Study 1.1

CHANNEL MORPHOLOGY UPSTREAM OF ENGLEBRIGHT RESERVOIR

November 2010

1.0 Project Nexus

Yuba County Water Agency's (Licensee or YCWA) continued operation and maintenance (O&M) of the existing Yuba River Development Project (Project) has a potential to affect channel morphology and fluvial processes, which could affect channel morphology upstream of the United States Army Corps of Engineer's (USACE) Englebright Dam.[1]

2.0 Resource Management Goals of Agencies and Indian Tribes with Jurisdiction over the Resource Studied

[Relicensing Participants - This section is a placeholder in the Pre-Application Document (PAD). Section 5.11(d)(2) of 18 CFR states that an applicant for a new license must in its proposed study *"Address any known resource management goals of the agencies or Indian tribes with jurisdiction over the resource to be studied."* During 2010 study proposal development meetings, agencies advised License that they would provide a brief written description of their jurisdiction over the resource to be addressed in this study. If provided before Licensee files its Proposed Study Plan and Licensee agrees with the description, Licensee will insert the brief description here stating the description was provided by that agency. If not, prior to issuing the Proposed Study Plan, Licensee will describe to the best of its knowledge and understanding the management goals of agencies that have jurisdiction over the resource addressed in this study. Licensee]

3.0 Study Goals and Objectives

The goal of the study is to quantify or characterize river form and process and interaction with the riparian zone in reaches upstream of the normal maximum water surface elevation of Englebright Reservoir potentially affected by the Project.

The objectives of the study are to develop information necessary to meet the study goal. Specifically, the study objectives include: 1) develop a quantitative and qualitative understanding of Project effects on substrate mobility, particle size distribution, trout spawning gravel distribution, spill channel flow effect on channel morphology, and erosion, and floodplain connectivity at multiple scales.

[1] Englebright Dam was constructed by the California Debris Commission in 1941; is owned, operated and maintained by the United States Army Corps of Engineers; and is not included as a Project facility in FERC licenses for the Yuba River Development Project.

4.0 Existing Information and Need for Additional Information

Considerable information exists. Much of this information has been obtained or developed by Licensee and is provided in YCWA's Yuba River Development Project relicensing Preliminary Information Package (YCWA 2009). The information includes but is not limited to:

- Topographic and hydrographic information of the Project-affected reaches (Preliminary Information Package, Section 3.0 General Description of River Basin and Appendix D - Project Maps)
- Hydrologic information, modeling and statistics for Project-affected reaches (Preliminary Information Package, Section 7.2 Water Resources and Appendix F - Hydrology)
- Operations procedures for Project facilities (Preliminary Information Package, Section 6.0 Project Location Facilities and Operations)
- Low altitude aerial video of all Project-affected reaches and facilities (Preliminary Information Package, Appendix E - Project Helicopter Video)
- Existing information regarding sediment yields (Preliminary Information Package, Section 7.1.5.1 Geology and Soils)
- Preliminary classification of Project reach types conducted by Licensee in 2009 (Preliminary Information Package, Section 7.1.7.2 Geology and Soils)
- Sediment management and volumes removed from Our House Diversion Dam (Preliminary Information Package, Section 7.7.1.2. Geology and Soils)

Information not included with the Preliminary Information Package, but that is available as Attachment 3.10A to Licensee's Instream Flow Study Proposal (Study 3.10) is a Habitat Mapping Report of the Yuba River Development Project done by Licensee in 2009. This report includes channel and habitat descriptions of ground-mapped and video mapped Project-affected streams; substrate, bank material, large woody debris (LWD) counts, estimated of quantity of salmonid spawning sized gravel, potential natural barriers to upstream fish movement, notes regarding access, and photographs.

To achieve the study goals, additional information is needed, which includes:

- Review of current and historic aerial photographs
- Field measurement of cross-section profiles
- Stage-discharge relationship, based on field measurement of calibration flows, to use in sediment transport model for sediment mobility and, in conjunction with flow frequency analysis, frequency of floodplain inundation
- Field measurement of longitudinal profile
- Field measurement of particle size and distribution, including specific measurement of patches of 0.25 to 2.5 inch (in.) diameter gravel (spawning-size gravel for trout).

