7.1 Geology and Soils

7.1.1 Overview

This section provides information regarding existing geology and soil conditions in the vicinity[1] of Yuba County Water Agency's (YCWA or Licensee) Yuba River Development Project (Project). Besides this general introductory information, this section is divided into six subsections: Sections 7.1.2 through 7.1.7 provide general information regarding geologic features, tectonic history, mineral resources, physiography, geomorphology, and soils in the Project Region[2] and Section 7.1.8 describes existing, relevant, and reasonably available information regarding geology and soils in areas upstream of the Project (i.e., on the Middle Yuba River upstream of Our House Diversion Dam, on Oregon Creek upstream of Log Cabin Diversion Dam, and on the North Yuba River upstream of New Bullards Bar Reservoir), within the Project Area,[3] and downstream of the Project (i.e., on the Yuba River downstream of the United States Army Corps of Engineers' (USACE) Daguerre Point Dam).

7.1.2 Geologic Features

The Project Region is located within the Sierra Nevada physiographic and geologic province. The geology within the Project Region has evolved through many complex interactions within and beneath the earth's crust. These processes include plate tectonics, where continents are created by various mechanisms and are transformed by other mechanisms. Other smaller-scale local processes, such as mass wasting, weathering, erosion, and sedimentation also constantly change the landscape.

The geologic history of the Project Region spans the period from the mid-Paleozoic (i.e., approximately 300-400 million years ago, or mya) to the present day. The deepest basement rocks were emplaced about 225 mya, but are actually younger than many of the overlying metamorphic, volcanic, and sedimentary rocks exposed in the Project Region. The basement rock and overlying rocks began to move westward with the formation of a subduction boundary on what was then the western margin of the North American land mass (Schweickert et al. 1984), located east of the present day Sierra Nevada. Paleozoic and Mesozoic terrains were both accreted upon and subducted beneath the continent. Accretion occurred along the continental margin in long, linear strips, striking roughly parallel to the present day Sierra crest. The subduction zone supplied the mantle with new rock to a depth great enough for the subducting plate to melt. The resulting magma eventually rose as both surface volcanic rock and as subsurface granitic plutons. The granitic plutons compose much of the core of the current Sierra Nevada. Concurrent with the development of the plutons, the hot magma intruded into the

[1] For the purposes of this document, Project Vicinity is defined as the area surrounding the Project on the order of a United States Geological Survey (USGS) 1:24,000 topographic quadrangle.
[2] For the purpose of this document, the Project Region is defined as the area surrounding the Project on the order of a county or national forest.
[3] For the purposes of this document, the Project Area is defined as the area within the Federal Energy Regulatory Commission (FERC) Project Boundary and the land immediately surrounding the FERC Project Boundary (i.e., within approximately 0.25-mile of the FERC Project Boundary) and includes Project-affected reaches between facilities and downstream to the next major water controlling feature, or structure.

folded sedimentary rocks, resulting in metamorphism and the creation of the famous Sierra Nevada gold deposits in the fractures (USFS and BLM 2002).

Uplift along the eastern margin of the Sierra produced erosion through the beginning of the Tertiary Period (65 mya), exposing the gold veins that had been created during the Mesozoic. These gold veins were eroded and the gold-laden sediments re-deposited throughout the ancestral Yuba River drainage, which ran approximately north to south across the peneplain that existed at the time. The "Tertiary River Gravels" are the source for much of the gold mined during the 19th century in the Yuba River drainage (USFS and BLM 2002).

The middle Tertiary was a time of volcanic eruptions that deposited lava, mudflows, pyroclastic flows, and ash throughout the Yuba River basin. These deposits filled many pre-existing drainages such as the ancestral Yuba River, as well as emplacing a cap of volcanic rock and volcanic debris on both the plutonic rocks and the eroded and intruded remnants of the pre-existing early Mesozoic rocks.

Uplift along the eastern Sierra Nevada margin resulted in the predominantly east-to-west trends of incised drainages evident today. Subsequent to the middle Tertiary volcanic eruptions and mudflows, three late Quaternary glacial stages, each with multiple sub-stages, occurred in the northwestern Sierra Nevada (James 2003; James et al. 2002).

The bedrock geology in the Project Region is composed of Paleozoic metasediments and metavolcanics (undifferentiated), Paleozoic and Mesozoic granitics (i.e., Valley Pluton, Cascade Pluton [see Day et al. 1985], Yuba Rivers Pluton [see Day et al. 1985, Day and Bickford 2004]), and a Mesozoic ophiolite complex (i.e., Smartville[4] Complex; see Beard and Day 1987, Day et al. 1985, Day and Bickford 2004). Tertiary auriferous (gold-bearing) sediments, including auriferous river gravels deposited by the ancestral Yuba River, are present in the eastern portions of the Project Region. Figure 7.1.2-1, located at the end of this section, presents a generalized geologic map of the parent material in the Project Vicinity. Table 7.1.2-1 below presents the relative percent of each rock type to the total acreage in the Project Vicinity.

Table 7.1.2-1. Description of generalized geologic rock types in the Project Vicinity.

Rock Type	Area (acres)	Percent (%)	Description	Age
Granodiorite	62,967	27	granitic rocks, mostly granodiorite	Permian to Tertiary
Mafic Volcanic Rocks	63,554	27	metavolcanic rock, part of ophiolite complex	Jurassic
Gabbro	25,198	11	part of ophiolite complex	Triassic to Cretaceous
Alluvium	22,050	10	Terraces, alluvium, riverbanks associated with Yuba River corridor	Pliocene to Holocene
Argillite	21,181	9	weakly metamorphosed metasedimentary rock	Permian to Jurassic
Intermediate Volcanic Rock	18,772	8	metavolcanic rock	Permian to Jurassic
Andesite	4,852	2	lava flows/pyroclastic flows	Mid to late Tertiary (2-24 mya)
Peridotite	2,439	1	ultramafic rock associated with the Big Bend Wolf Creek Fault Zone	Later Proterozoic to Early Jurassic
Sandstone	2,315	1	ancestral Yuba River deposits	Eocene to Pleistocene

[4] In 2008, the people of this community petitioned to have the name changed to Smartsville, with an 's' in the middle of the name. However, the USGS gage refers to the former spelling of the community name. Therefore in this document, the community is referred to as such.

Table 7.1.2-1. (continued)

Rock Type	Area (acres)	Percent (%)	Description	Age
Slate	2,484	1	undifferentiated metamorphosed sedimentary	Triassic to Late Cretaceous
Schist	3,235	1	Metamorphosed sedimentary rock	Early Proterozoic to Cretaceous
Water	3,814	2	N/A	N/A
Total	**232,861**	**100%**		

Source: Ludington et al. 2005

7.1.3 Tectonic History

Uplift of the Sierra Nevada began approximately 3 to 5 mya (Unruh 1991; Wakabayashi and Sawyer 2001; Henry and Perkins 2001), which is approximately coeval (synchronous) with the uplift of the Carson Range, bordering the Tahoe basin on the east, at 3 mya (Surpless et al. 2000). The uplift was accompanied by westward tilting of the range, stream incision, and downwarping of the Central Valley.

Most faults resulted from late Paleozoic and Mesozoic tectonic collisions. Faults that were re-activated in the late-Cenozoic are predominantly high-angle, northwest-trending, east-dipping, normal faults resulting from extensional stresses (Schwartz et al. 1977). Deformation is pronounced in bands of weak, ultramafic rock (Bennett 1983).

The Big Bend–Wolf Creek Fault Zone transects the Project's New Bullards Bar Reservoir in the western portion of the reservoir. This fault system marks the western margin of the Foothills fault system. The northern portion of this fault zone can be broken into three different segments. The southern segment, south of Highway 49, named the Wolf Creek fault, extends from Auburn to Grass Valley. The central segment, which includes the Marys Ravine, Pine Grove, Jones Ravine, and Birchville faults, extends from Grass Valley to New Bullards Bar Dam. New Bullards Bar Dam lies within the northern portion of the Foothills fault system, which is composed of a major Mesozoic fault system that extends from south of Fresno to north of Oroville and marks the location of ancient subduction and accretion (Geomatrix 2004). The northern segment, composed of the Oroleve-Woodleaf, Sucker Run, and Maynards Ranch faults, extends from southwest of New Bullards Bar Dam northwest to Fields Ridge (Geomatrix 2004).

Geomatrix Services, Inc. (Geomatrix) completed a review of existing data in 2004 for the above faults. Most of the faults were found to be inactive and are not considered a seismic source for the New Bullards Bar Dam. The two faults that were considered active were the Little Grass Valley fault and the Cleveland Hill fault, at 18 miles and 19 miles from the dam site, respectively. The Sanborn Mine (Camel Peak) fault is also considered active due to the lack of consensus on the activity status. Of these potential seismic sources, the controlling fault is the Little Grass Valley fault with a Maximum Credible Earthquake magnitude of 6.75 at a distance of 14.9 miles from the dam. The estimated median (50^{th} percentile) horizontal peak bedrock acceleration at the site due to a maximum magnitude earthquake on this source is 0.12g.[5] In addition, a random minimum earthquake was analyzed. The "minimum earthquake"

[5] The "g" is a common value at acceleration equal to 9.8 meters per second per second.

recommended by the Division of Safety of Dams (Fraser and Howard 2002) has a magnitude of 6.25 with a duration of 14 seconds and a peak horizontal acceleration of 0.15g at the median level, and 0.2g at the 84th percentile. It is recommended at the conclusion of Geomatrix's report that the "minimum earthquake" of 6.25 should be used for analyses of the main dam (Geomatrix 2004).

The Swain Ravine Fault Zone is located approximately 18 miles east of the confluence of the Feather and Yuba rivers, parallel to the Big Bend Wolf Creek Fault Zone. The Cleveland Hill Fault is the northern extension of this zone near Lake Oroville. The 1975 Oroville earthquake, which occurred on the Cleveland Hill fault, also developed cracks over the northern portions of the Swain Ravine Fault (Page and Sawyer 2004 [Appendix E of Geomatrix 2004]). The locations of the Swain Ravine and Big Bend–Wolf Creek Fault Zones are depicted on Figure 7.1.2-1.

7.1.4 Mineral Resources

Gold mining is the dominant mineral resource activity, the dominant influence on how the Yuba River looks today, and the primary reason people settled in the area. Lode gold mining began in 1853 (CDOC 2003) with exploitation of surface deposits of placer gold, followed by riverbed, quartz, and alluvial gravel mining. Deep mines and gigantic hydraulic operations followed as the more-easily accessed deposits were depleted (SNEP 1997). After 1900, quartz gold mining grew in importance.

Many abandoned and active mines are scattered throughout the Yuba River system, and environmental damage from historic hydraulic mining for gold is visible throughout the river corridor. Mercury was imported from the Coast Range and used for gold extraction. Mercury remains sequestered in sediments within the Project Region and continues to be a potential source of mercury to Yuba River surface water. For a discussion of mercury, refer to the Water Resources section of this Pre-Application Document (Section 7.2).

Erosion of exposed mining material and transport of it to local river channels are the most likely indirect effects of mining operations, with sediment transport potentially affecting stream channel morphology.

The western edge of the northern half of the Sierra Nevada range has many other important minerals (Diggles et al. 1996). While the Sawyer Decision of 1884 caused the end of hydraulic gold mining, other gold mining techniques also declined after 1900. More than 20 other minerals were mined between 1900 and 1960. Most of the western belt is geologically permissive for gold, chromium (i.e., chromite ore), copper, and manganese. "Geologically permissive" is defined by the environment of formation, including estimates of undiscovered resources to a depth of 0.6 mile, though not all deposits are known. About a third of the belt has one or more of these metals. Also included are barite, molybdenite, and tungsten, which were also important in the development of the communities near the Sierra Nevada range. Chrysotile (i.e., white asbestos) is found in veins in serpentinized ultramafic rocks near margins of serpentinite bodies. Serpentine and ultramafic rocks are generally found along fault zones such as the Big Bend–Wolf Creek Fault Zone in the Project Area.

The California Debris Commission constructed USACE's Daguerre Point Dam in 1906 to prevent hydraulic mining debris originating in the Yuba River watershed from flowing into the Feather and Sacramento rivers. USACE's Englebright Dam was constructed in 1941 by the California Debris Commission. Although no hydraulic mining has occurred in the upper Yuba River watershed since construction of Englebright Dam, the historical mine sites continue to contribute sediment to the river.

As of 1994, sand and gravel mining exceeded gold mining in economic importance in California. California leads the nation in sand and gravel aggregate production, and virtually all aggregate is mined from alluvial deposits (Kondolf 1995). Sand and gravel are mined from channel deposits of the Bear, Feather, Yuba, and American rivers (WE&T 1991). Aggregate deposits are abundant in the alluvium in the lower parts of the drainage basins. Though demand for aggregate remains high in California, there is little likelihood of new aggregate mining operations in the Project Region due to access and location limitations (Aspen 2000). Aggregate extraction can have effects upon the river profile (e.g., knickpoint migration upstream), can cause loss of spawning gravels, and can undermine instream structures.

Potential hazards associated with historic or inactive mining operations include hidden or abandoned tunnels and mine shafts (Aspen 2000). The mines with exposed and erodible spoil materials located adjacent to an active channel are the sites most likely to be indirectly affected by Project operations of streamflow management. The potential delivery and mobility of instream sediment has not been assessed for every mine. Figure 7.1.4-1, located at the end of this section, shows all active and inactive mines in the Project Region. Table 7.1.4-1 below summarizes the number of active and inactive mineral extraction/exploration activities and current activity in the Project Region.

Table 7.1.4-1. Mines in the Yuba River Development Project Vicinity.

Mineral	Current Activity	Number
Unknown Mineral	Occurrence	15
	Prospect	2
	Unknown	3
Asbestos	Occurrence	1
Chromium	Occurrence	4
	Past Producer	4
	Producer	1
	Unknown	1
Clay	Occurrence	3
Copper	Occurrence	5
	Past Producer	1
	Prospect	4
	Unknown	1

Table 7.1.4-1. (continued)

Mineral	Current Activity	Number
Gold	Occurrence	83
	Past Producer	106
	Plant	2
	Producer	15
	Prospect	9
	Unknown	59
Gold, Copper	Past Producer	1
Gold, Silver	Producer	1
Iron	Occurrence	5
	Prospect	1
	Unknown	3
Limestone	Occurrence	1
Manganese	Occurrence	3
	Prospect	2
Molybdenum	Unknown	1
Molybdenum, Arsenic, Gold	Occurrence	1
Nickel	Unknown	1
Sand, Gravel, Construction	Occurrence	1
	Past Producer	1
	Producer	19
	Unknown	4
Silica	Producer	1
Stone – Crushed, Dimension, Stone	Producer	1
	Occurrence	2
Tungsten	Occurrence	1
Total	**--**	**369**

7.1.5 Physiography and Geomorphology

The Sierra Nevada crest forms the eastern limit of the Yuba Basin and trends north-northwest with steep, eastward-dipping escarpments to the Tahoe Basin. Downfaulting of the eastern Sierra face has affected drainage evolution by beheading channels and creating channels that now have their headwaters facing east (James and Davis 1994). Uplifting and tilting of the Sierra Block reorganized drainage networks and initiated a period of sustained channel incision (Curtis et al. 2005a, 2005b), and many of the modern channels have elevations below the Tertiary channels. The ancestral (Tertiary) Yuba River has cut about 985 feet below a surface defined by the San Juan, Washington, and Harmony ridges (James 2003). These ancestral deep channels drained north-northwest across the strike of the modern drainages (James 1991). The channels were filled first by very coarse, bouldery material rich in gold, followed by finer gravel and sand filling also rich in gold (James and Davis 1994). These Tertiary gravel deposits are the source of the gold heavily mined in the late 1800s.

