Study 3.3

INSTREAM FLOW STUDY

January 2017

1.0 Project Nexus

South Sutter Water District's (SSWD) continued operation and maintenance (O&M) of the existing Camp Far West Hydroelectric Project (Project) has a potential to affect fish habitat in the Bear River downstream of Camp Far West Dam.

2.0 Study Goals and Objectives

The goal of this Instream Flow Study (Study) is to supplement existing information regarding habitat for fishes in the Bear River downstream of Camp Far West Dam.

The objective of the Study is to collect data adequate to meet the Study goal.

The Study does not include the development of potential requirements in the new license.

3.0 Existing Information and Need for Additional Information

3.1 Species Records and Historical Instream Flow Study

Existing, relevant and reasonably available information regarding fishes in the Bear River downstream of Camp Far West Dam is provided in Section 3.2.3 of SSWD's Pre-Application Document (PAD). Information regarding Endangered Species Act (ESA)-listed fishes in the Bear River from the non-Project diversion dam to the Feather River (i.e., lower Bear River) is provided in Section 3.2.3 of the PAD.

As a summary, sporadic and limited fish surveys have occurred in the Bear River downstream of Camp Far West Dam. Based on this limited information, two anadromous fishes listed as threatened under the ESA (Central Valley spring-run Chinook salmon [*Oncorhynchus tshawytscha*] Evolutionarily Significant Unit [ESU] and California Central Valley steelhead [*O. mykiss*] Designated Population Segment [DPS]) have been reported to occur. Critical habitat for spring-run Chinook salmon ESU extends in the Bear River from the Feather River to approximately River Mile (RM) 5 (i.e., 5 miles upstream on the confluence), while critical habitat for CV steelhead DPS extends from the Feather River to the non-Project diversion dam at RM 16.9. In addition, four special-status fishes are reported to occur. These are CV fall- and late-fall-run Chinook salmon ESU, which is considered sensitive by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS) (NMFS-S) and a species of concern (CSC) by the California Department of Fish and Wildlife (Cal Fish and Wildlife); and hardhead minnow (*Mylopharodon conocephalus*), Sacramento splittail

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(*Pogonichthys macrolepidotus*) and Sacramento-San Joaquin roach (*Lavinia s. symmetricus*), each of which is considered a CSC by Cal Fish and Wildlife. Other fishes reported to occur include black crappie (*Pomoxis nigromaculatus*), Pacific lamprey (*Lampetra tridentate*), riffle sculpin (*Cottus gulosus*), speckled dace (*Rhinichtys osculus* ssp.), Sacramento squawfish (*Ptychocheilus grandis*), Sacramento sucker (*Catostomus o. occidentalis*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), Western mosquitofish (*Gambusia affinis*), and resident trout (*O. mykiss*).

Additionally, existing information indicates that flows in October and November influence the Chinook salmon run size, with reports as high as 300 in 1984 and as low as zero in 1985.

Existing information also shows that, in some years, salmonids build redds in the lower Bear River, with most of the reported redds occurring from RM 5 to RM 16.

SSWD found that an instream flow study was conducted in the lower Bear River in the mid-1980s. The study was first reported by SSWD in 1988, and later summarized in a report by Cal Fish and Wildlife in 1991 (CDFG 1991).[1]

SSWD found little information regarding aquatic habitat in the lower Bear River. Section 3.2.1 of the PAD describes a habitat mapping study conducted by SSWD in 2015 and reported that the lower Bear River is generally less than 0.5 percent in gradient, with no falls, cascades, chutes, rapids, step runs, pocket water, or sheet flow habitat types, which are generally associated with steeper gradients and coarser substrate. The substrate of the mapped units is dominated by gravel with mostly cobble sub-dominant. Sand is a minor component though is often subdominant. Increasing amounts of exposed bedrock and cobble substrates occur in the upstream direction to just downstream of the diversion dam. Very little silt occurs in the active channel, though the banks are often composed of this finer material.

SSWD found little instream cover, and most what was observed was due to the introduced giant cane (*Arundo donax*) concentrations that line and often extend across the channel. The giant cane is pervious to flow, however, and serves to scour pools and develop some spawning gravel concentrations of spawning gravel (i.e., 2 millimeters [mm] to 64 mm), but occasionally up to 128 mm nearer the diversion dam. The report suggested that the giant cane provides cover and habitat heterogeneity.

Existing, relevant and reasonably available information regarding flows and water temperature in the Bear River downstream of Camp Far West Dam is provided in Sections 3.2.2.5 and 3.2.2.9 of the PAD, respectively.

In general, minimum flows (mean monthly) releases typically ranged between 10 and 15 cubic feet per second (cfs) from July to March and between 25 and 30 cfs in April, May and June from

[1] The California Department of Fish and Wildlife was previously the California Department of Fish and Game. In this PAD, the California Department of Fish and Wildlife if referred to as "*Cal Fish and Wildlife*" except in references that were published before the name change in 2012. In those cases, Cal Fish and Wildlife is referred to as the "*California Department of Fish and Game*" or "*CDFG*."

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Water Year (WY) 1990 through WY 2014. The primary full-flow rated gage used for flow characterization in the lower Bear River is the Wheatland gage (USGS 11424000), which is located approximately 6.5 miles downstream of Camp Far West Dam and reflects releases from Camp Far West Reservoir through the powerhouse, low-level outlet and spills over Camp Far West Dam less diversions at SSWD's Conveyance Canal and CFWID's Canal. The Wheatland gage has been in active operation since October 1928. Figure 3.1-1 shows average monthly streamflow for the Bear River near Wheatland gage for WYs 1967 through 2014. Maximum monthly flows in the Bear River are significantly higher than monthly averages because they typically represent significant precipitation events.