- Distribution and size of channel morphological features such as bedrock outcrops, boulders, gravel accumulations, and floodplains.
- Assessment of condition of riparian zone and distribution of riparian vegetation (e.g., bars, alluvial fans).
- Spill channel flow and erosion.
- Extent and description of influence of New Bullards Bar Reservoir elevation on Slate Creek.
- Extent and description of influence of Our House Diversion Dam on Middle Yuba upstream of Our House Diversion Dam.
- Extent and description of influence of Log Cabin Diversion Dam on Oregon Creek upstream of Log Cabin Diversion Dam.

5.0 Study Methods and Analysis

The study includes collecting data to develop a quantitative and qualitative understanding of the effects of regulation on the interactions of hydrology, channel morphology, and the riparian environment in stream reaches upstream of the Englebright Reservoir potentially affected by the Project.

5.1 Study Area

The study area includes: 1) the Middle Yuba River from Our House Diversion Dam to the confluence with the North Yuba River; 2) Oregon Creek from the Log Cabin Diversion Dam to the confluence with the Middle Yuba River; 3) the North Yuba River from New Bullards Bar Dam to the confluence with the Middle Yuba River; 4) the portion of the Yuba River from the confluence of the North and Middle Yuba rivers downstream to the normal maximum water surface elevation of Englebright Reservoir; and 5) the portion of the Middle Yuba, Oregon Creek, and Slate Creek affected by base-level control exerted by either the diversion dam (Our House, Log Cabin) or reservoir water level (New Bullards Bar).

If YCWA proposes an addition to the Project, the study area will be expanded if necessary to include areas potentially affected by the addition.

5.2 General Concepts and Procedures

The following general concepts and practices apply to the study:

- Personal safety is the most important consideration of each fieldwork team.
- Licensee will make a good faith effort to obtain permission to access private property where needed well in advance of entering the property.
- Field crews may make minor variances to the FERC-approved study in the field to accommodate actual field conditions and unforeseen problems. When minor variances are made, Licensee's field crew will follow the protocols in the FERC-approved study.

- When Licensee becomes aware of major variances to the FERC-approved study, Licensee will issue an e-mail to the Relicensing Contact List describing the variance and reason for the variance. Licensee will contact by phone the Forest Service (if the variance is on National Forest System land), USFWS, SWRCB and CDFG to provide an opportunity for input regarding how to address the variance. Licensee will issue an e-mail to the Relicensing Contact List advising them of the resolution of the variance. Licensee will summarize in the final study report all variances and resolutions.
- Licensee's performance of the study does not presume that Licensee is responsible in whole or in part for measures that may arise from the study.
- Global Positioning System (GPS) data will be collected using either a Map Grade Trimble GPS (sub-meter data collection accuracy under ideal conditions), a Recreation Grade Garmin GPS unit (3 meter data collection accuracy under ideal conditions), or similar units. GPS data will be post-processed and exported from the GPS unit into Geographic Information System (GIS) compatible file format in an appropriate coordinate system using desktop software. The resulting GIS file will then be reviewed by both field staff and Licensee's relicensing GIS analyst. Metadata will be developed for deliverable GIS data sets.
- Licensee's field crews will record incidental observations of aquatic and wildlife species observed during the performance of this study. All incidental observations will be reported in the appropriate Licensee report (e.g., incidental observations of special-status fish recorded during fieldwork for the Special-Status Turtles – Western Pond Turtle Study will be reported in Licensee's Stream Fish Populations Study report). The purpose of this effort is not to conduct a focus study (i.e., no effort in addition the specific field tasks identified for the specific study) or to make all field crews experts in identifying all species, but only to opportunistically gather data during the performance of the study.
- Field crews will be trained on and provided with materials (e.g., Quat) for decontaminating their boots, waders, and other equipment between study sites. Major concerns are amphibian chytrid fungus, and invasive invertebrates (e.g., zebra mussel, *Dreissena polymorpha*). This is of primary importance when moving: 1) between tributaries and mainstem reaches; 2) between basins (e.g., Middle Yuba River, Yuba River, and North Yuba River); and 3) between isolated wetlands or ponds and river or stream environments.