Tertiary channels and gravels were buried first by rhyolitic and then by andesitic volcanics, then were severely eroded and exposed by deep fluvial incision. The modern Yuba River began incising 5 mya (Curtis et al. 2005a). Modern foothill channels strike perpendicular to the paleochannel and have downcut, leaving the deposits of the paleochannels as upland gravels (Merwin 1968). The basin was also affected by extensive Quaternary glacial erosion.

The current Yuba River basin drains the northwestern Sierra Nevada through a series of deep canyons cut by mountain channels, separated by high, steep-sided ridges and a parallel drainage network. The parallel drainage network results in narrow interfluves, small tributary contributing areas, and low tributary sediment loads under natural conditions; prehistoric debris fans at tributary junctions were not common (James and Davis 1994). Stratigraphic evidence indicates the presence of stepped, Quaternary terraces similar to piedmont channels flowing out of the Sierra (James 1988), but these terraces are generally now buried by mining sediment.

Tahoe National Forest (TNF) has compiled a geomorphic data layer primarily differentiating colluvial hillslopes and eroding hillslopes (USFS 2010b). Geomorphology interpretation of the TNF was performed by Adaptive Management Services Enterprise Team (AMSET) geologists. The mapping followed the revised mapping standards set forth in the national geomorphology guidelines (Haskins et al. 1998). Geomorphological mapping was accomplished by viewing 1987 1:24,000 scale aerial photographs through a stereoscope and drawing geomorphic "map unit" polygons on mylar sheets overlying the photographs. The geomorphology layer was developed from a mass wasting map "Geology and Slope Instability map of a Portion of the Tahoe National Forest, California" by Don Lewis, TNF Geologist. Initially mapped units by Lewis that were presented on the hard-copy map include: block slides, debris slides, slides of intermittent type, and areas of shallow slope failure and slope creep. There is no known documentation of the mapping; however, it is known that the mapping was based on field work. Because the mapping had been field verified, it was presumed to represent slope stability features with a greater degree of accuracy. The full metadata are available from the TNF AMSET.

Not surprisingly, water dominates the geomorphic type within the existing FERC Project Boundary. If that is removed for consideration, then colluvial hillslopes represent 56 percent of the area, eroding hillslopes represent 18 percent, and inner gorges and human influence represent the remainder. These percentages are based on using the first descriptor only (Description 1). The second and third descriptors, which are the less active geomorphic types, also show that there is potential mass wasting within many of the Map Units. There is no information about the erodibility or stability of the material or the amount or whether the material is delivered to a water body. Mass wasting was fairly broadly defined and it is unclear as to the potential actual failure any of these units may incur.

Table 7.1.5-1. Description of geomorphology map units designated on the Tahoe National Forest within the FERC boundary.

Map Unit	Description 1	Description 2	Description 3	Total Acres within FERC Boundary	% of Total Coverage within FERC Boundary	% of FERC Boundary[1]
Ch	colluvial hillslope	--	--	10.9	0.19%	0.14%
Ch/Ds3	colluvial hillslope	debris slide	--	23.0	0.39%	0.29%
Ch/Ds5	colluvial hillslope	debris slide	--	18.1	0.31%	0.23%
Ch/Dsb3	colluvial hillslope	debris slide basin	--	11.3	0.19%	0.14%
Ch/Eh	colluvial hillslope	eroding hillslope	--	13.7	0.24%	0.18%
Ch/Sc2	colluvial hillslope	undifferentiated stream channel	--	1,323.1	22.70%	16.95%
Ch/Sc2/Ds3	colluvial hillslope	undifferentiated stream channel	debris slide	1.9	0.03%	0.02%

Table 7.1.5-1. (continued)

Map Unit	Description 1	Description 2	Description 3	Total Acres within FERC Boundary	% of Total Coverage within FERC Boundary	% of FERC Boundary[1]
Ch/Sc2/Hi	colluvial hillslope	undifferentiated stream channel	human influence	31.0	0.53%	0.40%
Eh	eroding hillslope	--	--	225.0	3.86%	2.88%
Eh/Ch	eroding hillslope	colluvial hillslope	--	10.6	0.18%	0.14%
Eh/Ch/Sc2	eroding hillslope	colluvial hillslope	undifferentiated stream channel	211.9	3.63%	2.71%
Eh/Sc2/Hi	eroding hillslope	undifferentiated stream channel	human influence	5.4	0.09%	0.07%
Hi/Ig	human influence	inner gorge	--	51.1	0.88%	0.65%
Ig	inner gorge	--	--	617.7	10.60%	7.91%
W	water	--	--	3,273.7	56.17%	41.94%
			Total	**5,828.4**	**100.00%**	**74.68%**

[1] The coverage does not include the Plumas National Forest within the FERC Project Boundary, so there are 1,977 acres not included in the geomorphology data layer that fall within the FERC boundary.

The effects of hydraulic mining are particularly significant where the Feather and Yuba rivers converge near Marysville (EDAW 2006). At the mouth of the Yuba River at the south edge of Marysville, 70 feet or more of sediment eventually filled the river channel. Upstream of Marysville, entire communities were buried under more than 40 feet of silt and gravel (Hoover et al. 1990). Sacramento River Flood Control Project levees were constructed along the Feather and Yuba rivers and their tributaries to prevent flooding of valley communities. These levees prevented these communities from becoming buried under the sediments that were washed down from the mountains. The levees were built even higher and designed to confine the floodwaters to a relatively narrow channel that would maintain sufficiently high velocities to efficiently convey sediment through the system, reducing the amount of dredging necessary to maintain navigation. As a result of the levees, Marysville, Olivehurst, and Linda are now many feet below the floodwater levels of the Feather and Yuba rivers.

Between 1852 and 1906, an estimated 366,500,000 cubic yards (yd^3) of hydraulic mining debris moved downstream from the upland mining areas of the greater Yuba River watershed and was deposited in the lower Yuba River, causing aggradation on the order of 26-85 feet (Adler 1980). This massive sedimentation in the channel and floodplains transformed the lower Yuba River into a braided, unstable stream system. Adler (1980) states that by 1906, the inflow of hydraulic mining debris from upland areas to the Lower Yuba had peaked and degradation became the dominant process along the lower Yuba River. Based upon historical channel cross-section data collected along the lower Yuba River during the late 1800s and early 1900s and updated in 1979, Adler concluded that the lower Yuba River channel below USACE's Englebright Dam had attained equilibrium by 1940 to a channel morphology similar to its pre-1849 channel configuration (i.e., a single stable channel with similar channel elevation), except the stream channel is now bordered by large cobble training walls that constrain the channel width in many sections (Adler 1980). The study further concludes that since 1940, almost 90 percent of the hydraulic mining debris deposited in the lower Yuba River remains today as quasi-permanent deposits in the floodplains. The cobble training walls, along with the massive deposits of hydraulic mining debris behind the training walls, are now a stable, generally immobile part of the Lower Yuba River system.

More recently, studies by the Three Rivers Levee Improvement Authority broadly state that as hydraulic mining sediment supplies decline, the rivers again will adjust to a new equilibrium. Ultimately, hundreds to thousands of years in the future, it is likely that the river channels will cut down to their pre-mining elevations and will begin migrating laterally (TRLIA 2006).

7.1.6 Erosion and Sedimentation

Hill slopes in the Project Region are generally less than 50 percent. The exceptions are within the inner gorges where channels have cut deeply into the underlying parent material. Hillslope steepness is shown Figure 7.1.6-1, located at the end of this section.

In the Project Region, undisturbed hillslope erosion rates are low compared to more rapidly eroding landscapes such as the Pacific Northwest. The Sierra Nevada mountain block continues to uplift, and the rate of downcutting and erosion depends in large part on the rate of tectonic uplift. In the upper Yuba River basin, hillslope sediment sources indicate low hillslope erosion rates and 95 percent of the watershed has negligible to moderate hillslope erosion potential (Curtis et al. 2005b, 2006). While the vast majority of hydraulic mining sediments were transported downstream to the lower Yuba River during the late 1800s to early 1900s, continued transport of stored channel sediments from gold mining is the primary contributor to annual sediment yield in the Project vicinity. Historic mining sediment remains the dominant sediment source; more recent modern 20th century hydraulic mining sediment constitutes less than 2 percent of the total volume, with logging, road construction, and other sources of increasing importance in the basin (James 1988).

A distributed-parameter model was developed as part of the CALFED Upper Yuba River Studies Program. This model, using Hydrologic Simulation Program-Fortran, a module of the United States Environmental Protection Agency's Better Assessment Science Integrating Point and Nonpoint Sources software, was developed to assess sediment transport as it relates to fish habitat, and the influences of land-use practices, dam management, and climate (Flint et al. 2004). This model was also used as a preliminary screening tool to evaluate the effect of incremental flow increases on water temperature. Numerous products have resulted from the studies in support of the model development (e.g., Flint et al. 2004; Snyder et al. 2004; Curtis et al. 2005b), which provide a comprehensive analysis of sediment sources, transport, and storage in the upper Yuba River watershed (Curtis et al. 2005a, 2006). The final model will be a tool for estimating sediment transport in channels and sediment accumulation in USACE's Englebright Reservoir (Curtis and Flint 2003; Flint et al. 2004). USACE's Englebright Reservoir was originally constructed as a debris dam to capture hydraulic mining debris. A later study on the sedimentation rate between 1940 and 2001 within USACE's Englebright Reservoir was completed by Snyder et al. (2004). Over the 61-year period, USACE's Englebright Reservoir accumulated 21.9×10^6 cubic meters of material, which now occupies 25.5 percent of the original storage capacity of the reservoir.

Mining gravel composes a significant portion of the bedload in the Yuba River. As discussed above, hydraulic mining has occurred in the upper watershed, and channel dredge mining has occurred in the lower watershed below USACE's Daguerre Point Dam. The amount of mining-derived sediment introduced into the Yuba River is greater than that introduced into the Feather, Bear, and American rivers combined (WE&T 1991). Channel reaches within the mining districts remain dominated by mining tailings after more than 100 years (James 1991). Nineteen percent of the total deposit in USACE's Englebright Reservoir is composed of gravels, indicating that bed load transport is significant in the Yuba River (Snyder et al. 2004), though Curtis et al. (2004, 2006) states that sediment discharge calculations indicate that bedload represents less than one percent of the total load for the Middle and South Yuba rivers in WY 2001, 2002 and 2003. The total deposit is equivalent to 21.9 x 10^6 cubic meters of material, of which about 65-69 percent is sand and gravel. Assuming no contribution of sediment from upstream areas impounded by other dams, the basin-wide sediment yield to USACE's Englebright Reservoir is about 340 tons/km^2/yr (873 tons/mi^2/yr). This yield is at the high end of the range for regional reservoirs, and is attributable to the history of hydraulic mining in the basin. Sixty years after cessation of down-valley sediment transport of hydraulic mine tailings, remobilized stored tailings provide 50 percent of the sediment budget. Tailings are mixed with sediment from other sources downstream. Twenty-two percent of the alluvium sediment 37 miles downstream in the Sacramento Valley is other alluvial sediment produced by human activities other than mining. Dilution is due to depletion of in-channel storage of tailings and to increased importance of local sediment sources. Sediment supplies to the lower basin are limited to local floodplain and channel storage, which are dominated by tailings and other alluvium respectively.

Sediment supply is very high in the Yuba River due to continued movement and availability of hydraulic mining debris. Curtis et al. (2006) estimates the Middle and South Yuba as annually transporting 5 tons/mi^2 (2 tonnes/km^2/yr) and 14 tons/mi^2 (5 tonnes/km^2/yr), respectively However, downstream of some dams the channel can respond either with coarsening of the bed, or there may be no change if the downstream channel was originally transport-dominated (e.g., channel was always bedrock control with little storage of sediment).

7.1.7 Soils

Soil types are strongly influenced by underlying bedrock. Soil orders in the Project Vicinity include Alfisols, Andisols, Entisols, Inceptisols, Mollisols, and Ultisols in combination with mesic or frigid soil temperature regimes and xeric, ustic, aridic, or aquic soil moisture regimes. Figure 7.1.7-1 located at the end of this section shows the dominant soil associations in the Project Vicinity. Table 7.1.7-1 summarizes the soil associations and their relative acreages.

Table 7.1.7-1. Soil associations in the Yuba River Hydroelectric Project Vicinity.

Soil No.	Soil Association	Acres	% of Total
s525	Josephine-Holland-Aiken	6,975	3
s620	McCarthy-Cohasset-Aiken	34,010	2
s1109	McCarthy-Ledmount	4,858	2
s844	Musick-Holland-Hoda-Chaix	41,669	18
s873	Orose-Mildred-Flanly	16,580	7
s821	Redding-Corning	1,966	1
s845	Rock outcrop-Mariposa-Jocal	32,869	14

Table 7.1.7-1. (continued)

Soil No.	Soil Association	Acres	% of Total
s825	San Joaquin	2,962	1
s837	Secca-Rock outcrop-Boomer	134	trace
s841	Sierra-Rock outcrop-Auberry-Ahwahnee	13419	6
s848	Sites-Rock outcrop-Boomer	9,225	4
s840	Sobrante-Rock outcrop-Auburn	38,755	17
s855	Sycamore-Shanghai-Nueva-Columbia	9,963	4
s870	Tisdale-Kilaga-Conejo	16	trace
s528	Wapi-Holland-Chaix-Arrastre	1,975	1
s8369	Water	2,401	1
s523	Weitchpec-Rock outcrop-Ishi Pishi-Ipish-Grell-Beaughton	302	trace
s874	Woodleaf-Surnuf-Sites-Mariposa	37,837	16
s822	Xerorthents-Xerofluvents	7,546	3
	Total	**2,328,601**	**100%**

The Project soil distribution coincides with the underlying bedrock. Table 7.1.7-2 below provides a summary of the soil series characteristics including parent material, geomorphic position, slope, elevation range, average precipitation, mean annual temperature, and drainage.

Erosion hazard within a soil series is often strongly dependent upon slope; in general, the steeper the slope, the more erosive the soil, although erosion potential on steeper slopes may be moderated by coarse, well drained soils, such as those derived from granitic parent material.

Table 7.1.7-2. Soil series and order summary description in the Project Vicinity.