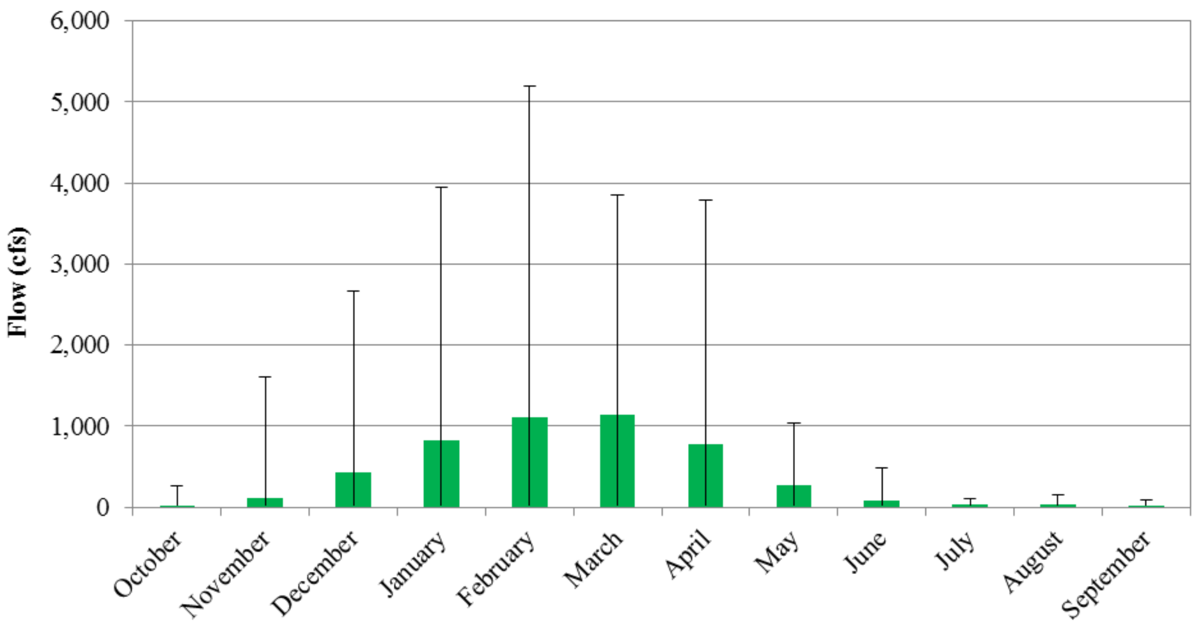

Figure 3.1-1. Mean monthly streamflow for the Bear River near Wheatland gage (USGS Gage 11424000) from WY 1967 through WY 2014.

Monthly temperature data collected by the California Department of Water Resources (DWR) from 1964 to 1987 near Wheatland reported temperatures ranging from as low as 6 degrees Celsius (°C) in winter months to as high as 30°C in the summer months. Data collected by SSWD from April 2015 to September 2015 reported mean daily water temperatures ranged from as low as 10°C just below the non-Project diversion dam in April to 30°C in early July in the vicinity of the Pleasant Grove Bridge near RM 7.4. Water temperatures in the Bear River warmed while moving downstream. At the four locations between Highway 65 (RM 11.4) and the Feather River confluence (RM 0.1), instantaneous water temperatures exceeded 20°C for most of the monitoring period.

Additional information, which will be provided by this Study, is needed to address the Study goal. Specifically, this Study will develop flow-habitat relationships for target fishes in the lower Bear River using a 2-dimensional flow model.

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Analyses performed as part of this Study will use results developed during the performance of SSWD's relicensing Studies 2.1, *Water Temperature Monitoring*, 2.2, *Water Temperature Modeling*, and 3.1, *Salmonid Redds*. In addition, the Study will use data from SSWD's Water Balance/Operations Model (Appendix G in the PAD).

4.0 Study Methods and Analysis

4.1 Study Area

For the purpose of this Study, the Study Area includes the Bear River from the non-Project diversion dam to the confluence with the Feather River.[2] Figure 4.1-1 shows a map of the Study Area.

[2] The 1.3 mile-long section of the Bear River from the Camp Far West Dam and the non-Project diversion dam is not included in the Study Area because it is primarily a backwater behind the diversion dam and does not have a significant floodplain. Further, andromous fishes, one of the target species, cannot access this section of river since the diversion dam is physical barrier to upstream migration, and there is no ESA-listed critical habitat in this section of river.

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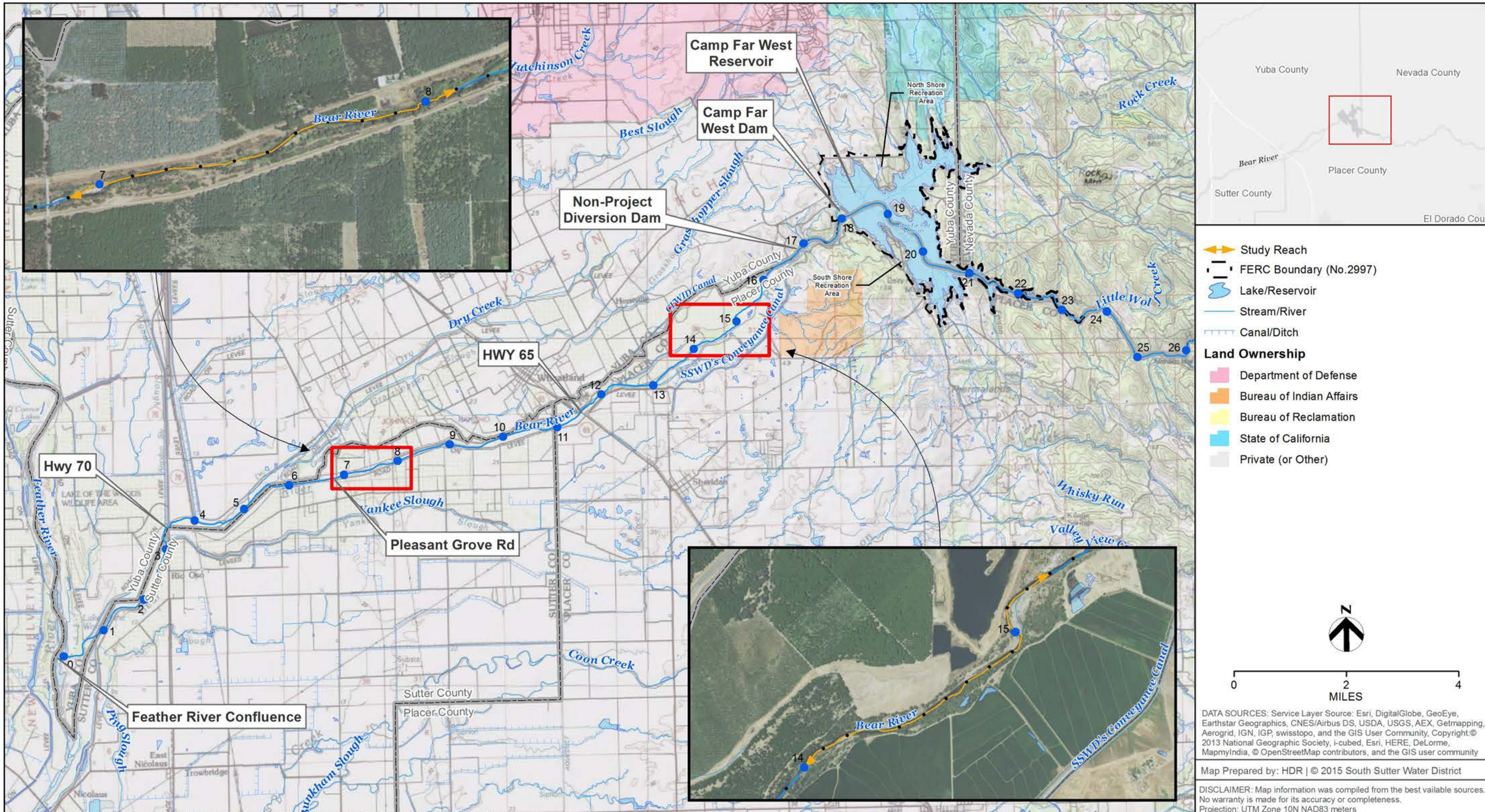

