TECHNICAL MEMORANDUM 1-1

Channel Morphology
Upstream of Englebright Reservoir

Yuba River Development Project
FERC Project No. 2246

October 2013

TECHNICAL MEMORANDUM 1-1

EXECUTIVE SUMMARY

In 2011, the Yuba County Water Agency (YCWA) conducted a channel morphology study in stream reaches upstream of the United States Army Corps of Engineers' Englebright Reservoir that are potentially affected by YCWA's Yuba River Development Project (Project). The study focused on channel morphology, riparian vegetation and sediment mobility.

Data collected at each of the seven intensive study sites included measurement of longitudinal profiles and cross sections, site sketches, facies mapping and quantification, and channel and bank stability evaluation. Each site encompassed a minimum length of 20 bankfull-widths. In addition to the seven intensive study sites, three sites were assessed for bedload deposition within the backwater effects above Log Cabin and Our House diversion dams and within the influence of the normal maximum water surface elevation (NMWSE) of New Bullards Bar Reservoir within Slate Creek.

In the intensive study sites, sediment mobility was estimated, along with the frequency of bed and particle-mobilizing flows and the changes in bedload transport capacity due to regulation. As a test of sediment mobility, tracer particles were placed in the Middle Yuba River and Oregon Creek. Additional study elements measured were:

- Bed armoring (surface-to-sub-surface ratio of D_{50} [median surface grain size] of exposed bars) was measured at four sites in the Middle Yuba River and one site in Oregon Creek.
- Sediment supply was estimated at seven sediment supply nodes using regional sediment yield estimates.
- Twenty-four tributaries to the Middle Yuba River, North Yuba River and Yuba River were evaluated for coarse sediment supply additions.
- Channel storage elements were evaluated at accessible locations at 21 sites on the Middle Yuba River and 10 sites on Oregon Creek.
- Spill effects at Log Cabin and Our House diversion dams and at New Bullards Bar Dam were evaluated, as were the effects of releases from New Colgate Powerhouse.

Six of the seven intensive study sites have gradients greater than 1 percent and are composed of coarse and generally resistant bed and bank material. Gradients are between 1 and 2.9 percent, except for the site on the mainstem Yuba River below the New Colgate Powerhouse. The mainstem Yuba River below the New Colgate Powerhouse has a gradient of 0.2 percent, which decreases as flows increase to floodprone depth indicating a likely influence of backwater effects from Englebright Reservoir that extends into the site. The North Yuba River site is the steepest at almost 3 percent. Reach-averaged D_{50} values range from 75 millimeters (mm) downstream of New Colgate Powerhouse to a maximum of 193 mm in the North Yuba River. Bedrock/boulder controls figure prominently in most of the intensive sites and range from 1 percent in Oregon Creek to a maximum of 66 percent at the North Yuba River site. Because of the amount of bedrock and boulder control, channel stability is good and bank erosion hazard is low to very low. Quantity of mobile material (i.e., D_{84}, which is generally less than 128 mm) ranges from a low of 1.6 cubic meters (m^3)/meter (m) of stream at the Yuba River upstream of New Colgate Powerhouse to a high of 29.2 m^3/m at the Yuba River downstream of New Colgate Powerhouse. The next highest value is the Middle Yuba River downstream of Oregon Creek at 6.9 m^3/m. The quantity of mobile material at the rest of the sites ranged from 2.1 to 3.0 m^3/m.

The areal extent of the Our House Diversion Dam deposit is approximately 11.4 acres (ac), and the areal extent of the Log Cabin Diversion Dam deposit is approximately 3 ac. Slate Creek has a deposit of about 0.6 ac, which was formed by backwater effects created by high flows in Slate Creek and the North Yuba River combined with a high water surface elevation in New Bullards Bar Reservoir.

The Middle Yuba River and Oregon Creek were evaluated for channel armoring. Armoring ratio is strongest below Oregon Creek at 5.4 and is considered strongly armored**,** but is moderate (between 1.4 and 2.7) at all other Middle Yuba River sites. The weakest armoring ratio is just above the Middle Yuba River/North Yuba River confluence, though it is still considered moderate. In Oregon Creek overall, the armoring ratio is moderate at 1.7.

Sediment sources have been reduced by dam placement, but active sources of sediment still remain. Sediment yield has been reduced when comparing the sediment yield With-Project and Without-Project. The ratio of With- and Without-Project yields S* ranges from zero in the North Yuba River below New Bullards to a maximum of 0.21 in the Middle Yuba River at the North Yuba River/Middle Yuba River confluence.

If tributaries add bedload, there is little evidence (e.g., alluvial fans) remaining near the confluences in the North Yuba River, Middle Yuba River and mainstem Yuba River channels. The likely exceptions for sediment additions are Dobbins Creek, Moonshine Creek, Studhorse Canyon, and Nevada Creek. A significant source of sediment to the Middle Yuba River is sediment transported over Our House Diversion Dam as some of the largest coarse sediment deposits are right below the dam. Up to 15,000 cubic yards [yds^3] (11,470 cubic meters) may have been contributed below the dam from the 1986 flood event, some of which remains in a large cobble bar just below the dam.

Channel storage of alluvially-derived sediment is located in active, semi-active, and inactive elements and ranges from about 14 to 84 m^3/m. In the Middle Yuba River, the amount of coarse sediment is about four times higher below Oregon Creek than above. Oregon Creek has the greatest amount of channel storage, but half of this amount is stable and composes the long-term terrace that forms Celestial Valley.

The spillway at New Bullards Bar Dam has been eroded to bedrock but there is no remaining evidence in the North Yuba River of material that was potentially removed. The Log Cabin and Our House diversion dams are passive-spillway dams that spill regularly; these spills do not cause erosion of a spillway. There is pass-through of coarse and fine sediment downstream during large flood events below Our House Diversion Dam and there may be pass-through over Log Cabin Diversion Dam of fine-grained material (e.g., washload). The banks downstream of

New Colgate Powerhouse are generally stable, mostly bedrock and boulder, with only a minor amount of bank erosion that could be due to peaking flows from the New Colgate Powerhouse.

Tracer particles were placed in the Middle Yuba downstream of Oregon Creek (Site 1) and Oregon Creek Celestial Valley Sub-Reach (Site 5) prior to a flood event in December 2012. Estimates of peak discharge at each of the sites for this event were 8,500 cubic feet per second (cfs) at Site 1 and 637 cfs at Site 5. The events had recurrence intervals of about 4.7 years and 2.3 years, respectively (With-Project hydrologic conditions). All but one of the particles placed at Site 1 were moved or buried. A cobble/gravel bar expanded near the lowermost transect during the flood event, so all the particles were shifted or buried and only one 180 mm particle was found. While there was no sediment added to the uppermost transect, only one 256 mm particle remained within 1 m and there was one painted cobble perched on the gravel bar well downstream of the transect. At Site 5, 30 percent of the particles were moved more than 1 m off the transects. 90 percent of the particles that moved were 90 mm and smaller.

Riparian communities are vigorous, complete with diverse species and age classes. Floods cause some shifting when gravel and cobble bars are inundated (e.g., widening of the exposed channel and reduction in vegetation along the margins). Inundation frequency of bankfull surfaces has a probability of occurrence about every year under With-Project hydrologic conditions, but would be higher (i.e., more than once a year) under Without-Project hydrologic conditions. The floodprone surfaces (i.e., twice the bankfull depth) have a probability of inundation about every 2 to 9 years under With-Project conditions versus every 1 to 6 years under Without-Project conditions.

There are adjustments to sediment supply and transport capacity comparing With- and Without-Project conditions. The presence of bedrock or other resistant channel boundaries or intrinsically low sediment transport rates can affect responses to dam construction. The capacity for channel adjustment is a function of the how transportable the bed sediment is, how erodible the bed and banks are, and whether there is opportunity for lateral mobility. There are hypotheses as to the adjustments to the channel due to dam construction: changes may be expected first in grain size of the stream bed, followed by construction or removal of in-channel bars, incision, and bank erosion; changes in stream planform and channel slope would be observed over a longer time frame. The existing condition of the Project-affected channels are that bed scour and grain size has likely increased, likely incision in certain depositional sections of the channel and possible decrease in frequency of mid-channel bars, but there is insufficient evidence as to what the condition was prior to the Project, and there are no measureable or distinct changes in planform when considering Without-Project conditions. Regardless of the pre-Project conditions, assessment of the existing condition of the channels is that it is fairly resistant to further change.

The Middle Yuba has a coarse and resistant bed and banks in most of its length, with few possibilities of lateral or vertical shifting. Locations on the upstream side of bends and within and downstream of long-term depositional areas are more alluvially dominated, but sediment transport is still very high and particles move with fairly high frequency. Sediment is available to the channel and is being transported at a higher rate than it is replaced; however, the estimates show that even under Without-Project conditions, the river would still have a sediment deficiency. The sediment deficit estimates highlight the fact that bedload transport equations rely on the availability of sediment for transport, which it is not in this system.

The same overall condition applies to the North Yuba River and the Yuba River upstream of the New Colgate Powerhouse (i.e., coarse bed and banks resistant to movement, with storage of sediment in small areas in deep pools, in velocity shadows, and on lateral bars). Mid-channel bars are uncommon but they exist in every one of the reaches, though whether or not they have been reduced in size or frequency since dam construction is unknown.

The Yuba River downstream of the New Colgate Powerhouse is a reach that appears to be accumulating sediment, though at a slower rate than it would under Without-Project conditions. The long-term bars (e.g., Rice's, French and Condemned) that existed before the Project will continue to exist, though there are some indications that the channel could shift to occupy French and Rice's bars. Because there are numerous floods within this most downstream section of the Yuba River, shifting is not only possible but likely.

Oregon Creek is much smaller than the other reaches but also has an estimated greater transport capacity than there is sediment available. Again, though, there are storage reservoirs of sediment and there is mobile sediment forming and reforming bed forms, bars, and floodplains. There is little likelihood of further change as the bed and banks appear to be stable under the current regime.

The study was conducted according to Study 1.1, *Channel Morphology Upstream of Englebright* Reservoir, with three exceptions. First, the FERC-approved study states that three exposed bars will be sampled in five locations. At the intensive study site established in the Middle Yuba River above Oregon Creek (Channel Morphology Study Site #2), despite thorough investigation within, above and below the study site, there were only two exposed bars available that were conducive to sampling.

Second, the FERC-approved study states that YCWA will give two weeks notice prior to any office meeting discussing site selection. Due to a very narrow window of opportunity to collect field data in the mainstem Yuba River below New Colgate Powerhouse, notice was given to Relicensing Participants on November 29, 2011, for a meeting on December 1, 2011 for data collection to occur on December 8-9, 2011. In spite of the short notice, several Relicensing Participants participated in the webinar. All those present agreed that the study site and transects would be adequate for the channel morphology study.

Third, the FERC-approved study states the study will be completed by the end of September 2012. In a Relicensing Participant meeting on April 12, 2012, Relicensing Participants requested that YCWA delay the high target calibration flows for Study 3.10, *Instream Flow Upstream of Englebright Reservoir*, from late spring 2012 to fall 2012. Study 1.1 relies on data from Study 3.10 and, therefore, completion of Study 1.1 was delayed. Additionally, the tracer particle component of Study 1.1 was not able to capture a high flow event in spring 2012. YCWA captured a high flow event in December 2012 and these data are included. Hydraulic and sediment transport models have been developed and were discussed with Relicensing Participants on January 30, 2013.

This study is complete.

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TECHNICAL MEMORANDUM 1-1

Channel Morphology Upstream of Englebright Reservoir[1]

Yuba County Water Agency's (YCWA) continued operation and maintenance of the Yuba River Development Project, Federal Energy Regulatory Commission (FERC) Project Number 2246 (Project), has the potential to affect channel morphology in the Yuba River basin downstream of Project facilities and upstream of the United States Army Corps of Engineers' Englebright Reservoir.[2]

1.0 Goals and Objectives

The goal of the study was to quantify or characterize river form and process in reaches downstream of Project facilities, and interaction with the riparian zone in reaches upstream of the normal maximum water surface elevation (NMWSE) of Englebright Reservoir potentially affected by continued Project operation and maintenance. Additionally, the study goal was to quantify and characterize coarse sediment supply and transport regimes under annual regulated (i.e., With-Project) and Without-Project conditions.[3]

The objectives of the study were to collect information necessary to meet the study goal. Specifically, the study objectives included developing a quantitative and qualitative understanding of Project effects on particle size distribution, substrate mobility, sediment supply, in-channel storage, spill channel flow effects on channel morphology and erosion, mainstem scour and/or deposition from New Colgate Powerhouse releases, and floodplain connectivity.

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[1] This technical memorandum presents the results for Study 1.1, *Channel Morphology Upstream of Englebright Reservoir*, that was included in YCWA's August 17, 2011, Revised Study Plans and included by FERC in its September 30, 2011 Determination and as modified by FERC's December 8, 2011 Determination. There have been no modifications to the study since FERC's December 8, 2011 Determination.

[2] Englebright Reservoir is formed by Englebright Dam. The dam is about 260 ft high, was constructed by the California Debris Commission in 1941, and is owned by the United States. When the California Debris Commission was decommissioned in 1986, administration of Englebright Dam and Reservoir passed to the USACE. The primary purpose of the dam is to trap and contain sediment derived from extensive historic hydraulic mining operations in the Yuba River watershed. Englebright Reservoir is about 9 miles long with a surface area of 815 acres. Englebright Reservoir when first constructed had a gross storage capacity of 70,000 ac-ft; however, due to sediment capture, the gross storage capacity today is approximately 50,000 ac-ft (USGS 2003).

[3] Without-Project refers to conditions in the river that would occur if Project facilities were not in place (i.e., no Project operations); other water projects (e.g., Pacific Gas and Electric Company's Drum-Spaulding Project and Narrows 1 projects and Nevada Irrigation District's Yuba-Bear Hydroelectric Project) would operate as they have operated historically.

2.0 Methods

2.1 Study Area

The study area included: 1) the Middle Yuba River from confluence with the North Yuba River to Our House Diversion Dam; 2) Oregon Creek from the confluence with the Middle Yuba River to the Log Cabin Diversion Dam; 3) the North Yuba River from the confluence with the Middle Yuba River to New Bullards Bar Dam; 4) the portion of the Yuba River from the NMWSE of Englebright Reservoir to the confluence of the North and Middle Yuba rivers; and 5) the portion of the Middle Yuba, Oregon Creek, and Slate Creek affected by base-level control exerted by either the Project's diversion dams (i.e., Our House and Log Cabin) or reservoir water level (i.e., New Bullards Bar Reservoir).

2.2 Study Sites

The study included seven "intensive study sites" that had a high level of evaluation[4] and three "non-intensive study sites" where data collected was limited[5] (Table 2.2-1). The intensive study sites were co-located with YCWA's relicensing Study 3.10, *Instream Flow Upstream of Englebright Reservoir*, and Study 6.1, *Riparian Habitat Upstream of Englebright Reservoir*. Transects[6] were selected in the field with interested and available Relicensing Participants from September 20 through 23, 2011 for the Middle Yuba River, Yuba River (Middle Yuba River/North Yuba River Reach), and Oregon Creek locations. The study site and cross sections in the Yuba River downstream of New Colgate Powerhouse were discussed and selected during a webinar with interested and available Relicensing Participants on December 1, 2011. The North Yuba River site was selected in the field with Relicensing Participants on February 9, 2012. The three non-intensive sites were located upstream of Project facilities.[7]

Table 2.2-1. Location of reaches where channel morphology study sites were located, and transects selected for channel morphology evaluation from among Study 3.10, *Instream Flow Upstream of Englebright Reservoir*, transects.

Stream	Reach Name	Location	Study Site Name	Study Site No.	Cross Section Numbers
INTENSIVE SITES					
Middle Yuba River	Oregon Creek Reach	Downstream of Oregon Creek: upstream and downstream of Moonshine Creek	Middle Yuba River downstream of Oregon Creek	1	9, 12, 13
	Our House Diversion Dam Reach	Upstream of Oregon Creek	Middle Yuba River upstream of Oregon Creek	2	2, 9, 12

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[4] The seven "intensive study sites" are consistently referred to in this technical memorandum as "intensive" sites due to the higher level of evaluation performed at these sites.

[5] The three "non-intensive study sites" are consistently referred to in this technical memorandum as "non-intensive" sites due to the lower level of evaluation performed at these sites.

[6] "Transect" refers to Physical Habitat Simulation (i.e., PHABSIM) cross sections; the term "cross section" is used for Study 1.1, *Channel Morphology Upstream of Englebright Reservoir*, but data collected are similar (i.e., distance and elevation across a channel perpendicular to flow).

[7] The FERC–approved study did not require YCWA to consult with Relicensing Participants regarding the location of the non-intensive sites.

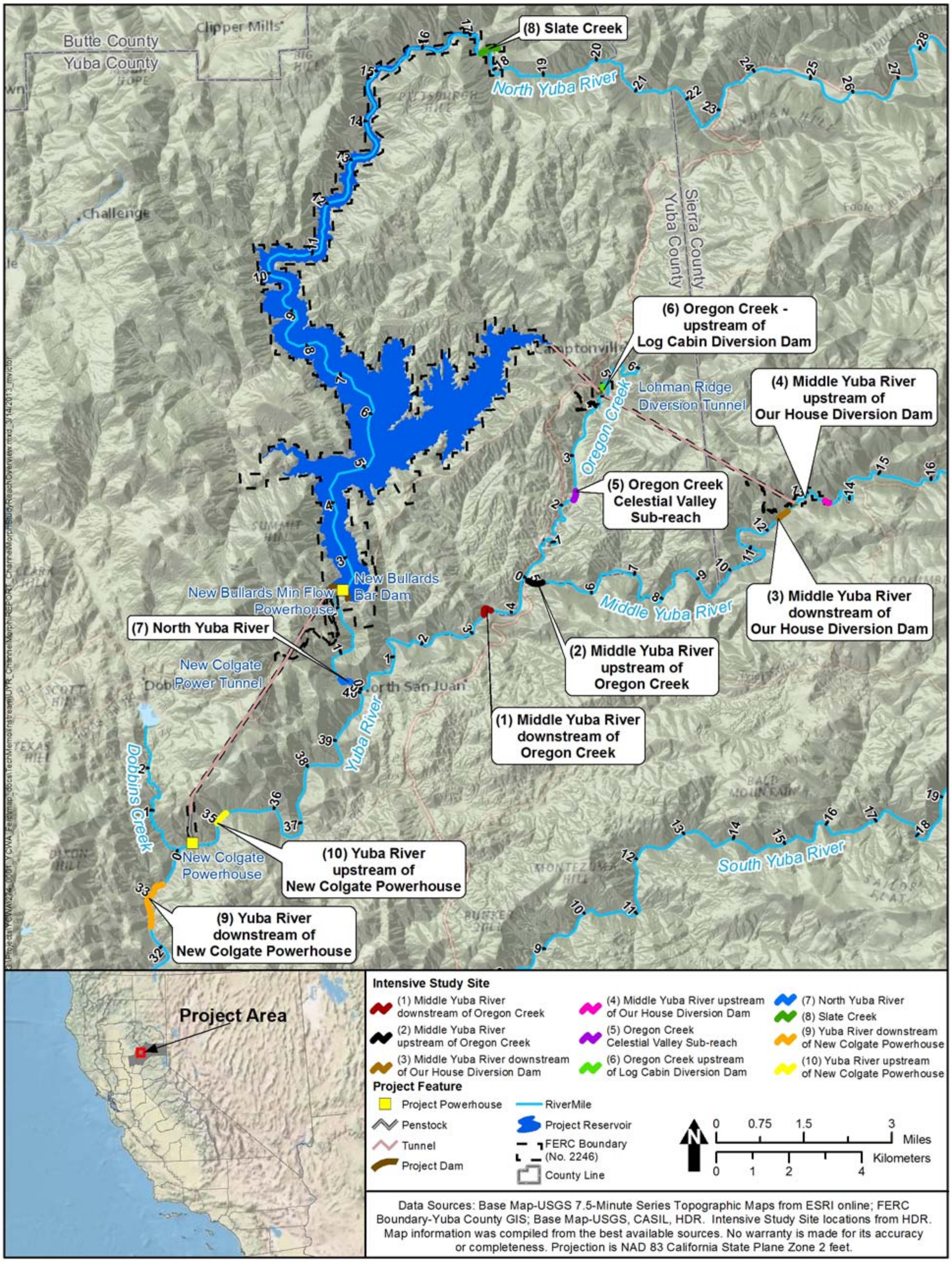
Table 2.2-1. (continued)

Stream	Reach Name	Location	Study Site Name	Study Site No.	Cross Section Numbers
INTENSIVE SITES (continued)					
Middle Yuba River (cont.)	Our House Diversion Dam Reach	Downstream of Our House Diversion Dam	Middle Yuba River downstream of Our House Diversion Dam	3	2, 4, 7
Oregon Creek	Log Cabin Diversion Dam Reach	Celestial Valley upstream of Ridge Road	Oregon Creek Celestial Valley Sub-Reach	5	8, 10, 12
North Yuba River	North Yuba River Reach	Upstream of Middle Yuba River/North Yuba River Confluence	North Yuba River	7	7, 8, 10
Yuba River	New Colgate Powerhouse Reach	Downstream of New Colgate Powerhouse	Yuba River downstream of New Colgate Powerhouse	9	1, 2, 3
	Middle Yuba/North Yuba River Confluence Reach	Upstream of New Colgate Powerhouse	Yuba River upstream of New Colgate Powerhouse	10	8, 11, 15
NON-INTENSIVE SITES[1]					
Middle Yuba River	No reach name – above Project facilities	Upstream of Our House Diversion Dam: within influence of base level control affected by Our House Diversion Dam	Middle Yuba River upstream of Our House Diversion Dam	4	1
Oregon Creek	No reach name – above Project facilities	Upstream of Log Cabin Diversion Dam: within influence of base level control affected by Log Cabin Diversion Dam	Oregon Creek upstream of Log Cabin Diversion Dam	6	1
Slate Creek	Slate Creek Reach	Within NMWSE of New Bullards Bar Reservoir	Slate Creek	8	1

[1] Sites were located to evaluate the effects of base-level control of the Project on bedload deposition. The level of analysis is limited to physical extent of bedload deposition and a “snapshot” of the channel just upstream of the influence that includes one cross section, a pebble count and a gradient. Sites were not associated with Study 3.10, *Instream Flow Study Upstream of Englebright Reservoir*.

A total of 24 cross sections were measured and analyzed in the 10 sites (Table 2.2-1).

Figure 2.2-1 shows an overview of the study area with seven intensive sites and three non-intensive sites marked by a number that corresponds to the study site number in Table 2.2-1.



Data Sources: Base Map-USGS 7.5-Minute Series Topographic Maps from ESRI online; FERC Boundary-Yuba County GIS; Base Map-USGS, CASIL, HDR. Intensive Study Site locations from HDR. Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness. Projection is NAD 83 California State Plane Zone 2 feet.

Figure 2.2-1. Study area and sites.

2.3 Data Collection

The parameters measured to determine current conditions at the intensive sites included longitudinal profiles, measurement of cross sections, site sketches, facies mapping and quantification, channel stability, and bank erosion. Data were collected at the intensive sites for a minimum length of 20-bankfull widths. Bankfull width was established using field indicators as described in Harrelson et al. (1994). The current conditions at the intensive sites were used to develop an assessment of channel and bed stability, sediment storage and mobility, and riparian interaction. Three cross sections were established at each of the intensive sites. A discharge measurement was taken to record the flow during data collection. Methods of data collection are described in Sections 2.3.1 through 2.3.15.

At the non-intensive sites, one cross section was established in which gradient and substrate sizes were measured.

In addition, YCWA evaluated channel armoring at four locations in the Middle Yuba River and one location with Oregon Creek, sediment supply evaluation at seven sediment-supply “nodes” within the Project Area,[8] input of bedload from 24 tributaries between Englebright Reservoir and Project facilities, channel storage in 10 sites in Oregon Creek and 21 sites in the Middle Yuba River, and evaluation of spill effects at Log Cabin and Our House diversion dams and at New Bullards Bar Dam.

2.3.1 Longitudinal Profile

A longitudinal profile was measured for each intensive study site, measuring at least 20 times the bankfull width unless there was a geomorphic change. Bankfull width was determined in the field using field indicators as described in Harrelson et al. (1994). An arbitrary elevation of 100 feet (ft) was assumed for the beginning of the study site. Water surface, thalweg, floodplain, and bankfull elevations were measured along the profile. Breaks in slope, such as at the base and top of riffles and at each cross section, were included as a “station” on the profile. Also included as a station was the location of each instream flow transect as established in YCWA relicensing Study 3.10, *Instream Flow Upstream of Englebright Reservoir,* if that transect was co-located within Study 1.1, *Channel Morphology Upstream of Englebright Reservoir,* study sites. Study 3.10, which evaluated the relationship between flow and fish habitat, collected transect cross-sectional data similar to data needed for this study. For Study 3.10, data are used within a suite of models (e.g., PHABSIM – Physical Habitat Simulation; Bovee 1997). Generally, a Study 1.1 intensive study site was a sub-section of a Study 3.10 site. Transects from Study 3.10 were therefore tied into the longitudinal profile when they occurred within channel geomorphology study sites.

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[8] For this relicensing, the Project Area is defined as the area within the FERC Project Boundary and the land immediately surrounding the FERC Project Boundary (i.e., within about 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.

2.3.2 Stream Cross Sections

Cross sections were selected from among the set of transects selected for Study 3.10 in most cases, but in all cases were selected within close proximity to a Study 3.10 site. Cross sections within run, riffle, and glide habitats were selected preferentially (i.e., no pool transects were selected). Cross sections were marked with headpins and tailpins (e.g., rebar, pins in bedrock) and global positioning system coordinates were recorded. All elevations were surveyed by standard differential survey techniques using an auto-level (Harrelson et al. 1994). Headpin and tailpin elevations, water surface elevations (WSEs), hydraulic controls, and above-water bed and bank elevations were surveyed. Bankfull width was determined in the field using field indicators as described in Harrelson et al. (1994). Cross section width included, at a minimum, the stage at twice the maximum bankfull depth (floodprone elevation). For the non-intensive study sites, a cross section was selected that was above the influence of backwater effects from Our House and Log Cabin diversion dams and New Bullards Bar Reservoir.

2.3.3 Stage-Discharge Relationship

The stage-discharge relationship was estimated from output of Study 3.10's PHABSIM modeling effort in the intensive sites. The model estimates discharge at up to 2.5 times the highest discharge measured during PHABSIM calibration flow measurements. The predicted modeling range for each intensive study site is provided in Table 2.3-1. This model was used to estimate discharge at bankfull and floodprone elevations; floodprone discharges were generally above measured calibration flows. PHABSIM transects included floodprone elevations.

Table 2.3-1. Predicted modeling range for PHABSIM modeling effort in intensive study sites (adapted from Table 2.5-2 of Interim Technical Memorandum 3-10, *Instream flow Above Englebright Reservoir*).

Stream	Study Site Name	Study Site No.	Predicted Modeling Range[1]	
			Lowest	Highest
Middle Yuba River	Middle Yuba River downstream of Oregon Creek	1	30	750
	Middle Yuba River upstream of Oregon Creek	2	30	750
	Middle Yuba River downstream of Our House Diversion Dam	3	30	750
Oregon Creek	Oregon Creek Celestial Valley Sub-Reach	5	8	250
North Yuba River	North Yuba River	7	40	3,125
Yuba River	Yuba River downstream of New Colgate Powerhouse	9	40	3,125
	Yuba River upstream of New Colgate Powerhouse	10	40	8,150

[1] Values are estimates only. Final model simulation extents are presented in Technical Memorandum 3-10, *Instream Flow Upstream of Englebright Reservoir*.

2.3.4 Site Map

A site map sketch was developed for each intensive site and included major features such as pools, riffles, bedrock outcrops, boulders, and sediment deposits; location of channel morphology cross sections and Study 3.10 transects; and substrate descriptions. The map was drawn to scale; (i.e., 10 square feet [sq ft] on the ground was represented by 0.04 square inch on the map).

Volume of the mobile sediment deposits was estimated using resistant boundary elements of the deposits such as bedrock or thalweg depth to estimate the depth; areal extent was measured or estimated from site maps. Depth was estimated by using the resistant boundary elements because it was not possible to probe the deposits with a metal probe due to the coarseness and depth of the material, and in some cases because the sediment was under deep water. The mobile-load grain size was defined for the purposes of this exercise as particles with D_{84} (the particle diameter where 84 percent of the particles are finer) generally less than 128 millimeters (mm), which was refined by facies mapping and whether particles can be moved easily by pushing a toe into the sediments (Wilcock et al. 2009).

2.3.5 Particle Size

Surficial substrate composition was evaluated by compiling a facies map, where the surface bed texture was delineated into relative abundance by dominant and sub-dominant grain-size classes using standard grain size divisions and names (Level I, Buffington and Montgomery 1999). Each patch of a distinct sediment unit representing a facies had a minimum size of 12 sq ft to be considered as part of the facies.

Wolman (1954) pebble counts were performed across each cross section within the intensive and non-intensive sites, and for each textural facies in the seven intensive sites. For the facies pebble counts, a minimum of 100 pebbles were measured for each facies and particles were counted from among several patches that represented the textural facies. Particles were measured using a gravel template, also known as a gravelometer (i.e., a square grain-size template), and a particle size distribution by number, not weight, was created. If particles could not be lifted to pass through the gravelometer, size class was estimated using a ruler along what was perceived as the intermediate axis (also known as the b-axis). When facies were composed of uniform sand or boulders, D_{50} (i.e., median particle size, or the particle size at which 50 percent of the particles are finer) was assumed based on the particle size (e.g., 1 millimeter [mm] for sand and 512 mm for boulders). The percentage of the reach composed of 512 mm particles or larger was estimated based on bedrock and particles greater than 512 mm from the pebble counts, as well as an estimate of the area composed of boulders and bedrock within the bankfull width as sketched within the facies map.