5.3 Study Methods

The study will be performed in six steps: 1) select study sites; 2) field measurements; 3) assess sediment mobility; 4) QA/QC data; 5) analyze data; and 6) prepare report. Each step is described below.

5.3.1 Step 1 - Select Study Sites

Licensees will co-locate study sites to the extent possible with the Licensee's Study 3.9 Instream Flow Above Englebright Reservoir and Study 6.1 Riparian Habitat Above Englebright Reservoir. Instream Flow study sites (transect or transect cluster locations as part of the PHABSIM ["Physical Habitat Simulation"] aspect of the Instream Flow study) are selected within a reach to represent the range of channel and habitat types in the reach (Bovee 1982). The characteristic feature of a PHABSIM study reach is homogeneity of the channel structure and flow regime. The sites chosen will represent those sites most likely to exhibit effects of Project features and operations on channel morphology and habitat features.

Based on historic and habitat mapping information, in the Middle and North Yuba rivers and in the Yuba River upstream of Englebright Reservoir, channel characteristics are primarily controlled by bedrock and boulders, rather than fluvial processes. In other words, these channels are not usually "self-formed" and boulders and bedrock control lateral and vertical stability. Bedrock channels are generally insensitive to short-term changes in sediment supply or discharge. Only a persistent decrease in discharge and/or an increase in sediment supply sufficient to convert the channel to an alluvial morphology would significantly alter bedrock channels (Montgomery and Buffington 1993). However, there may be localized changes to morphology and substrate distribution that may affect aquatic ecology.

Characteristics of the areas where channel morphology sites will be placed are gradients less than 2 percent, accumulations of gravel and finer material in channel and on margins, and floodplain and/or terrace development. Based on habitat mapping information, the study could consider nine possible study-site locations (Table 5.3-1).

Table 5.3-1. Potential location and character of channel morphology study sites.

Stream	Potential Location	Character
Middle Yuba River	Below Oregon Creek in the vicinity of Freemans Crossing	Moderately and unconfined channel, ~1% gradient, alluvial and depositional.
	Above Oregon Creek	Steeper (>1% gradient), confined, more transport-dominated than below Oregon Creek, though some lateral cobble/gravel bar development.
	Below Our House Dam	Steeper (>1% gradient), confined, more transport-dominated bedrock control channel
	Above Our-House Dam, within influence of base level control effected by Our House Diversion	Low gradient (1.7% map gradient), depositional.
Oregon Creek	Vicinity of Celestial Valley	Confined 1.6% gradient, planar bedform, gravel-sized material in channel and on margins.
	Above Log Cabin Dam within influence of base level control effected by Log Cabin Diversion.	Confined ~1.8% map gradient.
North Yuba River	Below New Bullards Bar Dam.	Reach has very little accessibility due to vertical cliffs, and dominance of bedrock and boulders within channel. Large, immobile substrate, lateral and vertical controls by bedrock limits responsiveness to changes in inputs of sediment and to changes in hydrology.
Slate Creek	Within high water influence of New Bullards Bar	Confined, 2.4% map gradient.
Yuba River	Below New Colgate Powerhouse	Confined, less than 1%, cobble and boulder-dominated bed with very deep pools immediately below the Powerhouse, but increasing alluvial deposition as move downstream.

One study site could potentially be selected in each location and, to the extent possible, each channel morphology study site will be co-located with PHABSIM study sites. The advantage of this is that PHABSIM study sites are usually in accessible areas and contain a range of habitat diversity represented in the reach. Data collected for the PHABSIM model is very similar to that needed for the sediment transport modeling and understanding floodplain inundation. Study sites will be selected to mimic as closely as possible the gradient, width, and vegetation as the reach characteristics within the study area. Licensee will invite interested and available Relicensing Participants into the field to comment on the channel morphology study sites.