Figure 4.1-1. Study Area of Instream Flow Study.

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4.2 General Concepts and Procedures

The following general concepts and practices apply to all SSWD relicensing studies:

- Personal safety is the most important consideration of each fieldwork team.
- If required for the performance of the study, SSWD will make a good faith effort to obtain permission to access private property well in advance of initiating the study. SSWD will only enter private property if such permission has been provided by the landowner.
- SSWD will acquire all necessary agency permits and approvals prior to beginning fieldwork for a study that requires them.
- Field crews may make variances to the study plan in the field to accommodate actual field conditions and unforeseen problems. When a variance is made, the field crew will follow to the extent applicable the protocols in and intent of the study plan.
- SSWD's performance of the study does not presume that SSWD is responsible in whole or in part for measures that may arise from the study.
- If Global Positioning System (GPS) data are required by a study plan, they will be collected using either a Map Grade Trimble GPS (i.e., sub-meter data collection accuracy under ideal conditions), a Recreation Grade Garmin GPS unit (i.e., 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 SSWD's consultant's relicensing GIS analyst. Metadata will be developed for deliverable GIS data sets. Upon request, GIS maps will be provided to NMFS, United States Fish and Wildlife Service, Cal Fish and Wildlife or State Water Resources Control Board in a form, such as ESRI Shapefiles, GeoDatabases, or Coverage with appropriate metadata. Metadata will be Federal Geographic Data Committee compliant.
- SSWD's field crews conducting relicensing studies will record incidental records of aquatic, botanical and wildlife species observed during the performance of a study. All incidental observations will be reported in the DLA and FLA. The purpose of this effort is not to conduct a focused study (i.e., no effort in addition to the specific field tasks identified for the specific study plan) or to make all field crews experts in identifying all species, but only to opportunistically gather data during the performance of a relicensing study. Species included for incidental observation will include, but are not limited to: bald eagle (*Haliaeetus leucocephalus*); golden eagle (*Aquila chrysaetos*); osprey (*Pandion haliaetus*); any bats or positive sign of bats; Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*), including redds and carcasses; northern western pond turtle (*Actinemys marmorata*); foothill yellow-legged frog (*Rana boylii*); American bullfrog (*Lithobates catesbeianus*); blue elderberry (*Sambucus nigra* ssp. *caerulea*); and aquatic invasive species.

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- Field crews will be trained on, provided with, and use materials (e.g., Quat disinfectant) for decontaminating their boots, waders, and other equipment between water-based study sites. Major concerns are amphibian chytrid fungus, and invasive invertebrates (e.g., zebra mussel, *Dreissena polymorpha*).
- If in the performance of a study, SSWD observes an ESA-listed or special-status species, within 30 days of the observation SSWD will submit to Cal Fish and Wildlife's California Natural Diversity Database a record, on the appropriate form, of the observation.
- If a study plan requires collection and reporting of time series data, the data will be provided at a minimum in Microsoft® Excel (*.xls) or HEC-DSS (*.dss) format. A viewer for *.dss files (HEC-DSSVue) can be obtained from the United States Army Corps of Engineers at the following website as of October 2015: http://www.hec.usace.army.mil/software/hec-dssvue/.
- If a field crew encounters human remains during field work, all work within a 100-foot radius of the discovery will stop immediately. The field crew will not disturb the remains in any way. The field crew will secure the area to the best of its ability, mark the location with flagging tape in such a way as to not draw attention to the remains, and record the location using a GPS unit or plot the location by hand on a map if no GPS unit is available. As soon as possible thereafter, the field crew will contact SSWD and the relicensing Cultural Resources Lead to report the discovery. SSWD will report the finding and initiate the appropriate steps required under State of California and federal law to address the discovery. Any human remains encountered will be treated with respect, and the field crew members will keep the location confidential and will not disclose the location of the discovery to the public or to any other study crews. The field crew will keep a log of all calls/contacts it makes regarding the discovery and that details the event. Work will not proceed in the secured area of the discovery until provided clearance by SSWD.

4.3 Methods

The Study will be performed in seven steps: 1) site selection; 2) field data collection; 3) hydraulic modeling; 4) Habitat Suitability Criteria (HSC) selection; 5) aquatic habitat modeling; 6) riparian analysis; and 7) time series modeling. Each of these steps is described below.

4.3.1 Step 1 – Site Selection

The establishment of two Study sites will be based on four sources of information: 1) existing salmon survey records from the lower Bear River in the mid 1980s (CDFW unpublished data); 2) existing habitat mapping results in SSWD's PAD; 3) existing Light Detection and Ranging (LiDAR) data collected either in 2008 or 2010 for the DWR Central Valley Floodplain Evaluation and Delineation Program and data collected in 2012 by Placer County in the lower Bear River, available through United States Geological Survey (USGS) as a National Elevation

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Dataset Digital Model (NOAA 2015);[3] and 4) topographic data and channel form analyses (Section 4.3.1.1, below). To ensure adequate representation of the variety of habitat types and channel forms present in the Study Area, each site will be long enough to sufficiently capture a diversity of channel forms and habitat types.

From preliminary information review, one site will be located between RM 15.3 and RM 14.0, and a second site will be located in the vicinity of Pleasant Grove Road, between RM 8.1 and RM 6.9.