2.3.6 Streambank Erosion Potential

Streambank erosion potential for both left and right streambanks in the intensive sites was determined based on a “bank erosion hazard index” method developed by Rosgen (1996) that classifies reaches into categories of relative bank erosion potential (i.e., very low, low, moderate, high, very high, and extreme). Measured criteria included the ratio of streambank height to bankfull stage, ratio of riparian vegetation rooting depth to streambank height, degree of root density, bank angle, and degree of bank surface protection. Each bank type was assessed for erosion potential. Length of the bank types was measured and each type was given a percentage of the reach that it represented. Reach-averaged bank erosion potential was calculated.

2.3.7 Channel Stability

Channel stability in the intensive sites was rated using the Pfankuch (1975) method as modified by Rosgen (1996) at each cross section. The types of banks and bed at each cross section represented a percentage of the reach and the reach-averaged channel stability was calculated. For example, bedrock banks with boulder substrate were very common and one cross section was bedrock bank/boulder substrate that represented 40 percent of the reach; the channel stability rating for bedrock in this type of channel is 35. The channel stability rating for each cross section is multiplied by the percentage that is represented by that cross section (e.g., 0.4*35 = 14) and totaled for all cross sections for the reach-averaged channel stability. If there was a bank/channel type that was not represented by a selected cross section, another channel stability rating was calculated at that location, and the percentage of the total reach represented by that bank/channel type was calculated so that the entire reach was represented in the reach-averaged channel stability result.

2.3.8 Extent of Deposition Upstream of Log Cabin Diversion Dam in Oregon Creek, Our House Diversion Dam in the Middle Yuba River, and Normal Mean High Water Elevation of New Bullards Bar Reservoir in Slate Creek

At the non-intensive sites upstream of Our House and Log Cabin diversion dams, the area of deposition due to backwater effects was measured by examining the channel and deposits upstream of the dams, using evidence of bedrock exposure in the bed and steeper gradient that indicated the channel was above the deposit line to determine the upstream extent. At the non-intensive site at Slate Creek, the area of deposition assumed to be associated with New Bullards Bar Reservoir's NMWSE was evaluated by surveying a longitudinal profile from the existing water surface, which was a known assumed elevation based on New Bullards Bar Reservoir WSE on the day of the survey, to above the upstream extent of a backwater deposit. Within this longitudinal profile, evidence for deposition related to backwater effects from high flows in Slate Creek and North Yuba River combined with a high reservoir WSE was investigated by tracing the maximum elevation of a deposit at the confluence of Slate Creek with the North Yuba River upstream until this elevation was exceeded. Additionally, the deposit was traced upstream to see where evidence of a backwater deposit disappeared.

Also measured were a cross section, characterization of the substrate with a Wolman pebble count along the cross section, and photographs at a location just upstream of the influence. While measuring the cross section, the gradient of the channel from upstream to downstream of the cross section was also measured.

2.3.9 Bed Armoring

Bed armoring was measured at four sites in the Middle Yuba River and one site in Oregon Creek (Figure 2.3-1): 1) Middle Yuba River below Our House Diversion Dam (Site 3); 2) Middle Yuba River above Oregon Creek (Site 2); 3) Middle Yuba River below Oregon Creek (Site 1); 4) Middle Yuba River above the North Yuba River confluence; and 5) Oregon Creek in Celestial Valley (Site 5). All but the Middle Yuba River above the North Yuba River confluence were within the intensive study sites. A total of three 4-sq-ft-area samples were taken from exposed bars within each of four channel armoring sites, with the exception of the Middle Yuba River upstream of Oregon Creek. Due to intensive mining and recreation activity and very limited exposed bars, only two bars conducive to sampling were found at the Middle Yuba River upstream of Oregon Creek site, though the entire reach was reviewed from the confluence of Oregon Creek to over 500 ft upstream of the intensive site.

Surface particles were removed to the depth of the largest particle that was part of the surface layer yet embedded into the substrate. All the surface particles larger than 31.5 mm (i.e., the size of openings of a field sieve used to separate the field-measured versus the sieved samples) were passed through a gravel template with 14 square holes of 0.5 phi-unit classes ranging from 2 mm to 180 mm. Particles larger than 180 mm were measured along the b-axis of the particle with a ruler and placed into a size-finer-fraction class through which it passed (e.g., a 296 mm boulder would pass a 362 mm hole but be retained on the 256 mm hole, so the boulder was considered part of the 362 mm class). Particles less than 32 mm were thoroughly mixed and a sub-sample was placed into a sample bag for off-site sieve analysis; total weight and sample weight were then recorded. When all the surface particles had been removed, counted, measured and weighed, the sub-surface particles were excavated to a depth equal to the depth removed for the surface particles. Particles were separated, weighed and bagged using the method described above for the surface samples. Field and lab data were combined for a particle distribution by weight for the surface and sub-surface particles.

2.3.10 Sediment Mobility

The cross section and long profile data from 21 transects in the intensive sites were used to evaluate discharges that mobilize particles composing the channel bed. Table 2.2-1 lists the cross sections evaluated at each intensive site. In addition, flows under the With-Project and Without-Project conditions were used to assess how Project operations have affected the frequency of bed- and particle-mobilizing flows and bedload transport capacity; methods are provided in Section 2.3.10.1.

2.3.10.1 Bedload Transport

Individual particle mobility was estimated for several particle sizes at each intensive site and at each transect. The particles evaluated included gravel and cobble sizes 2, 4, 8, 16, 32, 64, and 128 mm (Wentworth Scale, p. 20 Vanoni [ed.] 1975), and the D_{16} (i.e., fine particles, or the particle diameter where 16 percent of the particles are finer), D_{50} (i.e., median-size particles), and D_{84} (i.e., coarse particles, or the particle diameter where 84 percent of the particles are finer) for each cross section. The critical Shields number (τ^*c) for each of the particle sizes were estimated using the formula (Guo 2002):

$d^* = [(G-1)g/\upsilon 2](1/3) * d_s$ and $\tau^*c = 0.23/ d^* + 0.054[1-\exp\{-(d^*)0.85/23\}]$

where d^* = dimensionless sediment diameter, G = specific gravity of sediment (25789.8 N/m^3), g = gravity (9.81 meter (m)/s^2), and υ = kinematic viscosity of water (1.42E-06 square meters/sec). Assumed water temperature of 45 degrees F (°F).

There were no dimensionless particle diameters less than 1, so the correction for the inaccuracies of the calculation of these values (Guo 2002) was not necessary.

Channel shear stress must exceed critical shear stress calculated for each particle for incipient motion to occur. Incipient motion is the point at which particles are just beginning to mobilize. A shear stress/stage relationship was developed for each cross section by WinXSPro, a cross section analyzer program developed by the Forest Service (Forest Service; Hardy et al. 2005). For this analysis, the hydraulic radius at which the calculated cross-sectional shear stress exceeds estimated critical shear stress for the D_{50} of that cross section is considered a “critical” stage. This critical stage analysis assumes that the bed is composed entirely of particles the size of the D_{50} and does not accommodate mixed-grain sizes that occur on most cross sections. However, this critical stage, and estimates of discharge associated with this stage (i.e., “incipient motion analysis”), may be useful as an indicator as to when bedload discharge becomes “meaningful.” The incipient motion analysis is an estimate of when movement occurs; in some cases movement was occurring even at the lowest flows, which is unlikely because these were flows that were viewed and no motion was occurring. Additionally, to calculate channel shear, a slope must be input to WinXSPro. The local water surface slope at the cross section (e.g., top and bottom of a run in which the cross section was located) was used as a low-flow slope, and the reach-averaged slope was used as a maximum slope. For example, the local slope at a cross section was 0.003 and was used as the low-flow slope, whereas the slope from the top of the intensive site to the bottom of the site was 0.015, and this reach slope was used as the high flow slope because it matches the bankfull and floodprone slopes.

Once the “critical” stage was estimated, the bedload at that stage was estimated using output from the Bedload Assessment in Gravel-Bedded Streams (BAGS) model (Wilcock et al. 2009; Pitlick et al. 2009). The BAGS model provides an estimate of discharge, then an equation that relates discharge to sediment discharge. Input into the BAGS model was adjusted to ensure that the predicted bankfull discharge was approximately equal to a known discharge (i.e., instream flow high flow measurement). The input of ‘n’ for the main channel to the BAGS program was used to represent roughness elements such as very large particles and converging or diverging flow. This value was often greater than that commonly used for open-channel flow (Barnes 1967; Arcement and Schneider 1984) but was adjusted until the predicted discharge at a moderate flow (assumed bankfull) matched the measured flow. The output of the model included a hydraulic radius/discharge relationship, and a discharge/bedload transport in tons/day relationship. The critical stage in the form of hydraulic radius was used to estimate a critical discharge. Then, the critical discharge/bedload transport relationship provided by BAGS, an equation that is generally a power function, was used with the average daily discharge records from Water Year (WY) 1970 through 2010 for the With-Project and Without-Project hydrology to determine the bedload discharge on each day the critical discharge was exceeded. The daily bedload transport was totaled for the period of record and divided by 42 years for an average annual bedload transport capacity under With-Project and Without-Project conditions.

For example, if the D_{50} of a cross section was 64 mm, the critical shear stress of that particle was calculated to be 55 N/m^3. This critical shear stress was exceeded when the hydraulic radius was 2.2 ft, which corresponds to a discharge of approximately 600 cubic feet per second (cfs). The With-Project hydrology data includes 14 days where the average daily flow exceeded the critical discharge. Bedload transport for those days was estimated using the discharge/bedload relationship calculated in the BAGS model and summed to total bedload transport over the period of record. This amount was divided by 42 years to estimate an annual bedload transport capacity. This same process was employed using Without-Project hydrology to provide a comparison between With-Project and Without-Project bedload transport capacity. The estimates of annual bedload transport capacity for each three cross section values were averaged for an annual bedload yield estimate by site.

Because of the uncertainty of the transport capacity estimates, a Monte Carlo simulation was performed on the estimates of critical discharge (i.e., the discharge at which "meaningful" movement occurs). Due to uncertainty in Manning's n, critical Shields Number and grain size, a distribution of values was specified to give an estimate of the range within which the true value lies. For Manning's n, a range of values was given based on the n values estimated using WSP 2339, n values used in BAGS to estimate a bankfull flow that matched field estimates, and n values used in WinXSPro at high and low flow. The range of Shield's numbers used a range from 0.03 to 0.054. The grain size used a range of the particles found within each site and determined to be part of the mobile, or transport, load based on location within the channel, size of the material, and evidence of movement. The Monte Carlo simulation program used was provided on a DVD from a short course (Sagehen 2009).

2.3.10.2 Tracer Particles

Tracer particles were placed across transects at two sites: 1) Middle Yuba River (Site 1, Middle Yuba River downstream of Oregon Creek); and 2) Oregon Creek (Site 5, Oregon Creek Celestial Valley Sub-Reach). Within each site, only two of the three channel morphology transects were conducive to tracer particle placement because there were local conditions of significant roughness elements, converging flow, or diverging flow that would influence movement. The particles were placed in the channel in May 2012 within the Oregon Creek site in anticipation of a discrete event that could mobilize particles. Since instream flow measurements had not been completed, the tracer particles were placed just downstream of Study 3.10 Transects 10 and 12 so as not to affect the instream flow measurements. Particles that included the D_{16} through the D_{84} (Table 2.3-2) were selected from quartz particles from the Bear River that did not match the color of existing particles and were painted colors based on size classes so as to provide clear separation of existing substrate. Tracer particles replaced native particles of similar size and were pressed into the substrate to mimic natural vertical location in the bed. Tracer particles were placed across the newly established cross sections (i.e., located with rebar staking on both banks) just downstream of the existing cross sections and the vertical location of each particle was noted. The location and size of each placed particle was recorded. Photographs were taken of each cross section after placement. Rocks were checked prior to fall storm events, and nine rocks were replaced due to slight movement. This movement was believed to be due to human influence rather than related to flow, as flow never exceeded 10 cfs at those sites.

Table 2.3-2. Cross section used in tracer particle study and particle sizes encompassed by tracer particles.

Study Site Name	Study Site Number	Cross Section Number	Particle Size (mm)		
			D_{16}	D_{50}	D_{84}
Middle Yuba River downstream of Oregon Creek	1	9	20	129	341
		13	14	70	514
Oregon Creek Celestial Valley Sub-Reach	5	8	3	54	244
		10	3	58	201

Tracer particles were placed on cross sections 9 and 13 in the Middle Yuba River in September 2012 using rocks available on-site and also painted colors based on size class. The location and size of each placed particle was recorded. Photographs were taken of each cross section after placement.

Following a flood event the first week of December of 2012 that was approximately 637 cfs in Oregon Creek and 8,500 cfs in the Middle Yuba River, rocks at both sites were evaluated and measurements were taken on December 10. The estimated peak instantaneous discharge for the flood event was developed by adding peak 15-minute historically-measured flows for December 2, 2012 for the Middle Yuba River below Our House Diversion Dam and Oregon Creek below Log Cabin Diversion Dam to synthetic accretions developed using methodology consistent with other accretion synthesis, based on the peak historically-measured 15-minute flows on Oregon Creek.

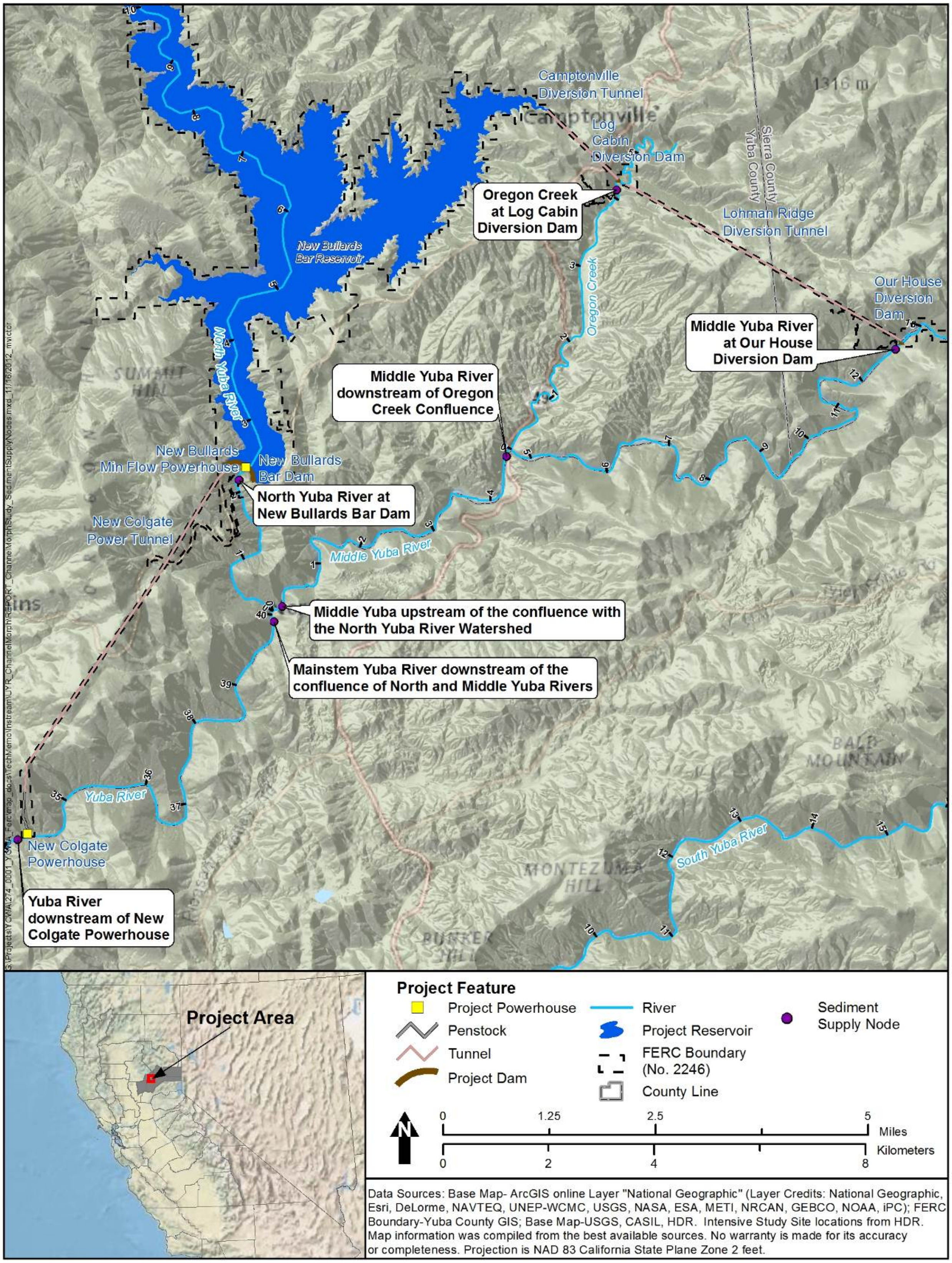
2.3.11 Sediment Supply

Sediment supply was estimated using regional estimates. As part of the California Bay-Delta Authority Upper Yuba River Studies Program, sediment yields in the Yuba River basin were estimated to be between 160 and 340 tonnes/square kilometer/year (Snyder et al. 2004) based on an estimated accumulation rate behind Englebright Dam. It was agreed among Relicensing Participants to use the average of 250 tonnes/square kilometer/year (713 tons/square mile (mi^2)/year) to estimate a total sediment yield at seven sediment supply nodes (the current drainage area is assumed to be zero upstream of each node) (With-Project) compared to the drainage area above the dam (Without-Project) (Figure 2.3-1). These sediment supply nodes include:

- North Yuba River at New Bullards Bar Dam
- Oregon Creek at Log Cabin Diversion Dam
- Middle Yuba River at Our House Diversion Dam, excluding drainage area above Nevada Irrigation District’s Milton Diversion Dam in the upper watershed
- Middle Yuba River downstream of the Oregon Creek confluence, excluding drainage area above Nevada Irrigation District’s Milton Diversion Dam in the upper watershed
- Middle Yuba River upstream of the confluence with North Yuba River, excluding drainage area above Nevada Irrigation District’s Milton Diversion Dam in the upper watershed

- Mainstem Yuba River downstream of the confluence of North Yuba and Middle Yuba rivers
- Yuba River downstream of New Colgate Powerhouse

Bedload was estimated to be 15 percent of the total sediment yield, based on a typical bedload range of 10 to 20 percent for the region (CDWR 2004; Snyder et al. 2004).



Data Sources: Base Map- ArcGIS online Layer "National Geographic" (Layer Credits: National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC); FERC Boundary-Yuba County GIS; Base Map-USGS, CASIL, HDR. Intensive Study Site locations from HDR. Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness. Projection is NAD 83 California State Plane Zone 2 feet.

Figure 2.3-1. Sediment supply nodes.

2.3.12 Input of Bedload from Tributaries

The aerial video of the Project and Project-affected reaches (YCWA 2009a), ArcGIS® Explorer (ESRI® 1999-2011), Google Earth®, and topographic maps were visually examined to assess if there were any indications of bedload additions. First, United States Geological Survey 1:24000 topographic maps from Terrain Navigator Pro (Ver. 9.1; software available from www.mytopo.com, a Trimble company) were used to indicate if a tributary existed as indicated by blue lines representing water courses. To evaluate potential bedload input from tributaries, the aerial photos from ArcGIS and Google Earth were used to determine if there was evidence of mass wasting on the hillslopes with a surface connection to the tributary, debris tracks through the tributary, and existence of alluvial fans and/or deposits in the channel at or near the tributary confluence. Occasionally, the video and maps were used to estimate volume of sediment deposited in an inaccessible reach; estimates of length and width were based on the geo-referenced photograph, but depth was estimated based on depth at similar sites and deposit character. Table 2.3-3 and Figure 2.3-2 show tributaries that were evaluated as potential contributors of bedload to the mainstem, and characteristics of those tributaries.

Table 2.3-3. Summary of potential tributary bedload input locations, accessibility, whether site can reasonably be accessed, the geology, and probable fate of the added material.

Drainage	Tributary	RM/Bank	Accessibility	Aerial Video Time Signature	Field Check?	Geology	Fate	Comments
Yuba River	Above Rice's Crossing	32.9/lba	From Yuba River	0:28:38	Yes	gb	Deep pool at confluence	No obvious fan or deposit
	French Ravine	33.1/lba	From Yuba River	0:29:09	Yes	gb	French Bar	No obvious fan but distinctive long-term bar; no obvious scour
	Unnamed 1	33.8/rba	Walk d/s from New Colgate PH	0:29:56	No	--	None	No evidence of fan or scour
	Dobbins Creek	33.9/lba	Walk d/s from New Colgate PH	0:30:08	Yes	gb, db	Condemned Bar	Condemned Bar may be result of long-term delivery from tributary
	Unnamed 2	34.6/rba	Walk u/s from New Colgate PH; begins below powerline road (se ESRI)	0:31:16	Yes	gb	May be boulder fan in Yuba River, but check mouth	May be failure off powerline road; 1,820' long x 70' wide
	Unnamed 3	35.1/lba	No	0:32:21	No	--	--	No evidence of fan or scour
	Unnamed 4	35.5/lba	No	0:32:30	No	--	--	No evidence of fan or scour
	Unnamed 5	36.75/rba	No	0:33:35	No	confluence qd & mv	Deposit near mouth but also above bedrock pinch point	No evidence of scour or failure in tributary
	Sweetland Diggings	37.0/rba	Yes, from top from Diggings	0:33:43	Yes (top)	qd, mining tailings	Cobble bar (but u/s of bedrock pinch, so may just be a deposition location)	May be a scour track from diggings to river but difficult to trace under veg. 2,590' long x 20' wide
	Unnamed 6	37.9/lba	No	0:35:55	No	mv	Rock fall may contribute thin veneer of coarse debris piled on channel margin	--
	Chute Ravine	38.1/lba	No	0:36:10	No	--	--	No evidence of fan or scour
	Sweetland Creek	38.6/rba	No	0:36:47	No	--	--	No evidence of fan or scour
North Yuba River	Quarry Tailings	0.8/lba	Tailings downslope off Marysville Road	0:40:02	Yes (top)	mv	Concave slope appears to be tailings failure. 1,530' from base of exposed tailings "failure" to North Yuba River Fan of coarse and fine sediment in high water mark of North Yuba River and bar building	Size of material difficult to say but appears to be residual material in fan near North Yuba River
Middle Yuba River	Sebastopol	0.7/rba	Yes at top from town of Sebastopol	1:44:24	Yes (top)	Big Bend/Wolf Creek fault; mining tailings; confluence of mv and Jgr	Coarse and fine material in main channel and built up on bar downstream of tributary confluence	May have been sluiced material from Sebastopol diggings to Middle Yuba River

Table 2.3-3. (continued)

Drainage	Tributary	RM/Bank	Accessibility	Aerial Video Time Signature	Field Check?	Geology	Fate	Comments
Middle Yuba River (continued)	Yellowjacket Creek/Mary's Ravine	1.4/lba	Yes - road but gated. Must obtain permission.	1:44:24	Maybe	Big Bend/Wolf Creek fault; mining tailings; confluence of mv and Jgr	Unclear if there is a deposit nor if there is scour of ravine	Minimal or minor fan - difficult to say.
	Unnamed 7	1.6/lba	no	1:48:12	No	--	--	No evidence of fan or scour
	Unnamed 8	1.7/lba	no	1:48:38	No	--	--	No evidence of fan or scour
	Clear Creek	3.0/rba	Road from ridge but may be gated	1:49:15	Maybe	Jgr	Large bar in river downstream of tributary	Unclear if tributary scoured
	Moonshine Creek	3.0/lba	Yes from campground (PHABSIM and Geo site)	1:50:18	Yes	Jgr	Deposit near mouth but also above confluence downstream of heavy recreational use and mining - unclear if from tributary	--
	Oregon Creek	4.7/lba	Yes from Hwy 49	1:53:03	Yes	Jgr and MzPz	Slight sediment fan at mouth	Oregon Creek is major tributary and has its own analysis
	Studhorse Canyon and Nevada Creek	6.9/lba	No due to private gate and potential marijuana grow site.	1:57:47	No	Jgr	Depositional area and may be fan but area is so wide and brush covered, it is difficult to say	No obvious scour from Nevada Creek or adjacent unnamed tributary - low likelihood of significant and recent sediment additions
	Unnamed 9	9.1/lba	No	2:02:31	No	MzPz	--	Appears from ESRI that there could be a fan but there is no evidence in the aerial video of a fan that impinges on the creek. There is no evidence of scour of the tributary from ESRI.
	Grizzly Creek	9.4/rba	No	2:03:00	No	MzPz, mining tailings	There is sand and gravel at the mouth of the tributary and a bar deposition in the mainstem from a sharp bend. It is not an obvious debris fan, and may just be deposition due to backwater effects from the downstream bend.	No evidence from ESRI of scour of tributary and little evidence from the aerial video of a fan. There are mining tailings and diggings at the head of the watershed, which makes it suspect, but there is no evidence of recent coarse sediment input to the Middle Yuba River.
	Unnamed10	11.7/lba	No	2:08:27	No	Jdi	Bedrock at mouth; no evidence of fan	No evidence of fan or scour, though there are lateral and point bars composed of cobble and finer material both upstream and downstream of tributary

Key: lba - left bank ascending; rba – right bank ascending; db –massive diabase; gb – gabbro; qd – quartz diorite and tonalite; Jdi – diorite; Jgr – Yuba River Pluton; mv – metavolcanic; MzPz – Mesozoic and Paleozoic rocks, undifferentiated.

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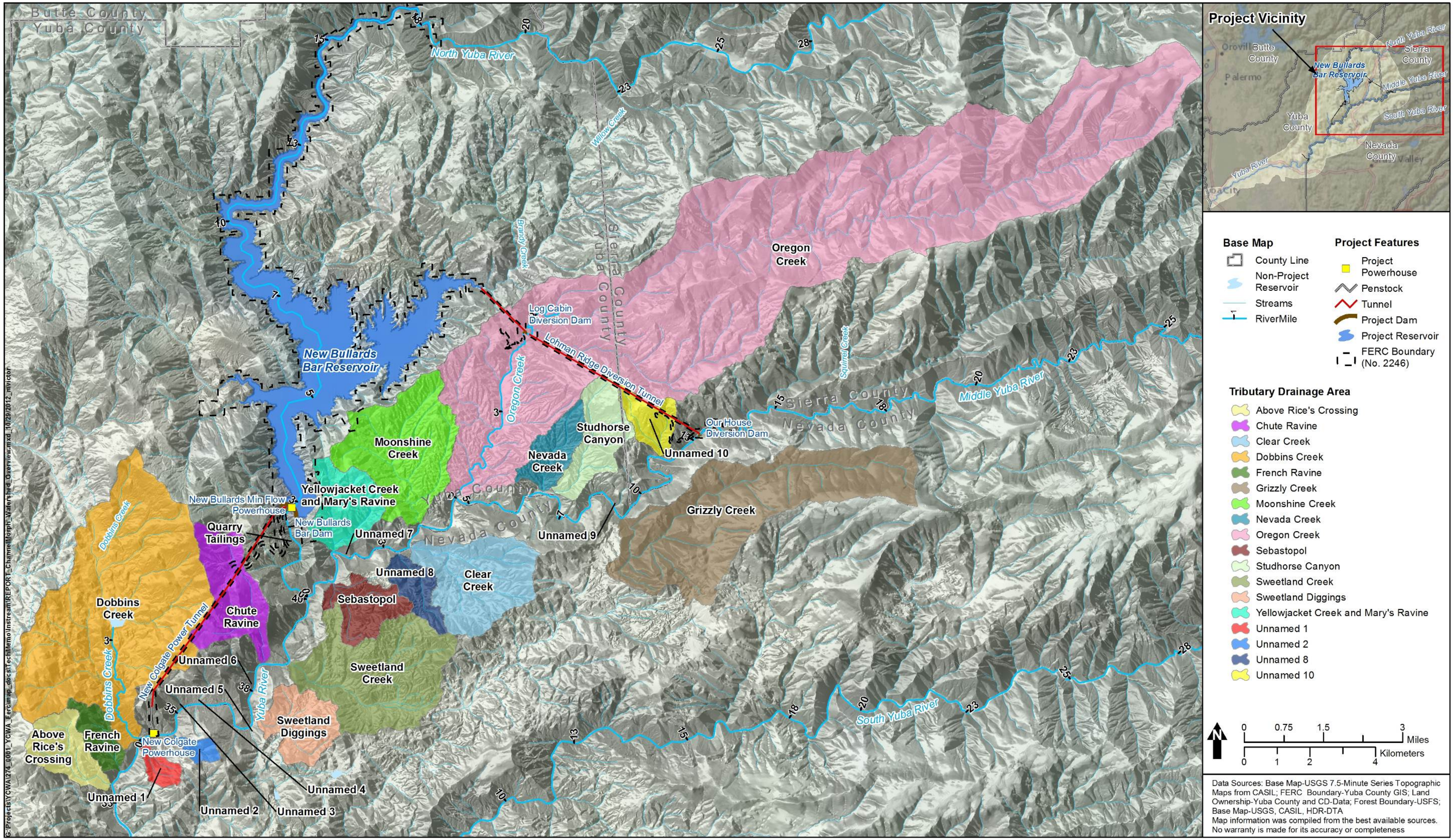

Data Sources: Base Map-USGS 7.5-Minute Series Topographic Maps from CASIL; FERC Boundary-Yuba County GIS; Land Ownership-Yuba County and CD-Data; Forest Boundary-USFS; Base Map-USGS, CASIL, HDR-DTA
Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness

Figure 2.3-2. Tributaries analyzed for potential sediment input to the Middle Yuba, North Yuba and mainstem Yuba rivers.