5.3.2 Step 2 – Data Collection

5.3.2.1 Stream Cross Sections

All elevations will be surveyed by standard differential survey techniques using an auto-level or total station instrument. Headpin and tailpin elevations, water surface elevations (WSE), hydraulic controls, and above-water bed and bank elevations will be referenced to a temporary benchmark serving a single transect or transect cluster. Cross-sections (also called “transects”) established and measured for PHABSIM analysis will include, at a minimum, the stage at twice the maximum bankfull depth (floodprone elevation). Every break in slope will form a vertical point on the graph, and what the breaks represent will be noted (e.g., top of bank, edge of floodplain, bankfull, extent of right or left bank that is “moveable”). The top of the rock elevation for bedrock within the channel, and the thalweg will be included. The thalweg will be assumed to be the minimum elevation below which the bed cannot erode, unless there are some other characteristics that suggest an alternative maximum scour depth at that cross section, which would then be estimated. Cross sections will be monumented with headpins and tailpins (e.g., rebar, pins in bedrock), benchmarks, and UTM coordinates.

No more than three-cross sections will be selected at any study site in which to measure the full suite of characteristics studied. Where co-located, no more than three PHABSIM transects from Licensee’s Instream Flow Study that represent the “area of interest” will be selected from approximately the middle of the study site. Some transects may be surveyed across areas of possible sediment deposition and potential spawning activities (i.e., glides, riffles and runs), and where channel geometry (including bankfull and floodprone characteristics if they occur) is most representative of the reach, and representative of potential effects of the Project to site-specific aquatic habitat within the reach. The middle of the PHABSIM study site will be selected preferentially because the sediment transport analysis needs three additional transects upstream and downstream to allow the model to stabilize and give accurate results at the area of interest. These three cross-sections upstream and downstream of the area of interest will be about 100 to 300 feet (ft) apart and be representative of study reach conditions. Upstream cross-sections will be far enough upstream from the area of interest that regimes being evaluated do not cause changes to the bed profile at upstream boundary, but channel geometry is still representative of the study reach. If needed for sediment transport modeling purposes, Licensee will place additional cross-sections within the PHABSIM study site at major bed profile changes, valley width changes, tributaries, changes in roughness, structures, or gages.

Licensee will invite interested and available Relicensing Participants into the field to comment on the channel morphology transect locations.

5.3.2.2 Stage-Discharge Relationship

For sediment transport modeling (and PHABSIM), calibration flows will be measured with the goal of achieving an even, logarithmic spacing of flows that allows for development of an adequate stage/discharge relationship sediment transport (and PHABSIM hydraulic) model. Stage/discharge measurements will be obtained at no fewer than three discharges. When a stage/discharge measurement is taken, discharge through the study site will be measured using manual velocity meters or a combination of an acoustic Doppler and manual velocity meters at an appropriate cross section(s).

5.3.2.3 Longitudinal Profile

A longitudinal profile will be done that includes the six transects above and below the area of interest within the PHABSIM site, the PHABSIM transects in the area of interest, and any additional cross sections needed as stated in 5.3.3.1 above. Transects must be located within 0.2 mile of each other (i.e., survey will not exceed 0.2 mile). PHABSIM transects within runs, riffle, and glide-habitat will be selected preferentially; pools may be skipped. Benchmarks used in the instream flow PHABSIM analysis (often there is one benchmark established for each cross-section) will be "tied together" so that only the lowermost benchmark has an assumed elevation of 100 ft. Water surface, thalweg, floodplain, and bankfull elevations will be measured along the profile, making sure to include breaks in slope and each transect location as a vertical.

5.3.2.4 Particle Size

Surficial substrate composition will be evaluated by compiling a facies map, which is delineation of the surface bed texture into distinct units by dominant and sub-dominant grain-size classes (Buffington and Montgomery 1999). Wolman (1954) pebble counts will be done across each transect and for each textural facies. Particles will be measured using a gravel template, also known as a gravelometer, a square grain-size template, and a particle size distribution by number (not weight) will be created. If particles can not be lifted to pass through the gravelometer, size will be estimated using a ruler..