Four level loggers will be installed in order to measure stage change in the Bear River downstream of the non-Project diversion dam. The locations will be: 1) at the upstream instream flow modeling site (between RM 15.3 and RM 14.0); 2) near the Highway 65 bridge (RM 11); 3) near the Pleasant Grove bridge (RM 7) and 4) near the Highway 70 bridge (RM 3.5).

Prior to starting field work, SSWD will invite interested and available Relicensing Participants to a one-day site review meeting. The purpose of the meeting will be to: 1) provide supporting information used to determine the final study site locations, and 2) describe the location of four stage recording pressure transducers to be installed. After reviewing the information in the morning, a short afternoon field trip will be conducted to view the instream flow study site locations.

4.3.1.1 Channel Form

To inform the process of representative site selection, a GIS-based LiDAR analysis will be used to delineate Study Area "Valley" into channel types. The "valley" will be defined as the area between the toes of the United States Army Corps of Engineers' (USACE) levees or other slope that restricts the channel from any lateral movement, which also defines the "confinement" of the channel. Confinement will be based on the width of the low flow active channel (LFAC) relative to the valley. The low flow active channel is hydrologically important in this regulated system because it reflects the dominant discharge during periods when the flow is controlled, usually between 10 cfs and 25 cfs. Based on habitat mapping and field reconnaissance, it was evident that this was where the vegetation transitions from hydric to more terrestrial types. The channel types that will be defined include, but are not limited to:

- Confined: Less than two LFAC that will fit within the valley walls.
- Moderately Unconfined: Two to four LFAC will fit within the valley walls and well developed gravel bars exist on one or both sides. Side channels and mid-channel bars are common.
- Unconfined: More than four LFAC will fit within the valley walls and floodplain is composed of a variety of vegetation types and depositional forms; floodplain is generally connected hydrologically to the main stem.

[3] If SSWD determines the existing LiDAR data are inadequate for the Study, SSWD will acquire airborne LiDAR data of the two Study sites. Ideally, data will be acquired during the winter, when leaves have fallen and river flow is less than 25 cfs.

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There may be other channel types within the Study Area that do not fit into these simplified categories; additional types may be added by SSWD, as needed. In addition, SSWD may modify definitions to better fit the types and range of types observed upon data review and field surveys.

To support the channel form analysis, historical aerial photographs (if existing and readily available, and of good quality) of the Study Area will be gathered from pre- and post-dam construction.

Lastly, to confirm the GIS-based LiDAR channel form classification, field validation will be conducted. In addition to the two Study sites described above, five random sites, each with a length of 20 channel widths, within each channel form identified during LiDAR analysis will be selected to quantify channel confinement, erosion extent and type along both banks, and type of bank material.

4.3.2 Step 2 – Field Data Collection

4.3.2.1 Channel Topography

For the purpose of hydraulic model surface development, additional topographic data will be collected using a variety of methods. Initially, LiDAR coverage will be evaluated and used to describe the majority of each Study site not submerged at the time the LiDAR was collected. Additional topography data collection will be completed utilizing a Real Time Kinematic (RTK) GPS topographic survey conducted on foot. In the event GPS reception is of poor quality, a Robotic Total Station (RTS), surveyed into the RTK survey network, will be used.

4.3.2.2 Substrate and Cover Type Mapping

Field crews will delineate substrate polygons covering each Study site using an iPad loaded with high resolution aerial photos and GIS layer data. Substrate polygons will be delineated based on classification strategies which correspond to substrate size for target species habitat use data (i.e., HSC) presented in Section 4.3.4. Substrate will be defined as being within the floodprone channel (the width of the channel at twice bankfull height). However, stable sediment adjacent to the more active channel should be characterized as well. Substrate and sediment will be mapped and classified into one of four storage element stability classes (after Curtis et al. 2005 and Kelsey et al. 1987) as set out in Table 4.3-1. The volume of the sediment stored in each class will be estimated by using the polygon area, and the depth will be estimated from the height above the thalweg or next lower surface. The stability of each storage elements can be assessed based on the size of the material, the location relative to the thalweg, and the age and type of vegetation.

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Table 4.3-1 Storage element stability classes.

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

Cover type mapping will be conducted at each Study site in detail by a combination of methods and will correspond to cover types (i.e., none, cobble, boulder/rip-rap, riparian vegetation, streamwood) for target species habitat use data (i.e., HSC) presented in Section 4.3.4.

Field mapping of riparian vegetation polygons will be performed by a crew of two botanists and the use of an iPad and a Trimble® Geo-6 (or similar) resource-grade GPS unit. Representative features will be mapped by hand directly with the devices onto pre-installed, rectified, high resolution color aerial photographs (i.e., local balloon imagery). Hard-copies of the aerial photos will also be used to map boundaries of reference polygons and make notes on their characteristics.

The GPS reference data will be exported into GIS, compiled into organized data sets and used to guide the digitizing of complete plant community/vegetation boundaries for each of the two Study areas with ArcMap 10. All resulting GIS data will be projected in NAD 83 State Plane California Zone III, Feet.

Observations of large woody material (LWM) will be documented within the bounds of the two Study sites. LWM will be counted as follows: all LWM greater than 3 feet (ft) in length within the active channel within four diameter classes (i.e., 4-12 inches [in.], 12-24 in., 24-36 in., and greater than 36 in.) and four length classes (i.e., 3-25 ft, 25-50 ft, 50-75 ft, and greater than 75 ft). More detailed measurements will be taken for key pieces located within Study sites. Key pieces of LWM are defined as pieces either longer than 0.5 times the bankfull width, or of sufficient size and/or are deposited in a manner that alters channel morphology and aquatic habitat (e.g., trapping sediment or altering flow patterns). Key piece characteristics to be recorded will include:

- piece location, either mapped onto aerial photos or documented with GPS
- piece length
- piece diameter
- piece orientation
- position relative to the channel
- whether the piece has a rootwad
- tree species or type (e.g., conifer or hardwood)

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- whether the piece is associated with a jam or not
- the number of large pieces in the jam
- recruitment mechanism
- function in the channel

LWM data will be collected and results will be included within the DLA.

Lastly, surface-level photographs will be taken for documenting the physical condition and general ecological biological characteristics of the two Study areas. Each photo location will be geo-referenced. The direction of each photo will be recorded using a compass and written descriptions for each photograph will be provided.