Series	Parent Material	Geomorphic Position	Slope (%)	Elevation (feet)	Avg. Annual Precipitation (inches)	Mean Annual Temperature (°F)	Drainage
Ahwahnee	Granitic	Footslopes, mountains	2-75	200-2,800	30	60	Mod deep, well drained
Aiken	Basic Volcanic	Gently sloping ridges, moderately steep to steep sideslopes	2-70	1,200-5,000	47	55	Very deep, well drained
Auberry	Intrusive, acid igneous	Foothills, mountainous uplands	5-75	400-3,500	22	62	Deep, well drained
Auburn	Amphibolite schist	Foothills	2-75	125-3,000	24	60	Shallow to moderately deep, well drained
Beaughton	Serpentinized peridotite	Mountains	5-60	1,500-5,000	45	55	Shallow, well drained
Boomer	Metavolcanic	Uplands	2-75	500-5,000	45	55	Deep and very deep, well drained
Chaix	Acid Intrusive Igneous	Mountains	5-75	1,200-6,500	40	54	Mod deep, somewhat excessively drained
Cohasset	Volcanic	Plateau-like uplands	2-50	800-5,500	53	51	Deep and very deep, well drained
Columbia	Alluvium	Flood plains and natural levees	0-8	10-155	12-25	61	Very deep, mod well drained
Conejo	Alluvium from basic igneous or sedimentary rocks	Alluvial fans/stream terraces	0-9	30-2,000	20	62	Very deep, well drained
Corning	Gravelly alluvium	High terraces with mound, intermound relief	0-30	75-1,300	23	62	Very deep, well or moderately well drained
Flanly	Acid intrusive igneous	Foothills	2-75	125-1,200	28	60	Mod deep, well drained

Table 7.1.7-2. (continued)

Series	Parent Material	Geomorphic Position	Slope (%)	Elevation (feet)	Avg. Annual Precipitation (inches)	Mean Annual Temperature (°F)	Drainage
Grell	Serpentine/ Ultramafic	Hills	7-50	3,000-5,000	15	47	Shallow, well drained
Hoda	Granodioirite/ Acid igneous	Mountains	2-75	2,000-4,000	60	55	Very deep, well drained
Holland	Granitic	Mountains	2-75	1,200-5,600	55	55	Very deep, well drained
Ipish	Ultrabasic	Mountainous uplands	5-50	200-5,000	30	48	Deep, well drained
Ishi Pishi	Serpentinitic meta ultramafic	Mountains	15-75	400-5,000	75	55	Deep, well drained
Jocal	Meta-Sedimentary	Mountains	2-75	2,000-5,000	50	50	Deep and very deep, well drained
Josephine	Colluvium from altered sandstone and extrusive igneous	Broad ridgetops, toeslopes, footslopes, sideslopes	2-75	200-5,500	45	50	Deep, well drained
Kilaga	Alluvium from mixed sources	Terraces	0-9	50-200	20	62	Deep and very deep, well drained
Ledmount	Andesitic Tuff Breccia	Mountain side slopes and narrow ridge tops	2-75	2,000-6,000	53	52	Shallow, well to somewhat excessively drained
Mariposa	Tilted slates/schists	Ridges and sides of mountains	2-75	1,600-5,600	55	53	Moderately deep, well drained
McCarthy	Andesitic mudflows	Gently to very steep sloping dissected plateau	2-75	2,000-6,000	55	52	Mod deep, well drained
Mildred	Basic intrusive igneous rock	Mountains	3-50	1,500-2,500	45	57	Mod deep, well drained
Musick	Colluvium from granitic rocks	Mountains	2-75	2,000-5,000	50	54	Very deep, well drained
Nueva	Alluvium from mixed sources	Floodplains	0-2	20-80	16	62	Very deep, somewhat poorly drained
Orose	Basic intrusive igneous	Foothills	3-30	125-1,900	28	60	Shallow, well drained
Redding	Alluvium	High terraces	0-30	40-2,000	22	61	Moderately deep to duripan, well or mod well drained
San Joaquin	Alluvium from predom. Granitic source	Undulating low terraces	0-9	20-500	15	61	Mod deep to duripan, well and mod well drained
Secca	Metabasic, basic, and ultrabasic volcanic	Gently sloping to steep mountainous	Gentle to steep	1,700-3,000	35-55	56	Mod well drained
Shanghai	Alluvium from mixed sources	Floodplains	0-2	20-150	18	62	Very deep, somewhat poorly drained
Sierra	Acid igneous	Foothills	Gently sloping to steep	200-3,500	20-38	59-62	Deep, well drained
Sobrante	Basic igneous and metamorphic	Foothills	2-75	125-3,500	32	60	Mod deep well drained
Surnuf	Gabbrodiorite	Mountains	8-50	1,400-2,800	45	57	Very deep, well drained
Sycamore	Mixed sedimentary alluvium	Floodplains	Nearly level	10-100	15-20	60-62	Poorly drained
Tisdale	Alluvium from mixed sources	Low terraces	0-2	20-80	18	62	Mod deep, well drained
Wapi	Eolian sand and overlying basalt	Basalt plain	0-20	4,000-4,400	8	52	Shallow, excessively drained
Weitchpec	Serpentinitic	Mountains	30-75	850-5,500	50	53	Mod deep, well drained

Table 7.1.7-2. (continued)

Series	Parent Material	Geomorphic Position	Slope (%)	Elevation (feet)	Avg. Annual Precipitation (inches)	Mean Annual Temperature (°F)	Drainage
Woodleaf	Ultramafic	Mountains	3-30	2,000-3,000	65	53	Mod deep, well drained
Xerorthent	Young soils not differentiated enough to separate from soil suborder. Shallow, developed in Mediterranean climate, not meeting the requirements of the other Entisols; associated with low-gradient alluvial material adjacent to the lower Merced River corridor.						
Xerofluvents	Young soils not differentiated enough to separate from soil suborder. Shallow, developed in Mediterranean climate, slopes of less than 25% and mean annual soil temperature above freezing and Holocene-age carbon; associated with low-gradient alluvial material adjacent to the lower Yuba River corridor.						

7.1.8 Existing Information

7.1.8.1 Upstream of the Project Area

Relevant and reasonably available information on generalized geology and soils upstream of the Project within the Sierra Nevada foothills and range has been incorporated into Sections 7.1.1 through 7.1.6. In addition, Licensee found six source documents regarding geology and soil conditions upstream of the Project. These are summarized here:

7.1.8.1.1 Yuba-River Hydroelectric Project and Drum-Spaulding Project Relicensings

Upstream of the Project Area in the Middle Yuba River and South Yuba River, Nevada Irrigation District (NID) and Pacific Gas & Electric Company (PG&E) have been conducting relicensing studies, including several related to geology, such as channel morphology, hydrologic alteration, instream flow/habitat mapping, and roads and trails. The full reports for these studies are available on NID's and PG&E's relicensing website (http://www.ycwa-relicensing.com).

Middle Yuba River - Habitat Mapping and Channel Characterization

Habitat mapping and channel characterization were conducted in the Middle Yuba River between Jackson Meadows Reservoir and Our House Diversion, and on Wilson Creek, which is a tributary to the Middle Yuba below Milton Diversion Dam. The Middle Yuba River between Milton Diversion and Our House dams was separated into three sub-reaches based on gradient, confinement, and geologic parent material. Overall, the channel is mostly bedrock-controlled with lateral and vertical stability. There is limited floodplain development, usually narrow floodplains or low terraces in a narrow band along the valley. As the channel proceeds downstream from Jackson Meadows Dam, it transitions from a steep bedrock-controlled transport stream to a low-gradient and low-lying, depositional riparian stream and forest. Floods and spill channel erosion have created some coarse lag deposits that have caused flow diversions into the adjacent riparian forest. Another sediment source is a high terrace that is being undermined, which is a source of gravel and fine sediment to a short section of stream just before numerous splits into the wetlands above Milton Reservoir. The lower half of the reach between Jackson Meadows Dam and Milton Diversion Dam is strongly affected by backwater effects from Milton Reservoir where the main channel splits into many smaller channels and wetlands dominate.

Large woody debris was quantified in ground-mapped sections of the Middle Yuba River, and the amount of wood removed from Jackson Meadows Reservoir and Milton Diversion Reservoir was estimated. Large woody debris is not common, with about 25 pieces/mile in the Middle Yuba River (within bankfull) below Milton Diversion Dam, and 52 pieces/mile above Milton Diversion Dam Impoundment. There is about 70 yd^3/yr removed from Jackson Meadows Reservoir and 10 yd^3/yr removed from Milton Diversion Reservoir.

The full study report, Technical Memorandum 2.3.2, is posted on NID's and PG&E's relicensing website (NID and PG&E 2010a). A digital video disk (DVD) of the low-altitude helicopter video, used to assist in the habitat mapping portion of the study, is available from NID and/or PG&E upon request as the size of the data precludes it being posted on the relicensing website.

Middle Yuba River - Channel Morphology Study

There were two sites selected for a 2009 channel morphology study: the Middle Yuba River above Wolf Creek, and the Middle Yuba River above the Milton Diversion Dam impoundment (Jackson Meadows Dam Reach). Current conditions were measured at three transects per site and along a longitudinal profile. Parameters measured included cross-section and longitudinal profiles, bankfull elevation and discharge, floodprone width, channel gradient, particle sizes of the channel bed and spawning gravel, bank and channel stability, and fine material quantity in pools and in spawning gravels. Much of the data was used in the development of a sediment mobility model and analysis. An assessment of "proper functioning condition" of the riparian zone was also conducted working closely with riparian and hydrology specialists. The study report, Technical Memorandum 2.1-1, is posted on NID's and PG&E's relicensing website (NID and PG&E 2010b).

Jackson Meadows Reservoir Bathymetric Survey

Licensees performed bathymetric surveys of Jackson Meadows Reservoir. Changes in volume were estimated based on as-built surveys, and the accuracy of these surveys cannot be independently verified. Oftentimes the amount of sedimentation is close to the "noise" of the uncertainty in the as-built data. Jackson Meadows Reservoir had a net change of -1,783 ac-ft, which leads to an estimate of sediment accumulation of about 1.1 ac-ft/mi^2/yr. Compare to Englebright Reservoir, which has an accumulation rate of about 0.6 ac-ft/mi^2/yr.

A digital video disk DVD with the complete report is available from NID and/or PG&E upon request as the size of the data precludes it being posted on the relicensing website.

Middle Yuba River - Hydrologic Alteration Study

One site on the Middle Yuba was selected for ramping rate analysis: Middle Yuba River below Milton Diversion Dam. Using historical 15-minute flow data collected at the YB-304 gage during water years 1997-2003, both flow and stage were analyzed for ten representative up-ramp and ten down-ramp events. Up-ramp events ranged in duration from 2 hours to 17 hours and had an increase in flows of approximately 10 cfs to 310 cfs. Down-ramp events ranged in duration from 2 hours to 5.5 hours and had a decrease in flows of approximately 350 cfs to 15 cfs. At the YB-304 gage site, these flow increases equate to a range of stage change of 0.6 and 2.4 feet, while the flow decreases equate to a range of stage change of 0.3 feet and 2.4 feet.

A spill cataloging analysis calculated the magnitude, duration, and volume of spill events for one location on the Middle Yuba River, at the Middle Yuba River below Milton Diversion Dam. Spills occurred at this location in 11 of the 20 years analyzed, during water years 1989 - 2008.

Indicators of Hydrologic Alteration (IHA) analysis was completed for two locations on the Middle River: Middle Yuba River below Milton Diversion Dam, and Middle Yuba River above Our House Diversion Impoundment. The IHA analysis was run for post-project water years 1989 through 2008 to determine the five groups of traditional IHA statistics that Richter suggests characterize the hydrologic attributes of a stream (Richter et al. 1996). The IHA results were presented in their entirety as well as a summary of results such as monthly median flows, 3-day maximum flows, and 7-day minimum flows. IHA results were also parsed by water year types for monthly median flows.

Flood frequency analysis was completed using the PeakFQ program at three locations on the Middle Yuba River: below Milton Diversion Dam; above Our House Diversion Dam; and below Our House Diversion Dam. Results included calculated flows for the 1, 1.5, 2, 5, 10, 25, 50, 100, 200 and 500-year recurrence intervals. The calculated results for the 1.5-yr recurrence interval were compared to bankfull flow as determined in the field.

The full study report, Technical Memorandum 2.2-4, is posted on NID's and PG&E's relicensing website (NID and PG&E 2010c).

Middle Yuba River – Roads and Trails Study

In 2008 and 2009, NID and PG&E conducted inventories of primary access roads and trails potentially affected by PG&E's Drum-Spaulding Project and NID's Yuba-Bear Hydroelectric Project. A field inventory was performed to identify how continued use of the transportation network could influence the condition of the Primary Project Roads and Trails. The field inventory provided data on specific attributes along each segment of road or trail, including locations of water crossings and road drainage features, and erosional features. About 30 percent of the segments were ranked as "poor," generally because of the condition of crossings (e.g., typically undersized), drainage features (e.g., damaged), or environmental damage (e.g., erosion and sedimentation). Most of the factors that lead to a poor road condition rating were related to conveyance of runoff, surface erosion of the road prism, and unstable areas. The full study report, Technical Memorandum 9-1, is posted on NID's and PG&E's relicensing website. (NID and PG&E 2010d)

7.1.8.1.2 South Feather Power Project Relicensing

The Slate Creek diversion tunnel transfers water from the Slate Creek Diversion Dam in the Yuba River basin to Sly Creek Reservoir in the Feather River basin (South Feather Power Project, FERC 2088). A Final Environmental Impact Statement (FEIS) was completed for this relicensing project in 2009 (FERC 2009). As part of the relicensing, several studies were conducted in the Project area; the Slate Creek Diversion Dam bypass reach is tributary to the North Yuba River above New Bullards Bar Reservoir.

7.1.8.1.3 Slate Creek Sediment Pass-Through

The Slate Creek Diversion Dam is operated by the South Feather Water and Power Agency (SFWPA) to divert water from the Slate Creek watershed (Yuba River basin) to Sly Creek Reservoir (South Fork Feather River basin). Much of the Slate Creek Diversion Dam impoundment is filled with cobble, gravel, sand, and silt (SFWPA 2007). The high rate of sedimentation is related to past hydraulic mining in the upstream source area. Delivery of material from upstream hydraulic mine sites and aggraded channel reaches to the Slate Creek Diversion Dam impoundment was exacerbated in the 1950's by the breaching of St. Louis Debris Dam, located approximately one mile upstream of the Slate Creek Diversion Dam on federally owned land administered by the United States Department of Agriculture, Forest Service (Forest Service). Sediment accumulation behind Slate Creek Diversion Dam currently affects the diversion tunnel, interferes with the low-level outlet in the dam, jeopardizes the release of minimum instream flows, and limits use of the impoundment for water storage (EA Engineering 2000).

Prior to 1986, the Licensee regularly passed bedload and suspended load sediment from upstream sources through a low-level outlet in the Slate Creek Diversion Dam during high flows, with the goal of maintaining reservoir storage capacity and flow regulation capabilities. Sediment pass through was discontinued in 1986 due to concerns by resource agencies over the effects of delivery of fine sediment and potentially contaminated sediment to downstream reaches of Slate Creek.