Three exposed bars at each site will be evaluated to assess the relative difference between surface and sub-surface particles size (e.g., armoring). One-hundred particles will be measured in a 1 meter (m) enclosure, surface particles will be removed to the depth of the largest particle. Sub-surface particles will be mixed and 100 particles will be measured from the sub-surface. Ratio of surface to sub-surface particle size will be an indication of armoring. Low values of $D_{50surface}$:$D_{50subsurface}$ (e.g., less than 1.3 means relatively weak armoring) are generally indicative of relatively high mean annual sediment transport rates, whereas high values of $D_{50surface}$: $D_{50subsurface}$ (e.g., greater than 4 means relatively strong armoring) are generally indicative of relatively low mean annual sediment transport rates (Dietrich et al. 1989, Parker 2004).

5.3.2.5 Site Map

A site map sketch will be done of the surveyed reach and will include major features such as pools, riffles, bedrock outcrops, boulders, bridges, sediment deposits; location of cross sections;

and substrate descriptions. Substrate will be separated into facies ("textural mapping"), given a textural type (Buffington and Montgomery 1999) and mapped. Grain size distribution of these textural patches will be measured with Wolman pebble counts (see Section 5.3.2.4) and area of each facies will be quantified.

5.3.2.6 Streambank Erosion Potential

Streambank erosion potential of each cross section for both left and right streambanks will be 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 include 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.

5.3.2.7 Channel Stability

Channel stability will be rated using the Pfankuch (1975) method as modified by Rosgen (1996). The Pfankuch procedure "was developed to systemize measurements and evaluations of the resistive capacity of mountain stream channels to the detachment of bed and bank materials and to provide information about the capacity of streams to adjust and recover from potential changes in flow and/or increases in sediment production." (Pfankuch 1975). Channel stability will be used to assess the potential for lateral or vertical movement, in addition as input to the riparian condition assessment (Section 5.3.3.8).

5.3.2.8 Input of Sediment from Tributaries

Some of the tributaries may be adding sediment to the Project reaches. The aerial video (HDR 2009) will be used to assess if an alluvial fan exists at the junction of the tributaries, or to assess if there are other indications of sediment input from the tributaries. If the tributary junction is easily accessible, a qualitative field review will be made of the junction if there are initial indicators from the aerial video that the tributary is a sediment source. Evaluation will include a discussion of the size and type of material delivered, the type of deposit, an estimate of the physical extent of the deposit, the geology of the tributary, any known sediment sources, and an estimate of sediment yield based on regional estimates. There will be no quantitative sediment budget done, however. A discussion of the availability and fate of sediment from tributaries will be included in the report.

5.3.2.9 Coordination with Licensee's Riparian Habitat Study Upstream of Englebright Reservoir

The assessment of the riparian zone in the channel morphology study sites will be conducted in close cooperation and collaboration with riparian and hydrology specialists. Licensee believes it will be beneficial to co-locate the channel morphology study sites with the study sites selected for Licensee's Riparian Habitat Upstream of Englebright Reservoir Study. At a minimum, existing data, including Geographic Information System (GIS) data, historical information, reports, maps, and aerial photography relevant to both channel morphology and riparian vegetation will be collected and reviewed where available for the selected sites.

5.3.2.10 Examine Effects of Uncontrolled Spill over Project Dams on Sediment Particle Size and Composition

History and magnitude of uncontrolled spill from Project dams will be summarized. Fate and distribution of sediment eroded from spill channels will be evaluated. Data collected during the site investigations (Sections 5.3.2.1-5.3.2.8) will be used in the analysis.

5.3.2.11 Examine Effects of New Colgate Powerhouse Tailrace on Channel Morphology and Sediment Distribution

The New Colgate Powerhouse discharges water into the Yuba River. The vicinity of the powerhouse release will be investigated for signs of erosion at the outflow and downstream on the channel banks. Since the backwater effect from the Englebright Reservoir is within 1.3 miles of the powerhouse, evidence of bank erosion, scour or extensive deposition that can be linked to that resulting from erosion and/or high magnitude discharges as a result of discharges from the tailrace will be investigated within this 1.3 mile area. Erosion, scour and deposition will be evaluated using the release history from New Colgate Powerhouse.

