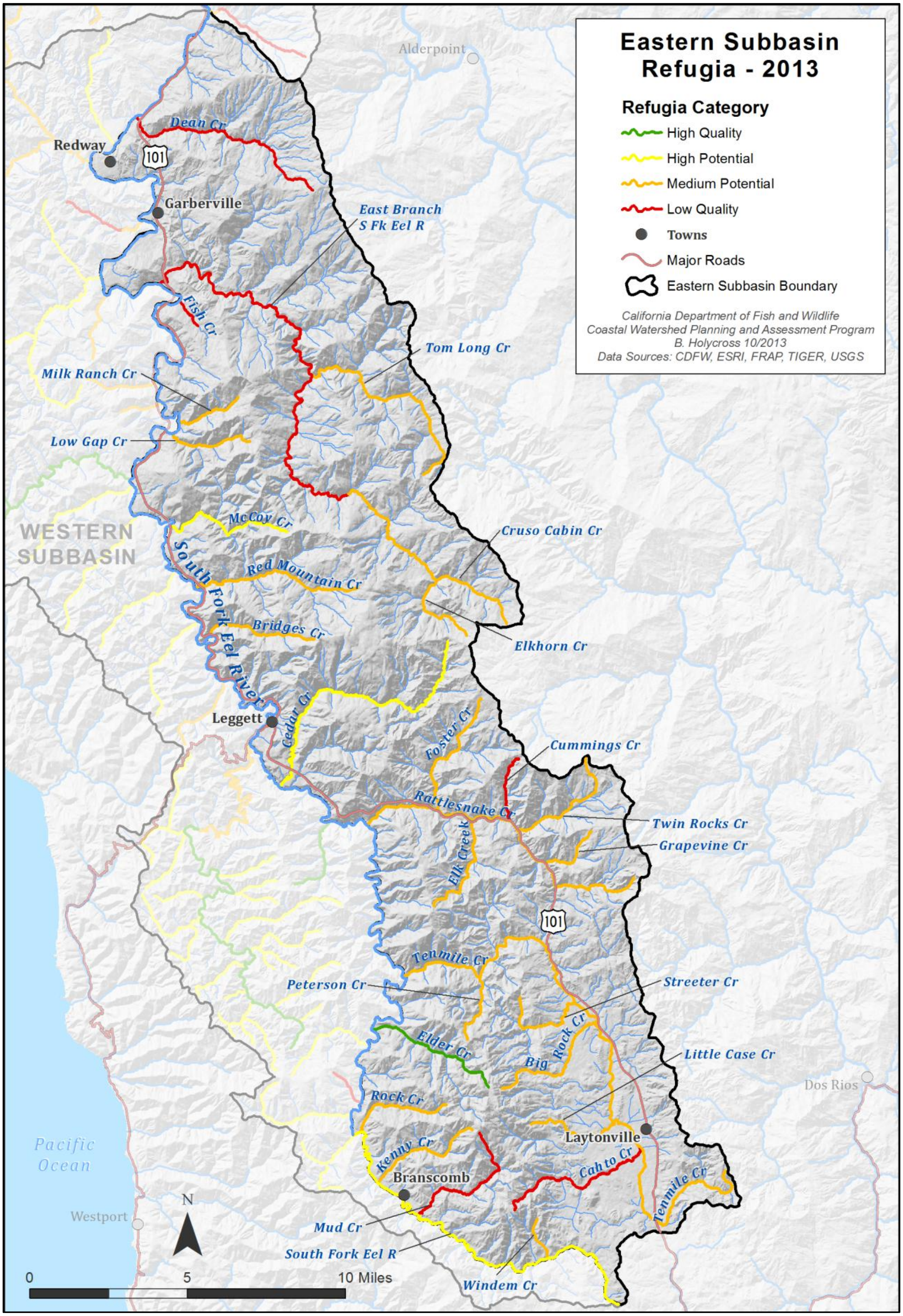

Figure 58. Refugia ratings in SF Eel River Eastern Subbasin streams.

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.

Expansion of residential areas and marijuana cultivation operations is a concern:

- 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.

Erosion related to timber harvest 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 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).