Under the SPT program approved in 2001, the low-level outlet in Slate Creek Diversion Dam may be opened for up to 24 hours to pass sediment downstream, subject to various seasonal, flow, and water quality constraints. SPT events were attempted in 2002, 2003, 2004, and 2005. Most of these events were unsuccessful at moving any significant amount of sediment due to hydraulic conditions at the dam. Prior to 2005, opening the low-level outlet resulted in only a brief pulse (30 seconds) of turbid water, probably from finer sediments that had settled in the outlet pipe, before the water ran completely clear. In 2005, sediment was cleared from the entrance to the diversion tunnel and the low level outlet. In December 2006, sediment was passed for only 60 minutes due to concerns of mechanical damage to the low-level outlet and valve. SFWPA is currently adaptively managing the SPT to increase the amount and size of sediment that flows downstream into Slate Creek.

7.1.8.1.4 Sediment Supply and Transport Study

A sediment supply and transport study was conducted by SFWPA in 2004-2005 that included a study site in Slate Creek, a tributary to the North Yuba River (SFWPA 2007). Information collected to support hypothesis testing at study sites included:

- identify geomorphically responsive channel study sites in Project reaches

- characterize regulated and unimpaired hydrology
- survey channel morphology and condition
- compare estimates of dominant discharge
- estimate average annual coarse sediment supply rates based on reservoir sedimentation
- model bed mobility thresholds and bedload transport rates
- compare mass balance of estimated coarse sediment supply and estimated bedload transport capacity
- identify sediment sources in the vicinity of Project facilities
- determine if a preponderance of empirical evidence and modeling results support or refute the hypotheses

The results showed that Slate Creek is in an "indeterminate response domain," indicating proportional reductions in sediment supply and the frequency of sediment transport. Bankfull discharge and regulated $Q_{1.5}$ (discharge at 1.5 yr return interval) were similar and greater than Q_{cr} (critical flow for bedload transport). Low Q_{cr} reflects the abundant supply of coarse sediment available for transport, evidenced by the high frequency of mobile sand and gravel patches occurring over much of the bed surface. Comparison of coarse sediment supply and transport at two Slate Creek study sites (upper site at about 0.8 mi downstream of Slate Creek Diversion Dam, and lower site at 7.5 miles below the diversion dam) indicated an approximate equilibrium at the upper site, and supply-limitation prior to and as a result of Project operation at the lower site. There was little or no apparent change in active sediment storage interpreted from historical aerial photography. Empirical evidence and modeling results do not indicate that Project operation and maintenance (O&M) has or will result in channel aggradation or degradation. The lack of Project-related geomorphic effects at these study sites reflects the limited ability of the Slate Creek Diversion to alter peak flows and the high sediment supply rate resulting from tributary inputs and sediment-pass-through at Slate Creek Diversion Dam.

SFWPA also evaluated reservoir sedimentation basin yield in the South Feather River basin (SFWPA 2007) and compared against Englebright Reservoir. Table E11.4.2-4 from the results of the study is reproduced below as Table 7.1.8-1. Also as a comparison, Lake Oroville experienced an annual sediment input from upstream sources of 470 ac-ft (579,510 m^3/year) (CDWR 2004a), two orders of magnitude less than estimated accumulation rates in Englebright Lake.

Table 7.1.8-1. Reservoir sedimentation and sediment yield (SFWPA 2007).

		South Feather Project Reservoirs				Yuba River Reservoir
		Little Grass Valley	Ponderosa[1]	Sly Creek	Lost Creek[2]	Englebright[3]
Placed in service		1961	1961	1961	1924	1940
Date of modern bathymetry		2004	2004	2004	2004	2001
Duration of accumulation	years (y)	43	43	43	37	61
Unimpaired drainage area	km^2	67	269	62	78	2,870
Regulated source area	km^2	67	42	62	78	1,192

Table 7.1.8-1. (continued)

		South Feather Project Reservoirs				Yuba River Reservoir
		Little Grass Valley	**Ponderosa[1]**	**Sly Creek**	**Lost Creek[2]**	**Englebright[3]**
Trap efficiency [4]	%	100%	80%	100%	35%	100%
Total accumulated sediment volume [5]	m^3	5,900,000	754,900	1,613,000	322,700	21,900,000
Total accumulated sediment mass [6]	tonnes (t)	6,769,000	853,000	1,822,700	376,000	24,747,000
Annual sediment accumulation rate	$t\ y^{-1}$	157,420	19,840	42,390	10,160	405,690
Annual coarse sediment accumulation rate [7]	$t\ y^{-1}$	29,910	3,700	8,050	1,930	77,080
Total average annual sediment yield [8]	$t\ km^{-2}\ y^{-1}$	2,360	594	682	374	340
Average annual coarse sediment yield	$t\ km^{-2}\ y^{-1}$	448	90	130	25	65
Denudation rate	$mm\ y^{-1}$	0.89	0.22	0.26	0.14	0.13
Unimpaired drainage area	km^2	67	269	62	78	2,870
Regulated source area	km^2	67	42	62	78	1,192
Trap efficiency [4]	%	100%	80%	100%	35%	100%
Total accumulated sediment volume [5]	m^3	5,900,000	754,900	1,613,000	322,700	21,900,000
Total accumulated sediment mass [6]	tonnes (t)	6,769,000	853,000	1,822,700	376,000	24,747,000
Annual sediment accumulation rate	$t\ y^{-1}$	157,420	19,840	42,390	10,160	405,690
Annual coarse sediment accumulation rate [7]	$t\ y^{-1}$	29,910	3,700	8,050	1,930	77,080
Total average annual sediment yield [8]	$t\ km^{-2}\ y^{-1}$	2,360	594	682	374	340
Average annual coarse sediment yield	$t\ km^{-2}\ y^{-1}$	448	90	130	25	65
Denudation rate	$mm\ y^{-1}$	0.89	0.22	0.26	0.14	0.13

1 Assumes 100 percent coarse sediment (>2 mm) trap efficiency in South Fork Diversion and Forbestown Diversion impoundments.
2 Assumes sediment accumulated 1924-1961 and negligible yield after 1961 due to trapping in Sly Creek Reservoir.
3 Englebright Reservoir data from Snyder et al. 2004.
4 Trap efficiency averaged from empirical relations by Brune (1953), Churchill (1948), and Brown (1943).
5 Accumulated sediment volume calculated from the difference between reservoir topography prior to sediment filling and the 2004 bathymetric surface.
6 Assumes average sediment density of 1.13 $t\ m^{-3}$ (Snyder et al. 2004).
7 Assumes coarse (>2 mm) –to-total ratio of 0.19 (Snyder et al. 2004).
8 All unit-area estimates based on regulated source area.

7.1.8.1.5 Sediment Supply from SFWPA Facilities

In the SFWPA Project area, field surveys indicated few erosion features directly related to Project facilities. Potential for future erosion is low, and accelerated erosion from roads and facilities is unlikely. Sediment produced in the vicinity of the facilities is small relative to the sediment transport capacity in the streams.

7.1.8.1.6 Large Woody Debris in Slate Creek and Slate Creek Reservoir

The upper study site in the Slate Creek Diversion Dam Reach is located approximately 0.8 mi downstream of Slate Creek Diversion Dam at an elevation of 3,379 feet and has a drainage area of approximately 132 square kilometers. The 403-meter-long study site exhibited forced pool-riffle morphology with predominantly cobble-gravel and gravel-cobble bed material. The site was characterized by a large, laterally continuous point bar deposit on the right bank and bedrock control at the downstream end. Average water surface slope was 0.0139, and average bankfull width was 19 meters. Mean large woody debris (LWD) frequency and volume were 1.0 piece/100 meters and 1 cubic meter/hectare, respectively. LWD frequency was 89 percent lower and volume was 97 percent lower than reported by Ruediger and Ward (1996) for channels in young timber stands (50 to 90 years old) in the Stanislaus National Forest. All LWD fell into the two smallest length and diameter classes. There were no key LWD pieces and no pieces influenced channel morphology or sediment storage.

The lower study site in the Slate Creek Diversion Dam Reach is located approximately 7.5 miles downstream of Slate Creek Diversion Dam at an elevation of 2,067 feet with a drainage area of approximately 157 square kilometers. The 430-meter-long study site exhibited forced pool-riffle morphology with predominantly cobble-boulder and boulder-cobble bed material and local bedrock control. Large point bar deposits occurred on the right bank at the upstream end and on the left bank at the downstream end. Average water surface slope was 0.0211, and average bankfull width was 19 meters. Mean LWD frequency and volume were 2.6 pieces/100 meters and 12 cubic meters/hectare, respectively. LWD frequency was 71 percent lower and volume was 77 percent lower than reported by Ruediger and Ward (1996) for channels in young timber stands (50 to 90 years old) in the Stanislaus National Forest. All of the LWD at the site fell in the three smallest length and diameter classes. LWD was found as solitary pieces oriented parallel to flow near the bankfull channel margin. There were no key LWD pieces and no pieces influenced channel morphology or sediment storage.

Slate Creek Diversion Dam Impoundment is a small impoundment at elevation 3,552 feet with a drainage area of 128 square kilometers. The impoundment capacity, however, has been significantly reduced by sedimentation and the current impoundment only extends about 100 feet upstream of the dam during low flows. Mean LWD frequency and volume were 1.4 pieces/100 meters and 32 cubic meters/hectare, respectively. All LWD fell in the three smallest length classes and two smallest diameter classes. Most of the LWD was found as solitary pieces and small accumulations on gravel bars at the upstream end of the impoundment area. LWD passes over Slate Creek Diversion Dam during high flows. The Licensee removes LWD from the upstream side of the dam and the trash rack at the diversion intake during high flows by closing the tunnel intake gates and allowing the flows to pass the LWD over the dam. During low flow periods, LWD that accumulates against the posts surrounding the “glory hole” in front of the trash rack must be mechanically removed. No records are available for the frequency of removal, volume of LWD removed, or its size distribution (K. Petersen, SFWPA, pers. comm., 2004). Current transport of LWD through Slate Creek Diversion Dam impoundment and over the dam to downstream reaches during high flows, combined with the relatively large downstream source area capable of supplying LWD to the channel as well as the similar LWD size distributions in the reservoir and downstream study sites, suggests that continued operation of Slate Creek Diversion Dam will not result in fewer key LWD pieces, lower LWD loading, or less LWD influence on channel morphology in the downstream reach.

7.1.8.2 In the Project Area

In addition to the information used to broadly describe geology and soil conditions in Sections 7.1.1 through 7.1.7, Licensee found five source documents regarding geology and soils conditions in the Project Area. Each of these is described here:

7.1.8.2.1 Slope Stability Downstream of New Bullards Bar Dam

In general, New Bullards Bar Dam is founded on typically hard and strong metavolcanic rock. Much of the rock on the downstream right abutment is fairly massive, and given its typically hard and strong condition it is often only slightly weathered on outcrop surfaces. However, rock within intensely fractured and sheared zones can be weak and highly weathered (Christensen Associates Inc. 2007).

In early 2006, a rockslide occurred on the slope downstream from the right abutment of New Bullards Bar Dam. The rockslide was initiated as a shallow wedge failure in the steep slope that had been undercut by excavation for the Burma Road. The initial failure occurred during or immediately following several days of intense rainfall. It blocked and damaged the road but did not directly affect Project facilities. Failure by progressive toppling and upslope migration of the developing headscarp and north sidescarp continued through the remainder of the 2005-2006 rainy season into April 2006, then ceased entirely. At road level, the slide is 120 feet wide at present and the hazardous area is considered to include the additional 160 feet long, vertical and overhanging road cut section of the road on the north. Block toppling and slope raveling may continue to enlarge the slide. A complete report on the geologic conditions contributing to the slide, the mechanisms of failure, the extent and effects of the slide, results of monitoring, and recommendations was filed with FERC.

7.1.8.2.2 Sediment Removal in Our House Diversion Dam Impoundment

Sediment has been removed from Our House Diversion Dam on four occasions:

- 1986 – Sediments had been accumulating in the impoundment for 18 years since construction of the diversion dam in 1968. The floods of February 1986 were believed to have contributed the bulk of the sediments. Phase I dredging began sediment removal on August 1, 1986; an unquantified amount was removed. On August 20, 1986, between 7,333 and 15,000 cubic yards was estimated to have been passed downstream through the release valve due to erosion of material in the reservoir, along with an additional unknown amount about a month later. YCWA discontinued removal in the fall of 1986, though an additional 15,000 cubic yards remained to be removed. An interim technical report provided alternatives for additional removal (EBASCO and Envirospere 1986).
- 1992 – Dredging removed 27,595 cubic yards of sediment between August 3 and September 5, 1992. Sediments were disposed of at a site at the Sierra Mountain Mills approximately 8 miles away (PG&E 1992).
- 1997 – Dredging removed 67,894 cubic yards of sediment between September 10 and October 30, 1997. Prior to removal, sediments were tested for mercury and found to be at

natural background levels. Sediments were sent to a dredging disposal site on Forest Service property approximately eighteen miles west of Our House Reservoir (PG&E 1997).

- 2006 – On December 31, 2005, an intense storm event carried sediments from the upstream reaches of the Middle Yuba River that partially blocked the low level outlet, tunnel intake structure, and fish water release outlet. Dredging removed 80,000 cubic yards of sediment between August 10 and September 15, 2006. Sediments were disposed of in an old quarry site on Marysville Road on Forest Service land approximately 1 mile south of Bullards Bar Dam (YCWA 2006).

Licensee is in the process of obtaining approval from the appropriate agencies for a sediment pass-through program at Our House Diversion Dam to avoid similar incidents in the future.

7.1.8.2.3 Sediment Removal in Log Cabin Diversion Dam Impoundment

Licensee is in the process of obtaining approval from the appropriate agencies for a sediment pass-through program at Log Cabin Diversion Dam.

7.1.8.2.4 Erosion Along Reservoir/Impoundment Shorelines

Licensee is unaware of any erosion areas along Project reservoir/impoundments that are not typical of similar reservoirs/impoundments in the Sierra Nevada.

7.1.8.2.5 Initial Channel Classification and Habitat Mapping upstream of USACE's Englebright Reservoir

An initial channel characterization of the Project reaches was recently developed by the Licensee in 2009, using available topographic information,[6] geologic maps (Saucedo and Wagner 1992), and ESRI/National Agriculture Imagery Program (NAIP) one-meter pixel color aerial imagery orthophotos from 2005.[7] The results of this desktop exercise approximate a Level 1 Rosgen classification (Rosgen 1996), but this exercise is not considered to be such a classification because there has been no field checking; this initial effort used only remote-sensing data. (Montgomery and Buffington 1993a, 1997; WFPB 1995) classes were used to hypothesize channel form and process, as presented in Table 7.1.8-2. Channels with the same gradient, confinement, and parent material are expected to behave similarly to changes in hydrology and in the wood and sediment delivered to the channel. For example, how a channel looks, where sediment and wood are stored, and when sediment moves are expected to be the similar within reaches of the same gradient, confinement, valley shape, and similar geologic parent material. This information was used as preparation for habitat mapping and study plan development. A habitat mapping report Attachment 3.9A of *Draft Study 3-09 Instream Flow Upstream of USACE's Englebright Reservoir Study*.

In addition to the 2009 habitat mapping, Licensee also collected some supplemental habitat and channel form data below Our House Dam (YCWA unpublished data). The data collected below

[6] Derived from Terrain Navigator Pro V.7 available from Maptech, Inc.©
[7] http://casil.ucdavis.edu/casil/imageryBaseMapsLandCover/imagery/naip_2005/county_mosaics/

Our House Dam has been used in the Habitat Mapping Report (referred to in, Attachment 3.9A of *Draft Study 3-09 Instream Flow Upstream of USACE's Englebright Reservoir Study*).