5.3.2.12 Large Woody Debris

Large woody debris data have been collected in Project reaches as part of the habitat mapping exercise (Attachment 3.10A to Instream Flow Study Proposal). Licensee records regarding quantity and fate of large woody debris removed from New Bullards Bar Reservoir, from Our House Dam, and from Log Cabin Dam will be summarized in Licensee's Pre-Application Document Section 7.1. Discussion of quantities of LWD found within the Project area will be included within the final study report, along with an analysis comparing to the quantities within Sierra Nevada streams of a similar form and location in the watershed.

5.3.3 Step 3 - Assess Sediment Mobility

The objectives of this component of the study are to evaluate discharges that mobilize particles that compose the channel bed and spawning gravel, and to assess how Project operations have affected the frequency of bed- and gravel-mobilizing flows.

Surveyed cross-sections and longitudinal profiles will be used to develop a calibrated hydraulic model for each reach. The model will be used to estimate shear stress (N/m^2) at each transect for a range of discharges. Hydraulic models will be constructed using the Hydraulic Engineering Center's River Analysis System (HEC-RAS, e.g., version 4.0 or 4.0.0) developed by the USACE (USACE 2006, 2008). Observed water surface elevations and discharges will be used to calibrate the hydraulic model to known stages. A rating curve developed from known stages and flows will be used as a downstream boundary condition of each model. Other hydraulic parameters used to calibrate the models are contraction and expansion ratios, and Manning's "n" roughness coefficient. If calibration is not possible using these parameters, thalweg elevations along the longitudinal profile will be used to interpolate new transects to improve model accuracy.

Bed shear stress (function of the hydraulic radius-slope product) is output from the hydraulic modeling. Bed shear stress (τ) is expressed as an average force (N/m^2) over the transect width. As output from HEC-RAS, a range of discharges (in cfs, X-axis) versus shear stress (in N/m^2, Y-axis) will be provided for each of the cross sections for which particle size analyses were done. In general, the HEC-RAS output parameter "Total Shear" will be used; this value represents the applied bed shear across the entire transect. In some cases, transects may have small side channels that should not be considered in the applied bed shear estimate. In these cases, the HEC-RAS bank stations will be adjusted to the extents of the main channel and the HEC-RAS output parameter "Channel Shear" will be used. Channel Shear only reports the applied bed shear stress for the main channel or the area between model bank stations.

Particle size analysis, developed by pebble counts, will be used to develop a particle size distribution for up to three cross sections in each study site. Critical shear stress (τ^*_{ci}, the shear stress threshold at which incipient motion occurs) must be exceeded for particle movement to occur. Shield's relationship for critical shear stress is defined as $\tau^*_{ci} = \beta\ (\gamma_s - \gamma)\ D_x$, where β = Shield's parameter (a dimensionless variable), γ = specific weight of the fluid, γ_s = specific weight of the sediment, and D_x = median particle diameter of interest. The particles of interest will include the largest particle in each of the five gravel classifications: 4, 8, 16, 32, and 64 mm (Wentworth Scale, p. 20 Vanoni [ed.] 1975), and the D_{16} (fine particles, or the particle diameter where 16 percent of the particles are finer), D_{50} (median-size particles), and D_{84} (coarse particles, or the particle diameter where 84 percent of the particles are finer) for each cross section. The Shield's parameter may vary from 0.02 to 0.086 with a common average value for gravel of about 0.046 (Miller et al. 1977; Buffington and Montgomery 1997, Mueller et al. 2005). A range of Shield's parameters (0.03, 0.045, and 0.060) will be used in the critical shear stress calculation to show the sensitivity to the Shield's parameter, and to be able to discuss the changes in mobility due to the differences in gradient within the reach, between the meso-habitat units, and between regulated and unimpaired flows. Critical shear for specific particles can then be compared against the bed shear/discharge relationship; when bed shear exceeds critical shear, particles can be mobilized