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2.3.13 Channel Storage of Sediment

Channel storage of sediment was evaluated at accessible locations at 21 sites on the Middle Yuba River and 10 sites on Oregon Creek (Figure 2.3-3). Storage elements generally included channel bars, floodplains, and terraces and were composed of alluvially-derived sediment. The volume of coarse sediment was assessed at locations as set out in Table 2.3-4 for a distance of about 325 feet. Sites did not overlap. As a target, the locations began and ended at a similar unit (e.g., the top of a riffle at the bottom and top of the evaluation location). The volume of channel storage above the thalweg was measured by measuring the length, width, and depth of coarse sediment storage. Storage elements were sorted into active, semi-active, inactive, and stable as set forth in Curtis et al. (2005a) and defined in Table 2.3-5.

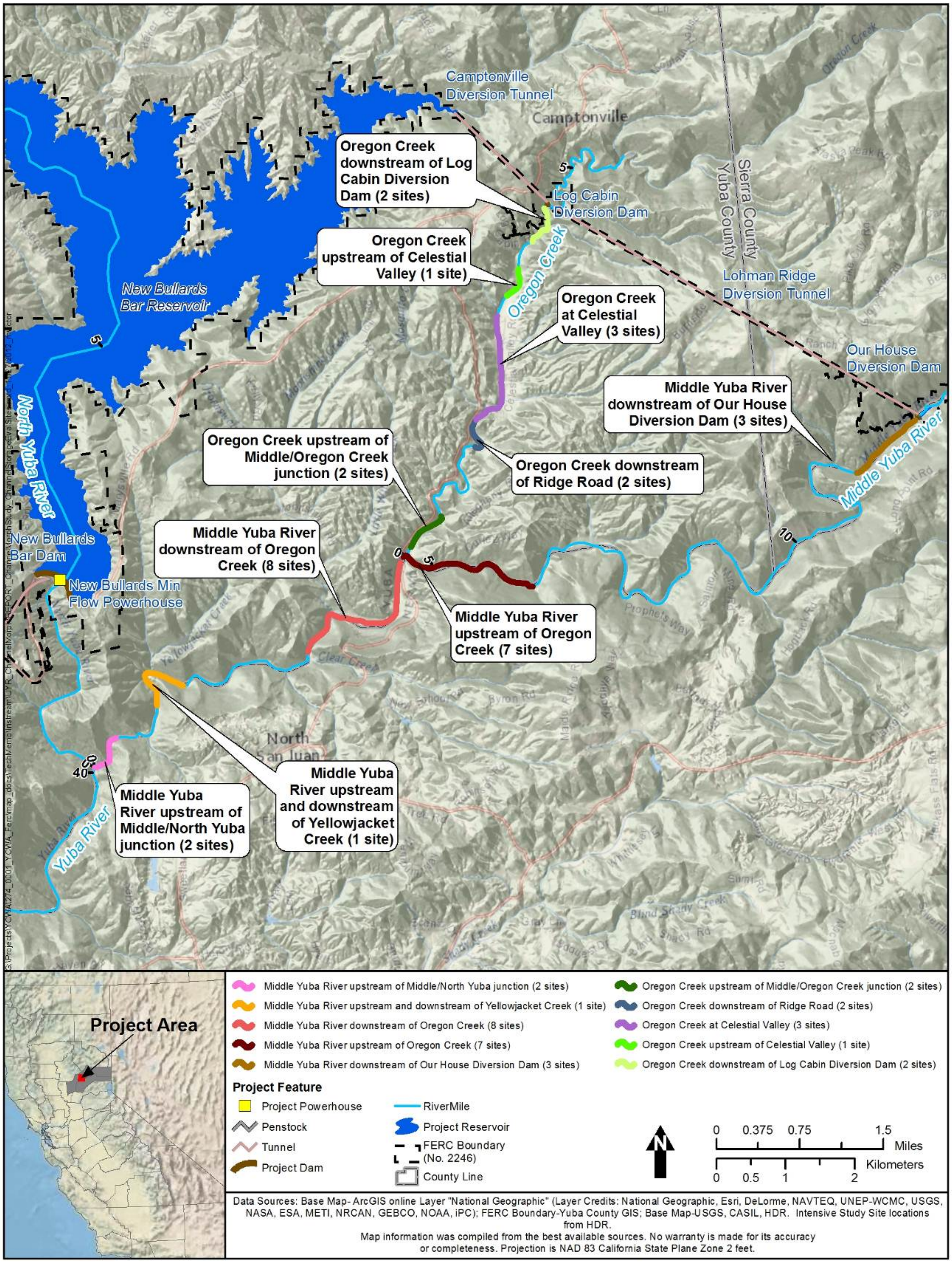
Table 2.3-4. Channel storage evaluation locations (upper and lower limit of accessibility) and number of sites evaluated at each location.

River	Location	Channel Storage Evaluation Access (River Mile)		CS - Number of Sites Evaluated (325 ft/site)
		Base	Top	
Middle Yuba River	Upstream of Middle Yuba River/ North Yuba River confluence	0	0.4	2
	Above and below Yellowjacket Creek	1	1.7	1
	Middle Yuba River downstream of Oregon Creek	3.1	4.5	8
	Middle Yuba River upstream of Oregon Creek	4.65	6	7
	Middle Yuba River downstream of Our House Diversion Dam	11.9	12.6	3
Total Middle Yuba River Sites		--	--	**21**
Oregon Creek	Celestial Valley	1.92	3	3
	Log Cabin - Lower above confluence with Middle Yuba River	0.1	0.5	2
	Log Cabin - Lower below Ridge Road	1.6	1.9	2
	Log Cabin - Upper above Celestial Valley	3.2	3.5	1
	Log Cabin - Upper below Log Cabin Dam	3.8	4.2	2
Total Oregon Creek Sites		--	--	**10**

Table 2.3-5. Storage element stability classes.

Stability Class	Description
Active	Moves at least once every few years.
Semi-Active	Susceptible to re-vegetation and moved every 5-20 years.
Inactive	Moves only during extreme events every 20-100 years and becomes well-vegetated in the interim.
Stable	Deposits are not accumulating under present climate or channel regime but may be susceptible to cutbank erosion.

Source: Curtis et al. 2005a



Data Sources: Base Map- ArcGIS online Layer "National Geographic" (Layer Credits: National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC); FERC Boundary-Yuba County GIS; Base Map-USGS, CASIL, HDR. Intensive Study Site locations from HDR.
Map information was compiled from the best available sources. No warranty is made for its accuracy or completeness. Projection is NAD 83 California State Plane Zone 2 feet.

Figure 2.3-3. Channel storage evaluation sites.

2.3.14 Effects of Uncontrolled Spill over Project Dams on Sediment Particle Size and Composition, and Flow Released from New Colgate Powerhouse

The historic occurrence and magnitude of spill events during the period from WY 1970 through WY 2012 were summarized for New Bullards Bar Dam, and for Our House and Log Cabin diversion dams. The fate and distribution of sediment eroded from the New Bullards Bar Dam spill channel and/or spill transported over the passive-spill diversion dams were evaluated. There is only one "spill channel" at New Bullards Bar Dam, but both Our House and Log Cabin diversion dams spill over the dams.

The streambanks downstream of the New Colgate Powerhouse were visually evaluated for signs of erosion. Erosion, scour and deposition were evaluated within the context of releases from New Colgate Powerhouse.

2.3.15 Coordination with YCWA's Study 6.1, *Riparian Habitat Upstream of Englebright Reservoir*

In the intensive sites, riparian transects were established at each of the cross section locations. Historical data (i.e., available historical air photos and anecdotal information) were compiled, and riparian vegetation communities were assessed as specified in Study 6.1, *Riparian Habitat Upstream of Englebright Reservoir*. To assess frequency of inundation of various near-channel surfaces (i.e., bankfull and floodprone), the stage-discharge relationship was estimated from Study 3.10, in combination with synthetic annual maximum mean daily data flow frequency curves for the With-Project hydrology conditions and the Without-Project hydrology conditions (Table 2.3-6). Hydrology data are included in Attachment 2-2F to Technical Memorandum 2-2, *Water Balance/Operation Model*. The methodology for performing the flood frequency analysis is described in the Technical Memorandum 2-1, *Hydrologic Alterations*.

Table 2.3-6. Return period, probability of occurrence and peak flow estimates With- and Without-Project conditions.

Study Site Name/ Study Site No.	Return Period (Years)	Probability	Peak Flow With-Project (cfs)	Peak Flow Without-Project (cfs)
Middle Yuba downstream of Oregon Creek (Site 1)	1.005	0.995	91	575
	1.01	0.99	131	694
	1.053	0.95	345	1,178
	1.111	0.9	571	1,577
	1.25	0.8	1,038	2,264
	1.5	0.6667	1,791	3,201
	2	0.5	3,131	4,647
	2.33	0.4292	3,931	5,437
	5	0.2	8,980	9,891
	10	0.1	15,280	14,900
	25	0.04	26,520	23,310
	50	0.02	37,590	31,330
	100	0.01	51,150	41,040
	200	0.005	67,520	52,720
	500	0.002	94,010	71,750

Table 2.3-6. (continued)

Study Site Name/ Study Site No.	Return Period (Years)	Probability	Peak Flow With-Project (cfs)	Peak Flow Without-Project (cfs)
Middle Yuba upstream of Oregon Creek (Site 2)	1.005	0.995	65	425
	1.01	0.99	93	512
	1.053	0.95	245	867
	1.111	0.9	407	1,163
	1.25	0.8	744	1,675
	1.5	0.6667	1,296	2,382
	2	0.5	2,294	3,485
	2.33	0.4292	2,899	4,094
	5	0.2	6,811	7,589
	10	0.1	11,850	11,610
	25	0.04	21,160	18,530
	50	0.02	30,600	25,270
	100	0.01	42,450	33,580
	200	0.005	57,100	43,740
	500	0.002	81,430	60,610
Middle Yuba downstream of Our House Diversion Dam (Site 3)	1.005	0.995	18	354
	1.01	0.99	30	427
	1.053	0.95	107	726
	1.111	0.9	206	977
	1.25	0.8	439	1,416
	1.5	0.6667	868	2,026
	2	0.5	1,726	2,986
	2.33	0.4292	2,275	3,521
	5	0.2	6,092	6,622
	10	0.1	11,310	10,250
	25	0.04	21,210	16,580
	50	0.02	31,330	22,820
	100	0.01	44,010	30,600
	200	0.005	59,550	40,210
	500	0.002	84,940	56,340
Oregon Creek Celestial Valley Sub-Reach (Site 5)	1.005	0.995	4	106.3
	1.01	0.99	7	132
	1.053	0.95	32	238
	1.111	0.9	66	325.6
	1.25	0.8	148	475.3
	1.5	0.6667	300	676
	2	0.5	599	977.2
	2.33	0.4292	786	1,138
	5	0.2	2,007	2,002
	10	0.1	3,517	2,907
	25	0.04	6,083	4,324
	50	0.02	8,435	5,584
	100	0.01	11,120	7,025
	200	0.005	14,130	8,665
	500	0.002	18,540	11,170
North Yuba River (Site 7)	1.005	0.995	0	1,567
	1.01	0.99	0.1	1,889
	1.053	0.95	0.7	3,189
	1.111	0.9	2.7	4,254
	1.25	0.8	14.3	6,080
	1.5	0.6667	67.7	8,555
	2	0.5	348.7	12,350
	2.33	0.4292	689.5	14,410
	5	0.2	8,830	25,930
	10	0.1	48,570	38,750
	25	0.04	302,700	60,100
	50	0.02	993,400	80,250
	100	0.01	2,906,000	104,500
	200	0.005	7,788,000	133,500
	500	0.002	25,840,000	180,400

Table 2.3-6. (continued)

Study Site Name/ Study Site No.	Return Period (Years)	Probability	Peak Flow With-Project (cfs)	Peak Flow Without-Project (cfs)
Yuba River downstream of New Colgate Powerhouse (Site 9)	1.005	0.995	391	2,162
	1.01	0.99	515	2,618
	1.053	0.95	1,123	4,473
	1.111	0.9	1,720	5,998
	1.25	0.8	2,915	8,620
	1.5	0.6667	4,825	12,180
	2	0.5	8,283	17,650
	2.33	0.4292	10,400	20,620
	5	0.2	24,650	37,240
	10	0.1	44,420	55,690
	25	0.04	84,420	86,340
	50	0.02	128,800	115,200
	100	0.01	189,500	149,800
	200	0.005	270,800	191,200
	500	0.002	420,000	257,700
Yuba River upstream of New Colgate Powerhouse (Site 10)	1.005	0.995	125	2,163
	1.01	0.99	179	2,618
	1.053	0.95	481	4,473
	1.111	0.9	821	5,998
	1.25	0.8	1,580	8,620
	1.5	0.6667	2,933	12,180
	2	0.5	5,651	17,650
	2.33	0.4292	7,431	20,620
	5	0.2	20,810	37,240
	10	0.1	41,600	55,690
	25	0.04	87,890	86,350
	50	0.02	143,200	115,200
	100	0.01	222,800	149,900
	200	0.005	334,900	191,200
	500	0.002	550,700	257,800

While the preferred method of performing flood frequency analysis requires historical instantaneous peak flow data, historical instantaneous peak flow data were not available for the study locations. Therefore, synthetic annual maximum mean daily data were used. Synthesis of peak flow for each of the seven channel morphology/riparian intensive study sites was performed by aggregating flow data and accretions developed as part of Technical Memorandum 2-2, *Water Balance/Operation Model*, hydrology development, as described in Attachment 2-2D and included in Attachment 2-2F for each location. The flood frequency analysis for these seven sites was not conducted as part of the Hydrologic Alteration study, but was conducted using the same methodology as was described in Section 2.5.1 of Technical Memorandum 2-1, *Hydrologic Alteration*.

3.0 Results

3.1 Channel Characteristics at Study Sites

Data were collected at the seven intensive sites and the three non-intensive sites. The physical data collected at each site are summarized in Table 3.1-1. Field data sheets collected for site longitudinal profiles, transect cross sections, site/facies maps, and particle size measurements are included in Attachment 1-1A. Plotted transect cross sections and site longitudinal profiles are included in Attachment 1-1B. Photographs of each transect are included in Attachment 1-1C.

Particle size distribution graphs are included in Attachment 1-1D. Maps of each of the intensive and non-intensive sites are included in Attachment 1-1E.

Table 3.1-1. Summary of data collected at the seven intensive sites (Sites 1, 2, 3, 5, 7, 9 and 10) and three non-intensive sites (Sites 4, 6 and 8).

Study Site Name	Study Site Number	Discharge (cfs)	Entrenchment Ratio	Bankfull Width (ft)	Floodprone Width (ft)	Width: Depth	% Slope			Reach-Average D_{50} (mm)	Mobile (D_{84} <128 mm) (m^3/m)	Bedrock/ Large Boulder (%)	Armoring Ratio	Pfankuch Channel Stability Rating	Bank Erosion Hazard	Exposed Bars	
							Water Surface	Bankfull	Floodprone							D_{50s} (mm)	D_{50ss} (mm)
Middle Yuba River downstream of Oregon Creek	1	40	1.7	72	120	28	1.3	1.4	1.5	120	6.9	5	5.4	61/good	9/very low	119	29
Middle Yuba River upstream of Oregon Creek	2	33	1.8	60	138	31	1.3	1.3	1.4	241	2.1	31	2.7	53/good	6/very low	83	33
Middle Yuba River downstream of Our House Diversion Dam	3	54	1.4	73	106	35	2.5	2.5	2.6	187	2.3	26	1.9	49/good	9/very low	6	3
Middle Yuba River upstream of Our House Diversion Dam	4	--	1.7	72	121	26	0.4	--	--	90	--	--	--	--	--	--	--
Oregon Creek Celestial Valley Sub-Reach	5	8	1.4	42	57	28	0.7	0.7	0.5	96	2.6	1	1.7	73/good	19/low	149	90
Oregon Creek upstream of Log Cabin Diversion Dam	6	--	1.8	25	45	11	2.6	--	--	64	--	--	--	--	--	--	--
North Yuba River	7	6	1.8	56	118	40	2.9	2.9	3.0	193	3.0	66	--	63/good	2/very low	--	--
Slate Creek	8	--	1.7	56	94	18	0.9	--	--	90	--	--	--	--	--	--	--
Yuba River downstream of New Colgate Powerhouse	9	64	2.2	153	287	33	0.2	0.03	-0.1	75	29.2[1]	6	--	67/good	10/low	--	--
Yuba River upstream of New Colgate Powerhouse	10	55	1.5	107	139	53	--	1.1	0.9	106	1.6	64	--	69/good	8/very low	--	--

[1] Volume does not include French Bar as it is a long-term feature and not considered part of the mobile load, though parts may be mobile.

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3.2 Channel Armoring

Three of the five sites selected to be measured for channel armoring are composed of fairly large material (Table 3.2-1). The bars available for excavation generally had a surface particle size that exceeded what is generally considered a "mobile" load (i.e., D_{84} greater than 128 mm). The exposed bars that could be sampled dictated the type of surface material encountered, and there were very large differences in D_{84} particle sizes among the bars that were exposed and could be sampled (i.e., median surface size ranged from 3 mm to 189 mm).

Table 3.2-1. Particles sizes and channel armoring data from sieve analysis of exposed bars at four sites in the Middle Yuba River and one site in Oregon Creek.

Study Site Name	Study Site No.[1]	Exposed Bars Particles				
		D_{84s} (mm)[2]	D_{50s} (mm)[2]	D_{50ss} (mm)[2]	Armoring Ratio	Average Armoring Ratio/Rating
Middle Yuba River Downstream of Oregon Creek	1	215	131	31	4.2	5.4/strong
		163	90	43	2.1	
		222	137	14	9.8	
Middle Yuba River Upstream of Oregon Creek	2	223	116	28	4.1	2.7/moderate
		100	49	38	1.3	
Middle Yuba River Downstream of Our House Diversion Dam	3	15	3	2	1.5	1.9/moderate
		24	3	3	1.0	
		56	13	4	3.2	
Middle Yuba River Upstream of Middle Yuba River/ North Yuba River Confluence	none	53	3	2	1.5	1.4/moderate
		136	32	108	N/A[3]	
		8	4	3	1.3	
Oregon Creek Celestial Valley Sub-Reach	5	292	156	113	1.4	1.7/moderate
		225	101	60	1.7	
		218	189	96	2.0	

[1] Channel armoring was performed at intensive sites 1, 2, 3 and 5; the Middle Yuba River Upstream of Middle Yuba River/North Yuba River Confluence site is not an intensive study site.
[2] D_{84s}: 84% of particles are less than this size on the surface; D_{50s}: Median surface particle size; D_{50ss}: Median sub-surface particle size
[3] N/A – Sub-surface particles are much larger than surface particles; surface particles are merely a thin veneer over coarser substrate and location is not armored.

On the Middle Yuba River, the coarsest material was found below Oregon Creek, while the finest material was found downstream of Our House Diversion Dam (Table 3.2-1). The Middle Yuba River site immediately downstream of Our House Diversion Dam and immediately above the confluence with the North Yuba River (i.e., the uppermost and lowermost sites) had the finest surface particles and least amount of channel armoring. The site on the Middle Yuba River above Oregon Creek had the fewest bars that were exposed; the bars that were available were heavily modified by recreational use or very coarse with little mobile substrate. Oregon Creek had the coarsest surface and sub-surface particles of any of the sample sites.

There was variability within each bar sampled, so the last column in Table 3.2-1 provides an average armoring ratio for the site, along with a rating of the relative armoring strength. Theoretically, the ratio of surface-to-sub-surface grain size (D_{50s}:D_{50ss}) provides a rough estimate of ability of the stream to move its own gravel. The surface is said to be armored when D_{50s}:D_{50ss} exceeds 1.0. Low values of D_{50s}:D_{50ss} that exceed 1.0 (i.e., less than 1.3 means relatively weak armoring) are generally indicative of relatively high mean annual sediment transport rates, whereas high values of D_{50s}:D_{50ss} (i.e., greater than 4 means relatively strong armoring) are generally indicative of relatively low mean annual sediment transport rates (Dietrich et al. 1989; Parker 2004).

- Weak – less than 1.3
- Moderate – between 1.3 and 4
- Strong – greater than 4

3.3 Sediment Mobility

3.3.1 Critical Shields Values

Table 3.3-1 shows the calculated critical Shields values for 2, 4, 8, 16, 32, 64, and 128 mm particle sizes, and the D_{16}, D_{50} and D_{84} of each transect. Within the intensive sites where sediment transport analysis was performed, the maximum critical Shields Value for the particles located on the transects was never higher than 0.054. Since all the particles measured were classified as passing through a certain size sieve opening, the upper boundary of the size class is the critical Shields value. The critical shear stress is presented for the particle at the upper end of the size class into which each particle falls. Particle size distribution graphs are included in Attachment 1-1D.

Table 3.3-1. Calculated Shields Values and Critical Shear Stress for particles 2 mm through 512 mm and D_{16}, D_{50} and D_{84} for each channel morphology transect within the intensive sites.

Study Site Name/ Study Site No.	**Size (mm)**	**2**	**4**	**6**	**8**	**11**	**16**	**23**	**32**	**45**	**52**	**64**	**90**	**128**	**180**	**256**	**358**	**362**	**512**
	Critical Shields Value	**0.040**	**0.048**	**0.052**	**0.053**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**	**0.054**
	Critical Shear Stress (N/m^2)	**1**	**3**	**5**	**7**	**10**	**14**	**20**	**28**	**39**	**45**	**55**	**78**	**111**	**156**	**222**	**310**	**314**	**444**
Middle Yuba River downstream of Oregon Creek (Site 1)	Transect 9							D_{16}					D_{50}			D_{84}			
	Transect 12									D_{16}					D_{50}				D_{84}
	Transect 13						D_{16}						D_{50}						D_{84}
Middle Yuba River upstream of Oregon Creek (Site 2)	Transect 2									D_{16}				D_{50}		D_{84}			
	Transect 9							D_{16}						D_{50}				D_{84}	
	Transect 12					D_{16}							D_{50}					D_{84}	
Middle Yuba River downstream of Our House Diversion Dam (Site 3)	Transect 2					D_{16}						D_{50}							D_{84}
	Transect 4							D_{16}						D_{50}					D_{84}
	Transect 7						D_{16}							D_{50}					D_{84}
Oregon Creek Celestial Valley Sub-Reach (Site 5)	Transect 8	D_{16}								D_{50}						D_{84}			
	Transect 10		D_{16}									D_{50}		D_{84}					
	Transect 12		D_{16}							D_{50}					D_{84}				
North Yuba River (Site 7)	Transect 7											D_{16}				D_{50}			D_{84}
	Transect 8											D_{16}				D_{50}			D_{84}
	Transect 10											D_{16}			D_{50}				D_{84}
Yuba River downstream of New Colgate Powerhouse (Site 9)	Transect 1								D_{16}			D_{50}		D_{84}					
	Transect 2									D_{16}			D_{50}		D_{84}				
	Transect 3											D_{16}	D_{50}		D_{84}				
Yuba River upstream of New Colgate Powerhouse (Site 10)	Transect 8								D_{16}					D_{50}					D_{84}
	Transect 11								D_{16}					D_{50}					D_{84}
	Transect 15						D_{16}						D_{50}						D_{84}

🟩 D_{16}	🟪 D_{50}	🟧 D_{84}

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3.3.2 Substrate Mobility

3.3.2.1 Bedload Transport

Sediment transport capacity was estimated using two publically available models through a three-step process. The process and models used for estimating annual bedload transport were placed on YCWA's website[9] on January 15, 2013 in preparation for discussion with Relicensing Participants on January 30, which process and models have now been included as Attachment 1-1F. A READ_ME document that summarizes the process, WinXSPro input and output, BAGS model input and output, and estimated annual bedload transport capacity calculations and results including a Monte Carlo simulation of critical discharge is included as Attachment 1-1F. Also included in Attachment 1-1F is a copy of the program from the short course (Sagehen 2009) used for the Monte Carlo simulation. For each transect at each channel morphology intensive study site, Table 3.3-2 provides:

- Particle Size used for Critical Shear. Critical shear stress was estimated for a particle size at each transect. Mostly, the critical shear stress was based on the D_{50}. In two cases, there was insufficient channel shear to mobilize the D_{50}, so the D_{35} was used. In two cases, there was very low channel shear so the maximum channel shear was used and a particle size estimated where the critical shear exceeded channel shear and incipient motion could occur.
- Discharge at Critical Shear. Discharge at which incipient motion is estimated to occur for the stated particle size under Without- and With-Project hydrologic conditions. Discharges greater than or equal to this discharge are assumed to be "meaningful" and are used in the estimation of annual bedload transport for that transect. This method is called the "WinXSPro" method for shorthand because a Monte Carlo Simulation (Monte Carlo) was later used to evaluate a range of critical discharge values (see Section 3.3.3.4).
- Annual Bedload Discharge (tons). A sum of the daily bedload discharge when estimated flow exceeds the critical discharge and divided by 42 (the number of years of record) for With- and Without-Project hydrologic conditions.
- T*. The ratio of With-Project to Without-Project annual bedload discharge.

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[9] http://www.ycwa-relicensing.com/Modeling%20Information/Forms/AllItems.aspx?RootFolder=%2fModeling%20Information%2fSediment%20Transport%20Models&FolderCTID=&View=%7b768D86D7%2dFC78%2d434C%2dB1DD%2d57D0A189345F%7d

Table 3.3-2. Annual bedload discharge and T* estimates for channel morphology intensive study site transects using WinXSPro critical discharge estimate.

Study Site Name/ Study Site No.	Transect No.	Particle Size used for Critical Shear (mm)	Without-Project Conditions		With-Project Conditions		T*	Average T* for Site
			Discharge at Critical Shear (cfs)	Annual Bedload Discharge (tons)	Discharge at Critical Shear (cfs)	Annual Bedload Discharge (tons)		
Middle Yuba River downstream of Oregon Creek (Site 1)	9	90	644	10,388	642	5,946	0.57	0.50
	12	128[2]	110	113,037	1,130	50,414	0.45	
	13	90	541	17,698	497	8,619	0.49	
Middle Yuba River upstream of Oregon Creek (Site 2)	2	128	847	22,993	874	13,947	0.61	0.49
	9[2]	128	1,052	989,206	1,033	344,008	0.35	
	12	90	397	60,085	405	30,788	0.51	
Middle Yuba River downstream of Our House Diversion Dam (Site 3)	2	64	288	42,551	282	23,038	0.54	0.59
	4	128	303	527,294	303	306,458	0.58	
	7	128	493	166,887	511	107,924	0.65	
Oregon Creek Celestial Valley Sub-Reach (Site 5)	8	45	308	34,186	300	5,223	0.15	0.16
	10	64	519	91,810	514	18,339	0.20	
	12	45	211	621,583	218	70,094	0.11	
North Yuba River (Site 7)	7	256	1,697	496,822	1,941	111,315	0.22	0.12
	8	256	848	508,643	644	11,005	0.02	
	10[1]	180	852	9,602,619	540	1,166,607	0.12	
Yuba River downstream of New Colgate Powerhouse (Site 9)	1	45[2]	4,586	8,336	4,624	2,842	0.34	0.76
	2	120[3]	4,804	8,373	5,008	7,340	0.88	
	3	38[3]	5,733	3,469	5,854	3,666	1.06	
Yuba River upstream of New Colgate Powerhouse (Site 10)	8	128	805	589	954	124	0.21	0.13
	11	128	1,822	2,038,654	2,056	318,129	0.16	
	15	90	1,513	2,208,773	1,334	20,184	0.01	

[1] Used reduced cross section that did not incorporate large immobile boulder bar on left-bank ascending.
[2] D_{35}.
[3] Particle size estimated from particle that would be at incipient motion at maximum channel shear.

Due to changes in flows that mobilize sediment, it is estimated that With-Project transport capability is about 0.12 to 0.76 that of Without-Project conditions. Oregon Creek, North Yuba River below New Bullards Bar Dam, and the Yuba River upstream of the New Colgate Powerhouse have the lowest ratios of With-Project to Without-Project hydrologic conditions annual bedload discharge at 0.16, 0.12, and 0.13, respectively. The most downstream site below New Colgate Powerhouse has the highest ratio of 0.76. The Middle Yuba River has about half of the transport capability that it had without the Project in place. The highest values, and likely over-estimates of critical discharge, were Transect 10 of the North Yuba River Site 7 (i.e., flow is not likely to exceed 180,400 cfs under Without-Project conditions, Table 2.3-6), and Transects 11 and 15 of the Yuba River upstream of New Colgate Powerhouse Site 10 (i.e., flow is not likely to exceed 258,000 cfs under Without-Project conditions).

There were occasions when the BAGS model would not allow sufficient adjustment of the n value to predict an accurate bankfull flow (Figure 3.3-1). The combination of particle size and roughness characteristics may be too far outside the model parameters for a useful prediction (Wilcock 2013b). The poorest predictions were with Transect 7 at the North Yuba River site, Transect 3 at the Yuba River downstream of Colgate Powerhouse, and Transect 11 at the Yuba River upstream of the Colgate Powerhouse. Additionally, the estimates of total sediment annual volume will be underestimated using the BAGS discharge/sediment discharge equation if the critical discharge, as estimated when critical shear exceeds channel shear, is set too high, thus fewer days where discharge exceeds critical discharge will be summed in the total bedload discharge for the year.