A summary of the methods used for this preliminary channel classification system appears here:

- Stream Longitudinal Profile: Stream longitudinal profiles were measured using maps available from Terrain Navigator Pro© (V. 7) software. Distance between contour lines was measured and a longitudinal profile was created. Map-based gradient, while an estimate, is often a good indicator of stream energy and process.
- Geology: Geology was determined using the geologic map of the Chico quadrangle (Saucedo and Wagner 1992). Geologic parent material is often important in sediment supply, substrate type, and channel form control.
- Confinement, Sinuosity, and Valley Shape: These variables were estimated using streaming imagery from ESRI using the program ArcGIS Desktop. These variables are useful in hypothesizing riparian condition and process, and long-term sediment history.

Table 7.1.8-2. Parameters relevant to channel types expected within gradient and confinement classes, separated by channel type.

	Braided	**Regime**	**Pool-Riffle**	**Plane-Bed**	**Step-Pool**	**Cascade**	**Bedrock**	**Colluvial**
Typical Bed Material	Variable	Sand	Gravel	Gravel, cobble	Cobble, boulder	Boulder	N/A	Variable
Bedform Pattern	Laterally oscillary	Multi-layered	Laterally oscillary	None	Vertically oscillary	None	--	Variable
Reach Type	Response	Response	Response	Response	Transport	Transport	Transport	Source
Dominant Roughness Elements	Bedforms (bars, pools)	Sinuosity, bedforms (dunes, ripples, bars) banks	Bedforms (bars, pools), grains, LWD, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, LWD, banks	Grains, banks	Boundaries (bed & banks)	Grains, LWD
Dominant Sediment Sources	Fluvial, bank failure, debris flow	Fluvial, bank failure, inactive channel	Fluvial, bank failure, inactive channel, debris flow	Fluvial, bank failure, debris flow	Fluvial, hillslope, debris flow	Fluvial, hillslope, debris flow	Fluvial, hillslope, debris flow	Hillslope, debris flow
Sediment Storage Elements	Overbank, bedforms	Overbank, bedforms, inactive channel	Overbank, bedforms, inactive channel	Overbank, inactive channel	Bedforms	Lee & stoss sides of flow obstructions	--	Bed
Typical Slope (m/m)	S < 0.03	S < 0.001	0.001 < S and S < 0.02	0.01 < S and S < 0.03	0.03 < S and S < 0.08	0.08 < S and S < 0.30	Variable	S < 0.20
Typical Confinement	Unconfined	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Pool Spacing (Channel Widths)	Variable	5 to 7	5 to 7	None	1 to 4	< 1	Variable	Variable

Source: Montgomery and Buffington (1993b)
Note: N/A Not applicable

Results - Preliminary Classification of Project Reach Channel Types

Generally, the Project reaches evaluated appear to be confined within resistant parent material. Gradients are generally greater than 1 percent. Table 7.1.8-3 summarizes the major characteristics of the Project reaches, based on this desktop exercise. Rosgen "Aa+," "A," and "B" types are believed to be found within the Project reaches, though some field checking is necessary to confirm this. The applicable Rosgen classes are typified as follows:

- Rosgen "Aa+": very steep (>10% gradient), deeply entrenched, debris transport, torrent streams. Very high relief. Erosional, bedrock, or depositional features; debris flow potential. Vertical steps with deep scour or plunge pools and waterfalls.
- Rosgen "A": steep (4-10% gradient), entrenched, cascading step/pool morphology. High energy/debris transport streams with stable plan and profile when bedrock or boulder dominated. Generally exhibit high transport potential and relatively low in-channel sediment storage.
- Rosgen "B": moderately steep to gently-sloped (2-4% gradient), moderately entrenched, riffle-dominated channel with infrequently spaced pools. Very stable plan and profile with stable banks.
- Rosgen "C": low-gradient (less than 2%), slightly entrenched, relatively sinuous with pools/riffle morphology, and well-developed floodplains and characteristic point bars. Channel plan and profile stability are dependent upon streambank stability and upstream watershed conditions and sediment regime.

Table 7.1.8-3. Project reach summary.

Project Reach	Length (mi)	Gradient (range)	Confinement	Rosgen
Middle Yuba	12.2	1.2% (1.0-2.9%)	confined	"B"
Oregon Creek	4.0	2.3% (0.9-7.4%)	confined	"A" and "B"
North Yuba	2.3	2.0% (0.9-5.5%)	confined	"A" and "B"
Yuba above New Colgate	6.0	1.7% (0.3-8.0%)	confined	"B"
Yuba below New Colgate	1.4	<1%	confined	"C" nearest approx.

Middle Yuba River – 1-3 percent gradient, confined, Rosgen "B"

The Middle Yuba River flows through a variety of parent materials, most notably resistant granitic rocks, and is bisected by the Big Bend-Wolf Creek fault within one mile of the junction with the North Yuba. The steepest section, at just below three percent, is located near the bottom of the reach, just below Klensedorf Point (Figure 7.1.8-1). There are numerous lower gradient sections, many of which are upstream of sharp bends that form "knickpoints." However, in any of these lower gradient sections where it appears that there is floodplain and side-channel development, sinuosity never exceeds 1.1 (i.e., valley length and channel length through the valley are approximately equal). Channels may be incised into cobble or boulder bars and resistant to movement across the valley, similar to a confined channel, and the floodplains are rarely accessed and have become terraces. Freemans Crossing is within a valley that is likely a long-term depositional area and has gradients of about one percent. It may be highly modified by human settlement, and channel location may be defined and maintained by artificial means such as dikes, berms, and hardened or reinforced stream banks. A multi-thread channel splits around an area known as "Emory Island" (~RM 6.5), though sinuosity is still fairly low at 1.1, and gradient is about one percent. Fieldwork would be necessary to further define these areas. Based on the gradient and confinement, expected dominant channel conditions are as follows:

- Overall channel form: plane-bed
- Typical bed material: gravel, cobble
- Bedform pattern: none (lacks 3-dimensional heterogeneity)
- Reach type: response with short sections of transport
- Dominant roughness: substrate, banks
- Dominant sediment sources: fluvial (from upstream), bank failures
- Sediment storage elements: overbank, inactive channel
- Typical slope: between 1 and 3 percent
- Typical confinement: variable

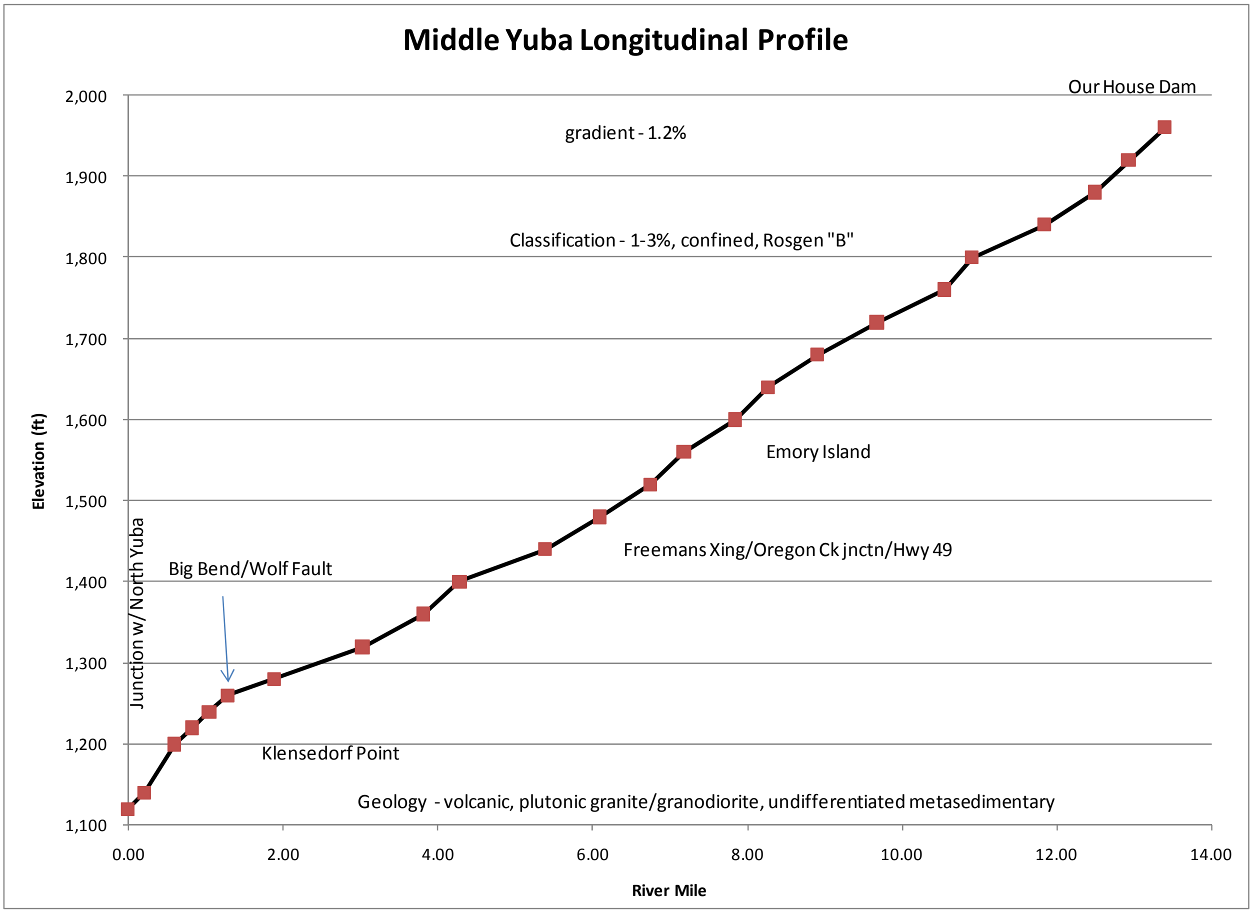

Figure 7.1.8-1. Longitudinal profile of Middle Yuba River between Our House Diversion Dam and the North Yuba River.

<u>Oregon Creek – variable gradient, confined, Rosgen "A," and "B" types</u>

There are three breaks within Oregon Creek, between which fluvial processes may vary (Figure 7.1.8-2). Oregon Creek flows mostly through resistant plutonic granitic material, though there is a short, steep section near the top that is composed of competent metasedimentary material. There is a short 4-8 percent gradient section just above the junction with the Middle Yuba River and another one above Celestial Valley. Celestial Valley appears to be a long-term depositional area and has gradients of about one percent. It may have been highly modified by human settlement and channel location may be defined and maintained by artificial means such as dikes, berms, and hardened or reinforced stream banks. Table 7.1.8-4 summarizes likely dominant channel conditions for the two types of channels within the reach (i.e., Rosgen A and B).

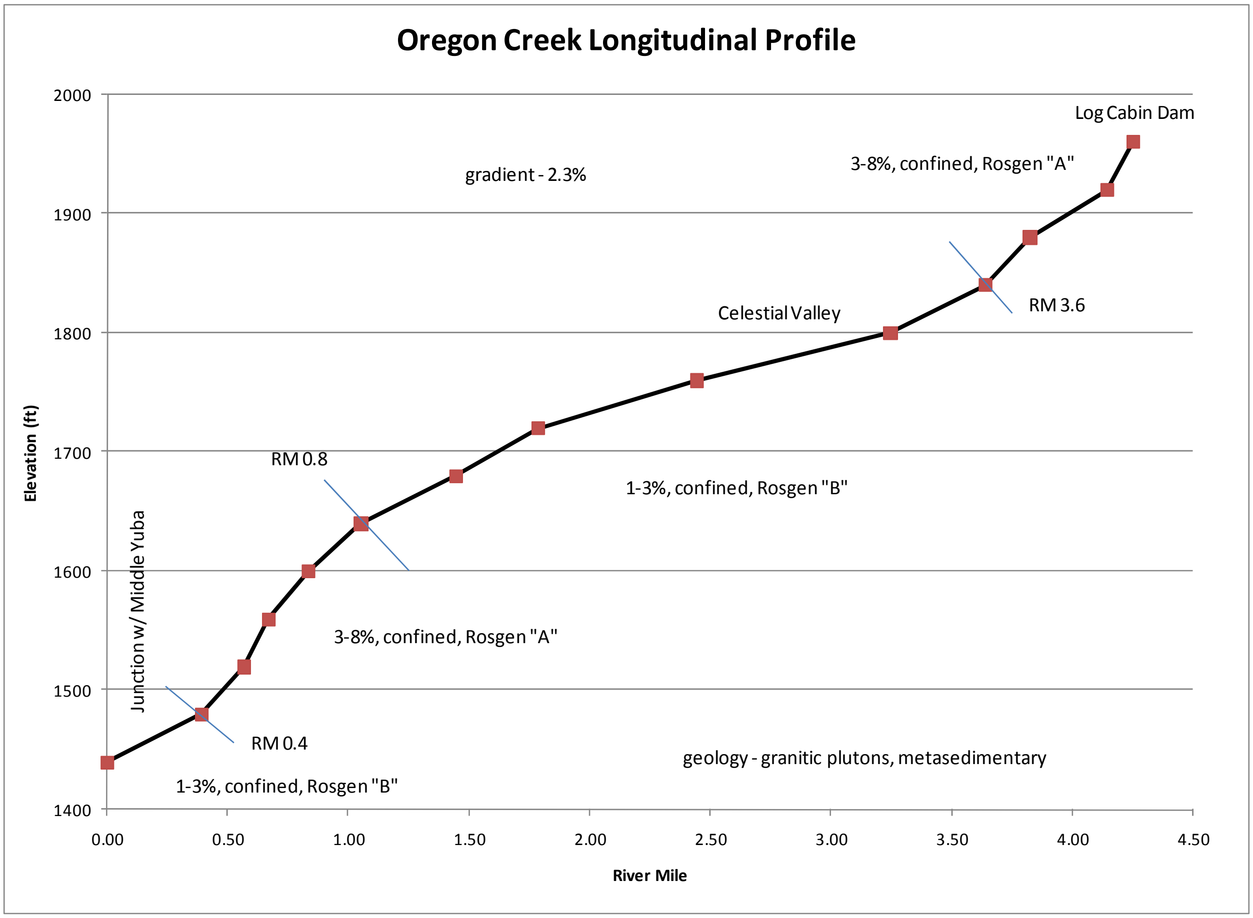

Figure 7.1.8-2. Longitudinal profile and channel classification of Oregon Creek.

Table 7.1.8-4. Oregon Creek and North Yuba River below Bullards Bar - hypothesized dominant channel condition based on gradient and confinement.