Flow exceedance values and recurrence intervals will be presented using the best available flow data under regulated and unimpaired conditions (e.g., modeled regulated or unimpaired daily annual maximum values). Exceedance flows are the percentage of time certain flows are met or exceeded (i.e., 25 percent exceedance represents a "high" flow as this is the flow that is met or exceeded only 25 percent of the time, and 50 percent exceedance represents the median flow). Flow recurrence intervals (which is the inverse of the flow exceedance) will be calculated using the PeakFQ statistical program developed by the USGS based on Bulletin 17B (USGS 1982). Results of the hydrologic models and PeakFQ analysis will be provided as tables that show recurrence interval (year) and the Bulletin 17B discharge estimate (cfs). For any given flow (which has an exceedance value/recurrence interval under regulated and unimpaired conditions), the critical shear of any particle can be seen to be above or below the bed shear for that cross section. If it is below the bed shear, the particle is probably not mobile; if it is above, mobility is more likely.

5.3.4 Step 4 - QA/QC Data

Following data collection, all data will be subject to quality assurance/quality control (QA/QC) procedures including, but not limited to: 1) checking field data sheets against entered data to be sure no corrections are needed; and 2) independent review of hydraulic and sediment transport models, 3) reviewing data and report for completeness. The datasets will also be reviewed graphically to check for errors.

5.3.5 Step 5 – Analyze Data

The goal of the study is to quantify or characterize river form and process and interaction with the riparian zone. Table 5.3-2 presents the relationship between potential channel morphology issues, data to be collected by this study, and data analysis that will occur as part of this study.

Table 5.3-2. Relationship between perceived channel morphology issues, data to be collected by this study, and data analysis that will occur as part of this study.

Issue	Data	Analysis
Project effects on channel morphology and channel condition below Project facilities	• Longitudinal profile • Cross sections • Substrate • Stage-discharge relationship • Hydrologic information – regulated and unimpaired • Age and function of riparian zone • Storage in reservoirs compared to regional/local sediment yield values • Channel and bank stability • Review of historical aerial photographs • Sketch map • Sediment mobility	• Longitudinal profile and cross sections will be used in the sediment transport model to estimate bed shear. Critical shear for specific particle sizes data can be calculated and used with the graph of bed shear to show the discharges where critical shear exceeds bed shear. Flow exceedance tables show the recurrence interval of flows under regulated and unimpaired conditions. Combining all the tools provides an estimate of flows that mobilize particles and the frequency of those flows under different operating conditions. • Stage-discharge relationship provides at what flow various surfaces in the riparian zone are inundated; combined with hydrology data provides the frequency of inundation for regulated and unimpaired conditions. • Age and function of riparian zone provides a history of disturbance and role of riparian zone in shape and form of channel. • Regional/local sediment yield and estimates of storage within Project diversions and reservoirs provides an estimate of the change in sediment availability (e.g., S* - Grant *et al.* 2003) • Assessment of channel and bank stability provides how likely the channel is to move from its current form • Historical photos show the relationship of current form and prior form (depending upon the photos available) • Sketch map provides context for assessment, and provides a facies map that provides a template for stratifying other physical and biological measurements.

Table 5.3-2. (continued)