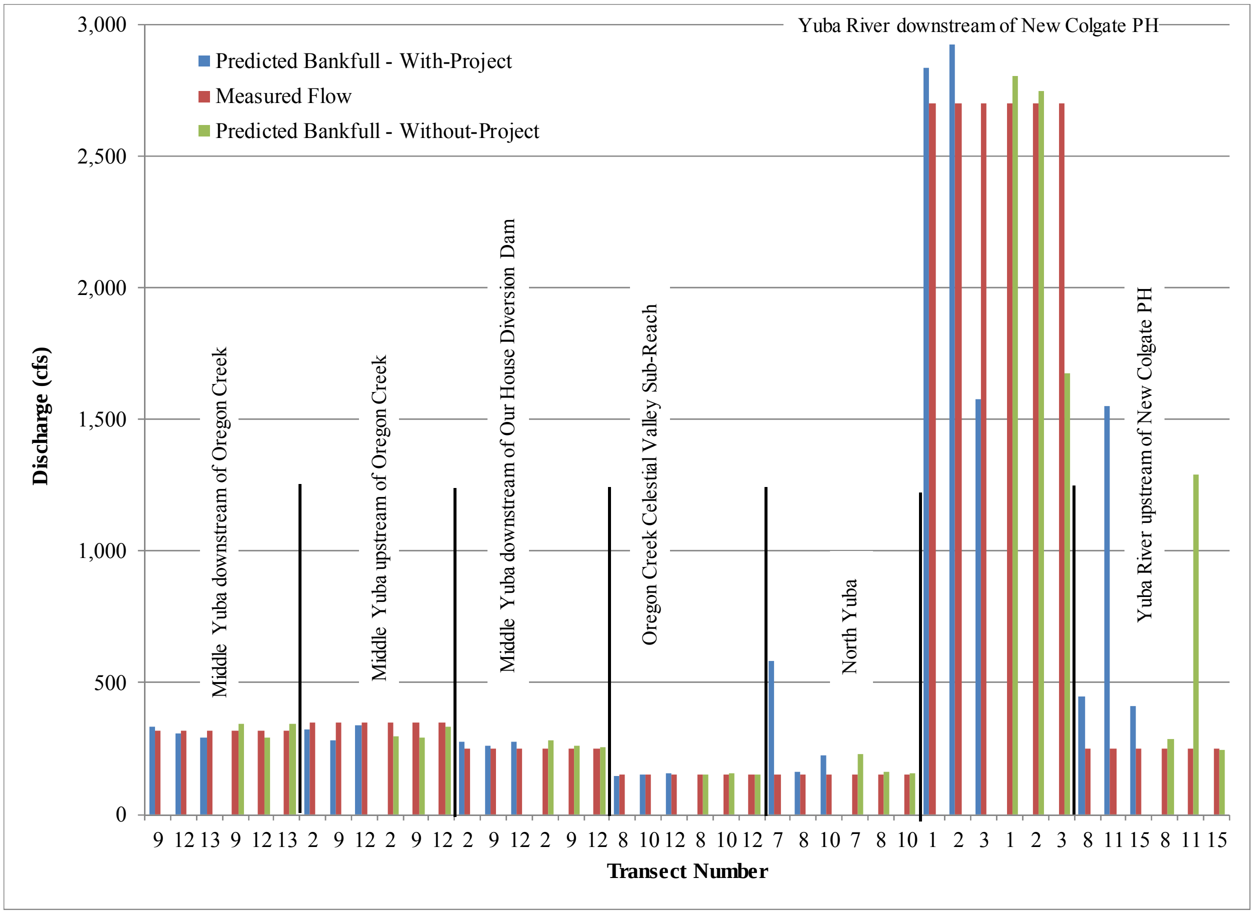

Figure 3.3-1. Comparison of predicted and measured flows under Without- and With-Project hydrologic conditions for each transect at each intensive channel morphology study site.

There are potentially three sources of error that could make a large difference in sediment rate calculation: 1) error in channel shear estimates due to unsteady and non-uniform flow, grain stress estimates (e.g., drag forces on individual grains is an estimate), and spatial variability within the cross section and along the channel; 2) grain size used in the model because the bed is made up of a heterogeneous mixture of sediment; and 3) when critical motion actually occurs (i.e., error in the estimate of critical shear). These sources of error are discussed in Wilcock et al. (2009). Additionally, a major assumption of sediment transport models is unlimited supply of sediment (i.e., all the sediment that is said to be mobile must be available and the sediment in transport may not be that which composes the bed). Because of the issues with absolute values of sediment transport, more confidence can be placed in the difference between rates, rather than actual values (Wilcock et al. 2009). The T* value is, therefore, of more use (Table 3.3-2) because it is a comparison of Without- and With-Project hydrologic conditions, and the relative difference can suggest how changes in flows (e.g., due to Project operations) may affect long-term transport. While the actual value of annual sediment transport is not known, the relative difference between the two may be used to show the sites with the greatest potential changes.

Confidence in the estimate can be increased with calibration. While the results of the BAGS models have not been calibrated, the estimate of sediment bedload transport in the Middle Yuba River brackets that of Curtis et al. (2005b) (Figure 3.3-2). The Curtis et al. (2005b) bedload transport is valid only for the range of flows observed during the study period 2001 to 2003, but is calibrated with bedload samples. The Middle Yuba River downstream of Oregon Creek bedload transport output from BAGS shows a consistent under-prediction compared to the Curtis et al. (2005b) data. The Middle Yuba River upstream of Oregon Creek BAGS bedload transport output shows an over-prediction between 100 and 1,000 cfs, and the Middle Yuba River downstream of Our House Diversion Dam compares fairly closely with the Curtis et al. (2005b) data above 90 cfs.

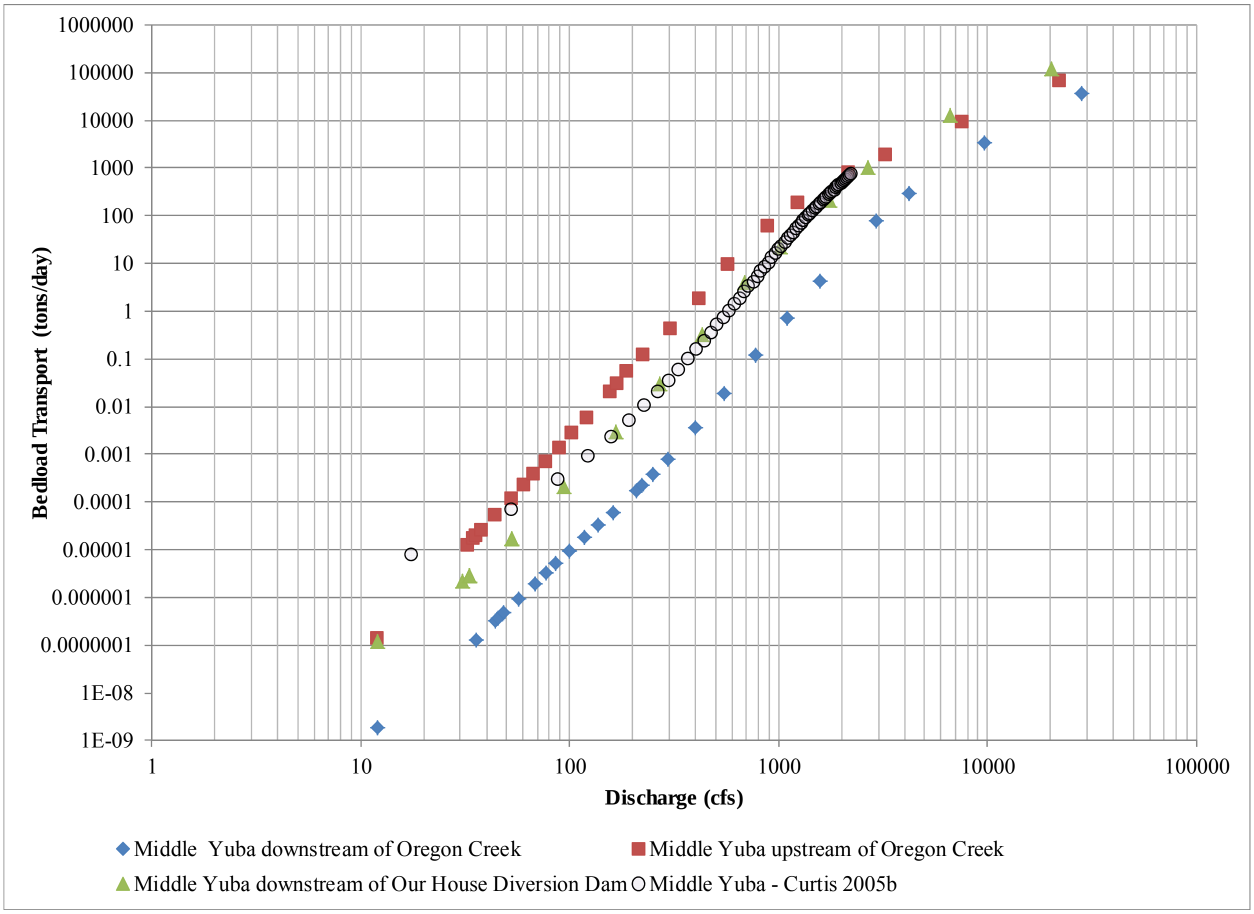

Figure 3.3-2. Relation of bedload transport to synthesized maximum daily flow (With-Project conditions) compared to Curtis et al. (2005b).

3.3.2.2 Tracer Particles

Tracer particles were placed prior to a flood event that occurred in late fall 2012. On December 2, 2012, a large flood event occurred that affected both sites where tracer particles had been placed. Estimates of peak discharge following the flood at each of the sites were 637 cfs at the Oregon Creek Celestial Valley Sub-Reach (Site 5) and 8,500 cfs at the Middle Yuba River downstream of Oregon Creek (Site 1). These events had estimated recurrence intervals of about 2.3 years and 2.5 years, respectively (With-Project conditions, interpolating results in Table 2.3-6)

In Oregon Creek, 33 percent of the particles moved during the flood event. Most of the particles moved from the thalweg, or deepest part of the channel. Particles of 64 mm and 45 mm (i.e., 43 and 50 percent, respectively) experienced the most movement, though more than a third of the 90 mm particles moved (Figure 3.3-3).

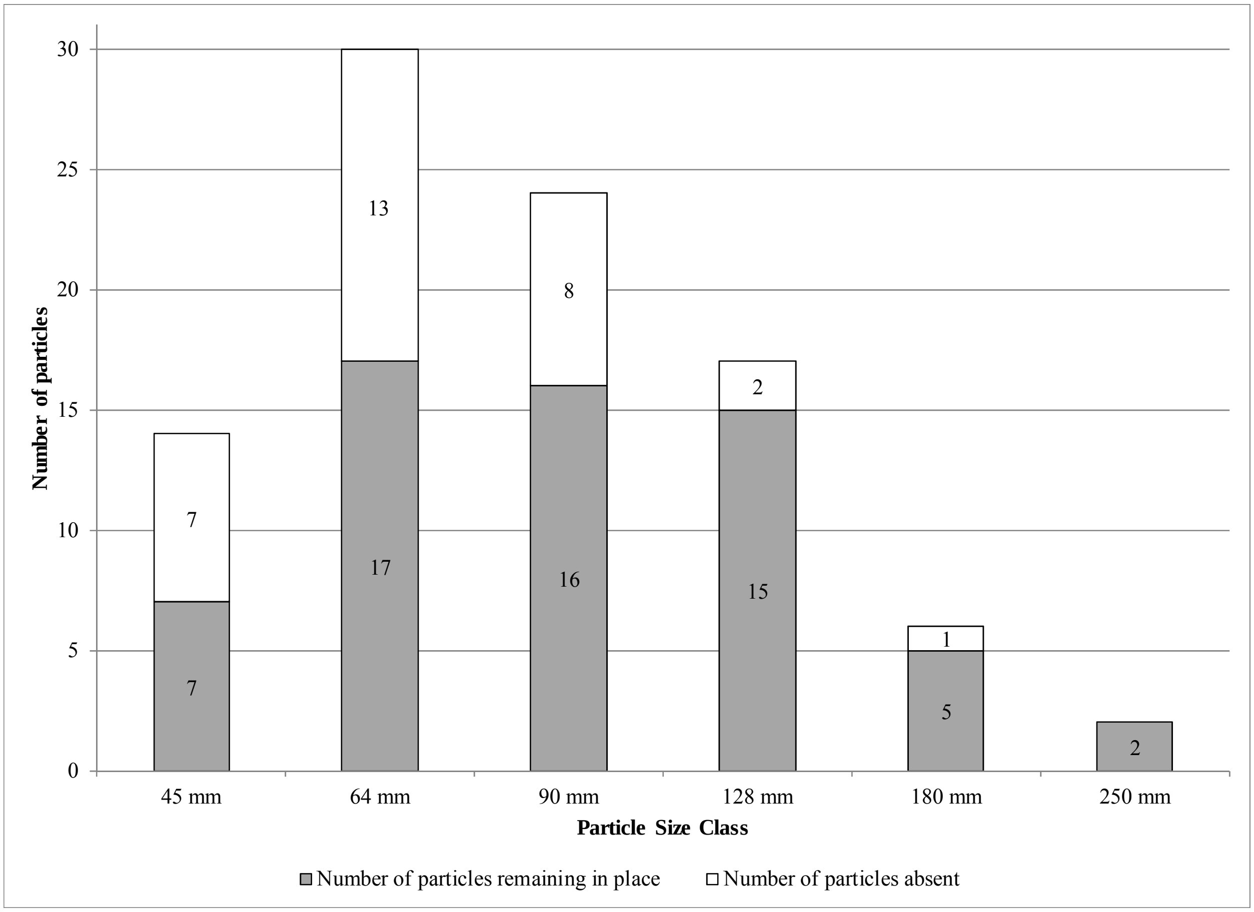

Figure 3.3-3. Tracer particle movement in Oregon Creek Celestial Valley Sub-Reach following December 2, 2012, flood event.

Despite re-establishing the transects and looking thoroughly, only two of the 31 tracer particles that were placed at the Middle Yuba River site were found on the transects after the flood event.

One 180 mm and one 256 mm particles remained on each of the two transects. On the lower transect (Transect 9), significant deposition occurred in response to the event; particles may have moved or been buried (Figure 3.3-4 and 3.3-5) but only one 180 mm particle remained on the margin. On the upper transect, one 256 mm particle remained tucked up against the bedrock margin. Additionally, there was one 90 mm particle was found perched on the cobble bar about 300 ft downstream from the upper transect.

Figure 3.3-4. Middle Yuba downstream of Oregon Creek Transect 9 from left-bank (ascending) to right bank in summer of 2012.

Figure 3.3-5. Middle Yuba downstream of Oregon Creek Transect 9 from left-bank (ascending) to right bank following flood event of December 2012.

The tracer particles are used to make a simple sort of calibration. While the discharge at which particles began to move (i.e., incipient motion) is not known, it is known that they moved during flow equal to or less than the maximum estimated discharge of a flood event. When reviewing the critical discharge values, if the estimated critical discharge exceeds the estimated flood event instantaneous discharge, this is a "point" and it is likely that the critical discharge is an overestimate.

3.3.2.3 Uncertainty in Predictions of Bedload Transport Capacity

Transport rates are difficult to estimate due to errors in the input (Wilcock et al. 2009). It is very important that the limitations to the sediment transport modeling exercise are understood. The problems are well established in Wilcock et al. (2009), and some of these are briefly described in the following.

One example limitation is the flow input, which is represented using boundary shear stress and is the force acting on the bed; only part of the force actually produces transport (i.e., grain stress) and it varies across the bed. This is not measured directly, but must be estimated based on discharge, channel geometry, and hydraulic roughness. Another problem is the sediment input, because transport depends on grain size and the range of sizes in the bed is highly variable. Also, the size of sediment in the bed may not match the size of the sediment that is being transported. A final example is the watershed and its history of influencing sediment supply, which contributes to the previous problem of sediment in transport not matching the sediment in the bed. Uncertainty in transport rates is large because the underlying physical mechanisms are non-linear and if input variables are off, there can be a very large error in transport rates. Despite these problems, sediment transport numbers are presented but should be used with caution.

Because of the uncertainty of Manning's n, channel shear stress, and particle size that is mobile, a range of values were used in a Monte Carlo simulation model (Sagehen 2009; Wilcock et al. 2009). Table 3.3-3 shows that the estimate of critical discharge (i.e., the flow at which channel shear exceeds critical shear for the D_{50} of the transect, "WinXSPro estimate") is usually much lower than that which is estimated using a range of values for the input variables of Manning's n, Shield's Number, and particle size ("Monte Carlo Simulation"). Standard deviation of the mean of critical discharge for the 1,000 calculations carried out by the simulation was often much higher than the mean itself; this is likely because the range of mobile particle sizes was fairly large (e.g., 64 to 128 mm), which creates a large range of critical discharge estimates. The Monte Carlo simulation yields over-estimates for the point at which particles move for Oregon Creek Celestial Valley Sub-Reach, given that particles were moving at peak flows of 637 cfs. However, in the Middle Yuba River downstream of Oregon Creek, which had tracer particles completely removed at flow less than or equal to 8,500 cfs, the simulation suggests that incipient motion could have occurred at flows as low as 3,500 cfs.

Table 3.3-3. Comparison of estimates of critical discharge using a comparison of channel shear estimated from WinXSPro versus critical shear of the D_{50} of the transect and the Monte Carlo simulation mean estimate including 95% confidence limits.

Study Site Name/ Study Site No.	Transect No.	WinXSPro Estimate	Monte Carlo Simulation Estimate of Critical Discharge (cfs)		
				95% Confidence Limit	
		Critical Discharge (cfs)	Mean	Upper	Lower
Middle Yuba River downstream of Oregon Creek (Site 1)	9	643	5,529	6,926	4,132
	12	1,120	5,455	7,419	3,491
	13	519	9,768[1]	12,460	7,076
Middle Yuba River upstream of Oregon Creek (Site 2)	2	861	3,364	3,640	3,088
	9	1,043	3,872	4,333	3,411
	12	401	7,130	8,040	6,220
Middle Yuba River downstream of Our House Diversion Dam (Site 3)	2	285	3,274	4,272	2,276
	4	303	5,007	6,385	3,629
	7	502	2,337	2,965	1,709
Oregon Creek Celestial Valley Sub-Reach (Site 5)	8	304	2,078[2]	2,574	1,582
	10	517	4,192[2]	5,341	3,043
	12	215	1,574[2]	1,895	1,253
North Yuba River (Site 7)	7	1,819	18,142	26,788	9,496
	8	746	10,011	13,743	6,279
	10	694	1,659	2,361	957
Yuba River downstream of New Colgate PH (Site 9)	1	4,605	40,834	49,002	32,666
	2	4,906	74,373	106,778	41,968
	3	5,794	38,795	46,123	31,467

Table 3.3-3. (continued)

Study Site Name/ Study Site No.	Transect No.	WinXSPro Estimate	Monte Carlo Simulation Estimate of Critical Discharge (cfs)		
		Critical Discharge (cfs)	Mean	95% Confidence Limit	
				Upper	Lower
Yuba River upstream of New Colgate PH (Site 10)	8	880	12,047	16,242	7,852
	11	1,939	4,049	5,406	2,692
	15	1,424	3,834	6,360	1,308

[1] Tracer particles showed that all particles moved in a flood event that had an estimated peak instantaneous] discharge of 8,500 cfs so any estimate of critical discharge over that amount is an overestimate.

[2] Tracer particles showed that 30 percent of the particles that incorporated D_{16} through D_{84} of each transect moved in a flood event that had an estimated peak instantaneous discharge of 637 cfs so any estimate of critical discharge over that amount is an overestimate.

The difference in critical discharge estimated by WinXSPro and Monte Carlo, which differed by as much as two orders of magnitude, did not result in a substantial difference in annual bedload transport capacity (Table 3.3-3). Values of annual sediment transport were based on flows that exceeded this mean estimated critical discharge from the Monte Carlo simulation (i.e., all daily average flows that exceeded this discharge had an estimate of the daily sediment discharge for that day summed and divided by 42 for an annual estimate of bedload transport). The higher critical discharge (i.e., higher than that estimated by WinXSPro) should result in a lower annual sediment load as fewer flows would meet that higher threshold. However, the estimate of annual bedload transport capacity is fairly non-sensitive to the estimate of critical discharge (Table 3.3-4). The exceptions are Transect 10 of Oregon Creek Celestial Valley Sub-Reach (With- and Without-Project), Transect 7 in the North Yuba River (Without-Project), and Transect 2 in the Yuba River downstream of the New Colgate Powerhouse (With-and Without-Project), where the WinXSPro estimate and the Monte Carlo critical discharge values resulted in a much different annual bedload estimate.

Table 3.3-4. Comparison of estimates of annual bedload discharge using a comparison of critical discharge using critical shear stress for cross section D_{50} particles to establish critical discharge and channel shear as estimated in WinXSPro versus the mean value of the critical discharge calculated by a Monte Carlo simulation (~1,000 iterations).

Study Site Name/ Study Site No.	Transect No.	Without-Project Conditions		With-Project Conditions	
		Annual Bedload Discharge (WinXSPro) (tons)	Annual Bedload Discharge (Monte Carlo) (tons)	Annual Bedload Discharge (WinXSPro) (tons)	Annual Bedload Discharge (Monte Carlo) (tons)
Middle Yuba downstream of Oregon Creek (Site 1)	9	10,388	10,286	5,946	5,910
	12	113,037	111,161	50,414	49,859
	13	17,698	16,808	8,619	8,158
Middle Yuba upstream of Oregon Creek (Site 2)	2	22,993	22,906	13,947	13,918
	9	989,206	963,676	344,008	338,875
	12	60,085	57,541	30,788	29,942
Middle Yuba downstream of Our House Diversion Dam (Site 3)	2	42,551	42,368	23,038	22,935
	4	527,294	511,434	306,458	297,126
	7	166,887	166,459	107,924	107,650
Oregon Creek Celestial Valley Sub-Reach (Site 5)	8	34,186	29,155	5,223	4,530
	10	91,810	20,277	18,339	3,736
	12	621,583	587,473	70,094	64,768
North Yuba River (Site 7)	7	496,822	480,798	111,315	82,835
	8	508,643	504,632	11,005	9,067
	10[1]	9,602,619	9,589,311	1,166,607	992,467

Table 3.3-4. (continued)

Study Site Name/ Study Site No.	Transect No.	Without-Project Conditions		With-Project Conditions	
		Annual Bedload Discharge (WinXSPro) (tons)	Annual Bedload Discharge (Monte Carlo) (tons)	Annual Bedload Discharge (WinXSPro) (tons)	Annual Bedload Discharge (Monte Carlo) (tons)
Yuba River downstream of New Colgate Powerhouse (Site 9)	1	8,336	7,576	2,842	2,462
	2	8,373	5,420	7,340	1,388
	3	3,469	2,738	3,666	2,179
Yuba River upstream of New Colgate Powerhouse (Site 10)	8	589	588	124	124
	11	2,038,654	2,037,421	318,129	318,081
	15	2,208,773	2,207,132	20,184	20,180

[1] Used reduced cross section that did not include large boulders on left-bank (ascending).

All of the Monte Carlo inputs and outputs, including mean, standard deviation of the mean, minimum and maximum estimates, are included in Attachment 1-1F.

Despite significant changes in critical discharge, there was little change in T* (i.e., the ratio of With-Project to Without-Project sediment transport) when the critical discharges used were from WinXSPro versus the mean critical discharge from the Monte Carlo simulation (Table 3.3-5). The exception is Transect-2 in the Yuba River downstream of New Colgate Powerhouse, where the T* value is very different. While there are uncertainties in the absolute value of sediment transport, the comparison between With- and Without-Project hydrologic conditions is fairly robust.

Table 3.3-5. Comparison of T* estimates using critical shear stress for cross section D_{50} particles and channel shear as estimated in WinXSPro to establish critical discharge versus the mean value of the critical discharge calculated by a Monte Carlo simulation (~1,000 iterations).

Study Site Name/ Study Site No.	Transect No.	T*	
		WinXSPro Estimate	Monte Carlo Mean Estimate
Middle Yuba River downstream of Oregon Creek (Site 1)	9	0.57	0.57
	12	0.45	0.45
	13	0.49	0.49
Middle Yuba River upstream of Oregon Creek (Site 2)	2	0.61	0.61
	9	0.35	0.35
	12	0.51	0.52
Middle Yuba River downstream of Our House Diversion Dam (Site 3)	2	0.54	0.54
	4	0.58	0.58
	7	0.65	0.65
Oregon Creek Celestial Valley Sub-Reach (Site 5)	8	0.15	0.16
	10	0.20	0.18
	12	0.11	0.11
North Yuba River (Site 7)	7	0.22	0.17
	8	0.02	0.02
	10	0.12	0.10
Yuba River downstream of New Colgate PH (Site 9)	1	0.34	0.32
	2	0.88	0.26
	3	1.06	0.80
Yuba River upstream of New Colgate PH (Site 10)	8	0.21	0.21
	11	0.16	0.16
	15	0.01	0.01

3.4 Sediment Supply

3.4.1 Sediment and Bedload Yield from Regional Estimates

Sediment availability is lower under With-Project conditions than under Without-Project conditions (Table 3.4-1). The greater the drainage area below the Project facility (e.g., Our House Diversion Dam), the greater the sediment availability.

Table 3.4-1. Estimates of sediment yield at sediment supply nodes based on regional estimate of yield and drainage area under the With-Project and Without-Project conditions.

Study Site Name	Drainage Area (mi^2)		Sediment Yield[1] (tons/mi^2/year)		Bedload Yield[2] (tons/mi^2/year)		S* (dimensionless)
	With-Project	Without-Project	With-Project	Without-Project	With-Project	Without-Project	
North Yuba River at New Bullards Bar	0	488.8	0	346,070	0	51,911	0.00
Oregon Creek at Log Cabin Diversion Dam	0	29.1	0	20,603	0	3,090	0.00
Middle Yuba River at Our House Diversion Dam	0	104.7	223[3]	74,128	0	11,119	0.00
Middle Yuba River downstream of Oregon Creek Confluence	23.0	156.8	16,284	111,014	2,443	16,652	0.15
Middle Yuba River upstream of Middle Yuba River/North Yuba River Confluence	36.5	170.3	25,842	120,572	3,876	18,086	0.21
Yuba River downstream of Middle Yuba River /North Yuba River Confluence	38.4	661.0	27,187	467,988	4,078	70,198	0.06
Yuba River downstream of New Colgate Powerhouse	69.1	716.1	48,887	506,999	7,333	76,050	0.10

[1] Assuming 708 tons/mi^2/year of sediment yield (250 tonnes/km^2/year).

[2] Assuming 15 percent of sediment yield is bedload.

[3] Though Our House Diversion Dam stores significant sediment from upstream, it was estimated that 7,333 to 15,000 yd^3 of material was passed during the 1986 flood (EBASCO and Envirosphere 1986). Assuming 62 lbs/ft^3 (0.837 tons/ yd^3, Dendy and Champion 1978), there was an addition of between about 6,100 to 12,600 tons in 1986. No estimates of sediment passed were made following other storms. An average of the lower and upper estimates is assumed and an annual input is estimated.

The greatest sediment availability recovery was at the site furthest downstream, the Middle Yuba River just above the Middle Yuba River/North Yuba River confluence, which has an estimated 21 percent of the Without-Project sediment availability (Table 3.4-1). The site below Our House Diversion Dam has an estimated sediment yield of zero due to the dam being in place. However, it is estimated that the 1986 flood event delivered between 6,100 and 12,600 tons of sediment over Our House Diversion Dam [EBASCO and Envirosphere 1986]. The average of the estimated through-flow of sediment for this single large flood event (9,350 tons) was divided by 42 to estimate an annual input and added to the With-Project availability; this small amount made no difference in the S* estimate. With regards to the other two Project dams, there are no estimates of sediment removed or passed below Log Cabin Diversion Dam, and it is assumed that New Bullards Bar Dam traps all upstream sources of sediment.

3.4.2 Input of Bedload from Tributaries

The tributaries evaluated within the Yuba River and Middle Yuba River drainages are listed in Table 2.3-3 and shown in Figure 2.3-2. The input of bedload from each is discussed below in order of largest tributary drainage area to smallest.

3.4.2.1 Oregon Creek

Oregon Creek is the largest tributary in a Project-affected reach, and is diverted by the Log Cabin Diversion at river mile (RM) 4.3. Oregon Creek has a drainage area of 35.2 square miles (sq mi), 83 percent of which is upstream of Log Cabin Diversion Dam. Log Cabin Diversion Dam prevents most of the coarse sediment from passing downstream, though fines (e.g., washload) likely are transported during spill events to varying degrees as a function of storm event size and duration. Log Cabin Diversion Dam has not been dredged in its 45 years of existence. Since there is no obvious deposition downstream, it is assumed that almost all the bedload sediment provided from upstream is stored behind Log Cabin Diversion Dam. Sediment supply estimates to Oregon Creek are discussed in Section 3.3.1. Oregon Creek terminates in the Middle Yuba River on the outside of a 90-degree bend in the river. As a result of this confluence orientation, there is no alluvial fan at the confluence of Oregon Creek and the Middle Yuba River, but there is a sand/gravel bar opposite of it that is not necessarily related to input from Oregon Creek and may be a combination of Oregon Creek and Middle Yuba River inputs. It appears that any material that has been added to the Middle Yuba River from Oregon Creek has been transported downstream.

3.4.2.2 Dobbins Creek

Dobbins Creek terminates on the upstream end of Condemned Bar on the mainstem Yuba River at about RM 33.9. No Project facilities occur on Dobbins Creek. The drainage area of Dobbins Creek is 11.7 sq mi; 54 percent is upstream of the non-Project Lake Francis Dam. Days after the completion of Lake Francis Dam in 1899, the dam was breached during an intense rainfall, sending over 16,000 yds^3 of material from the dam downstream (Schuyler 1907). The breach also sent a tremendous amount of water downstream and likely mobilized bank and channel sediment in Dobbins Creek.