4.3.2.3 Hydraulic Calibration

Water Surface Elevation (WSE), discharge, and spot calibration depths and velocities will be collected throughout each model domain at three calibration flows. These hydraulic parameters will be measured using a combination of standard techniques. Spot velocities, depths and WSE measurements will be collected over the entire longitudinal profile of each model site. Site discharge will be measured at multiple locations and at least twice per day, according to standard USGS methods (Rantz 1982).

WSEs will be collected using a Trimble® R-8/10 RTK GPS or Trimble® Robotic S8 total station at a minimum of 50 spot locations throughout the wetted channel for each calibration flow. At the same locations, depth and velocity validation data will be collected by Swoffer® flow meters or an Acoustic Doppler Current Profiler (ADCP) in which data are spatially referenced using an onboard Trimble® R-10 RTK GPS.

The site discharge, or target calibration flow, is the discharge released at the control point (i.e., Project dam or diversion), whereas the measured calibration flow represents the actual discharge at the model site as measured with calibrated flow meters. The source of any differences between target and measured flows primarily depends on the accuracy of flow control at the upstream control point and intervening accretion or loss between the control point and the Study site. Discharge at each site will be measured using a combination of manual velocity meters and, if required, an ADCP near the upstream end of each site or at the best measurement location identified in the field. The model of Swoffer® velocity meter to be used is accurate at velocities ranging from 0.1 to 25.0 feet per second. Published technical specifications for the Teledyne RDI® Rio Grand 1200 kHz ADCP are: velocity accuracy: ±0.25 percent of the (water + boat), velocity ±0.25 centimeter per second, a velocity resolution of 0.1 centimeter per second and maximum water velocity of ±20 meters per second.

The three target flows for aquatic habitat modeling will be 25 cfs, 75 cfs, and 200 cfs. The target flow of 200 cfs will be used as the primary calibration data set. WSEs corresponding to flows greater than 200 cfs will be measured by field staff, or if field conditions are not considered safe, data will be collected at multiple locations in each Study site using pre-deployed stage recording

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devices (i.e., Onset U-20 Hobo pressure transducers). Initial WSEs will be surveyed for validation purposes when the instrumentation is installed and again when the instrumentation is removed.

It is anticipated that hydraulic-habitat relationships modeled in each Study site will extend from approximately 10 cfs to 500 cfs but this range will ultimately be dependent on the overall quality of site specific rating curves. The upper limits of the riparian inundation rating curves will be dependent on the highest flow recorded during the course of the Study.

On-site photographs will be collected to document site conditions during each survey flow event. A representative collection of site photos, arranged by calibration survey flow will provided in the report as an attachment.

In addition to the pressure transducers installed at each instream flow study site, four pressure transducers will be installed in the Bear River to document stage and flow changes throughout the reach. Exact locations will be determined during the SSWD hosted site-selection meeting. The transducers will be maintained for one calendar year.

4.3.2.4 Quality Control

For each field survey conducted, the Trimble® R8/R10 GPS receiver base station will be set up over a locally installed benchmark. The base station will record GPS positions during the survey while sending out real time kinematic corrections via a radio link to RTK rover units (R8/R10) which collect positions and data. After the first survey session, one of the day’s static GPS data files collected by the base station will be submitted to the National Oceanic and Atmospheric Administration’s (NOAA) Online Positioning User Service (OPUS). OPUS returns a position corrected and mapped into the high accuracy National Spatial Reference System (NSRS).

Using Trimble® Business Center software, the OPUS-corrected position will then be used to correct the network of rover collected points from that survey session. For all subsequent survey sessions, the base station will be manually assigned to the OPUS corrected position and all rover data collected in the established coordinate system consistent with the first survey session.

Field staff will record the height of the receiver above the benchmark, note the base coordinate as entered into the unit, and note serial numbers, height of receivers above ground, and file names used on each of the rovers each survey day.

4.3.2.5 Level Logger Installations

Level loggers will be installed for approximately one year beginning in late 2016 or early 2017. Onset Model U20 Leveloggers (or similar) with internal data loggers will be used to measure stage and temperature every 15 minutes. These loggers are factory calibrated and have a level accuracy of ±0.010 foot (ft) and a temperature accuracy ±0.05 degrees Celcius (°C). The accuracy of each logger will be checked periodically by comparing the instrument reading to the actual water depth. For this type of instrumentation, stream stage is related to absolute pressure, which is a combination of water pressure and atmospheric pressure. Readings will be taken to

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continuously measure stream stage. At each site, a level logger will be submerged at a fixed location to measure the submerged water pressure. At one location a Barologger will be installed to measure atmospheric pressure and temperature. The atmospheric pressure values will be used to calculate the true net water levels of the submerged loggers.

Loggers will be downloaded at least once every two months or as conditions allow. During each download period, care will be taken to record the exact time of level logger removal and replacement within the stream channel. In addition, the logger location will be marked with GPS and/or flagging or photographed to ensure that the device is replaced as close to its original position as was possible. Water surface elevations will be surveyed during each download event.

During each visit, data will be downloaded to an optic shuttle or directly to a personal computer. In addition, operation/calibration, battery life, and general housing condition of the loggers will be assessed.

Stream discharge (i.e., stream flow) measurements will be taken at each site following United States Department of Interior, United States Geological Survey (USGS)-approved methods. Measurements will be performed by wading the wetted stream channel at each monitoring site. And not taken if flows are deemed unsafe to wade.

4.3.3 Step 3 – Hydraulic Modeling

4.3.3.1 Surface and Mesh Development

Hydraulic modeling for each Study site will use River2D (Steffler and Blackburn 2002). The River2D model uses the finite element method to solve the basic equations of vertically averaged 2D flow incorporating mass and momentum conservation in the two horizontal dimensions (Steffler and Blackburn 2002). The model incorporates a simplified shallow groundwater representation to allow elements at the water's edge to have vertices above and below the water surface. The location of the water's edge is interpolated from the three points of each triangular element spanning the point of zero depth. It is relevant to point out that the shallow groundwater equations used in the River2D model do not represent complex surface-groundwater exchange mechanisms (i.e., shallow/deep aquifer, water table, upwelling, gains/losses) but are only used to deal with the representation of water surface elevations in the model domain.

The main input parameters for the River2D model include channel surface topography, bed roughness (in the form of an effective roughness height), and upstream and downstream hydraulic boundary conditions (i.e., water levels and discharge). Accurate topography is the primary variable that allows for the development of a well calibrated model.