Issue	Data	Analysis
Project effects on floodplains	• Cross sections • Stage-discharge relationship • Hydrologic information • Age and function of riparian zone • Historical aerial photographs	• Cross sections provide the location and elevation of bankfull, depositional surfaces, and floodplains. • Stage-discharge relationship provides at what flow various surfaces are inundated; combined with hydrology data provides the frequency of inundation for regulated and unimpaired conditions. • Age and function of riparian zone provides the history of floodplain development and role vegetation plays in the history, development and future of the channel. • Historical photos show the history and interaction of the active channel with floodplains, conversion to or from terraces; changes in vegetation; disturbance history.
Project effects on bedload distribution	• Textural facies mapping • Channel armoring • Evaluation of tributary inputs of sediment. • Evaluation of influence of diversions and reservoir level.	• Textural mapping yields a visual record of channel conditions, and provides an areal weighting of grain sizes. • Ratio of surface to sub-surface particles provides an armoring ratio. Surface layer is commonly coarser than the sub-surface, and the size distribution of the sub-surface gravel is often similar to that of the transported bedload. Low values of $D_{50surface}$:$D_{50subsurface}$ (e.g., less than 1.3 means relatively weak armoring) are generally indicative of relatively high mean annual sediment transport rates, whereas high values of $D_{50surface}$: $D_{50subsurface}$ (e.g., greater than 4 means relatively strong armoring) are generally indicative of relatively low mean annual sediment transport rates. • Discussion of tributary input of sediments and fate within the Project streams. • Discussion of base level control on Slate Creek, Oregon Creek upstream of Log Cabin Diversion, and Middle Yuba upstream of Our House Diversion.
Project effects on LWD	• Habitat mapping LWD data (Attachment 3.10A to Instream Flow Study Proposal) • Licensee summary of history and fate of LWD removed from reservoir and diversions	• Discussion of quantity of LWD within Project reaches compared to similar Sierra Nevada streams.
Project effects on particle size and composition from dam release outlets, minimum flow, uncontrolled spill	Summary of spill history	• Discussion of channel form, sediment size and distribution as it relates to hydrology created by releases from dam outlets and minimum flow releases flow, and erosion and/or hydrology due to spill releases from Project dams

Table 5.3-2. (continued)

Issue	Data	Analysis
Project effects on channel morphology and sediment distribution from releases from New Colgate Powerhouse	• Bank erosion assessment below New Colgate PH • Assessment of scour and deposition below New Colgate PH • Flow release history from New Colgate PH.	• Discussion of erosion, scour, and deposition using flow release history for New Colgate Powerhouse.

5.3.6 Step 6 – Prepare Report

At the conclusion of the study, YCWA will prepare a report that includes the following sections: 1) Study Goals and Objectives; 2) Methods; 3) Results; 4) Discussion; and 5) Description of Variances from the FERC-approved study proposal, if any. The report will include the following attachments:

- Scanned field data (*.PDF format) of cross sections, longitudinal profiles, sketch maps, and particle size measurements. Raw data may be made available to Relicensing Participants prior to the publishing of the final study report upon request, and if Licensee has completed its QA/QC review of the data.
- For each geomorphic study site, data associated with each of the geomorphic parameters will be shown in a tabular format.
- Maps showing study site and transect locations.
- Photo-documentation and UTM coordinates of transects; UTM coordinates of longitudinal profile downstream and upstream limits.
- Transects and longitudinal profiles will be graphically plotted, with bankfull and flood prone widths identified.
- Pebble counts for up to three transects per study site will be graphically plotted as cumulative particle size distribution curves.
- The hydraulic/sediment transport model input and output files.
- Table showing the critical shear stress (N/m^2) for gravels (4, 8, 16, 32, 64 mm), and the D_{16}, D_{50}, and D_{84} for each transect using Shield's parameters of 0.03, 0.045, and 0.060.
- Graphs presenting shear stress (N/m^2) versus discharge (cfs) for each transect (up to three transects per study site).
- Flow exceedance tables under regulated and unimpaired conditions.
- Summary of riparian condition.

6.0 Study-Specific Consultation

The study includes one study-specific consultation:

Licensee will invite interested and available Relicensing Participants into the field to comment on the channel morphology study sites and the transect locations.

7.0 Schedule

Licensee anticipates the schedule to complete the study as follows assuming the PAD is filed on November 1, 2010 and FERC issues its Study Determination by October 4, 2011:

Study Site and Transect Selection..October 2011
Field Work ....April - September 2012
Data Entry, QA/QC, & Analysis.. July - September 2012
Report Preparation ....July - October 2012

8.0 Consistency of Methodology with Generally Accepted Scientific Practices

Geomorphology studies are common to hydroelectric relicensing projects to determine channel condition, and determine whether flow or sediment measures are necessary and/or whether channel restoration is necessary. Field methods have been used recently in other California relicensing efforts. Determination of shear stress versus discharge is discussed for HEC RAS model use (Brunner 2008, USACE 1989 and 1981).

9.0 Level of Effort and Cost

[Relicensing Participants – Licensee will include a cost range estimate for this study in its Proposed Study Plan. Licensee]

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