Dobbins Creek terminates on the upstream side of Condemned Bar, which is located a few hundred feet downstream of New Colgate Powerhouse. The bar is an alluvial fan several feet thick. Dobbins Creek is incised several feet upstream of Condemned Bar. The exposed banks of the incised Dobbins Creek are composed of large cobbles in a matrix of sand and gravel. A low-water crossing at the lower end of Dobbins Creek has been washed out in the past and appears to be regularly inundated. Lake Francis Dam was reconstructed following the 1899 failure and has been in place for almost 100 years. Lake Francis may limit the amount of sediment contribution from upstream of the dam, but Dobbins Creek has contributed coarse and fine sediment to the Yuba River in the past, and appears to be a chronic source.

Condemned Bar is mentioned as a gold mining site prior to the construction of Lake Francis Dam (Chamberlain 1879), indicating the longevity of the bar. The present size of Condemned

Bar is approximately 800 ft long and 350 ft wide. The bar has a substrate of very coarse cobbles, and boulders up to 5 ft, larger than most substrate found on the Yuba River. There are recent sand deposits on the upper surface of the bar that indicate regular inundation from the Yuba River. In an aerial view, it appears as though Condemned Bar has locally confined the Yuba River to a narrow, deep channel along the canyon wall.

Despite fluctuations in flow from New Colgate Powerhouse, the fine material added from Dobbins Creek may be somewhat protected from rapid or frequent mobilization. The Yuba River makes a sharp bend when it hits the relatively immobile Condemned Bar, leaving a pocket of slack water on the upstream side of the bar, the substrate of which is a veneer of fine material over cobbles. When gravel or finer material is added from Dobbins Creek during flood flow, some of it appears to be transported quickly as the North Yuba River becomes narrow, swift, and cobble- and boulder-dominated adjacent to the Bar. There are sand and gravel bars downstream of Condemned Bar, some of which may be contributed to by Dobbins Creek.

3.4.2.3 Grizzly Creek

Grizzly Creek enters the Middle Yuba River at about RM 9.4 and has a drainage area of 7.9 sq mi. No Project facilities occur on Grizzly Creek. The tributary enters on the outside of a 90-degree bend in the Middle Yuba River. The site is inaccessible, so analysis is based on review of aerial video. A vegetated gravel and sand deposit at the mouth of Grizzly Creek appears on the aerial video. Just downstream of this deposit is scoured to bedrock around the outside of the bend. Sand and gravel deposits continue downstream on the leeward sides of large cobble bars. There is an abundance of cobble deposition upstream of Grizzly Creek. Based on this evidence, sediment contributions from Grizzly Creek do not appear to exceed the ability of the Middle Yuba River to move the deposits, and sediment inputs from upstream on the Middle Yuba River appear to be more influential on its morphology than Grizzly Creek.

3.4.2.4 Sweetland Creek

Sweetland Creek enters the mainstem Yuba River at about RM 38.1, and has a drainage area of 4.8 sq mi. No Project facilities occur on Sweetland Creek. Sweetland Creek drainage features the Sebastopol Diggings and the small community of Sweetland. The site is inaccessible, so analysis is based on review of the aerial video. The creek enters the Yuba River on the outside edge of a sharp bend, and there is little to no evidence of sediment contribution. This section of the Yuba River, both upstream and downstream, is dominated by bedrock and boulders. Either the sediment quantity is small or it is quickly transported by the Yuba River.

3.4.2.5 Moonshine Creek

Moonshine Creek enters the Middle Yuba River at about RM 3.5, and has a drainage area of 4.1 sq mi. No Project facilities occur on Moonshine Creek. The creek terminates at an alluvial fan about 56 ft long, 31 ft wide, and 3 ft deep at its distal end. The contributing alluvium is primarily sand with small cobbles and gravels. The Middle Yuba River channel bed and bars in this area are dominated by cobble-sized substrate, and the finer sediment coming from Moonshine Creek is quickly assimilated into the Middle Yuba River. Little evidence of deposition exists past the riffle crest downstream of the tributary, although there is some sand deposition in the deep pools downstream. It is not possible to separate the contribution from Moonshine Creek to this fine-grained deposit.

3.4.2.6 Clear Creek

Clear Creek enters the Middle Yuba River at about RM 3.0, with a drainage area of 3.1 sq mi. No Project facilities occur on Clear Creek. The site is inaccessible, so analysis is based on review of the aerial video. Analysis of the aerial video shows an alluvial fan at the mouth of the creek composed of mostly gravel, as well as a large vegetated mid-channel bar located just downstream of the creek mouth. There is also a large deposit of similar composition in the pool tail just upstream of the confluence, so it is unclear how much sediment is contributed by Clear Creek.

3.4.2.7 Studhorse Canyon and Nevada Creek

Studhorse Canyon, with a drainage area of 1.7 sq mi, and Nevada Creek, with a drainage area of 1.1 sq mi, are adjacent watersheds with tributaries that enter the Middle Yuba River at RM 7.0 and 6.8, respectively. No Project facilities occur on Studhorse or Nevada creeks. Their combined drainage area is 2.8 sq mi. Landowners denied access to this location, so analysis is based on review of the aerial video. Emory Bar is located at the confluence of these tributaries with the Middle Yuba River. Emory Bar is a very large, well-vegetated, cobble- and boulder-dominated bar that dissects the Middle Yuba River. The bar is vegetated with upland species of pine, indicating stability; it is a named, long-term feature on the Middle Yuba River. The tributaries themselves, or any sediment contributed by these tributaries, are not apparent on the aerial video, though they may be somewhat responsible for the longevity of Emory Bar.

3.4.2.8 Chute Ravine

Chute Ravine has a drainage area of 2.2 sq mi and enters the mainstem Yuba River at RM 38.1. No Project facilities occur on Chute Ravine. This section of the Yuba River has an exposed bedrock bank, and is dominated by boulders. The site is inaccessible, so analysis is based on review of the aerial video. There is no evidence from the aerial video of any sediment contribution from Chute Ravine.

3.4.2.9 Yellowjacket Creek and Mary’s Ravine

Yellowjacket Creek and Mary’s Ravine join together just before entering the Middle Yuba River at RM 1.4. No Project facilities occur on Yellowjacket Creek or Mary’s Ravine. The combined tributary has a drainage area of 1.7 sq mi. There is an alluvial fan through which the tributary confluence flows into the Middle Yuba River. The alluvial fan is made of sand with some small gravel, and is approximately 10 ft long, 4 ft wide, and 2 ft deep at the distal end of the fan. The sediment is likely transported to the Middle Yuba River at higher flows, although there is no evidence of it in the Middle Yuba River other than a small amount of deposition in the margins and leeward sides of cobble bars. This deposition may also be from upstream sources as there is little difference in sediment deposition in the Middle Yuba River upstream and downstream of the confluence.

3.4.2.10 Smaller Tributaries

Quarry Tailings on North Yuba River

There are exposed surficial deposits and material that were cast over the side during excavation from a quarry on the hillside on the Marysville Road above the North Yuba River (RM 0.8). Review of the aerial video shows what appears to be side-cast material just above the high water mark in the North Yuba River. There is a bar on the right bank (ascending) that may be contributed to by erosion of this side-cast material. This material appears to be an active source of gravel and smaller-sized material to the North Yuba River and is depositing locally. Because the North Yuba River has little sediment additions from upstream due to New Bullards Bar Dam, this is one of the few local sources adding sediment. There are deposits of particles less than 128 mm (e.g., mobile particles) that were quantified downstream within the Channel Morphology Intensive Site 7, North Yuba River downstream of New Bullards Bar (see Table 3.1-1), which may be receiving sediment from this source.

Sweetland Diggings

A small, unnamed tributary meets the mainstem Yuba River at RM 37, with a drainage area of 1.6 sq mi. There are some mining sites in this drainage including Sweetland Diggings, and a portion of Birchville Diggings. The site is inaccessible, so analysis is based on review of the aerial video. Despite evidence of terrestrial surficial disturbance, there is little evidence from aerial video and photographs that the mining sediment in the Sweetland Diggings watershed reaches the Yuba River. The Yuba River in this section is bedrock- and boulder-dominated, with short sections of a thin veneer of cobbles upstream of pinch points or bends.

Sebastopol

A small, unnamed tributary meets the Middle Yuba River at about RM 0.7, with a drainage area of 1.3 sq mi. Most of the drainage is located within the small community of Sebastopol and part of the town of North San Juan. The site is inaccessible, so analysis is based on review of the aerial video. There is a large cobble bar immediately downstream of the tributary, with fine material deposited on the upstream end of the bar, and across from the tributary. Upstream and downstream of the bar, the Middle Yuba River channel is bedrock-dominated, so it appears that the Sebastopol tributary may supply significant amounts of sediment. The estimated dimensions of the deposit are approximately 750 ft long, 150 ft wide, and 4 ft deep (estimated from the aerial video), or about 17,000 yds^3 (13,000 m^3) stored locally, and more has likely been transported and stored downstream.

Upstream of Rice's Crossing

An unnamed tributary enters the mainstem Yuba River downstream of French Bar and upstream of Rice's Crossing (RM 32.8). The tributary has a drainage area of 1.4 sq mi. There is little evidence of its sediment contribution as it terminates in a scour pool of over 12 ft deep. A small deposit of sand near the mouth of the creek and a large sand bar immediately opposite the creek (a point bar), indicate that this tributary may contribute fine sediment.

French Ravine

French Ravine is a small tributary that terminates in the mainstem Yuba River at French Bar (RM 33.1). French Ravine does not appear to have contributed any significant amount of sediment to French Bar as there is no evidence of deposition at the confluence with French Ravine.

Unnamed 2

Analysis of the aerial video at the small tributary referred to as Unnamed 2 suggests the presence of a scour track; however, field investigation revealed that the track is bedrock and there is no sediment accumulation from possible erosion through the track at the confluence with the mainstem Yuba River. The drainage at Unnamed 2 is not a tributary but merely a swale where storm-related surface runoff flows across bedrock.

Unnamed 1, 3, 4, 5, 6, 7, 8, 9, and 10

Based on analysis of the aerial video at the group of small tributaries referred to as Unnamed 1, 3, 4, 5, 6, 7, 8, 9, and 10, there was no evidence of an alluvial fan at the mouth of the tributaries or scour within the tributary and the sites were not easily accessible for field verification. It is assumed that sediment input from these tributaries is minimal and of minor significance.

3.5 Channel Storage of Sediment

3.5.1 Sediment Stored in Project-Affected Area

Channel storage of sediment in the channel, bars, floodplains, and terraces was measured in the Middle Yuba River at 21 sites downstream of Our House Diversion Dam and in Oregon Creek at 10 sites downstream of Log Cabin Diversion Dam (Table 2.3-4). Table 3.5-1 summarizes the relative amounts of channel storage in the reaches examined.

Table 3.5-1. Summary of channel storage of coarse sediment in Middle Yuba River and Oregon Creek downstream of Project diversion dams.

Reach	Surveyed Length (m)	Number of Measured Elements	Active[1] (m^3/m)	Semi-Active (m^3/m)	Inactive (m^3/m)	Stable (m^3/m)	Total (m^3/m)
Middle Yuba River upstream of Oregon Creek	1,152	124	6.6	6.2	1.0	--	13.8
Middle Yuba River downstream of Oregon Creek	1,173	108	12.2	20.3	21.4	--	53.9

Table 3.5-1. (continued)

Reach	Surveyed Length (m)	Number of Measured Elements	Active[1] (m³/m)	Semi-Active (m³/m)	Inactive (m³/m)	Stable (m³/m)	Total (m³/m)
Middle Yuba River Total	**2,325**	**232**	--	--	--	--	--
Middle Yuba River Average	--	--	**9.4**	**13.3**	**11.3**	--	**34.0**
Oregon Creek	1,031	109	6.0	13.7	29.7	34.5	83.9

[1] Activity levels are defined in Table 2.3-5.

There is a significant increase in channel storage on the Middle Yuba River below Oregon Creek compared to above Oregon Creek, especially in the semi-active and inactive activity levels. There were no stable channel storage elements identified in the Middle Yuba River.

Much of the channel storage measured has been a part of some type of gold mining (Curtis et al. 2005a). There may be some sample bias due to accessibility of sites. From aerial video analysis, it is clear that there is significant coarse sediment storage around RM 7 of the Middle Yuba River at Emory Bar, which could not be evaluated in the field-based survey due to access limitations. Near the confluence of the Middle and North Yuba rivers, there is a decrease in stored coarse sediment as compared to near the Oregon Creek confluence. Figure 3.5-1 shows the relative amounts of coarse sediment at various locations along the Middle Yuba River.

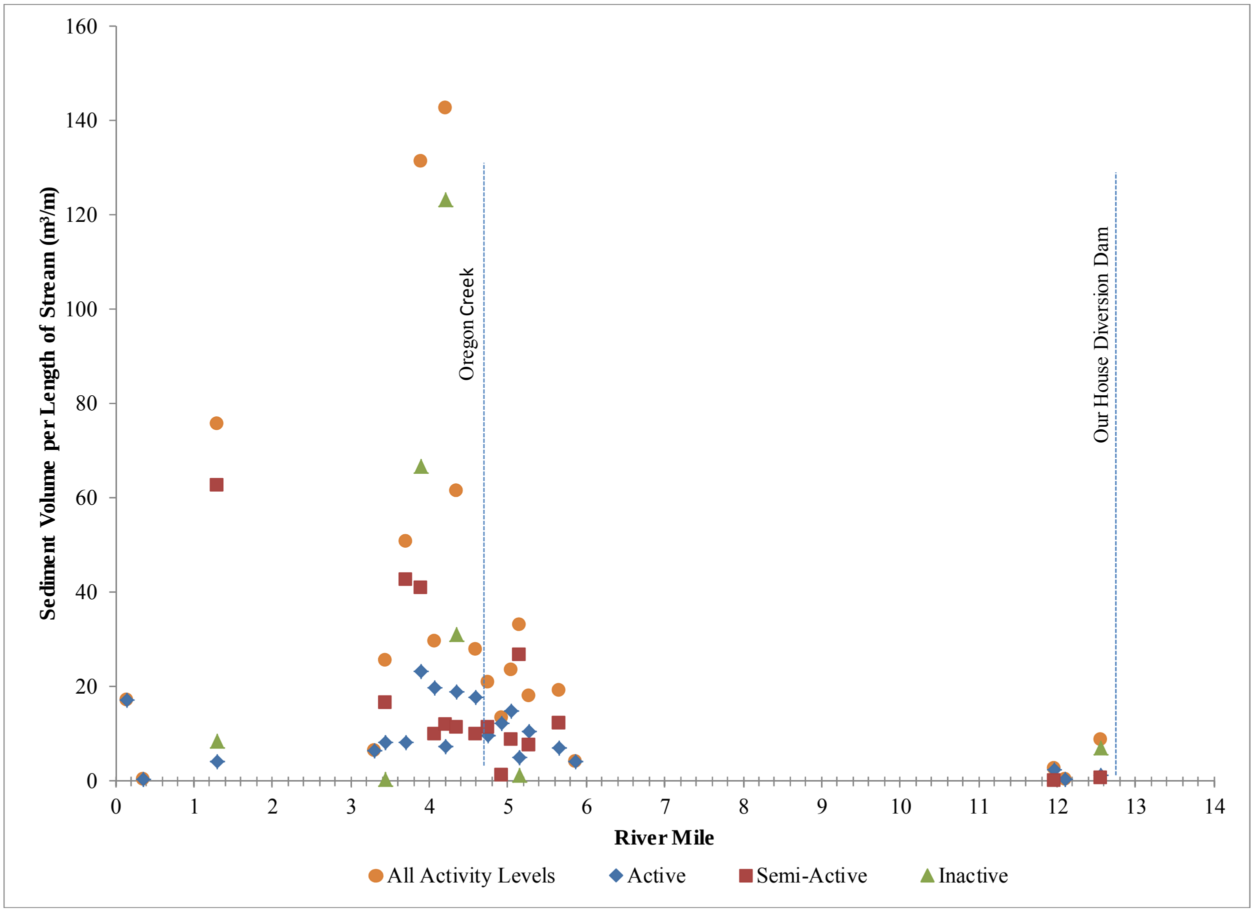

Figure 3.5-1. Channel storage in the Middle Yuba River downstream of Our House Diversion Dam.

Oregon Creek had a large amount of channel storage in and below Celestial Valley. The largest channel storage element measured in the study was an abandoned terrace in Celestial Valley. Figure 3.5-2 shows the relative amounts of channel storage at various locations along Oregon Creek.

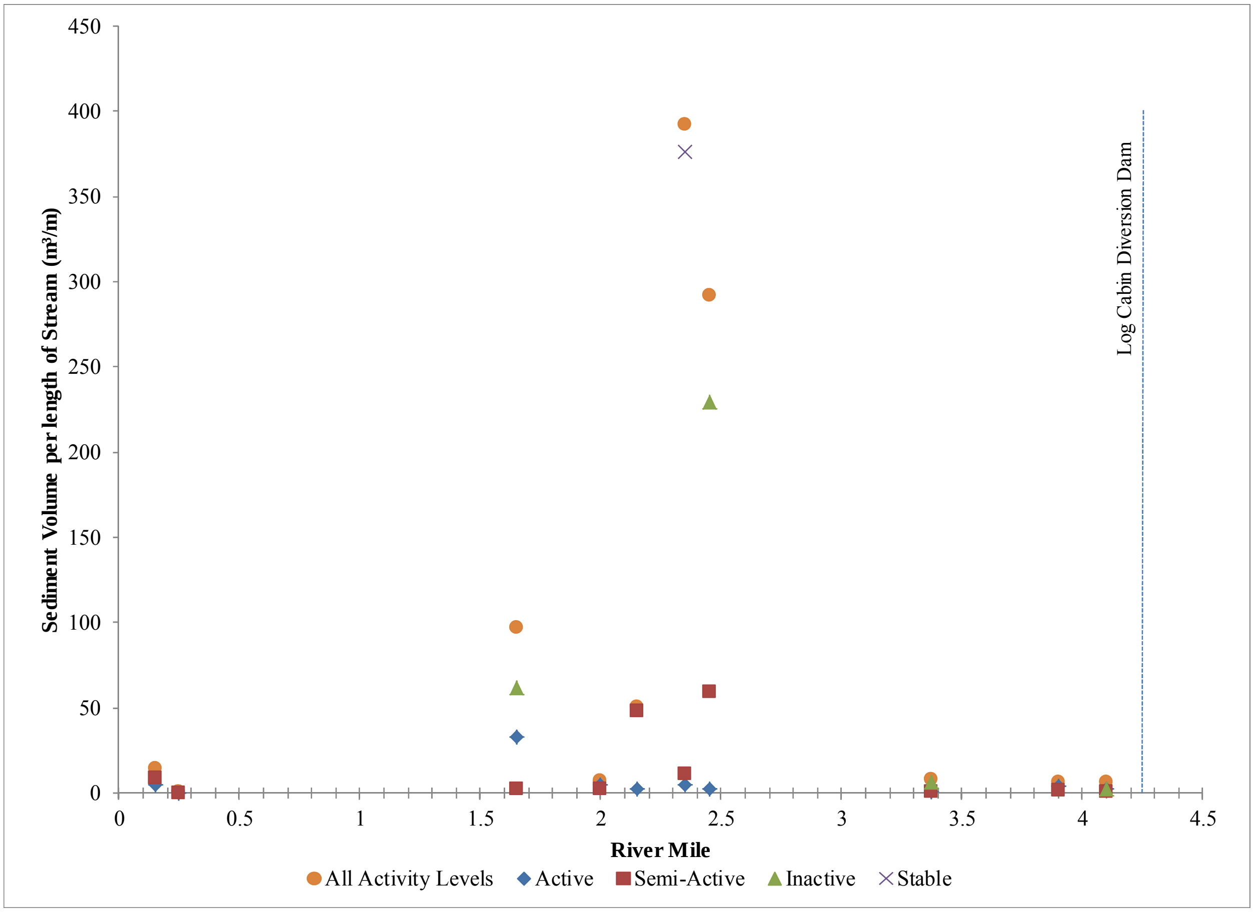

Figure 3.5-2. Channel storage in Oregon Creek downstream of Log Cabin Diversion Dam.

3.5.2 Sediment Storage Upstream of Project Facilities

The aerial extent of sediment that is stored upstream of the Project was evaluated at three locations: Our House Diversion Dam, Log Cabin Diversion Dam, and above the NMWSE of New Bullards Bar Reservoir in Slate Creek.

3.5.2.1 Our House Diversion Dam

Our House Diversion Dam is a 55 ft tall dam that began operations in 1968. Sediment has been removed from Our House Diversion Dam on several occasions, usually in response to large storm events that delivered the bulk of the sediments (EBASCO and Envirosphere 1986). In 1986,[10] 1992,[11] 1997,[12] and again in 2006,[13] excavation operations by YCWA within the impoundment were conducted to clear sediment away from the valve structures on the dam and diversion intake. The volume removed is summarized in Table 3.5-2.

Table 3.5-2. Estimated volume of sediment removed from Our House Diversion Dam between 1986 and 2006.

Year	Cubic Yards Removed	Comments
1986[1]	Not quantified	Unknown amount removed; the 1986 flood event is assumed to be the primary source of impounded sediments. Some 7,333 to 15,000 cubic yards estimated passed downstream in 1986; 15,000 cubic yards estimated as remaining behind dam.
1992[2]	27,595	Disposed of off-site
1997[3]	67,894	Disposed of off-site
2006[4]	80,000	Disposed of off-site

[1] EBASCO and Envirosphere 1986
[2] Pacific Gas and Electric Company (PG&E) Hydro Engineering and Construction Department 1992
[3] PG&E 1997
[4] YCWA 2006

Our House Diversion Dam impounds water on the Middle Yuba River and influences sediment deposition 3,400 ft upstream of the dam (Attachment 1-1E, page 4). The sediment deposition area within the impoundment is 11.4 acres (ac). The cross section located about 375 ft above the sediment deposited due to backwater influence was surveyed in 2012 and was also surveyed in 2008 as part NID and PG&E's Instream Flow Study, for the Yuba Bear Hydroelectric Project and Drum-Spaulding Project relicensings (Nevada Irrigation District and Pacific Gas and Electric 2011); the current and previous cross-section surveys are shown in Figure 3.5-3. From the surveys it appears the channel bed has remained fairly stable from 2008 through 2012, while

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[10] Sediments had been accumulating in the impoundment for 18 years since construction of the diversion dam in 1968 (EBASCO and Envirospere 1986). 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 and location of disposal was not specified. Necessary permits and approvals were obtained for sediment disposal. On August 20, 1986, between 7,333 and 15,000 yds^3 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 yds^3 remained to be removed.

[11] Dredging removed 27,595 yds^3 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 from the dam (PG&E 1992). Necessary permits and approvals were obtained for sediment disposal.

[12] Dredging removed 67,894 yds^3 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 land approximately 18 miles west of Our House Diversion Dam (PG&E 1997). Necessary permits and approvals were obtained for sediment disposal.

[13] 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 yds^3 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 New Bullards Bar Dam (YCWA 2006). Necessary permits and approvals were obtained for sediment disposal.

there may have been some aggradation on the cobble bar adjacent to the channel. The D_{50} of the substrate in the Middle Yuba River upstream of the influence of Our House Diversion Dam impoundment is 90 mm (small cobble) and the D_{84} is 180 mm (large cobble). The Middle Yuba River has a gradient of 0.4 percent in the channel upstream of the influence of the diversion. The channel is moderately entrenched (1.7 floodprone width: bankfull width).

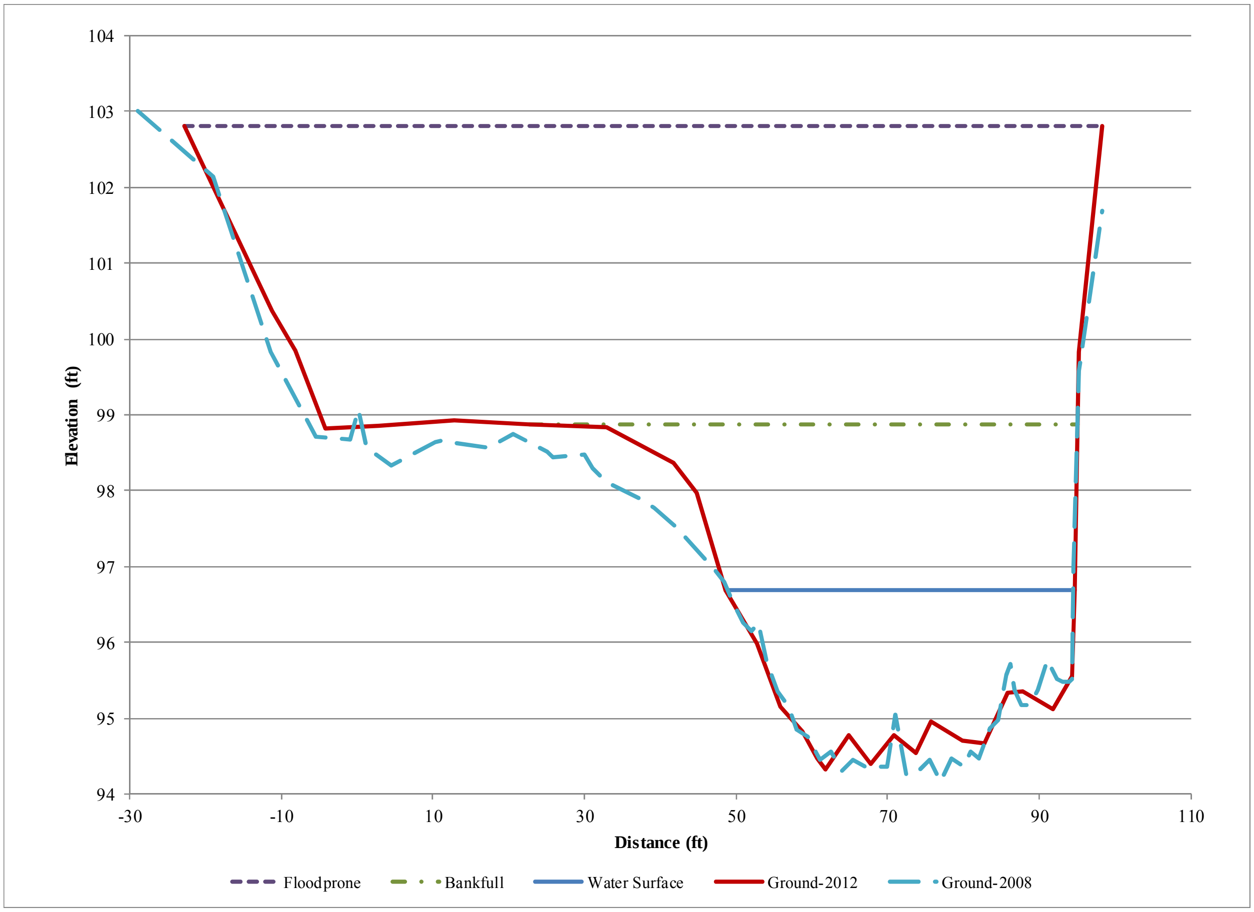

Figure 3.5-3. Cross section of Middle Yuba River approximately 375 ft upstream of Our House Diversion Dam impoundment in 2008 and 2012.

3.5.2.2 Log Cabin Diversion Dam

The Log Cabin Diversion Dam deposit covers an area of over 3 ac and extends about 2,000 ft upstream of the dam (Attachment 1-1E, page 6). At normal low-flow/low-water conditions, Oregon Creek meanders through large deposits of sediment within the area of influence until it reaches the diversion inlet. As mentioned earlier, Log Cabin Diversion Dam has not been dredged. Oregon Creek has a gradient of 2.6 percent upstream of the influence of the diversion dam (above the deposit). The D_{50} of the substrate in Oregon Creek about 75 ft upstream of the influence of Log Cabin Diversion Dam deposit is 64 mm (very coarse gravel) and the D_{84} is 122 mm (small cobble). The channel is moderately entrenched at this location (1.8 floodprone width: bankfull width) (Figure 3.5-4).

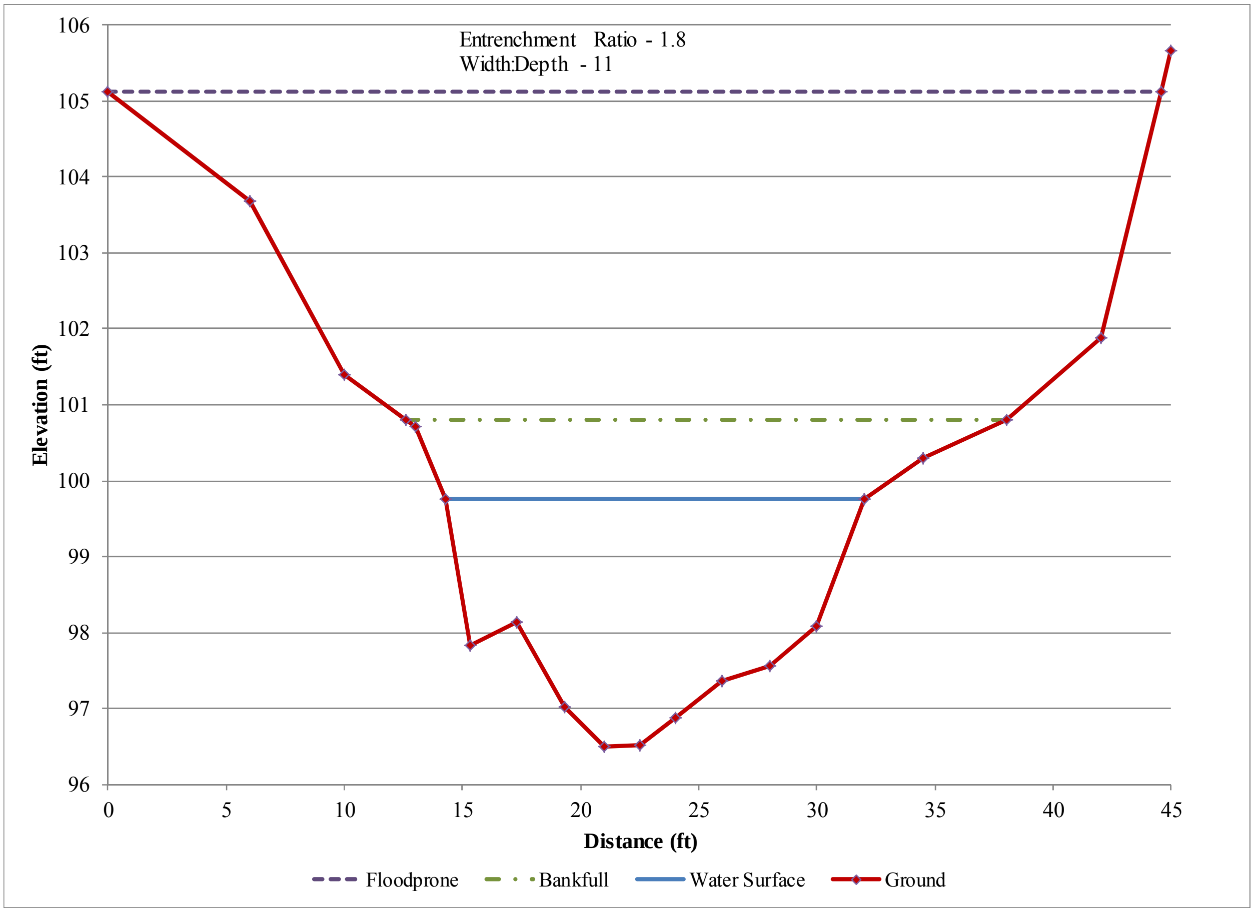

Figure 3.5-4. Cross section of Oregon Creek 75 ft upstream of Log Cabin Diversion Dam impoundment.