Topographic surfaces will be constructed by combining the total station survey data, RTK GPS standard survey data, bathymetric data, and the LiDAR ground return data. In order to increase the definition in areas of topographic gradient and variability, breaklines will be defined within the topographic surface. Breaklines enforce the topographic surface to 'snap' to the entire length of the line and are used to define features with large vertical gradient changes, such as cascades, tow of slopes, and boulders.

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Before entering the data into the River2D model, topographic data from the site will be reviewed for errors in ArcMap and ArcScene using the high resolution imagery. Triangulated Irregular Networks (TINs) will be developed to visualize the data in two and three dimensions

Mesh development will follow procedures outlined in the R2D_Mesh Users Manual (Waddle and Steffler 2002). When building a computational mesh, it is important to optimize for computational performance without sacrificing mesh quality. Using the topographic surface nodes to define the mesh is not recommended as the computational requirements for such a model exceed the limits of the software and currently available computer hardware. Instead, a low density uniform mesh is developed and then refined using a variety of techniques.

As recommended by the R2D_Mesh's *Users Manual*, a balance between mesh density and computational burden will be addressed in part by applying a procedure called 'wet refinement,' which places nodes at the centroid of each mesh element. This process ensures the appropriate mesh density in wetted areas only, while limiting mesh density in dry areas.

Another method used to refine the mesh is to review mesh-generated elevation contours as compared to bed elevation contours at an interval of 0.82-ft with a goal of close contour approximation. Since the topographic points and mesh nodes are not in the same location, the contours will not be exactly the same. Therefore, to increase contour agreement, additional nodes will be added in topographically complex areas.

A third method used to refine the mesh will be to identify large elevation differences between topographic data points and the interpolated elevation of each mesh triangle. Most often, large elevation differences exist in areas of high gradient (e.g., cascade) or significant localized topographic relief (e.g., cliff or vertical bank). Mesh triangles that exceed a 0.82-ft difference threshold are highlighted yellow in the mesh development software and further refined until the difference is no longer detected.

QI is a mesh quality index where a value of 1.0 represents a mesh comprised of perfect equilateral triangles. The goal minimum triangle quality index (QI) for each computational mesh is 0.15. Low QI values (i.e., <0.10) do not necessarily compromise model quality, but will increase computational run times. Tools in the mesh development software are used to improve geometry to achieve the minimum goal QI value.

One base mesh representing the model domain will be used for all simulation runs. However, it will be necessary to make small changes if model run time errors (i.e., eddy shedding velocity oscillation, extremely high velocity, or Froude number) occur. To achieve the appropriate mesh density over all simulation flows, the single mesh will be iteratively refined in the context of the full range of possible wetted areas.

4.3.3.2 Flow Model Calibration

Flow model parameters such as bed roughness (Ks, in the form of an effective roughness height), substrate transmissivity (*tr*) and eddy viscosity can be adjusted during model calibration to

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reflect field conditions. A stage-wise approach with target criteria for model performance will be used to guide calibration. The specific stages and criteria are discussed below.

The term Ks is scientific notation for bed roughness factor (in meters) and the term refers to gradation of material in the river. Compared to traditional one-dimensional models, where many two-dimensional effects are abstracted into the resistance factor, the 2D resistance term accounts only for the direct bed shear (Steffler and Blackburn 2002). Ks is iteratively varied as necessary to match observed water surface elevations using the default transmissivity of *tr* = 0.1. In general, the initial Ks value entered is 1-3 times the grain size documented during field data collection. A single optimal value of Ks (i.e., homogeneous substrate material) or multiple regional Ks values (i.e., heterogeneous substrate material and/or large elevation changes) may be selected for each Study site based on the model performance results.

Groundwater transmissivity (*tr*) is a user-defined variable which corresponds to groundwater flow and the relationship to surface flow. The default value is 0.1 which ensures that ground water discharge is negligible. Because subsurface flow may be present at the Study site, the default value of *tr* will be modified to aid in the wetting and drying of off-channel or backwater areas. For comparison, results of the transmissivity sensitivity tests are compared to aerial imagery and field photos.

For the initial hydraulic model, hydraulic calibration tests will be conducted using the target calibration flow of 200 cfs. Bed roughness and transmissivity will be varied as necessary to match observed WSEs and wetted area. As part of normal calibration, K and *tr* values are incrementally adjusted through an integrative sensitivity analysis until modeled WSEs calibrated well to observed WSEs. In addition to the WSE comparisons, velocity and depth predictions were compared to field measured data to evaluate changes made to Ks.

The target criterion for mean error in WSE between simulated versus observed data is, to a large extent, based on the accuracy of the RTK GPS equipment used to measure WSE. The channel gradient and topography also take into consideration where frequent shoals, cascades, and riffle habitats can increase differences between field data and model data. In a comprehensive report on hydraulic modeling YCWA (2013) states:

> For WSE, the SRH2D v2.1 model [i.e., 2D hydraulic model] can only be as accurate locally as the bed elevation variation arising from the presence of cobble substrate throughout most of the river. This means that if a bed elevation measurement is made on the top of a cobble versus in the space between cobbles, then the model's WSE will be different between those two locations simply because of bed topography. Therefore, the benchmark for model performance for WSE is a combination of the WSE measurement error (i.e., ~0.15 - 0.2 ft) and the bed elevation uncertainty due to measurement method accuracy and bed substrate variability (i.e., ~0.25 - 0.35 ft). These errors are not uniform, but are statistically distributed with uncertainty. Therefore, WSE performance will also be statistically distributed with uncertainty. There is no single constant WSE deviation value that can be correctly stated as the acceptable threshold for

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model performance. Note that the highest quality topographic survey recognized by the USACE has an accuracy of 0.5 ft.

Given the expected site characteristics in the Study sites, a goal of 0.10 ft difference between simulated and observed WSE will be targeted. This target will exceed the aforementioned industry standards.

Similarly, no specific target calibration criteria exist for velocity or depth parameters as these variables are greatly influenced by the differences in topographic detail between the field conditions, initial bed file detail, and the final bed detail resulting from the interpolated mesh. Using professional judgment and standard industry practice, velocity and depth variables are reviewed for reasonableness and significant errors in depth (i.e., 0.33 ft mean error) and velocity (i.e., 0.5 feet per second mean error) are evaluated. For all sets of model calibration variables, the correlation coefficient (r) and the coefficient of determination (r2) (i.e., percent of variance in an indicator variable explained by a factor and the measure of the proportion of variance of model results, respectively) were calculated. In general, coefficients greater than 0.7 are expected while coefficient of determination values for velocity magnitude are expected to be within a range of 0.4 and 0.8 (Pasternack 2011).