Variable	3-8%, confined, Rosgen "A"	1-3%, confined, Rosgen "B"
Overall channel form	step-pool	plane-bed
Typical bed material	cobble, boulder	gravel, cobble
Bedform pattern	vertically oscillary	none-low 3D heterogeneity
Reach type	transport	response, w/ some transport
Dominant roughness	bedforms (steps, pools), substrate, LWD, banks	substrate, banks
Dominant sediment source	fluvial, hillslope, debris flow	fluvial, bank failure, debris flow
Sediment storage elements	bedforms	overbank, inactive channel
Typical slope	between 3 and 8%	between 1 and 3%
Typical confinement	confined	variable

<u>North Yuba River below New Bullards Bar Dam – 1-3 percent gradient, confined, Rosgen "A" and "B"</u>

While channel is dominated by gradients below three percent (average gradient of 2%), there are short sections where the gradient is more than three percent, and one short section that is above five percent (Rosgen "A") located at approximately mid reach (Figure 7.1.7-3). Just above the steepest section, the gradient flattens to less than one percent. In viewing the NAIP orthophotos, it appears that the channel has been mostly scoured to bedrock (composed of Mesozoic volcanic rocks of the Smartville Complex), though there are some small inset bars (cobble and smaller) on the inside of some bends. The channel is not sinuous, and it appears that the active scour zone encompasses the entire valley floor (e.g., there is no apparent floodplain or terrace development). Refer to Table 7.1.7-4 for dominant hypothesized channel conditions within the two channel types of this reach.

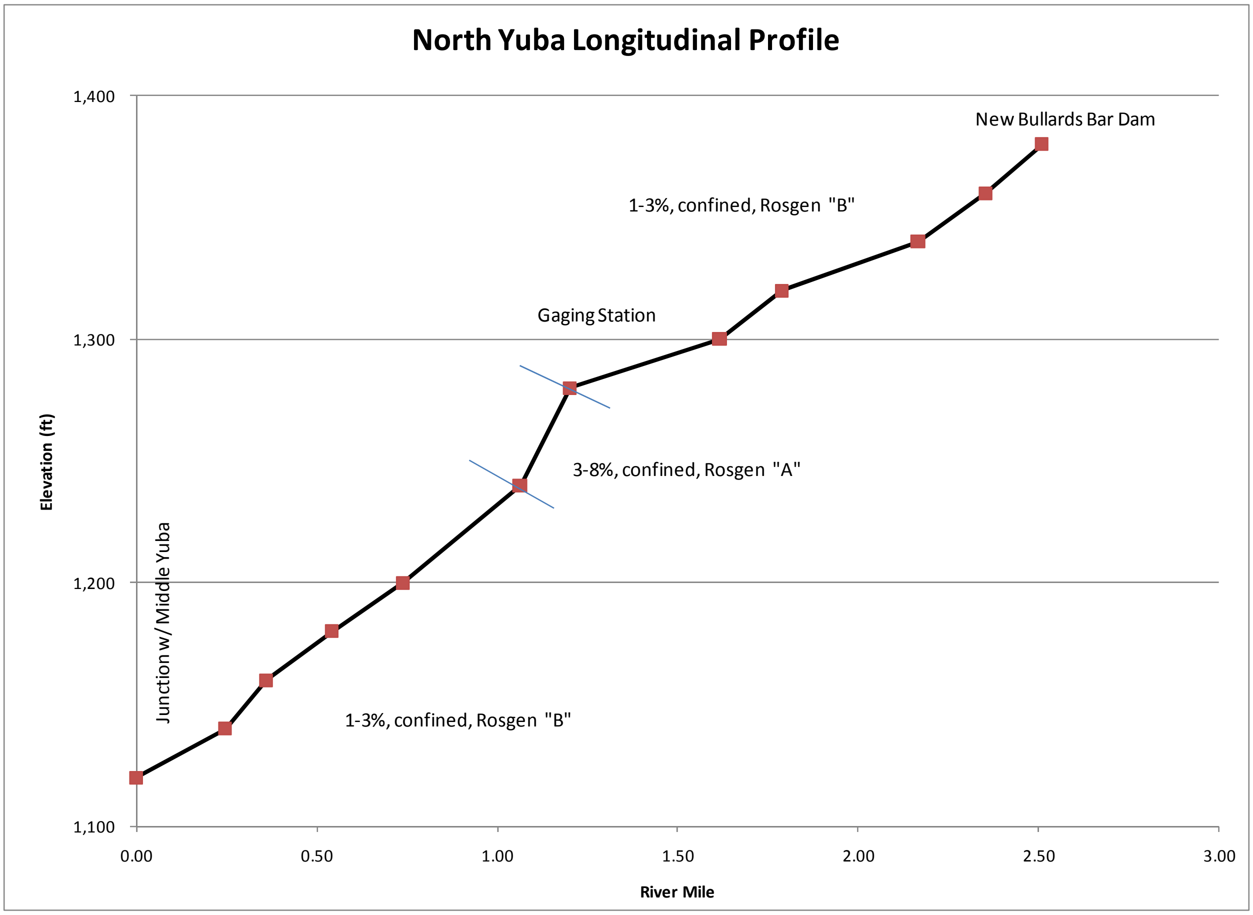

Figure 7.1.8-3. Longitudinal profile and initial channel classification of North Yuba between the junction with Middle Yuba and New Bullards Bar Dam.

<u>Yuba River above New Colgate Powerhouse – 1-3 percent gradient, confined, Rosgen "B"</u>

Channel is dominantly bedrock-controlled, with only very short boulder/cobble sections. Plan and profile are resistant to change. Sinuosity is very low as there are no plan and profile sections strongly influenced by alluvial processes. Most of the channel gradient is less than four percent with the exception of the contact between the Pleasant Valley pluton gabbroic rocks and the volcanic rocks of Smartville Complex, which results in a short, steep (8 percent gradient) section (Figure 7.1.8-4). A few other short, approximately five percent gradient sections occur as the stream bends sharply around resistant bedrock knobs. While the channel has been classified as "1-3 percent, confined, Rosgen B," the dominance of bedrock controls influences flow hydraulics and sediment movement. Conventional hydraulic geometry does not really apply in these highly variable channels (Tinker and Wohl 1998). Pools appear to be long, deep trench pools through the bedrock notches, and are short, shallow and perhaps more run-like in the broader boulder/cobble dominated sections. Sediment is sparse and transport is efficient, (i.e., sediment transport capability far exceeds sediment availability).

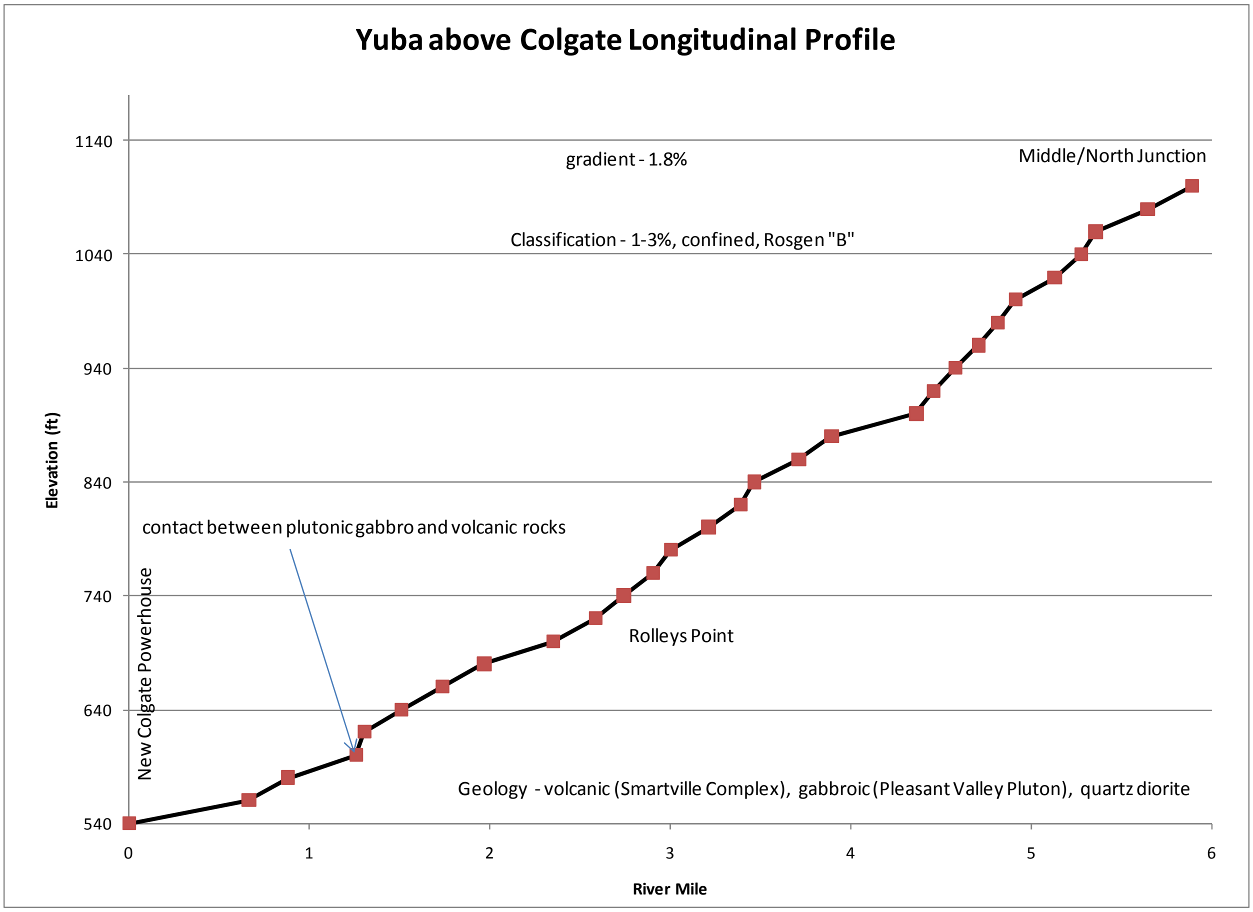

Figure 7.1.8-4. Longitudinal profile and initial channel classification of Yuba River between the New Colgate Powerhouse and the Middle/North Yuba junction.

Yuba River below New Colgate Powerhouse – <1 percent gradient, confined

This reach extends from the normal maximum water surface elevation from USACE's Englebright Reservoir (RM 32.2), defined as occurring at Rice Crossing, to the New Colgate Powerhouse (RM 33.6). Although the maximum water surface elevation from the lake occurs at Rice Crossing, the effects of the base level control from the lake level extend upstream, probably to the powerhouse. There are large sand and gravel bar deposits up to and including French Bar about 0.8 miles upstream (RM 33.0). These deposits, and the lack of deposition upstream, indicate that most of the fine-grained (gravel and smaller) sediment supplied from upstream is depositing within this short reach and into USACE's Englebright Reservoir. There are small point and lateral sand/gravel bars upstream of French Bar but mid-channel roughness (probably boulders) shows that the channel is gradually becoming more coarse in the upstream direction. There are no topographic lines that cross the channel, so gradient and longitudinal profile cannot be measured. It is assumed that the gradient is less than one percent and the channel is approaching a "regime" channel, though it is still confined within resistant valley walls. A Rosgen "C" type channel is the best approximation, but those channels have better defined floodplains and pool/riffle sequences than is likely in this backwater-influenced zone. Some hypothesized channel parameters (based on Table 7.1.8-2) are:

- Overall channel form: Regime (balance between sedimentation and deposition over time)
- Typical bed material: sand
- Bedform pattern: multi-layered
- Reach type: Response with transport sections increasing in the upstream direction
- Dominant roughness: sinuosity, bedforms (dunes, ripples, bars), banks
- Dominant sediment sources: fluvial (from upstream), bank failures, inactive channel
- Sediment storage elements: overbank, bedforms, inactive channel
- Typical slope: <1 percent
- Typical confinement: unconfined

7.1.8.3 Downstream of the Project Area

The Yuba River downstream of Englebright Dam is one of the more thoroughly studied rivers in the Central Valley of California. Information is available from both previously conducted studies dating back to the early 1900s through current information gathering efforts from ongoing data collection, monitoring, and evaluation activities. Considerable information relating to the impacts of hydraulic mining and the operation of the Yuba River as an element of the state flood control system have been developed. Additionally, extensive information regarding geomorphic drivers, landforms and boundary conditions, hydrogeomorphic dynamics, physical habitat and ecological dynamics, and river management actions have been developed through time.

The Yuba River downstream of Englebright Dam was tremendously impacted by mining debris influx between 1850 and 1940. Between 1852 and 1906, an estimated 366,500,000 cubic yards (yd^3) of hydraulic mining debris moved downstream from the upland mining areas of the greater Yuba River watershed and was deposited in the lower Yuba River, causing aggradation on the order of 26-85 feet (Alder 1980). Changing regulations eventually curtailed hydraulic mining in California, but several decades passed before the most immediate impacts of hydraulic mining abated.

Adler (1980) states that by 1906, the supply of hydraulic mining debris flowing from upland areas to the lower Yuba had peaked and degradation became the dominant process along the lower Yuba River. Based upon historical channel cross-section data collected along the lower Yuba River during the late 1800s and early 1900s and updated in 1979, Adler concluded that the lower Yuba River channel below USACE's Englebright Dam had attained equilibrium by 1940 to a channel morphology similar to its pre-1849 channel configuration (i.e., a single stable channel with similar channel elevation), except the stream channel is now bordered by large cobble training walls that constrain the channel width in many sections. The study further concludes that, since 1940, almost 90 percent of the hydraulic mining debris deposited in the lower Yuba River remains today as quasi-permanent deposits in the floodplains. The cobble training walls, along with the massive deposits of hydraulic mining debris behind the training walls, are now a stable, generally immobile part of the Lower Yuba River system.

In general the hydraulic mining sediment balance in the Yuba River below Englebright appears stable in the decadal time frame. Sediment budget and digital elevation model (DEM) differencing analysis by Pasternack and the Yuba Accord River Management Team (RMT) indicate that while there is a shortage of gravel and bed load at the uppermost end of the reach (just below Englebright Dam), and a net sediment outflow from the Timbuctoo reach (RM 19 – RM 21), the overall sediment balance between Englebright Dam and the Feather River confluence is stable.

CDWR and USACE (2003) analyzed the incipient motion conditions for flows of 4,000, 40,000, 65,000, 121, 000, and 161, 000 cfs using HEC-RAS hydraulic output and a sediment transport tool known as the Shields Diagram that relates. For each flow they determined the maximum particle size moved by the flow. This approach assumes that the entire mixture of sediment is this size and does not account for the effects of a heterogeneous bed.

Additional studies of localized reaches (Sawyer et al. 2010 and Pasternack 2008) have shown that each morphological unit experienced the "full transport" (Shields Stress t* values of > 0.06) sediment transport regime over a unique range of flows. Thus, a single incipient motion threshold for the river is not appropriate as a metric for evaluating lower Yuba River sediment transport conditions and fluvial geomorphology.

The Yuba River downstream of Englebright Dam remains the focus of research efforts originating at University of California at Davis and the Yuba Accord River Management Team, as well as other efforts. A summary list of recent information currently available includes, but is not limited to:

- Topographic and geologic maps, including a digital elevation model (DEM) of the Yuba River downstream of USACE's Englebright Dam (M&E Program 2010)[8]
- Hydrologic modeling and statistics for the Yuba River (YCWA 2007)
- Operations procedures for Project facilities (YCWA 2009)

[8] M&E Program documents and work products are located at the River Management Team (RMT) web site, www.yubaaccordrmt.com.