3.5.2.3 Slate Creek

Slate Creek is a tributary to the North Yuba River located upstream of the Project that drains into New Bullards Bar Reservoir near the upstream-most extent of the reservoir at NMWSE conditions. Slate Creek Diversion Dam is located at RM 9.1 of Slate Creek, and is owned and operated by the South Feather Water and Power Agency (SFWPA) to divert water from the Slate Creek watershed to Sly Creek Reservoir. The Slate Creek Diversion Dam impoundment is filled with cobble, gravel, sand, and silt mostly related to past hydraulic mining in the upstream source area (SFWPA 2007). Delivery of material from upstream hydraulic mine sites and aggraded channel reaches to the Slate Creek Diversion Dam impoundment was exacerbated in the 1950s by the breaching of St. Louis Debris Dam, located approximately 1 mile upstream of the Slate Creek Diversion Dam on Forest Service land. Prior to 1986, SFWPA regularly passed bedload and suspended load sediment from upstream sources through a low-level outlet in the Slate Creek Diversion Dam during high flows; however, this practice was discontinued in 1986 due to concerns regarding fine sediment and potentially contaminated sediment delivered to downstream reaches. A sediment pass-through program (SPT) was approved in 2001 and SPT events were attempted in 2002, 2003, 2004, and 2005. Most SPT attempts were unsuccessful at moving any significant amount of sediment (SFWPA 2007).

"Perfect" conditions for creating a deposit in Slate Creek due to the base level control of the North Yuba River/New Bullards Bar WSE would occur during a high flow event in the North Yuba River that is coincident with high flows in Slate Creek, and when New Bullards Bar Reservoir water surface is also high. Slate Creek (Attachment 1-1E, page 8) was surveyed on June 4, 2012 when New Bullards Bar Reservoir was at an elevation of 1,951.44 ft, which was used to establish an initial elevation upon which the survey was based. The mouth of Slate Creek is at elevation 1,953 ft. NMWSE of New Bullards Bar Reservoir is 1,956 ft.

There is a sediment deposit at the mouth of Slate Creek that has a maximum elevation of 1,967.7 ft and this upper surface is composed of sandy material. The deposit is a fan that slopes steeply into the North Yuba River and more gently towards Slate Creek, with the lower slopes composed of cobbles. The sand could only be deposited during high water when either North Yuba River or Slate Creek were experiencing overbank flow and water was sufficiently slow to allow deposition of material in suspension (e.g., sand). The conditions that are conducive to this sort of deposit occurred twice in the period of record – once in February 1986 and once in January 1997 (Table 3.5-3). There were other times that the North Yuba River was flooding (e.g., 1980 and 2005), but the reservoir level was quite low so the backwater effect into Slate Creek would have been reduced. The size of the cobble substrate, existence of a cobble bar, and age of the vegetation near the mouth of Slate Creek support the existence of a high flow event about 10-15 years ago, so it is likely that the 1997 event created the maximum backwater effect. The deposit at the mouth of Slate Creek also coincides with high water indicators in the North Yuba River adjacent to Slate Creek, and across the North Yuba River on a large cobble bar.

Table 3.5-3. High inflows of North Yuba River and Slate Creek and water surface elevations in New Bullards Bar Reservoir.

Date	Slate Creek Discharge[1] (cfs)	North Yuba River Discharge[1] (cfs)	Water Surface Elevation of New Bullards Bar Reservoir (ft)
13-Jan-80	10,611	38,780	1,872.74
18-Feb-86	9,023	30,396	1,955.44
2-Jan-97	8,717	43,458	1,954.37
31-Dec-05	7,437	30,084	1,927.69

[1] Flows are based on historically gaged flows on the North Yuba River at Jones Bar and Slate Creek below the Slate Creek Diversion Dam, and synthetic accretions downstream from those locations.

The maximum elevation of the deposit at the mouth of Slate Creek was used as the elevation indicating the extent of backwater effect into Slate Creek. The contiguous deposit was traced upstream into Slate Creek until it merged with the active channel at about 319 ft upstream from the confluence. Above this point, the gradient of Slate Creek steepens and there are additional coarse deposits that are not related to the reservoir level but are independent. Slate Creek was surveyed to an elevation over 1,968 ft to assure that the entire potential backwater-affected area was evaluated.

The D_{50} of the substrate in Slate Creek upstream of the influence of New Bullards Bar Reservoir is 90 mm (small cobble) and the D_{84} is 280 mm (small boulder). The gradient of Slate Creek is 0.9 percent above the influence of New Bullards Bar Reservoir (Figure 3.5-5). Slate Creek is moderately entrenched above the influence of the backwater effects (1.7 floodprone width: bankfull width) (Figure 3.5-6).

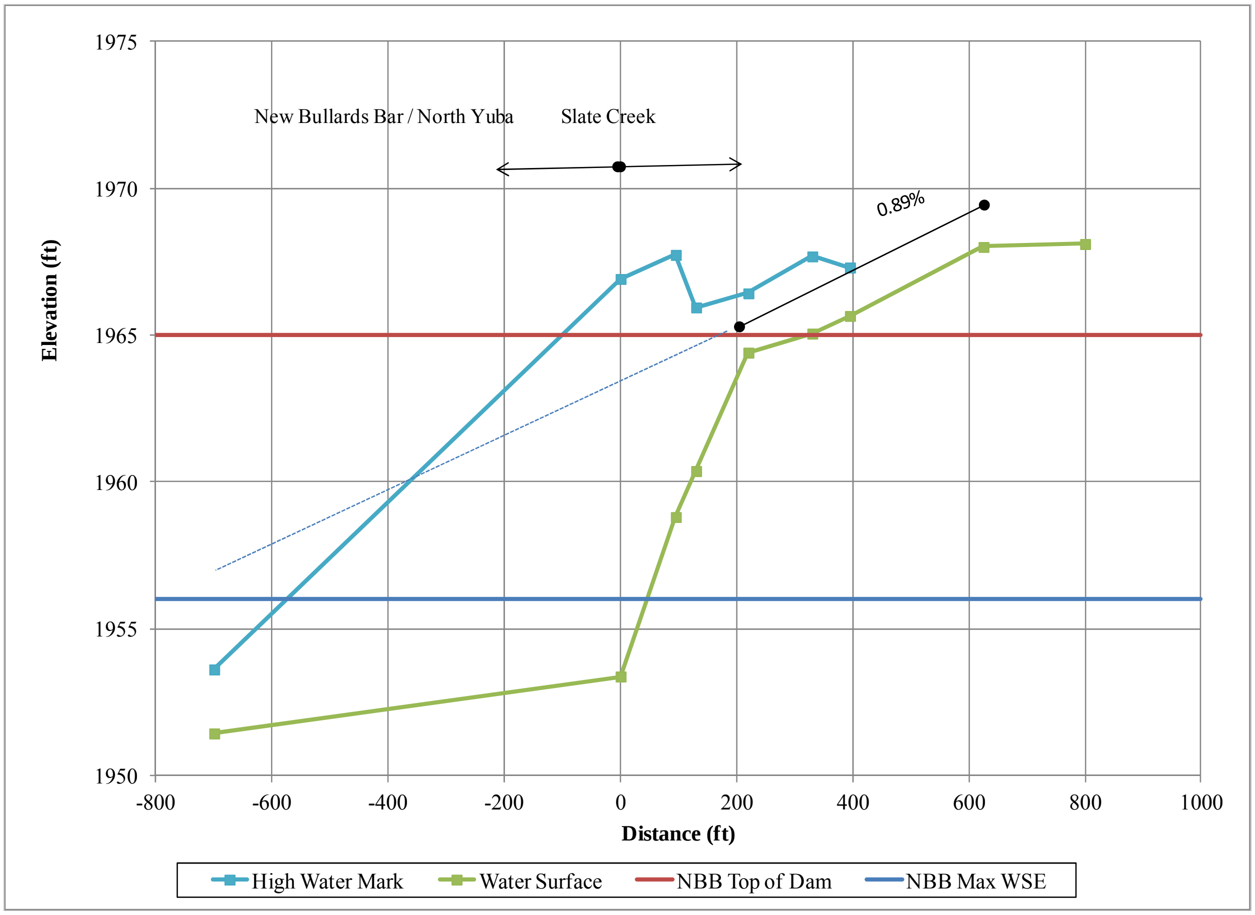

Figure 3.5-5. Longitudinal profile of Slate Creek and the North Yuba River from below the confluence into Slate Creek upstream of the backwater influence.

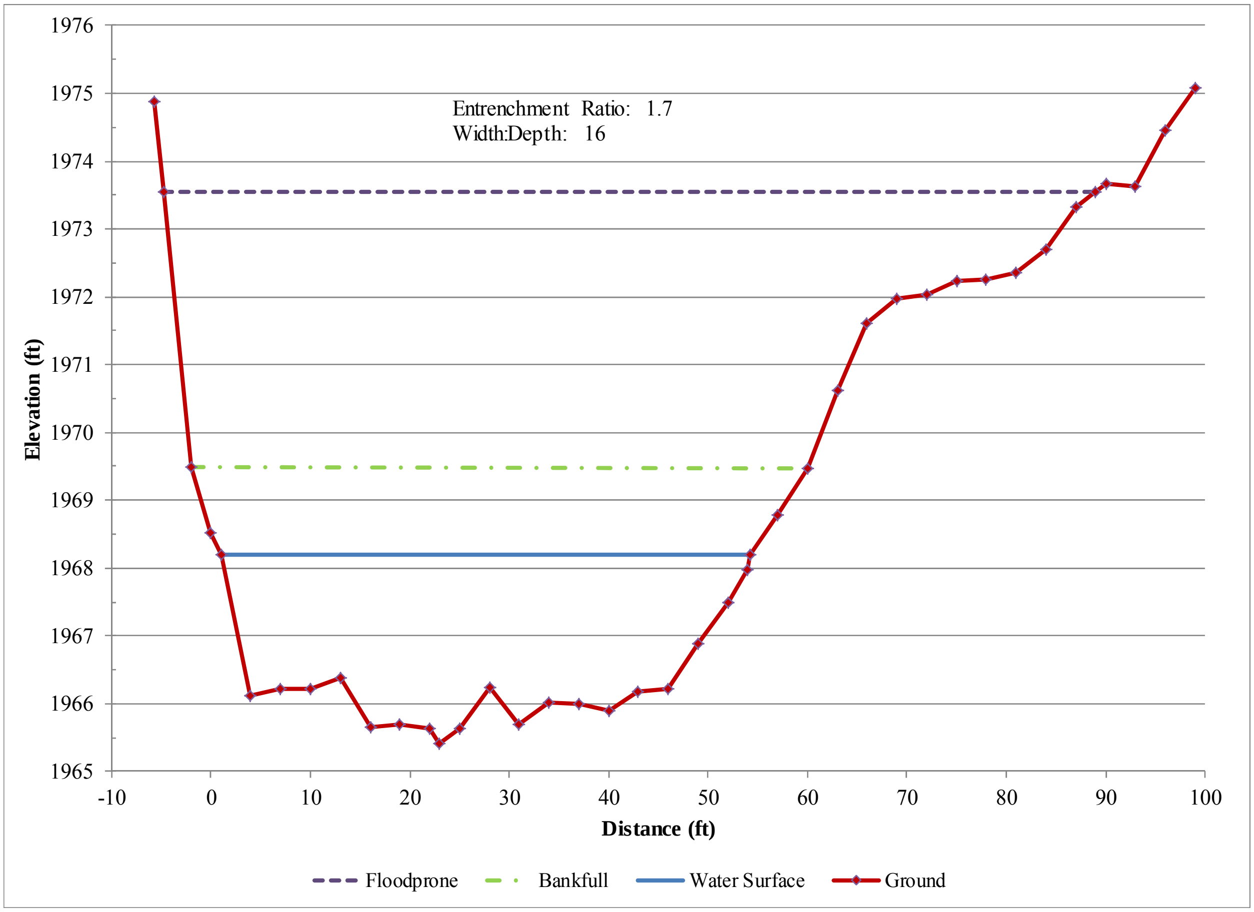

Figure 3.5-6. Cross section of Slate Creek above the influence of the NMWSE of New Bullards Bar Reservoir.

3.6 Spillway Erosion and Erosion Associated with New Colgate Powerhouse Releases

The three Project dams (i.e., Our House Diversion Dam, Log Cabin Diversion Dam, and New Bullards Bar Dam) were evaluated for evidence of spillway-related erosion as a source of sediment supply to stream channels.

3.6.1 Our House Diversion Dam

Our House Diversion Dam spills regularly over the passive-spill dam. There is no spill channel; thus, there is no spill channel erosion. The plunge pool below the dam is scoured to bedrock, as evidence of localized displacement of channel sediment.

The dam spilled on 1,869 days (i.e., out of 14,976 days from WY 1970 through WY 2010) with spills ranging from 1 cfs to a maximum of 20,940 cfs in 1997 (Figure 3.6-1, mean daily flows). There were five events when the mean daily flow was over 10,000 cfs. These occurred between December and February in 1980, 1981, 1986, 1997, and 2005. The median value of the non-zero spills was 254 cfs. The 75th percentile (i.e., the 75th percentile represents the flow rate at which 75 percent of flows during the period of record are less than this value) was 764 cfs, and the 25th percentile (i.e., 25th percentile represents the flow rate at which 25 percent of flows during the period of record are less than this value) was 46 cfs.

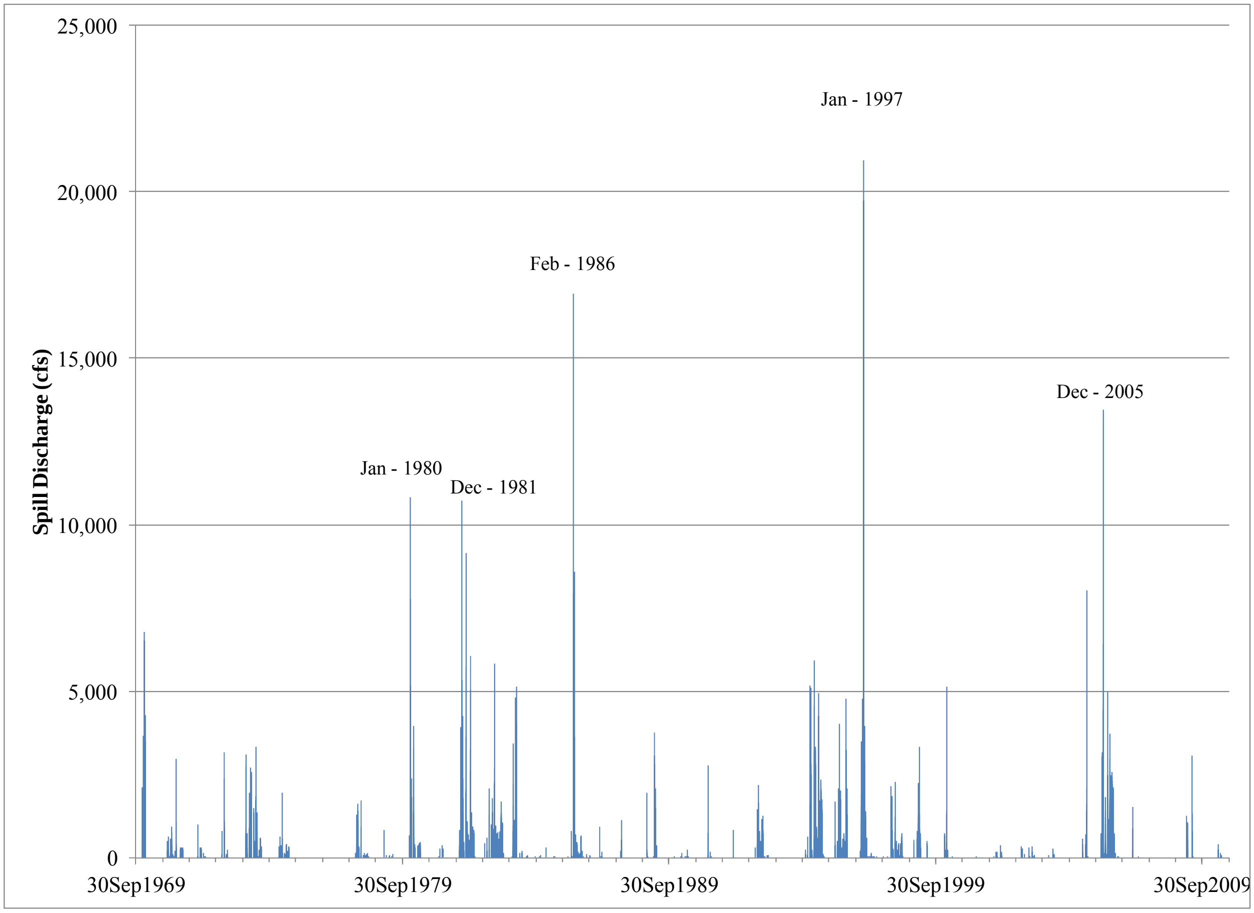

Figure 3.6-1. Spill events at Our House Diversion Dam from WY 1970 through WY 2010.

3.6.2 Log Cabin Diversion Dam

Log Cabin Diversion Dam spills regularly over the passive-spill dam. There is no spill channel; thus, there is no spill channel erosion. The plunge pool below the dam is scoured to bedrock, as evidence of localized displacement of channel sediment.

From WY 1970 through WY 2010, the dam spilled on 501 days, with spills ranging from 1 cfs to a maximum of 5,340 cfs in 1986 (Figure 3.6-2, mean daily flow). There were eight events when the mean daily flow was over 2,000 cfs. These occurred between December and February in 1970, 1980, 1981, 1982, 1986, 1997, and 2005. The median value of the non-zero spills was 218 cfs. The 75th percentile was 466 cfs, and the 25th percentile was 80 cfs.

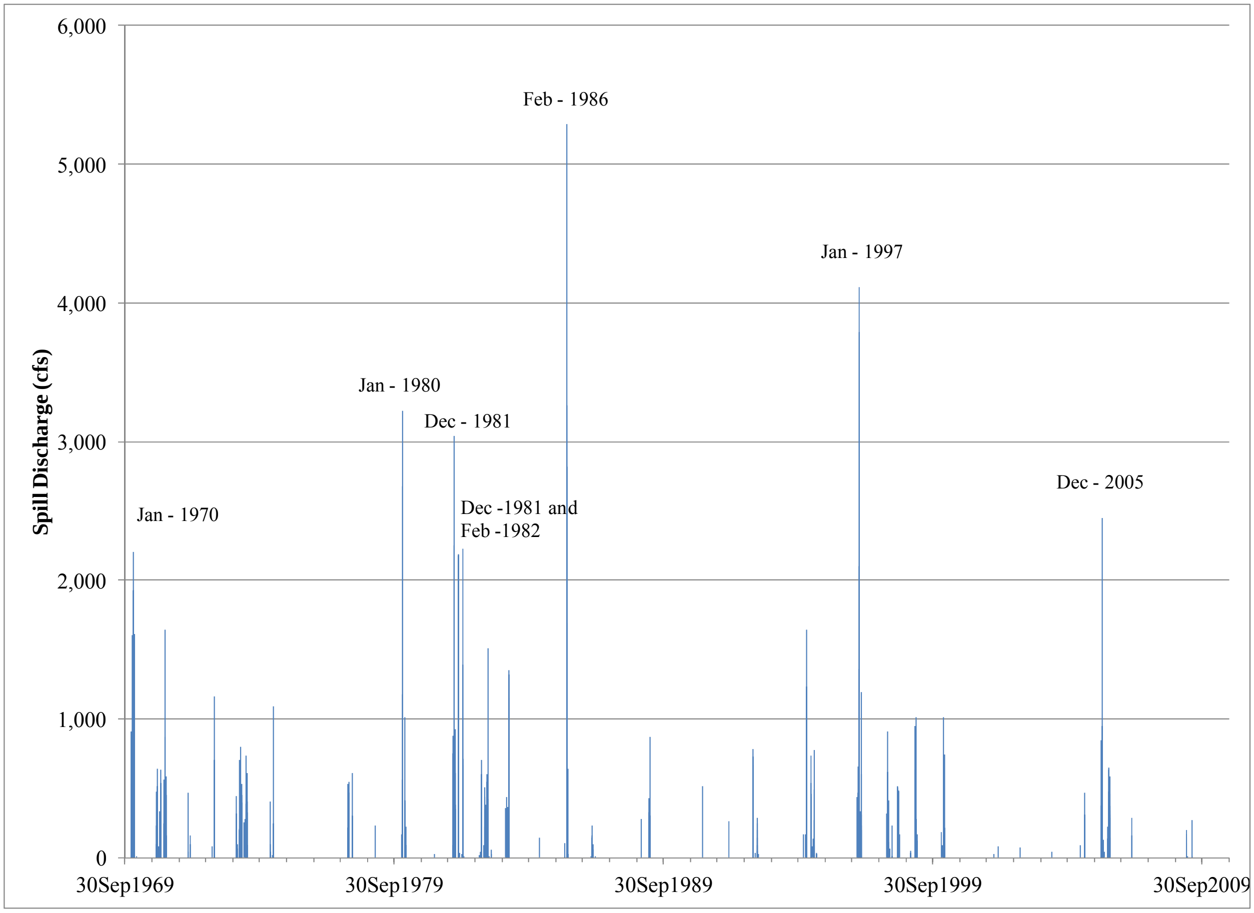

Figure 3.6-2. Spill events over at Log Cabin Diversion Dam from WY 1970 through WY 2010.

3.6.3 New Bullards Bar Dam

The New Bullards Bar Dam Spillway is a very steep concrete chute that discharges onto a steep bedrock wall. Below the reinforced concrete, there is a wide swath of exposed bedrock that forms the spill channel. The plunge pool is deeply scoured to bedrock. There are no obvious deposits that remain in the North Yuba River downstream of the spill that are traceable to spill events, as the bed is composed of very coarse material and very low amounts of deformable substrate.

From WY 1970 through WY 2010, the dam spilled on 761 days, with spills ranging from 1 cfs to a maximum of 53,633 cfs, which occurred in 1997 (Figure 3.6-3, mean daily flow). There were six events when the mean daily flow was over 20,000 cfs. These occurred between January and May in 1970, 1974, 1986, 1997, 2005 and 2006. The median value of the non-zero spills was 2,000 cfs. The 75th percentile was 4,255 cfs, and the 25th percentile was 1,000 cfs.

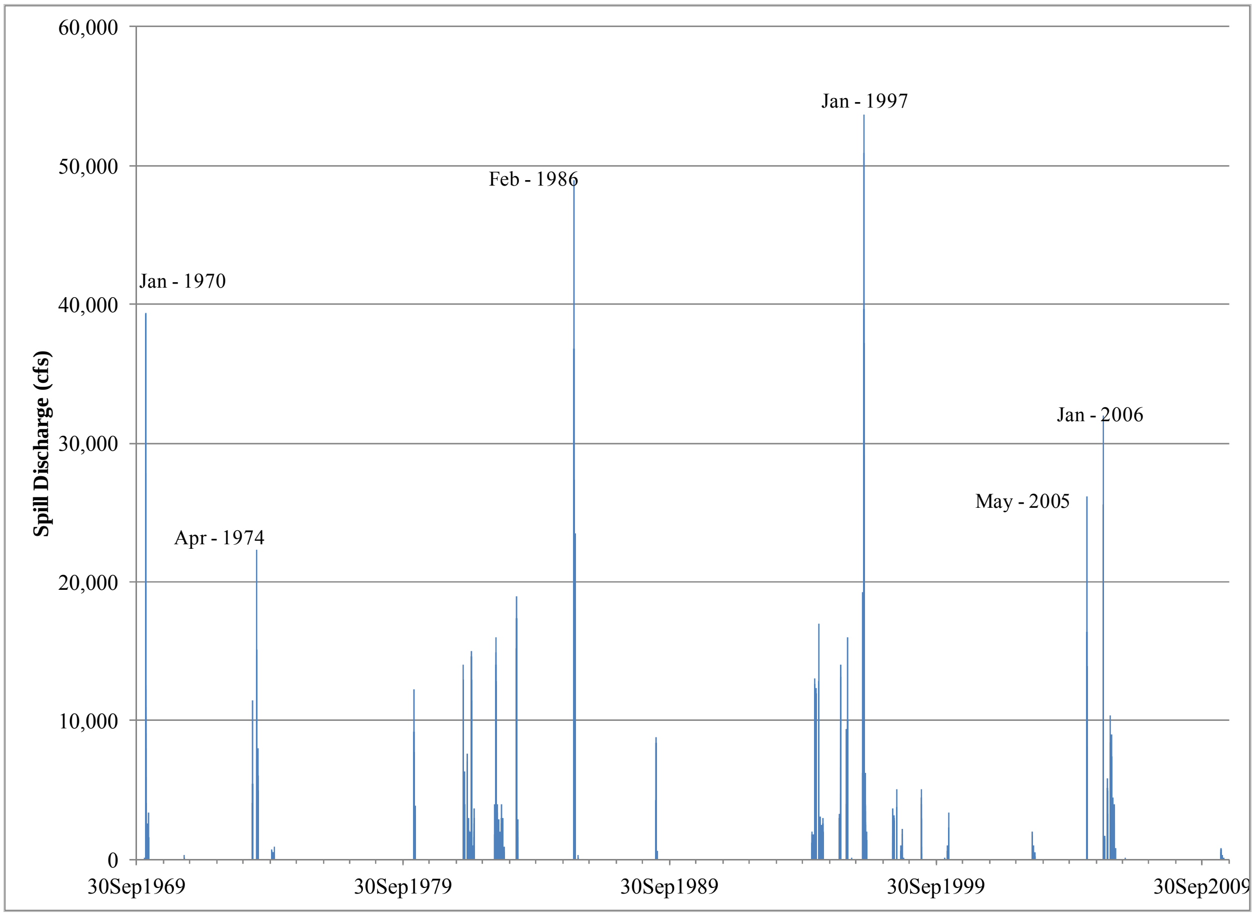

Figure 3.6-3. Spill events through New Bullards Bar spill gates from WY 1970 through WY 2010.

3.6.4 New Colgate Powerhouse

Because the New Colgate Powerhouse releases create a peaking reach from the powerhouse to the inflow to Englebright Reservoir, this reach was evaluated for effects of peaking on bank erosion. Large flow changes at the New Colgate Powerhouse are generally due to operations responding to power market conditions and occasional flow changes due to short-term powerhouse outages. Ramping rates can be as much as increases from flows near zero to the full capacity of 3,430 cfs and from full capacity back to near zero flow in less than 15 minutes. The short-term flow changes are almost entirely driven by electric grid response. Although large changes and ramping rates do occur, they can be generally characterized as occurring a few times a day and mostly less than the full range of release capacity.

The banks immediately adjacent to and just downstream of the New Colgate Powerhouse are composed of boulder and bedrock material (Figures 3.6-4 and 3.6-5). The banks for the entire reach are composed of resistant bedrock and boulder (Figure 3.6-6) until about the top of Site 9. Only about 9 percent of the reach is composed of erodible-type material, based on the bank erodibility assessment for the channel morphology study (Figures 3.6-7 through 3.6-9).

Figure 3.6-4. Aerial view of New Colgate Powerhouse outflow.

Figure 3.6-5. View from downstream at instream flow Transect 20 looking upstream to New Colgate Powerhouse outflow.

Figure 3.6-6. Bedrock/boulder bank type.

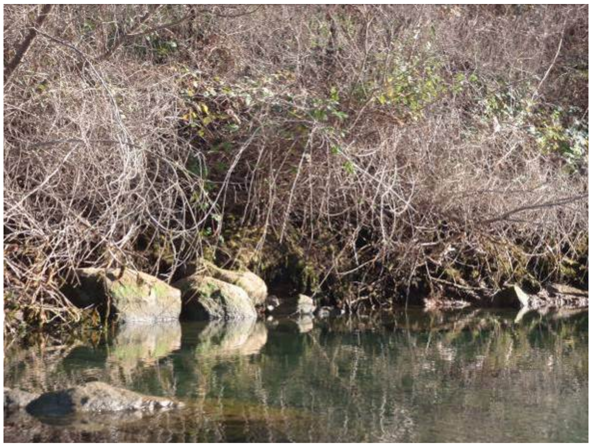

Figure 3.6-7. Boulders and vegetation with silt soil bank type.