Flow field velocity vectors (i.e., the direction and magnitude) are used to evaluate velocity prediction reasonableness during the calibration process, but are otherwise not incorporated into the statistical review process.

Model convergence for a given hydraulic simulation is achieved and accepted when the inflow (Qin) equals outflow (Qout) and the solution change is nominal. Solution change is the relative change in the solution variable over the last time step. Specific criteria thresholds do not exist for these parameters and are largely based on the magnitude of the simulation discharge and the professional judgment of the modeler. The solution change goal will be 0.0001, or less. These values are consistent with recommendations for these metrics made in the River2D User Manual (Steffler and Blackburn 2002).

4.3.3.3 Rating Curve Development

Other than highly detailed topography, the downstream rating curve, also known as the downstream model boundary condition, is the most important element of the simulation process. Without site-specific field data, hydraulic simulation starting parameters (i.e., starting water surface elevations) can only be estimated and often rely on rating curves developed for another location and channel geometry.

On-site rating curves will be developed using a combination of field measurements of stage and discharge, stage recording pressure transducers and 15-minute USGS gage records. Stage recorders will be deployed at the top and bottom of the Study site to passively record stage over time. To relate WSE to discharge, WSE will be measured directly above each installed logger at the time of deployment. A barometric pressure transducer will also be located at the site to compensate for changes in atmospheric pressure. For validation purposes, WSEs are measured during calibration flow surveys in the vicinity of the recorder.

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4.3.4 Step 4 – Target Species and Habitat Suitability Criteria

Based on existing and available fish information and special-status listings for the Study Area, the following two fish species will be modeled in each Study site: 1) fall-run Chinook salmon and 2) hardhead minnow. Habitat modeling for additional ESA-listed or special-status fishes will be included in this Study if results from SSWD's relicensing Study 3.1, *Salmonid Redd,* or Study 3.2, *Stream Fish Populations,* document these ESA-listed fish species or special-status fishes in the Study Area, and HSC for these fishes are readily available and applicable to the riverine conditions of the Study Area. In advance of habitat modeling, SSWD will host a one-day technical HSC workshop to discuss the species to be modeled, modifications to the proposed HSC (if warranted) and the potential inclusion of additional species if documented during performance of Studies 3.1 or 3.2. A regional HSC expert will be in attendance and facilitate the HSC workshop. SSWD will, in good faith try to come to agreement on final HSC during the workshop, but due to schedule requirements, will proceed with modeling if no agreement is made.

Habitat suitability criteria define the range of microhabitat variables that are suitable for a particular species and lifestage of interest. Variables typically defined with HSC include depth, velocity, instream cover and bottom substrate. HSC values range from 0.0 to 1.0, indicating habitat conditions that are unsuitable to optimal, respectively. HSC provide the biological criteria input to the River2D model which combines the physical habitat data and the habitat suitability criteria into a site-wide habitat suitability index (i.e., Weighted Usable Area or WUA) over a range of simulation flows. WUA is defined as the sum of stream surface area within a nodal area model domain or stream reach, weighted by multiplying area by habitat suitability variables, most often velocity, depth, and substrate or cover, which range from 0.0 to 1.0 each. Target species and lifestage HSC for fall-run Chinook salmon will use those developed for use during the Yuba River Development Project (FERC No. 2246) relicensing Instream Flow Study (YCWA 2013). Spawning, juvenile and rearing lifestages will be modeled.

It is anticipated that these HSC may require some modification to appropriately be used in this Study as the general river conditions under which the curves were developed may differ significantly from current conditions in the lower Bear River. Modifications to HSC will be made by a regional HSC expert familiar with the proposed curves and any changes will be thoroughly documented in the final report. HSC transferability tests, as outlined by Thomas and Bovee (1993), will not be applied to this Study, given the periodic and limited number of salmonid observations in the lower Bear River.

Hardhead will be modeled using HSC developed for Nevada Irrigation District's Yuba-Bear Hydroelectric Project (FERC No. 2266) relicensing and PG&E's Drum-Spaulding Project (FERC No. 2310) relicensing (NID and PG&E 2011). Table 4.3.2 identifies the target species, lifestages and associated HSC to be used in this Study.

Table 4.3.2. Target Species and Habitat Suitability Criteria.

Target Species	Lifestages to be Modeled	HSC Source	HSC Modification Expected
Fall-run Chinook Salmon	Spawning, fry, juvenile	YCWA 2013	Yes
Hardhead MInnow	Juvenile, adult	NID and PG&E 2011	No

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Preliminary HSC for fall-run Chinook salmon are presented in Table 4.3-3 and plotted in Figure 4.3-1. As stated above, SSWD may modify these HSC based on a review of channel and flow conditions at the time when the HSC input data were collected.

Table 4.3-3. Fall-run Chinook salmon HSC values (YCWA 2013).

Life Stage	Velocity HSC		Depth HSC		Substrate[1]/Cover[2] HSC	
	ft/sec	Suitability	ft	Suiatbility	--	Suitability
Spawning	0.22	0.00	0.25	0.00	31	0.00
	0.85	0.20	0.45	0.10	32	1.00
	1.30	0.52	0.65	0.20	195	1.00
	1.55	1.00	0.75	0.50	196	0.00
	2.95	1.00	0.95	1.00	--	--
	3.25	0.50	2.00	1.00	--	--
	5.32	0.00	3.00	0.20	--	--
	--	--	4.80	0.02	--	--
	--	--	7.80	0.02	--	--
	--	--	7.90	0.00	--	--
Fry	0.00	1.00	0.00	0.00	none	0.25
	0.10	0.99	0.10	0.12	cobble	0.40
	0.20	0.95	0.20	0.31	boulder/riprap	0.33
	0.30	0.89	0.30	0.58	riparian vegetation	1.00
Fry (continued)	0.40	0.81	0.40	0.85	stream wood	1.00
	0.60	0.65	0.50	0.99	--	--
	0.70	0.56	0.60	1.00	--	--
	0.80	0.49	0.80	1.00	--	--
	0.90	0.42	0.90	1.00	--	--
	1.10	0.30	1.10	1.00	--	--
	1.30	0.22	1.20	1.00	--	--
	1.40	0.19	1.50	0.92	--	--
	1.70	0.13	1.90	0.75	--	--
	2.00	0.10	2.00	0.69	--	--
	3.62	0.00	2.30	0.55	--	--
	--	--	2.40	0.48	--	--
	--	--	2.50	0.45	--	--
	--	--	2.70	0.38	--	--
	--	--	3.10	0.26	--	--
	--	--	3.30	0.21	--	--
	--	--	3.40	0.18	--	--
	--	--	3.60	0.16	--	--
	--	--	3.70	0.14	--	--
	--	--	3.90	0.11	--	--
	--	--	4.30	0.07	--	--
	--	--	4.50	0.06	--	--
	--	--	4.60	0.05	--	--
	--	--	4.80	0.05	--	--
	--	--	5.10	0.04	--	--
	--	--	5.20	0.03	--	--
	--	--	5.60	0.02	--	--
	--	--	18.40	0.02	--	--
	--	--	18.50	0.00	--	--