- PHABSIM habitat modeling of the Yuba River conducted by Beak Consultants for the California Department of Fish and Game (Beak 1989)
- Two-dimensional hydrodynamic habitat modeling (River2D) of the Yuba River conducted by the U.S. Fish and Wildlife Service (Gard 2007; 2008)
- Two-dimensional hydrodynamic modeling (SRH-2D) of the Yuba River by U.C. Davis for the River Management Team (M&E Program 2010)
- Low-altitude aerial video of the Yuba River (YCWA 2009)

Licensee found that significant source documents regarding geology and soils downstream of the Project have been synthesized by EDAW (2006) for the Feather/Yuba Rivers Levee Repair Draft Environmental Impact Report EIR.

Specific groundwater and other characteristics within the Feather River are presented therein. A geomorphic study was performed for the Third Phase of the Sacramento River Bank Protection Project to develop a geomorphically based framework for bank protection evaluation and strategies (WE&T 1991). A studied section of the Yuba River extends from Marysville (RM 0) to USACE's Daguerre Point Dam (RM 11.4). This section of river is presently a severely aggraded system that has incised into the mining-derived sediment. A total of 3,500 linear feet of bank protection was mapped as "damaged" in this section, but the priority for rehabilitation is low relative to sites on the lower Sacramento River and sloughs.

In 2008, the SWRCB approved petitions to change YCWA's water-right permits to implement the Yuba River Accord ("Yuba Accord"), a consensus-based, comprehensive program to protect and enhance 24 miles of aquatic habitat in the lower Yuba River, extending from USACE's Englebright Dam downstream to the river's confluence with the Feather River near Marysville (RMT 2009). The Yuba Accord consists of a Fisheries Agreement and several other elements. As part of the Yuba Accord, assessments of physical habitat conditions are being conducted to describe flow and fluvial geomorphological interactions, and to serve as the basis for physical habitat (e.g., reach, mesohabitat unit, flow and temperature) relationships with fish population parameters. To date, morphological units have been mapped on the Timbuctoo Bend on the lower Yuba River using field-based reconnaissance and GIS-based analysis of existing data layers (Pasternak and Eilers 2009; Pasternack 2008). In addition, at this same location digital elevation model differencing was used to quantify flood-induced morphodynamic change (Sawyer et al. 2009 in press). As part of this study, pre- and post-May 2005 flood topography mapping was done, cross-sections and velocity data were collected along three transects to validate a two dimensional hydrodymic model, and sedimentary characteristics were visually assessed and mapped (Moir and Pasternack 2008).

Information from ongoing data collection, monitoring, and evaluation activities, particularly from the Yuba Accord M&E Program (M&E Program) addressing geomophological conditions and physical habitat conditions in the Yuba River downstream of Englebright Dam that will be available for the conduct of this study includes, but is not limited to:

- Hydrologic water balance/operations model of the Yuba River (Relicensing Study Proposal 2.2)
- Substrate and cover classification maps of the Yuba River downstream of USACE's Englebright Dam to characterize microhabitat and mesohabitat conditions (M&E Program).
- Mesohabitat classification map of the Yuba River (M&E Program)

Airplane-based photography of the lower Yuba River occurred in 1937, 1947, 1952, 1958, 1984, 1986, 1991, 1995, 1996, 1997, 1999, 2002, and annually since 2004. Historical imagery has largely not been geo-rectified. Most imagery since 1999 is geo-rectified. The National Agricultural Imagery Program has 1-m resolution imagery from 2009 that represents the highest quality geo-rectified imagery available for the present condition.

A combination of boat-based, ground-based, and LIDAR (Light Detection and Ranging) mapping has been used to create a much higher spatial resolution than the 1999 map. Point spacing on the floodplain was finer than 1 point every 2 feet. In the channel, the spacing was more variable, but still on the order of 1 point every 5-20'. The EDR ("Englebright Dam Reach", the Yuba River from Englebright Dam to Deer Creek) was mapped too, but the Narrows is still not mapped as of spring 2010. No sizable data gaps exist downstream of the Narrows - all islands, backwaters, and side channels were mapped. A report explaining the data collection and map production procedures is available from the RMT.

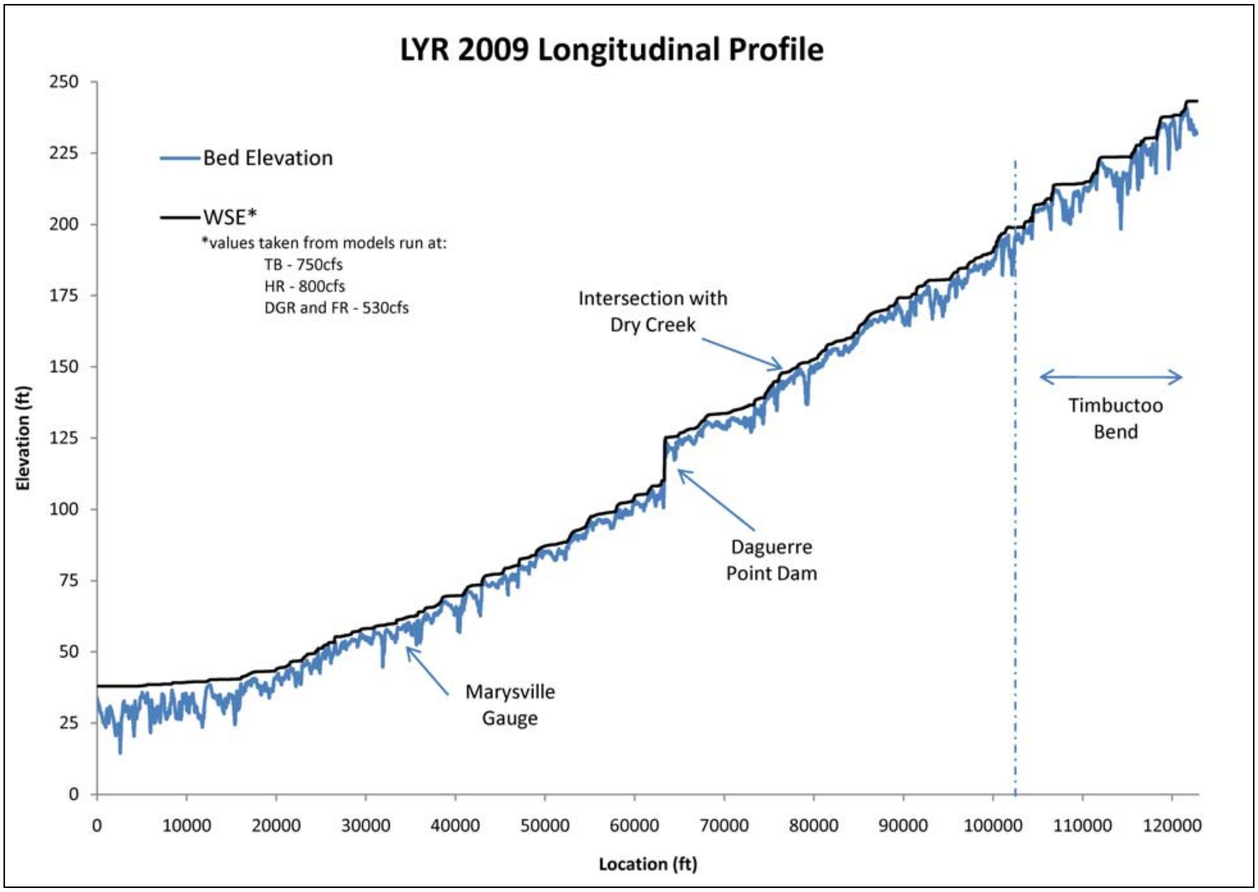

Figure 7.1.8-5. Longitudinal profile of Yuba River below Timbuctoo Bend.

In spring 2010, the RMT approved a protocol for mapping the substrate and cover for the entire lower Yuba River systematically. The approach uses a visual classification system for substrate with size divisions that are determined by properties of the statistical distribution of particle sizes in a gravel-bed river. Prior to initiating the survey, field crews were tested twice on the method using 17 samples with various size mixtures of sediment taken from the lower Yuba River (and subsequently returned there). Beginning in July 2010, crews have been using real-time differential GPS units to field-map polygons of the surficial bed material down to polygon sizes greater than 10 m^2. The coverage is for the wetted area of about 5,000 cfs, as predicted using the 2009 topographic map and the associated SRH models for the whole river. The mapping effort will be complete by December 2010.

Several different hydrodynamic models have been used to study lower Yuba River hydraulics. Beak Consultants, Inc (1989) used the IFG4 method to characterize the hydraulics of the lower Yuba River. They designated 31 transects with at least 20 points to represent the proportional occurrence of habitat types in each reach. USACE (2002) made HEC-RAS and FLO-2D hydraulic models of the channel and floodplain with coarse 400 ft by 400 ft cells (i.e. 400 ft internodal spacing) for use in studying terrestrial flooding during large floods. The U.S. Fish and Wildlife Service Instream Flow Branch (Gard, 2007, 2008) performed 2D hydraulic modeling of 18 sites for flows of 400-4500 cfs (the full range of controllable flows).

Professor Greg Pasternack of the University of California at Davis was sponsored by the USFWS to perform 2D hydrodynamic modeling of two different sites on the lower Yuba River over a range of discharges with FESWMS. One site was the Timbuctoo Bend Apex Riffle (TBAR) whose topography was independently mapped in 2004 and 2005 (before and after the May 2005 flood peak of 42930 cfs). The 2004 TBAR topography was modeled at flows of 400, 622, 827, 1200, 135, 1800, 2250, 2700, 4500, 5620, 11600, and 42930 cfs. The other site that FESWMS was used to model was the Englebright Dam Site (EDS) in the narrow canyon just below Englebright Dam. This site included the Narrows II Pool just downstream of Englebright Dam, a run, and then another pool upstream of Narrows I. This site was mapped in 2005 and FESWMS was used to model discharges of 800, 1190, 8809, 9580, 25100, 31800, and 91400 cfs.

The RMT sponsored an extension of the modeling effort for the lower Yuba River. In 2010, the RMT prepared computational meshes for the entire lower Yuba River downstream of the highway 20 bridge to go with the pre-existing ones for upstream of the bridge. The model reaches now include the EDR (Englebright Dam Reach), Timbuctoo Bend, the Hammon Reach (Highway 20 bridge to DPD), the Daguerre reach (DPD to USGS Marysville gaging station), and the Feather Reach (USGS gaging station to confluence with the Feather River). Extensive observational data was collected 2008-2010 to test the models, including water surface elevation points, LIDAR points collected on the water surface to create a continuous water surface elevation map for the flow on the day of that flight, a dataset of water depths was collected at cross-sections in December 2009, and over 6000 observations of velocity between December 2009 to August 2010. 1-m resolution SRH models of the lower Yuba River were run from 500 cfs to 5000 cfs.

Detailed map and model information are available on the RMT public web site, www.yubaaccordrmt.com.

7.1.9 List of Attachments

None

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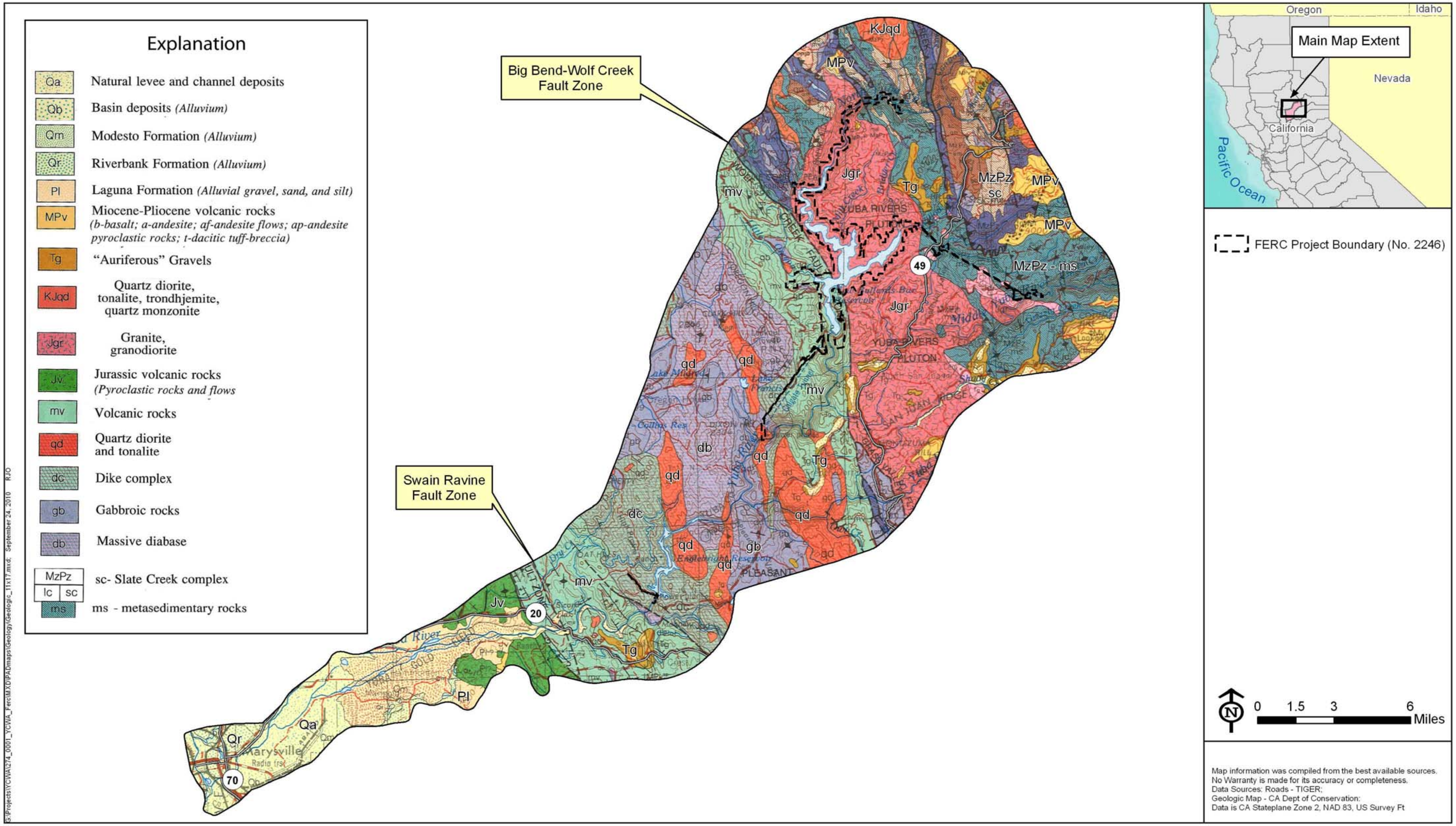

Figure 7.1.2-1. Geologic map of the Project Vicinity.