Figure 3.6-8. Sandy bank type.

Figure 3.6-9. Vegetated soil bank type.

3.7 Interaction with Riparian Zone

Complete results are available in Study 6.1, *Riparian Habitat Upstream of Englebright Reservoir Study*. Summary of historical change and current interaction with the riparian zone are presented below.

3.7.1 Historical Change

YCWA conducted historical photograph analysis for seven riparian assessment sites that were co-located with the seven channel morphology intensive study sites (Table 2.2-1). Analysis was focused on visible changes in vegetation and channel alignment overtime and in many cases, was limited due to poor photograph resolution, especially in early photographs (Attachment 6.1-C). The photographs available were from the years 1937, 1952, 1969, 1993, 1998 and 2009. Not all years were available at all sites (Table 3.7-1).

Table 3.7-1. Summary of riparian and channel changes as noted in aerial photographs between 1937 and 2009.

Study Site Name/ Study Site No.	1937	1952	1969	1993	1998	2009	Summary of Change
Middle Yuba River downstream of Oregon Creek (Site 1)	X	X	--	--	X	X	No obvious channel change except between 1937 and 1952 - cobble bar between T8 and T11 narrowed. Peak event in 1940 may have contributed.
Middle Yuba River upstream of Oregon Creek (Site 2)	X	X	--	--	X	X	No obvious channel change. Increase in riparian vegetation between 1937 and 1952, decrease between 1952 and 1998, increase between 1998 and 2009. High flow events in 1955, 1986 and 1997 may have contributed to decreases; subsequent increases during periods of relatively normal flow.
Middle Yuba River downstream of Our House Diversion Dam (Site 3)	--	--	X	X	X	X	No obvious channel change. Riparian vegetation increasing from 1969 to 2009. Large flood events that caused filling of Our House Dam reservoir (Table 3.5-2) were not evident in changes in riparian vegetation through historical photo analysis.
Oregon Creek Celestial Valley Sub-Reach (Site 5)	--	--	X	X	X	X	No obvious changes in near-stream riparian vegetation and channel alignment, though photo resolution is poor. Increase in floodplain vegetation from 1969 to 1993.
North Yuba River (Site 7)	X	X	--	--	X	X	No obvious changes related to vegetation and channel alignment were evident.
Yuba River downstream New Colgate Powerhouse (Site 9)	X	--	--	--	X	X	No obvious changes related to channel alignment were evident. There was an increase in riparian vegetation along the wetted edge increased near Rice's Crossing between 1998 and 2009, which may be due to disturbance and subsequent recovery following the 1997 flood event.
Yuba River upstream of New Colgate Powerhouse (Site 10)	X	--	X	--	X	X	No obvious changes related to vegetation and channel alignment were evident.

3.7.2 Riparian Vegetation and Channel Interaction

In a channel that does not have deformable bed and banks, determining bankfull flow is difficult. There are few gravel bars and determination was dependent upon perennial vegetation and small deposits of sand, which indicates incipient floodplain development. In addition, flow is controlled so the 1.5-year frequency for bankfull conditions that is typical in self-formed, uncontrolled channels is likely not as relevant for channel-forming conditions (i.e., low magnitude, high frequency, or bankfull flows, do most geomorphic work in self-formed channels [Dunne and Leopold 1978]). Based on these limited field indicators, bankfull discharge was lower than a 1.5-year return frequency for all but one intensive study site (Table 3.7-2). This shows that either the flows are moving onto and creating incipient floodplains more frequently than in a non-regulated system or that the indicators are so poor that the bankfull elevation may be misrepresented. Additionally, the effect of using mean daily flows rather than instantaneous flows is that the peaks will be flattened and there will be less variability from day to day and year to year. There will be a higher "density" of flows within a more moderate range, rather than having the diversity of flows associated with the instantaneous values, and bankfull flows are relatively low and would have a higher probably of occurrence. Inundation of near-stream environments affects the riparian community, so frequency of this inundation and changes to the frequency due to regulation are important.

Table 3.7-2. Bankfull discharge based on field indicators and recurrence intervals for field-based bankfull and discharge at 1.5-year recurrence interval using With-Project synthesized hydrology.

Study Site Name/ Study Site No.	Bankfull Discharge based on Field Indicators (cfs)	Recurrence Interval based on With-Project Flow Conditions[1] (years)	Discharge at 1.5-year Recurrence Interval[1,2] (cfs)
Middle Yuba River downstream of Oregon Creek (Site 1)	404	1.07	1,791
Middle Yuba River upstream of Oregon Creek (Site 2)	298	1.07	1,296
Middle Yuba River downstream of Our House Diversion Dam (Site 3)	284	1.16	868
Oregon Creek Celestial Valley Sub-Reach (Site 5)	136	1.23	300
North Yuba River (Site 7)	326	1.96	68
Yuba River downstream of New Colgate Powerhouse (Site 9)	2,710	1.23	4,825
Yuba River upstream of New Colgate Powerhouse (Site 10)	379	1.04	2,933

[1] Synthesized flow using mean daily maximum values WY 1969 through WY 2010.
[2] With-Project synthesized hydrology.

YCWA's characterization of existing riparian habitat is a combination of data provided by field surveys for vegetation, including observations of germination, conducted for YCWA's relicensing Study 6.1, Riparian Habitat Upstream of Englebright Reservoir, and data collected on channel morphology intensive study sites. Inundation frequency is derived from estimates of bankfull and floodplain elevation from the channel morphology study; stage-discharge relationships are estimated from calibrated PHABSIM models (Study 3.10 *Instream Flow Upstream of Englebright Reservoir*) and combined with return frequencies modeled from data provided from Study 2.1 *Hydrologic Alterations.* The PHABSIM models are only calibrated to about 2.5 times the maximum measured flow (Table 2.3-1), so estimates of discharge at floodprone elevation are beyond the calibrated range. For example, the Middle Yuba models are only calibrated to 750 cfs but floodprone estimates are above 3,000 cfs. However, in the case of the Middle Yuba River downstream of Oregon Creek, floodprone is estimated to be about 8,400 cfs. A storm event estimated to have a peak discharge of 8,500 cfs inundated the floodplain and looked to be coincident with the floodprone elevation, which gives more confidence in the extrapolation.

Table 3.7-3. Description of riparian vegetation and inundation frequency under With- and Without-Project conditions.

Site	Vegetation	Bankfull Discharge Estimate (cfs)	Inundation Frequency Bankfull		Floodprone Discharge Estimate (cfs)	Inundation Frequency Floodprone	
			With-Project	Without Project		With-Project	Without Project
Middle Yuba River downstream of Oregon Creek (Site 1)	Vigorous; hydrologically connected; woody species present of various ages and species	404[1]	1.0	1.0	8,408	2.5	1.2
Middle Yuba River upstream of Oregon Creek (Site 2)	Vigorous; hydrologically connected; woody species present of various ages and species	298[2]	1.1	<1	6,994	5.2	4.6
Middle Yuba River downstream of Our House Diversion Dam (Site 3)	Vigorous; hydrologically connected; woody species present of various ages and species with the exception of locations dominated by boulder and bedrock material incapable of sustaining vegetation.	283[3]	1.2	<1	3,014	2.9	2.0
Oregon Creek Celestial Valley Sub-Reach (Site 5)	Vigorous; hydrologically connected; woody species present of various ages and species	136[4]	1.2	1.0	1,916	4.8	4.7
North Yuba River (Site 7)	Vigorous; hydrologically connected; woody species present of various ages and is very limited in locations due to bedrock and boulder dominating riparian zone.	326[1]	2.0	<1	2,640	3.0	1.0
Yuba River downstream New Colgate Powerhouse (Site 9)	Vigorous; hydrologically connected; woody species present of various ages and species with the exception of the upper areas on cobble bars and less cover in bedrock-dominated locations.	2,710[5]	1.2	1.0	41,308	9.2	6.1
Yuba River upstream of New Colgate Powerhouse (Site 10)	Vigorous; hydrologically connected; woody species present of various ages and species, though several locations were dominated by bedrock and boulder so were incapable of supporting riparian vegetation.	379[6]	1.0	<1	3,539	1.6	1.0

[1] Average of values for each transect using MANSQ/discharge relationship from PHABSIM

[2] Bankfull discharge was estimated using MANSQ conveyance/discharge relationship for Transect 2; Transects 9 and 12 were estimated using the log-log relationship from PHABSIM.

[3] Average of values for each transect using log/log stage/discharge relationship from PHABSIM

[4] Bankfull discharge was estimated using MANSQ conveyance/discharge relationship for Transects 8 and 10; Transect 12 was estimated using the log-log relationship

[5] Bankfull discharge was estimated using log/log stage/discharge relationship from PHABSIM for Transect 3 only (aka T-6 PHABSIM).

[6] Bankfull discharge was estimated using MANSQ conveyance/discharge relationship for Transects 8 and 11; Transect 15 was estimated using the log-log relationship

4.0 Discussion

The objective of this channel morphology study was to quantify or characterize river form and process in reaches downstream of Project facilities, and interaction with the riparian zone in those reaches and within zones potentially affected by facilities upstream. Multiple lines of evidence of existing channel form were used to develop an understanding of existing condition of the Project-affected channels and potential condition if there are changes in project operations. An additional element, or objective of the study, was to understand the interactions of the Project-affected streams with the riparian environment, which is affected by and affects sediment availability, transport and storage.

4.1 Linking Sediment Availability, Transport Capability, and Channel Storage

Channel form and process is a complex interaction of numerous elements such as material within and available to a channel and the forces that move the sediment. All the data collected for this study were used to develop an understanding of how Project operations affect sediment; the sediment available; how sediment is transported; and where sediment is stored.

4.1.1 Sediment Availability

The form of a channel is a balance between the sediment that is available for storage or transport, and the ability of the stream to transport that sediment. Project operations change the sediment that is available to a stream and the way that flow is delivered such that the ability of the stream to move sediment is modified. While long-term sediment storage may be unaffected (e.g., those deposits in terraces or large, immobile cobble bars), short-term storage (e.g., changes that will be evident over the period of a hydro license) can experience a net gain or net loss. Sediment is stored upstream of Log Cabin Diversion Dam in Oregon Creek, Our House Diversion Dam on the Middle Yuba River, and New Bullards Bar Dam on the North Yuba River and sediment supply immediately below these facilities is considered near zero. Our House Diversion Dam, however, is an incomplete block and as much as 6,100 to 12,600 tons of sediment was passed during a 1986 event where spill was about 17,000 cfs (EBASCO and Envirosphere 1986). Another event in 1997 spilled almost 21,000 cfs and may have also carried sediment past the dam, though no estimate was made. The only spill channel in the system (New Bullards Bar Dam) is situated over bedrock with little additional input during spills because there is no evidence below the spill channel that sediment is being added, nor is there significant continuing erosion adjacent to the spill channel.

Sediment input to each stream was estimated using regional estimates of sediment yield (Snyder et al. 2004) on a per-square-mile basis. Each square mile below the dams is estimated to add 708 tons of sediment per year. The greater the area below a dam, the greater the sediment availability below the dam. None of the streams have sufficient drainage area below the dam to achieve a substantial increase in sediment availability. The best ratio of With-Project to Without-Project sediment availability was seen on the Middle Yuba River above the Oregon Creek confluence.

Downstream of Project facilities, using the existence of long-term alluvial fans as evidence of long-term sediment supply, there are sediment sources from Dobbins Creek into the Yuba River below New Colgate Powerhouse, Yellowjacket Creek into the Middle Yuba River at RM 1.4, Sebastopol unnamed tributary into the Middle Yuba River at RM 0.7, and quarry tailings sidecast into North Yuba River just below New Bullards Bar Dam. These sources are insufficient to see an effect beyond the confluence, such as excessive channel aggradation in the form of large mid-channel bars or abraided channel. There is likely additional input from tributaries, but there is no remaining evidence of this input within the mainstems, probably due to high transport capability.

4.1.2 Transport Capability

Most of the streams have a high transport capability. This can be seen even without the use of a complex sediment transport model. With the exception of the Yuba River downstream of the New Colgate Powerhouse, the surface of the bed is coarse as the smallest reach-averaged median particle size is 64 mm, which represents very coarse gravel, the largest is 241 mm (i.e., large cobble), and the average across all sites is 126 mm (i.e., small cobble). Large boulders and bedrock control 1 to 66 percent of the bed and banks, such that even estimating D_{50} became difficult with so much immobile material. Bank erosion was very low and channel stability rating was very high (as estimated using Pfankuch 1975), reflecting these resistant channel materials. Channel form of this system is categorized as “imposed” rather than “self-formed.” Whipple (2004) conceptually designated fluvial channels into two types: 1) an imposed channel form composed of an immobile bed that is boulder-choked, supply-limited, has a small drainage area, with stochastic sediment supply and flooding (e.g., random and does not follow a pattern) versus 2) self-formed channels that have mobile bed and banks with transportable sediment, with a system that is transport-limited, and less random sediment supply and flooding (e.g., less susceptible to big floods and less variation in sediment supply). Of the reaches considered in this study, only the Yuba River downstream of the New Colgate Powerhouse could be considered self-formed. The Oregon Creek Celestial Valley Sub-Reach appears to be a combination of self-formed and imposed channel types as there are deformable banks and sections of the channel that are composed of mobile, deformable substrate; however, these sections are intermixed with very coarse, immobile cobble and boulder substrate. Wilcock et al. (2009) makes a further distinction of fully alluvial and non-alluvial. Fully alluvial channels are at equilibrium where transport rates in and out are balanced over periods of a storm or longer, and channels are formed of material that is being transported; none of the upper Project reaches could be considered fully alluvial.

4.1.2.1 Transport and Substrate

Generally, as sediment transport capacity increases, as predicted by the BAGS model, particle size and boulder/bedrock control increase (Figure 4.1-1 and 4.1-2). The relationship is affected by elements such as unquantified roughness which may cause significant overestimates in sediment transport in the North Yuba River and the Yuba River upstream of the New Colgate Powerhouse sites, local and regional sediment supply that exceeds or is below regional estimates, and backwater effects from Englebright Reservoir in the case of the Yuba River downstream of the New Colgate Powerhouse.

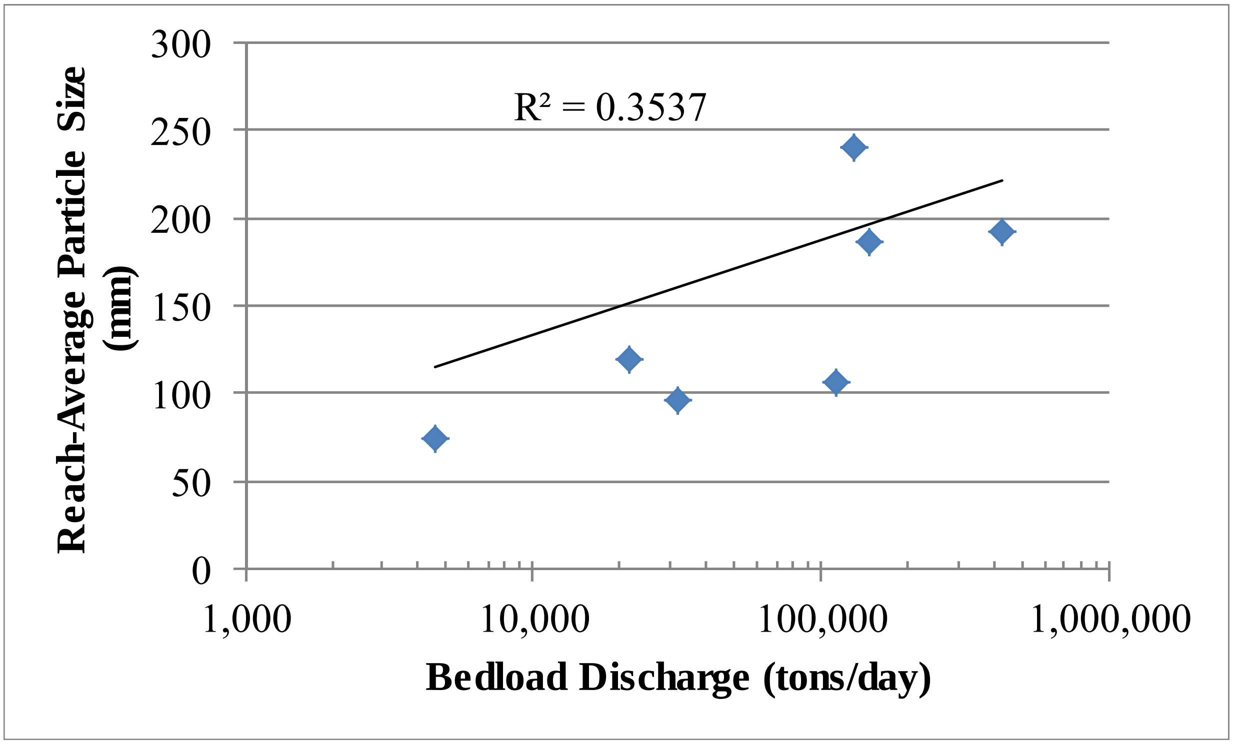

Figure 4.1-1. Relationship of estimated average bedload discharge at each intensive study site and particle size.

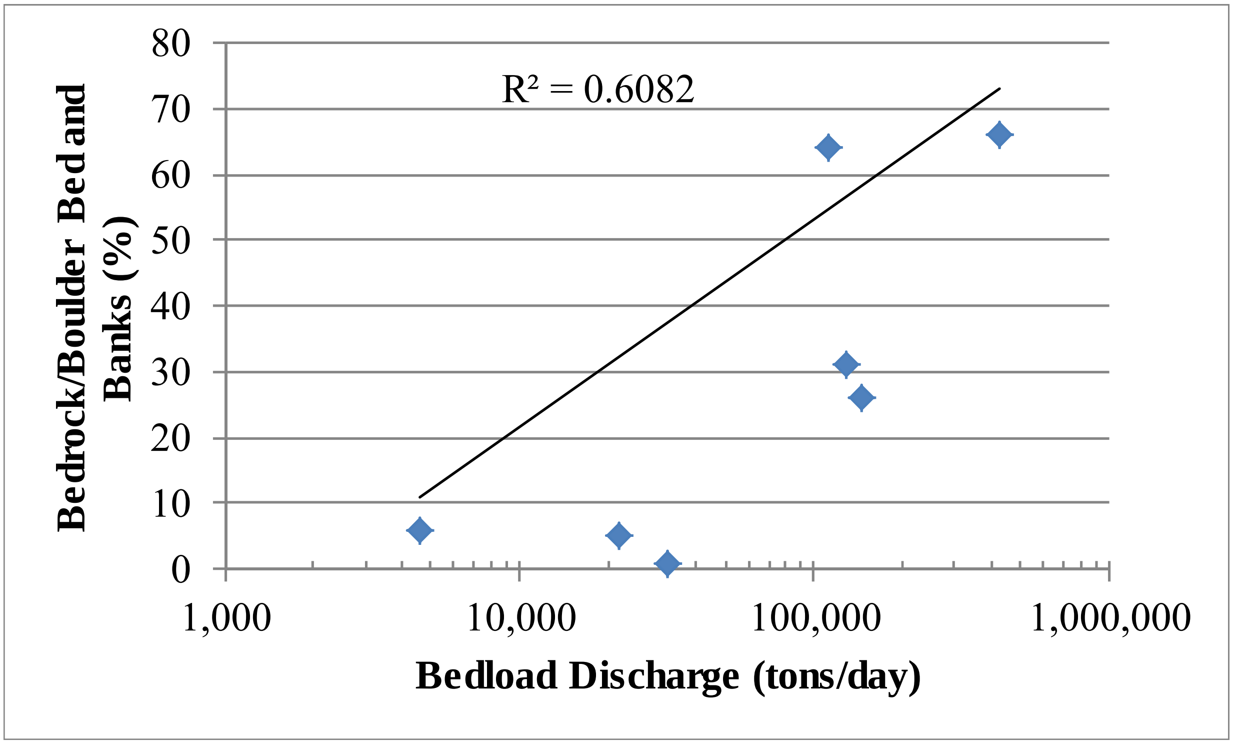

Figure 4.1-2. Relationship of estimated average bedload discharge at each intensive study site and bedrock/boulder composition in the bed and banks.

4.1.2.2 Transport Test using Tracer Particles

Mobility in the Middle Yuba River and Oregon Creek was achieved with an event that had a fairly high recurrence interval, based on With-Project hydrology. In the Middle Yuba River where tracer particles were placed (Transects 9 and 13), it was estimated that critical discharge is about 600 cfs (WinXSPro estimate, With-Project, Table 3.3-2). During a December 2013 storm event that caused discharge flows of approximately 8,500 cfs, all particles moved or were buried. While it is unknown at what discharge the particles began to move, it is known that 8,500 cfs (i.e., recurrence interval of 4.7 years under With-Project hydrology) will move particles D_{84} and finer in this channel.

In Oregon Creek, the event generated flows over 600 cfs (2.3-year recurrence interval) and 30 percent of particles 180 mm and finer were mobilized. However, of these particles that moved, 90% were less than 90 mm (i.e., only three of the moved particles were larger than 90 mm). Critical discharge for 45 mm particles was estimated to be between 200 and 500 cfs for the two transects with tracer particles, and 50 percent of 45 mm particles were removed. However, 64 mm and 90 mm particles also moved in this moderate event; location within the thalweg led to enhanced movement of the larger particles.

4.1.2.3 Transport and Storage

The location with the highest amount of storage of particles less than approximately 128 mm (i.e., considered mobile particles) was in the Yuba River downstream of the New Colgate Powerhouse (Figure 4.1-3). This site experiences backwater effects from Englebright Reservoir, is a lower position in the watershed, as compared to the other sites, and has a lower overall gradient. Therefore, the site has access to all the sediment supplied from upstream, in addition to having low bedload transport capacity.

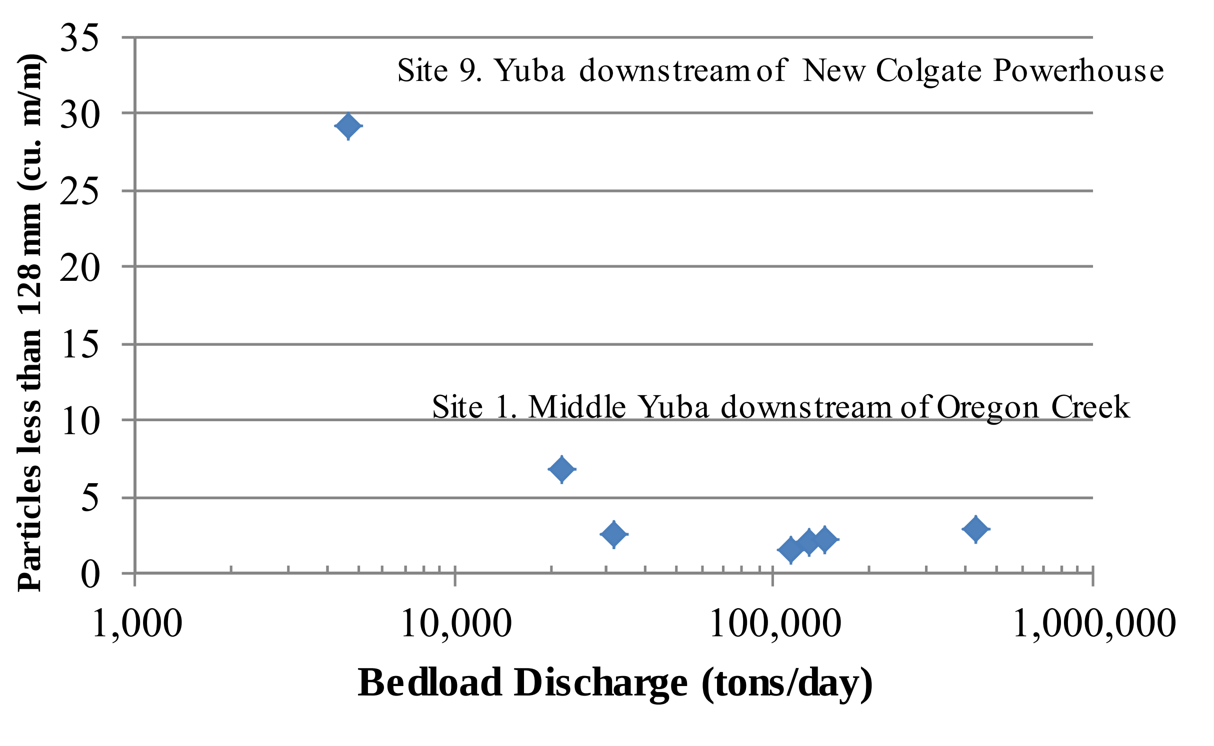

Figure 4.1-3. Relationship of estimated average bedload discharge at each intensive study site and stored particles approximately 128 mm or less. Note that Sites 9 and 1 have the highest amount of particles less than 128 mm and are labeled; the other sites fall below 5 m^3/m and are not labeled.

The location with the next highest amount of stored mobile particles was within the Middle Yuba downstream of Oregon Creek. This site is just below Freemans Crossing, which is a large long-term depositional site, and is constantly being reworked by recreational mining and other human perturbance. This local source is probably a constant supply of mobile sediment and in fact new deposition occurred in the study site following a flood event.

The rest of the intensive study sites had about the same amount of storage of mobile material per unit of stream, regardless of increasing transport capacity (Figure 4.1-3).

4.1.2.4 Transport and Sediment Supply

Channel armoring is a measurement of the disparity between the surface and sub-surface that arises when transport rate exceeds local supply rate (Dietrich et al. 1989). Armoring is assumed when the surface of a channel bed is coarser than the sub-surface of the channel bed. This coarse surface layer can be attributed to sediment supply being cut off and selective erosion that causes coarsening. This relationship is shown in the Middle Yuba River where three sites were sampled for armoring ratio with a continuum of armoring ratio and bedload transport capacity (Figure 4.1-4).

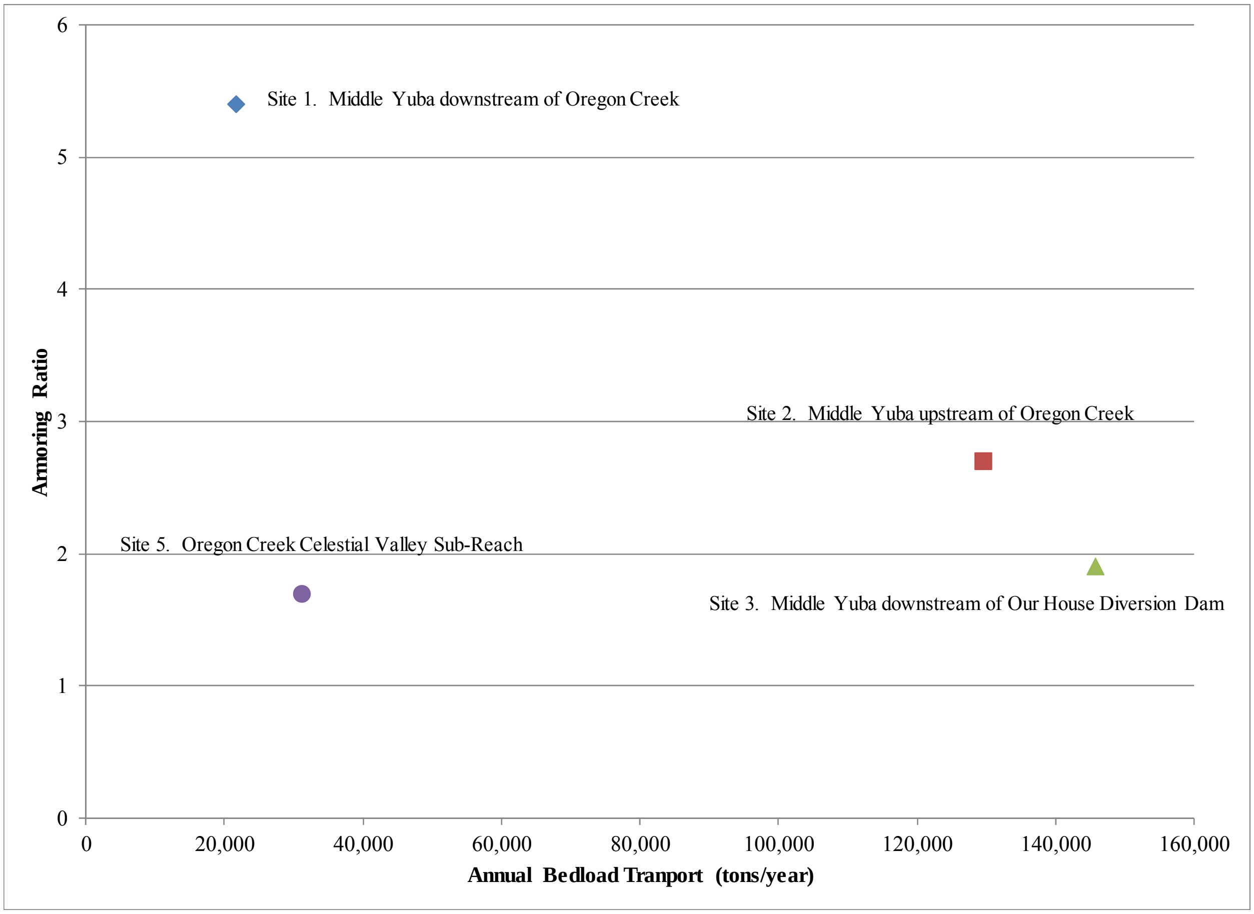

Figure 4.1-4. Armoring ratio as a function of annual bedload transport for the Middle Yuba River and Oregon Creek.