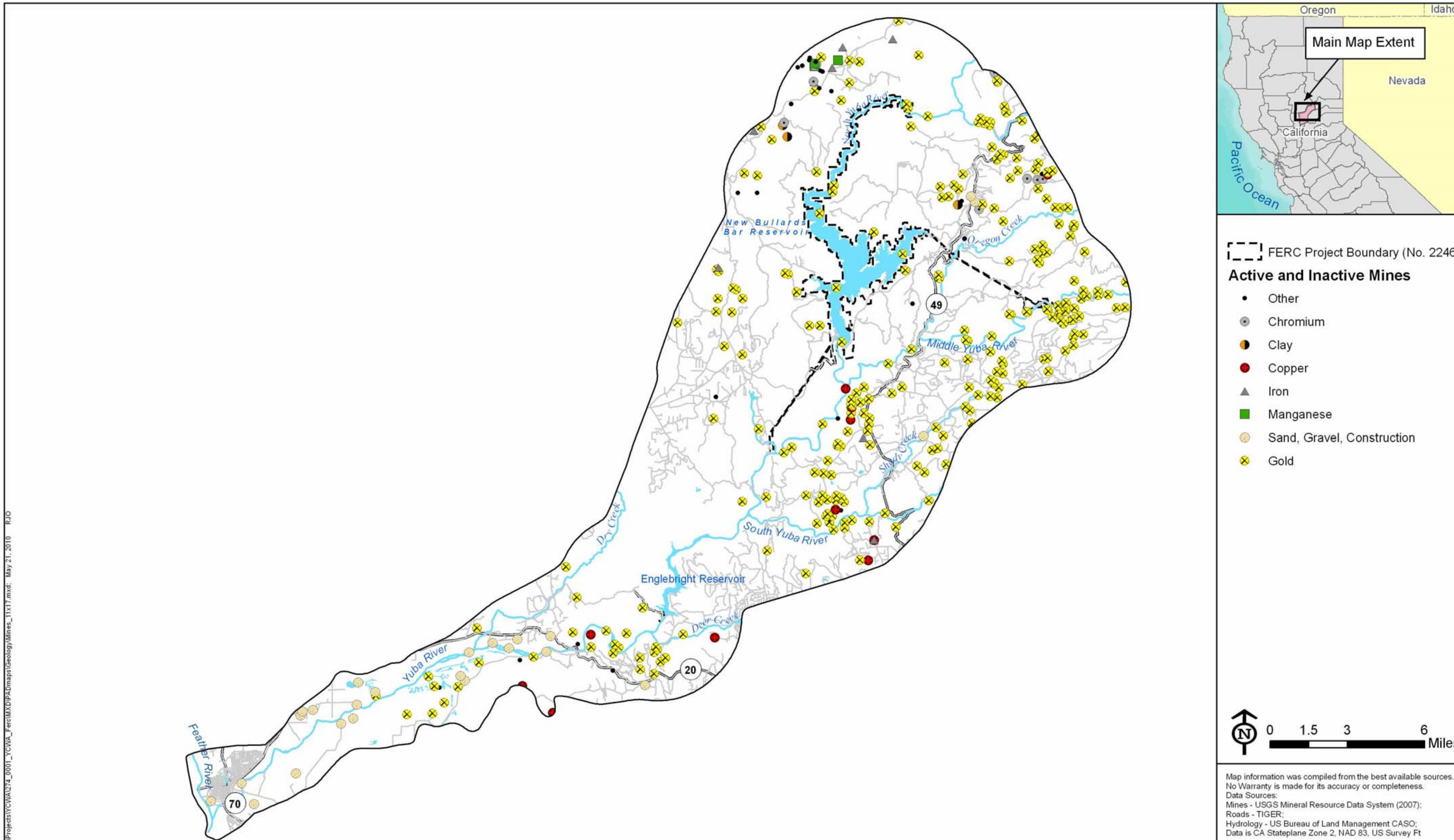

Figure 7.1.4-1. Active and inactive mines in the Project Vicinity.

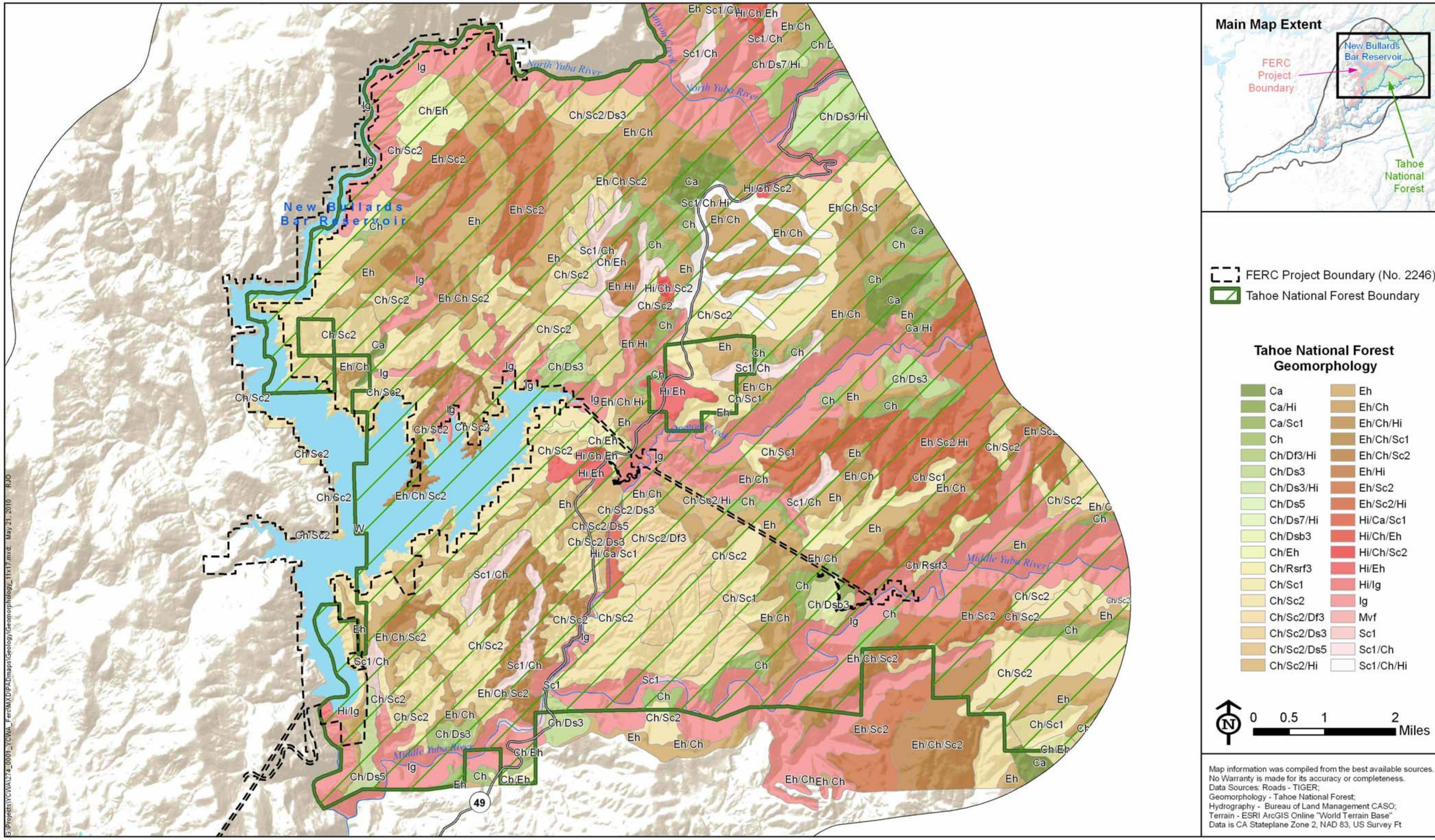

Figure 7.1.5-1. Geomorphology of the Tahoe National Forest within the Project Vicinity.

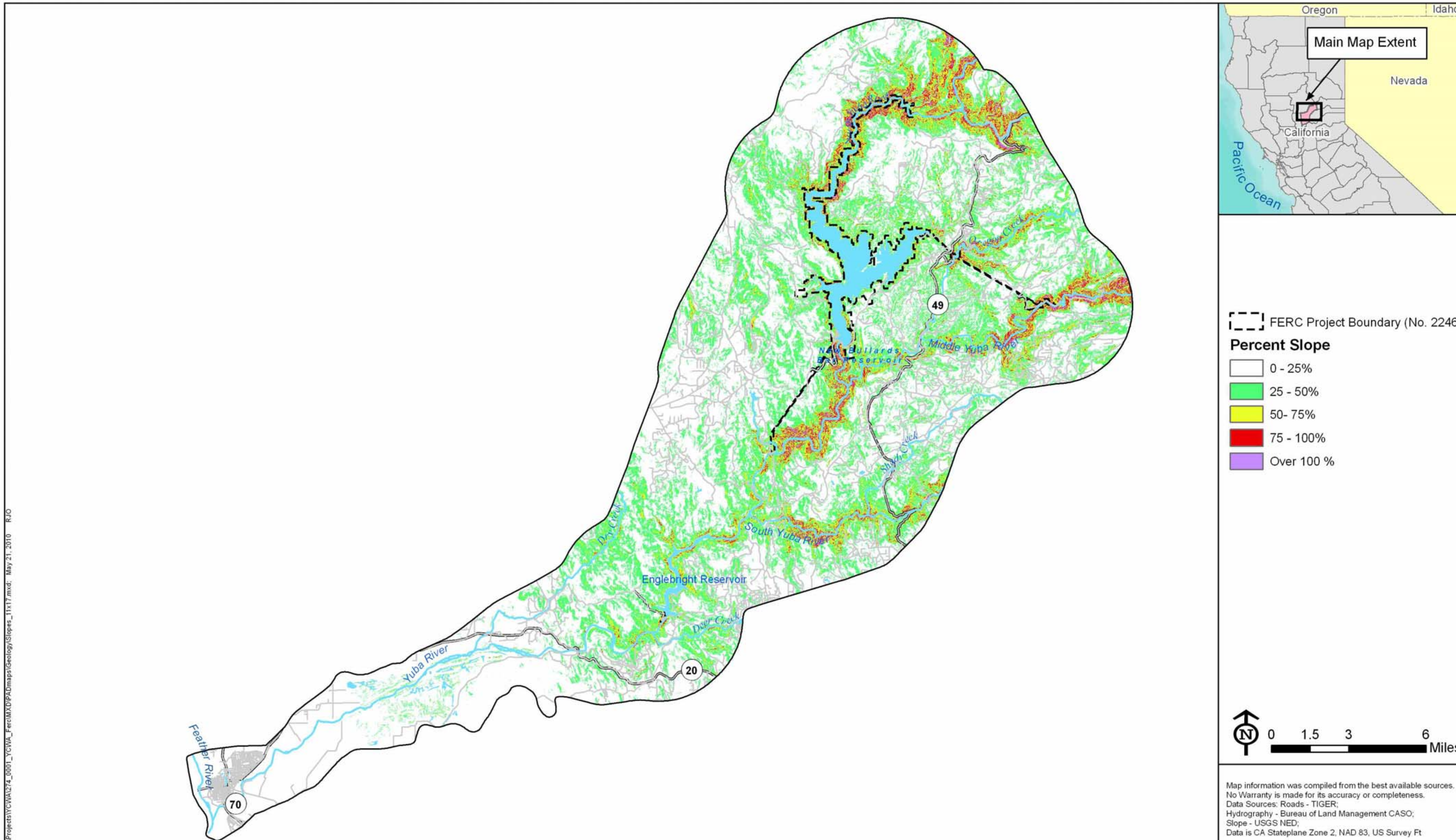

Figure 7.1.6-1. Slopes in the Project Vicinity.

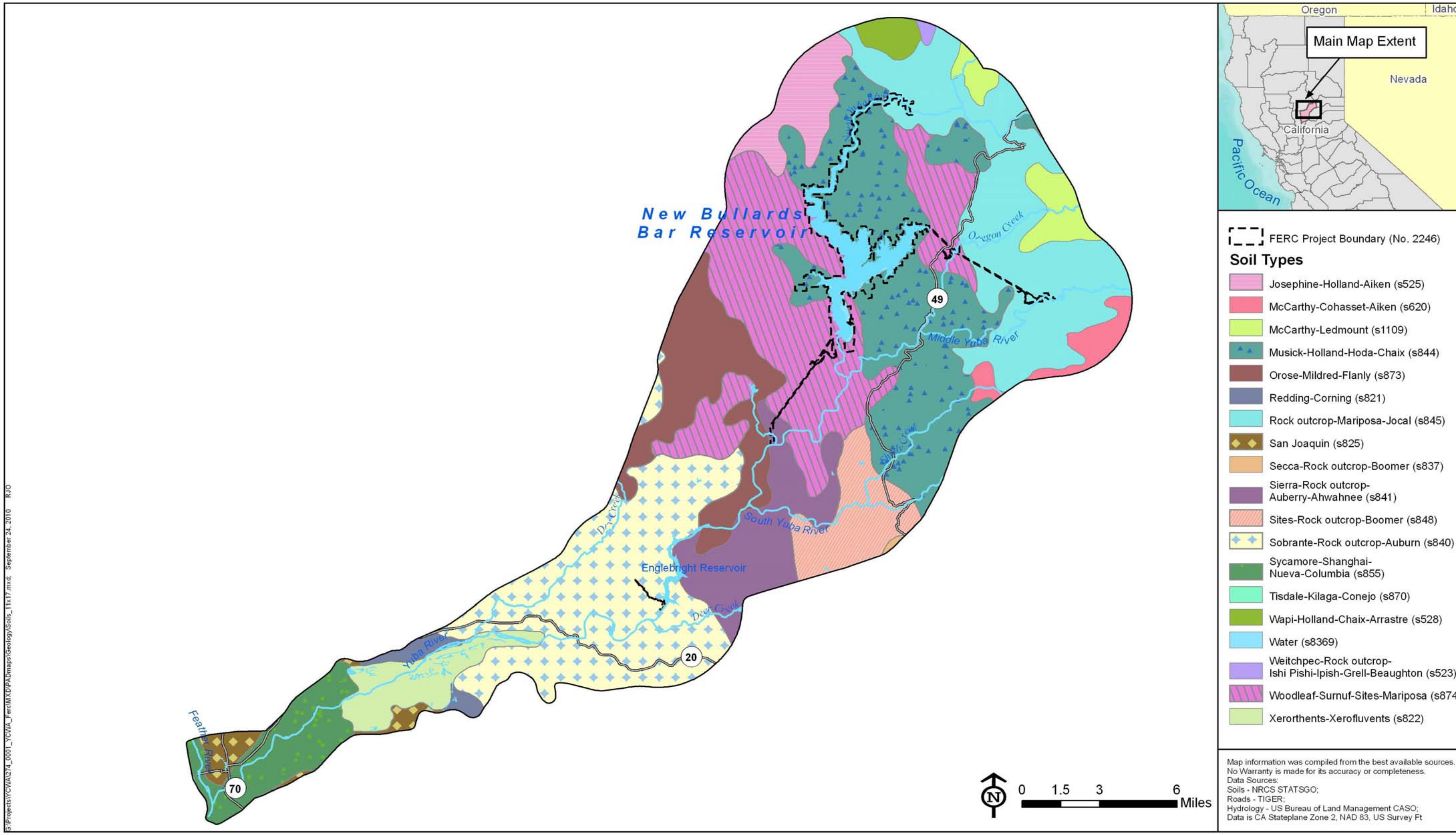

Figure 7.1.7-1. Soil associations in the Project Vicinity.

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