The most downstream study site on the Middle Yuba River (i.e., Middle Yuba River downstream of Oregon Creek) had the highest sediment availability. This location also had the highest armoring ratio and lowest estimated annual bedload transport rate. Conversely, the Middle Yuba River downstream of Our House Dam has the lowest armoring ratio, the highest estimated annual bedload transport rate, and the lowest sediment input as it is just downstream of a dam that stores much of the sediment available from upstream sources. The sites on the Middle Yuba River above and below Oregon Creek were sampled in fairly coarse material of exposed bars, with a distinctive separation between surface and subsurface, while the samples below Our House Dam had to be sampled from small accumulations of gravel on the channel margin as there were no other exposed bars. Conversely, Oregon Creek does not follow the pattern expressed by the Middle Yuba River sites; it has a low armoring ratio and low annual bedload transport. This is likely because the surface median particle size of the exposed bar was large at 101 to 189 mm (cobble size), as was the sub-surface at 60 to 113 mm (very coarse gravel to small cobble), which leads to a low armoring ratio of material with low mobility.

4.1.3 Sediment Storage

There is sediment storage in the Middle Yuba and Oregon Creek. Oregon Creek is a third order stream and has 84 m^3/m of sediment storage, mostly due to the large amount of stable storage in Celestial Valley. This estimate of sediment storage exceeds that estimated by Curtis et al. (2005a) for a third-order channel which was 15 m^3/m. Curtis et al. (2005a) calculated an average storage of 70 m^3/m in the fourth order channels of the Middle Yuba River and South Yuba River, whereas 34 m^3/m was estimated during this study. However, also in the current study, amounts may be underestimated because one of the largest deposits of storage in the Middle Yuba River could not be measured due to lack of landowner permission for access (e.g., Emory Bar). The Curtis et al. (2005a) data may be higher than that estimated for this study because it includes Shady Creek, which has extensive mining sediment deposits of 378-676 m^3/m, which would skew the Curtis et al. (2005a) data higher than that measured in this study because there are no substantial mining tailings like those found in Shady Creek. The estimate of 34 m^3/m storage in the Middle Yuba River translates into approximately 757,000 tons of sediment if the average of 34 m^3/m were to be extrapolated to the entire length of the Middle Yuba River.[14] The estimate of an average of 49 m^3/m storage in Oregon Creek, excluding the stable storage of Celestial Valley, translates into an estimate of about 370,000 tons for the entire length of each stream.

4.1.4 Availability, Transport, and Storage of Sediment

Many studies state that dams store sediment and change the transport capacity of the remaining sediment in the channel downstream of the dam (e.g., Grant et al. 2003, Dietrich et al, 1999 and Snyder et al. 2004). Figure 4.1-5 shows the potential discrepancy under With-Project conditions.

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[14] Assuming 62 lbs/ft^3 (0.837 tons/yd^3, 0.667 tons/m^3, Dendy and Champion 1978).

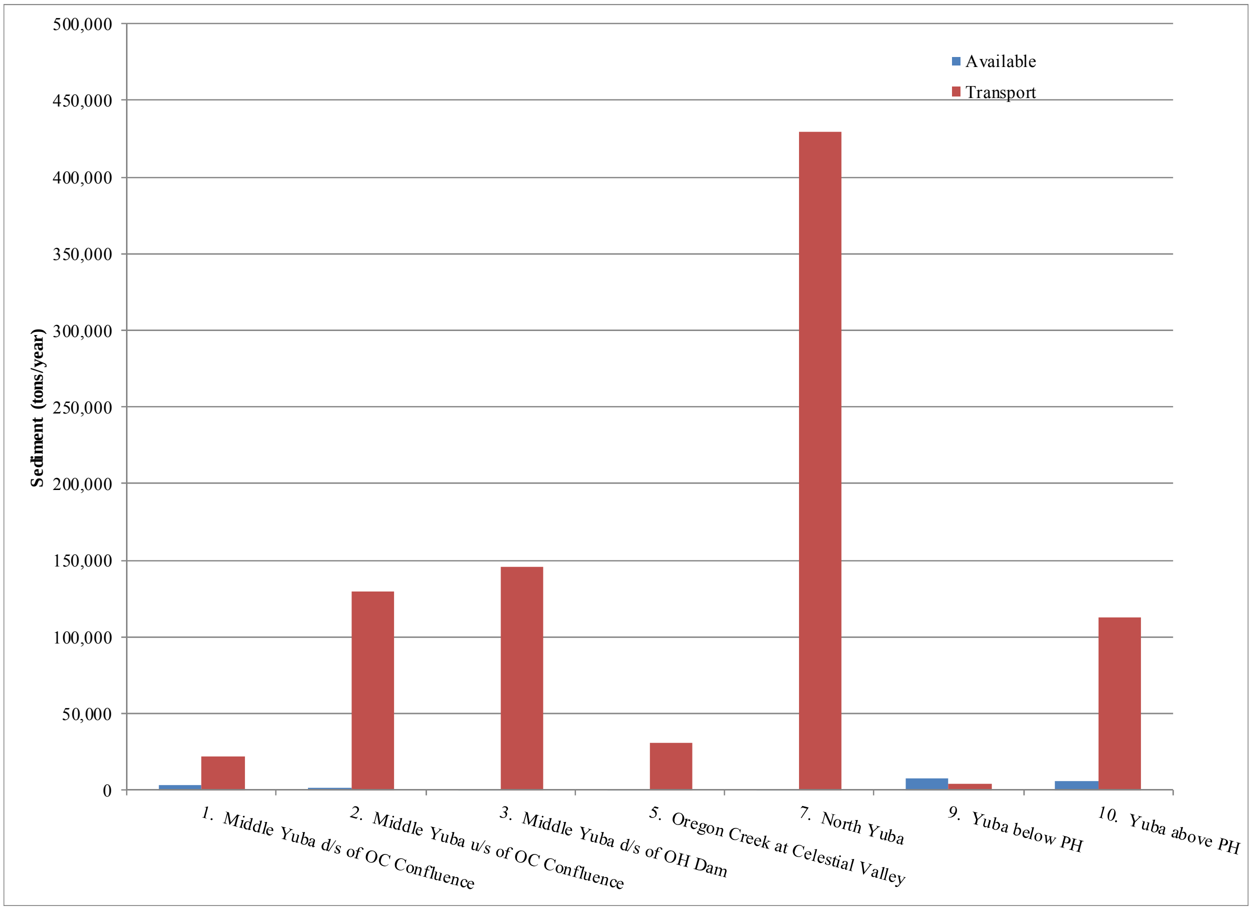

Figure 4.1-5. Comparison of sediment available to each intensive study site and transport capacity under With-Project conditions.

However, the sediment transport capacity estimate from the BAGS model is based on an assumption that all sediment is available to be transported. That is not the case in this study, and the transport capacity is likely an over-estimate.

In addition, in the North Yuba and the Yuba River upstream of the New Colgate Powerhouse, there are one and two transects, respectively, that did not model well (i.e., the modeled discharges are higher than that measured during a known water surface elevation) and the sediment transport estimates are presumably excessive. In spite of that, it is likely that transport exceeds availability of sediment in all but the Yuba River downstream of the New Colgate Powerhouse among sites evaluated in this study. Figure 4.1-6 shows the discrepancy in sediment available versus that transported under Without-Project conditions.

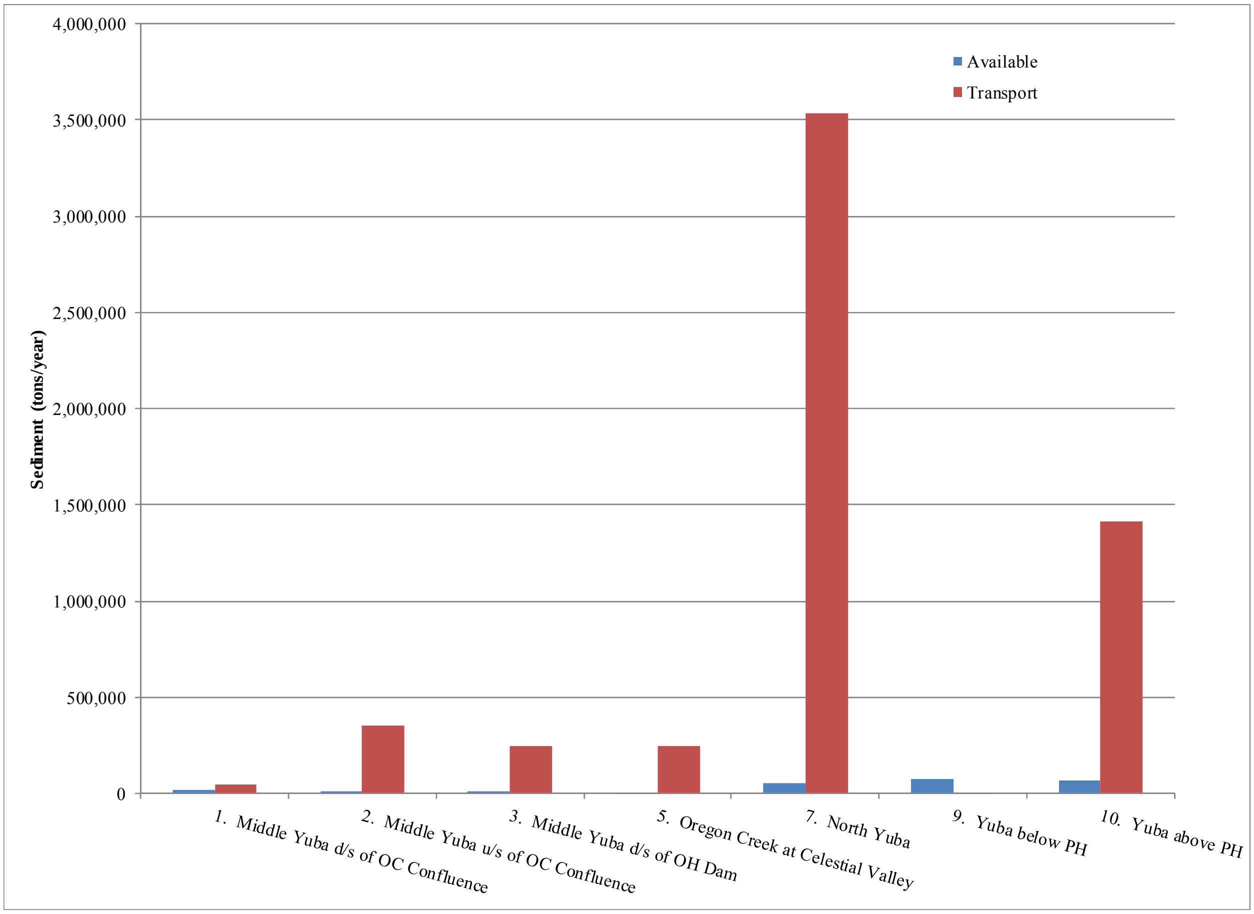

Figure 4.1-6. Comparison of sediment available to each intensive study site and transport capacity under Without-Project conditions.

Transport still far exceeds that which would be available even under Without-Project conditions. If the transport rate was as high as that estimated, it would seem that there would be no sediment left within any of the channels, even without the Project storing sediment, but there is sediment in the reaches. These results are useful in that they show it is likely that sediment is being moved out of the channels at a greater rate than it is being replaced, but must be seen in the context that not all sediment is being excavated and there are sediment reservoirs that are maintained. This may be explained by remembering that there was an incredibly large historic delivery of sediment to this watershed during the hydraulic mining era, so sediment availability may still be higher than would be presumed from the literature, although it may be perched in and below old mining sites. James (2006) reported 109 x 10^6 m^3 was produced in the 31 years (between 1853 to 1884) in the Middle Yuba below Milton Dam alone, and the Middle and North Yuba combined produced 179 x 10^6 m^3. Also, the Yuba River watershed is comparatively steep and is largely bedrock and large-substrate controlled, so transport capacity may indeed be high although the planform is not changing or the bed degrading in most places. As the watershed recovers from the Gold Rush, it continues to move large amounts of sediment through the system, but a significant amount remains. The Middle Yuba River has an estimated 760,000 tons of sediment stored, and Oregon Creek has 370,000 tons.

Grant et al. (2003) proposed an analytical framework to assess the effects of dams given the adjustments to sediment supply and transport capacity using ratios of With- and Without-Project conditions (i.e., S* and T*). The presence of bedrock or other resistant channel boundaries or intrinsically low sediment transport rates can affect responses to dam construction. The capacity for channel adjustment is a function of the how transportable the bed sediment is, how erodible the bed and banks are, and whether there is opportunity for lateral mobility. Hypotheses were presented by Grant for when the relationship between these ratios differed from equality (Figure 4.1-7).

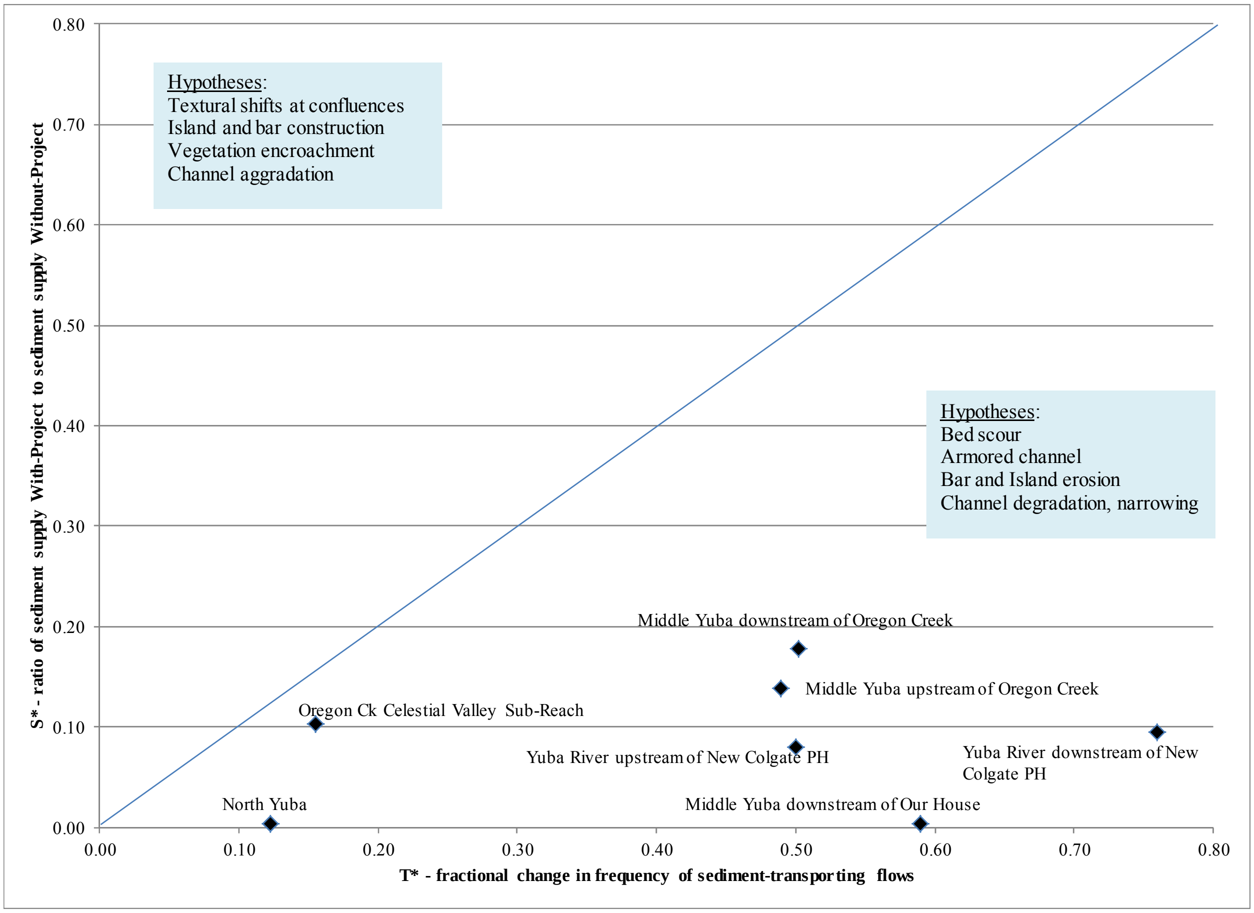

Figure 4.1-7. Predicted channel adjustments in relations to the fractional change in frequency of sediment transporting flows (T*) and the ratio of sediment supply With-Project to that of sediment supply Without-Project (S*).

All of the intensive study sites fall on the right side of unity, though some are further right than others and would likely have stronger indicators of the hypotheses being supported. Changes may be expected first in grain size of the stream bed, followed by removal of in-channel bars, incision, and bank erosion. Changes in stream planform and channel slope would be under a longer time frame (Wilcock et al. 2009, Parker 1990). Individually, Grant's hypotheses are discussed in the current study context:

- Bed scour (and grain size coarsening): Likely. Most of the bed material at all but one of the sites (Yuba River downstream of the New Colgate Powerhouse) is very coarse and largely immobile. There are deposits of small cobble, gravels, and sand within and among the larger material indicating through-flow of mobile material but these are not self-formed, alluvial channels, with the possible exception of the Yuba River below the Colgate Powerhouse. The bed surface prior to dam construction is unknown and within the steep channels in the Project area, the surface may still have been dominated by coarse material but some coarsening is likely. While there has likely been bed scour since dam construction, the existing condition is not expected to change further, no matter what the change in operations is.

- Armored channel: Not diagnostic. While the bed surface is composed of large material with few fines, the sub-surface is composed of similar material, neither of which is mobile. The parts of the bed that are mobile are not strongly armored, nor are the exposed bars that are composed of coarse material that forms the much of the bed. Armoring does not particularly apply as a diagnostic hypothesis in these imposed channel forms. High introduced sediment loads and frequent transport events may give rise to an armored channel with abundant fines (Dietrich et al. 1989), but there are not high sediment loads in this system (i.e., so high that a channel becomes braided or alluvial). The sub-surface layer is not composed of the material load that is moving through the system except in the small marginal gravel bars; in those marginal bars, the surface and sub-surface are approximately equal indicating that after deposition, there was no winnowing of the surface layer. These gravel/sand bars are likely ephemeral and moved annually.

- Bar and island erosion: Possible. The bars may have been larger and more frequent prior to dam construction. However, many bars have been there over the course of the license (e.g., Condemned Bar, Emory Island, the bar on the inside bend at the confluence of Moonshine Creek and the Middle Yuba River) as seen from historical aerial photo review and historical records. The bars that remain under current conditions may be sources of cobble material, as seen from erosion along the margins of the mid-channel and lateral bars in the Middle Yuba River downstream of Oregon Creek, the lateral bar upstream in the Middle Yuba River upstream of Oregon Creek, and the lateral bars in the Yuba River downstream of the New Colgate Powerhouse. Freemans Crossing, located just downstream of Oregon Creek in the Middle Yuba but upstream of the intensive study site Middle Yuba downstream of Oregon Creek, is a long-term depositional area with recreational mining disturbing the bed. This material is likely a source to downstream locations and may have been the source of the added material to the study site following the December 2012 flood event.

- Channel degradation: Possible. The extent of incision is limited by very coarse material and bedrock controls. There are some perched gravel and cobble bars in each reach, which may have been coincident with the river surface prior to dam construction but the age of these bars appears to post-date regulation. That may be because they are regularly inundated, were placed or shifted recently, or will not support a riparian community. The frequency of inundation may have been reduced both due to incision and reduction of peak flows. However, flows rise above what was estimated to be bankfull about every year under With-Project hydrology conditions, under Without-Project hydrology, flows would have gotten to that level more than once per year. The upper surfaces (i.e., estimated floodprone) are inundated every 2-9 years under With-Project hydrology and every 1-6 years under Without-Project hydrology so frequency of inundation would appear to be little changed.

- <u>Channel narrowing or changes in stream planform: Not likely</u>. Change in channel form requires rearrangement of large quantities of sediment and take longer than other adjustments. Evaluation of historical aerial photos shows that there has been little change in planform. The existing conditions within imposed channel forms and coarse substrate and bank material make any further change unlikely.

4.1.5 Riparian Interaction

The results indicate that the hydrologic connectivity supports healthy riparian vegetation communities. The riparian vegetation is vigorous in all areas, with diverse ages of woody riparian species, indicating that germination and recruitment have continued to be active over a period of time. Vegetation coverage is more limited in areas dominated by bedrock substrates, such as on the Yuba River upstream of the New Colgate Powerhouse (Site 10). However, small areas with finer substrates in the same study reach (i.e., immediately downstream of Transect 15) support full coverage of diverse riparian species of all ages, indicating that the limitation is substrate-based, not flow-related.

4.2 Summary of Channel Process and Form in Project-Affected Channels

The Middle Yuba River has a coarse and resistant bed and banks in most of its length, with few possibilities of lateral or vertical shifting. Locations on the upstream side of bends and within and downstream of long-term depositional areas are more alluvially dominated, but sediment transport is still very high and particles move with fairly high frequency. Sediment is available to the channel and is being transported at a higher rate than it is replaced; however, the estimates show that even under Without-Project conditions, this would still be the case. This highlights the fact that bedload transport equations assume an unlimited supply of sediment for transport, which it is not the case in this system.

The same overall condition applies to the North Yuba River and the Yuba River upstream of the New Colgate Powerhouse (i.e., coarse bed resistant to movement with storage of sediment in small areas in deep pools, in velocity shadows, and on lateral bars). Mid-channel bars are uncommon but they exist in every one of the reaches, though whether or not they have been reduced in size or frequency is unknown.

The Yuba River downstream of the New Colgate Powerhouse is a reach that appears to be accumulating sediment, though at a slower rate than it would under Without-Project conditions. The long-term bars (e.g., Rice's, French and Condemned) that existed before the Project will continue to exist, though there are some indications that the channel could shift to occupy French and Rice's Bar. Because there are numerous floods within this most downstream section of the Yuba River, shifting is not only possible but likely.

Oregon Creek is much smaller than the other reaches but also has an estimated greater transport capacity than there is sediment available. Again, however, there are storage reservoirs of sediment and there is mobile sediment forming and reforming bed forms, bars, and floodplains. There is little likelihood of further change as the bed and banks appear to be stable under the current regime.

5.0 Study-Specific Consultation

The FERC-approved study required three study-specific consultations, each of which is discussed below.

5.1 Study Site Selection

> YCWA will consult with Relicensing Participants on study site selection. Specifically, YCWA will send an e-mail notice to Relicensing Participants as early as possible but no less than 2 weeks in advance regarding an office meeting to select potential study sites. During the meeting, maps, the aerial video (HDR 2009a [YCWA 2009a]) and the habitat mapping data (HDR 2009b [YCWA 2009b]) will be reviewed and potential sites for study will be selected.

YCWA selected several study sites in consultation with Relicensing Participants, as required in the FERC-approved study plan. These sites were selected from a very limited set of possibilities due to the lack of access to significant portions of the streams within the Project Area. An email notice was sent to the Relicensing Participants on August 15, 2011 regarding an office meeting to be held on September 19, 2011 to discuss the selection of sites, cross-sections and transects for the Study 1.1, *Channel Morphology Upstream of Englebright Reservoir Study,* Study 3.10, *Instream Flow Upstream of Englebright Reservoir Study,* and Study 6.1, *Riparian Habitat Upstream of Englebright Reservoir Study*. This office-based meeting was held in preparation for the field visit that occurred over the next four days (September 20–23, 2011). The transect selection information packets were posted on YCWA's relicensing website on September 9, 2011, and a notice was sent to Relicensing Participants to prepare for the visit to Our House Diversion Dam Reach, Oregon Creek Reach, and Log Cabin Diversion Dam Reach. Participants at the meeting included the Forest Service, State Water Resources Control Board (SWRCB), and California Department of Fish and Wildlife (CDFW).

In the mainstem Yuba River below New Colgate Powerhouse, flows are generally between 400 and 1,400 cfs due to upstream flow and releases from New Colgate Powerhouse, which is too high to evaluate channel conditions. A Project outage was scheduled for November 16, 2011, which provided a good opportunity for the reconnaissance effort. YCWA explored the Yuba River between New Colgate Powerhouse and Englebright Reservoir to evaluate site characteristics for Studies 1.1 and 6.1. There was a very limited window of opportunity to collect data in this reach. This site was not visited in the previous site selection visit in September 2011 due to time constraints, limited accessibility, and flow conditions that were too high to allow an appropriate evaluation of channel character. The next low flow opportunity did not occur until the next scheduled outage in fall 2012, which necessitated a study variance, since the study plan schedules called for the report to be completed by fall 2012.

YCWA set up a webinar to present to Relicensing Participants the data that was collected during the November 16, 2011 outage. After consultation with the Forest Service, CDFW, National Marine Fisheries Service (NMFS), and SWRCB, it was agreed to meet on December 1, 2011. An email notice was distributed on November 29, 2011 with an information package that presented the results of the reconnaissance/habitat mapping of the reach. The meeting was in lieu of a transect selection field visit, which allowed YCWA to proceed with data collection on December 8 and 9, 2011. The Forest Service, SWRCB, NMFS and CDFW participated in the webinar, and concurred with the extent and location of the study site, and with selection of three transects on the mainstem Yuba River below New Colgate Powerhouse.

The North Yuba River below New Bullards Bar presented major challenges for site selection. The area has access limitations and the substrate is very large, of which very little is deformable. Therefore, this area was not considered to be particularly representative of a response reach, and sediment transport modeling was not recommended. It was necessary to discuss the site and potential study modifications with Relicensing Participants. To combine the visit with other site visits for other studies, an email notice was distributed on January 9, 2012 to propose several February dates in which to visit this location, among others. The site visit was also discussed at a meeting at YCWA's Marysville office on January 11, 2012.

5.2 Field Visit

> YCWA will invite interested and available Relicensing Participants into the field to comment on the channel morphology cross section locations in sites selected during previous consultation (Section 5.3.1). Notice for the field visit will be sent to Relicensing Participants as early as possible, but no less than 2 weeks prior to field site visits.

An email notice announcing field-based transect selection was sent on August 18, 2011, for site and transect selection in September 2011. Four days of field visits confirmed site and transect selection in seven locations during September 20–23, 2011. Participants included the Forest Service, CDFW, SWRCB and NMFS. Of the seven locations, five were confirmed as channel morphology/riparian study sites. Ten to 16 transects were selected in each reach for Study 3.11. Three cross sections were selected for Study 1.1 from among those selected in Study 3.10. No Study 1.1 sites/transects were selected on September 22, 2011. A notice was sent on January 9, 2012 for site and transect selection continuation in the North Yuba River below New Bullards Bar Dam (above the Middle Yuba River and North Yuba River confluences) for a field visit on February 9, 2012. The extent of the study site and three transects were agreed to by Relicensing Participants.

5.3 External Review of Sediment Transport Models

> The hydraulic and sediment transport models will be placed on YCWA's website for external review by Relicensing Participants. YCWA will schedule a conference call with Relicensing Participants within two weeks of posting the models to discuss them.

An email notice announcing a January 30, 2013, meeting was sent to Relicensing Participants on January 15, 2013. The models were posted on YCWA's website on January 16, 2013. The discussion regarding the models and inputs used for the models was held at HDR's Sacramento office with interested and available Relicensing Participants on January 30, 2013. A conference call line was established and both in-person and on-line attendance occurred.

6.0 Variances from FERC-Approved Study

The study was performed in conformance with the FERC-approved Study 1.1 *Channel Morphology Upstream of Englebright Reservoir*, with three variances. First, the FERC-approved study states that three exposed bars will be sampled in five locations. At the intensive study site established in the Middle Yuba River above Oregon Creek (Site 2), despite thorough investigation within, above and below the study site, there were only two exposed bars available that were conducive to sampling.

Second, the FERC-approved study states that YCWA will give two weeks notice prior to any office meeting discussing site selection. Due to a very narrow window of opportunity to collect field data in the mainstem Yuba River below New Colgate Powerhouse, notice was given to Relicensing Participants on November 29, 2011, for a meeting on December 1, 2011 for data collection to occur on December 8-9, 2011. Despite the short notice, several Relicensing Participants participated in the webinar, including representatives of the Forest Service, CDFW, SWRCB, and NMFS. All those present agreed that the study site and transects would be adequate for the channel morphology study.

Third, the FERC-approved study states the study will be completed by the end of September 2012. In a Relicensing Participant meeting on April 12, 2012, the Forest Service, United States Fish and Wildlife Service, CDFW and SWRCB requested that YCWA delay the high target calibration flows for Study 3.10 from late spring 2012 to fall 2012. Study 1.1 relies on data from Study 3.10 and, therefore, completion of Study 1.1 was delayed. Additionally, the tracer particle component of Study 1.1 was not able to capture a high flow event in spring 2012. YCWA captured a high flow event in December 2012 and these data are now included. Hydraulic and sediment transport models have been developed and were discussed with Relicensing Participants on January 30, 2013.

7.0 Attachments to this Technical Memorandum

This technical memorandum includes six attachments:

- Attachment 1-1A	Field Notes [1 Adobe pdf file: 11.6 MB; 188 pages formatted to print double sided on 8 ½ x 11 paper]
- Attachment 1-1B	Transect Cross Sections and Longitudinal Profiles [1 Adobe pdf file: 385 kB; 32 pages formatted to print double sided on 8 ½ x 11 paper]
- Attachment 1-1C	Photographs of Channel Morphology Transects and Sites [1 Adobe pdf file: 5 MB; 28 pages formatted to print double sided on 8 ½ x 11 paper]
- Attachment 1-1D	Particle Size Graphs [1 Adobe pdf file: 140 kB; 28 pages formatted to print double sided on 8 ½ x 11 paper]
- Attachment 1-1E	Maps of Study Sites [1 Adobe pdf file: 30.7 MB; 4 pages formatted to print double-sided on 8 ½ x 11 paper and 10 pages formatted to print double-sided on 11 x 17 paper]
- Attachment 1-1F	Bedload Transport Files [Model files. 37 Excel files. 2 Adobe pdf files: 9 MB; 34 pages formatted to print double sided on 8 ½ x 11 paper and 11 x 17 paper.]

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