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Table 4.3-3.(Continued)

Juvenile	0.00	1.00	0.20	0.00	none	0.30
	0.10	1.00	0.55	0.50	cobble	0.50
	0.20	0.99	1.50	1.00	boulder/riprap	0.50
	0.30	0.98	2.50	1.00	riparian vegetation	1.00
	0.40	0.97	3.50	0.35	stream wood	1.00
	0.50	0.96	5.00	0.35	--	--
	0.60	0.94	6.00	0.20	--	--
	0.70	0.92	11.90	0.00	--	--
	0.80	0.89	--	--	--	--

[1] Mean particle diameter (mm) in substrate polygons.

[2] Cover type notes: substrate polygons must contain >30% cobble or >10% boulder/riprap, and cover includes 3ft buffer around edge of riparian vegetation or 6ft buffer around stream wood.

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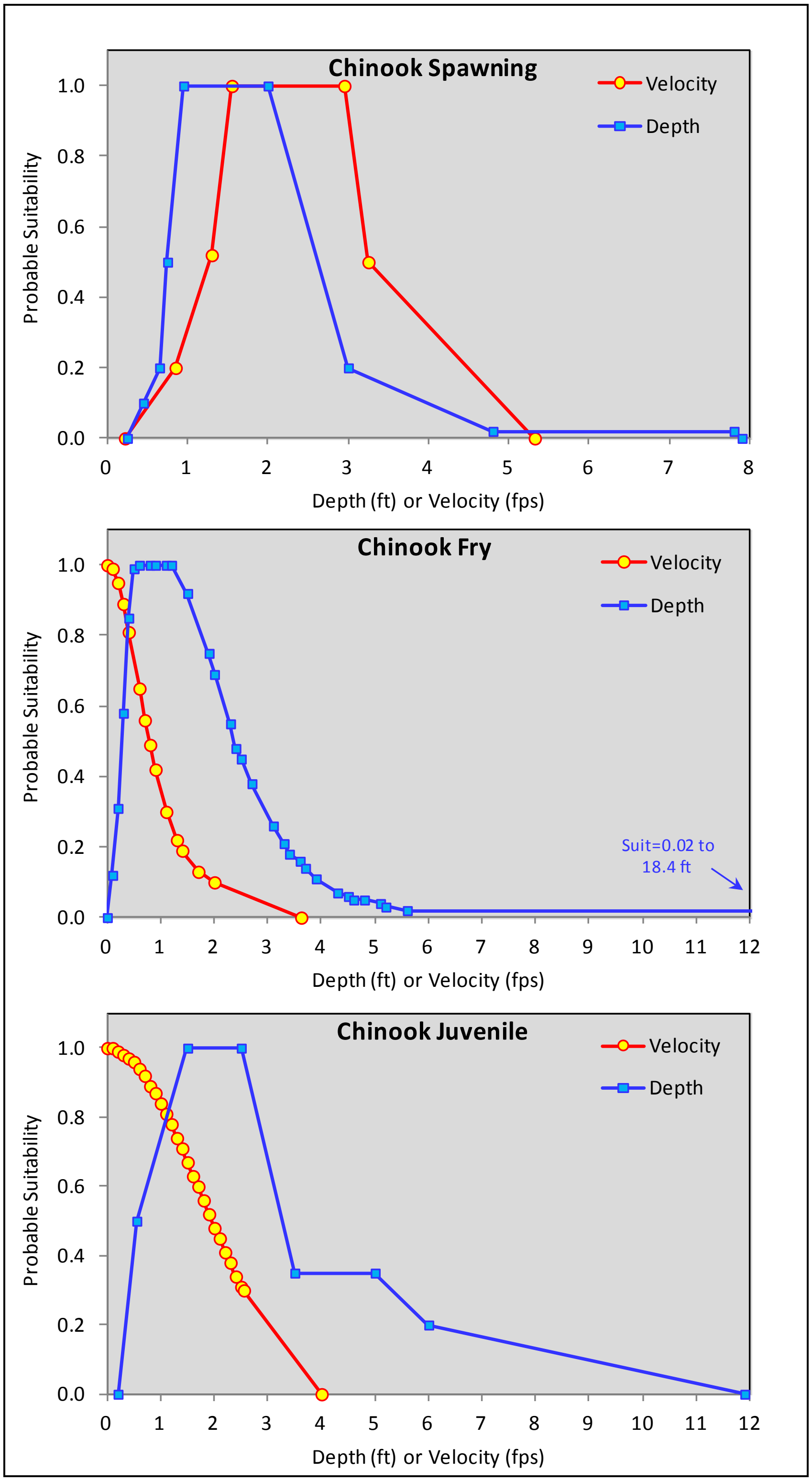

Figure 4.3-1. Depth and velocity HSC curves for spawning, fry, and juvenile fall-run Chinook salmon (YCWA 2013).

The HSC for hardhead minnow are presented in Tables 4.3-4 and plotted in Figures 4.3-2, respectively.

Table 4.3-4. Hardhead suitability for juvenile and adult life stages (NID and PG&E 2011).

Life Stage	Velocity HSC		Depth HSC	
	ft/s	Suitability	ft	Suitability
Juvenile	0.00	1.00	0.50	0.00
	0.25	1.00	0.67	1.00
	1.75	0.25	3.67	1.00
	2.60	0.00	8.71	0.10
	--	--	18.00	0.10
Adult	0.00	0.82	0.66	0.00
	0.20	1.00	2.62	1.00
	0.90	1.00	18.00	1.00
	2.13	0.22	--	--
	3.50	0.00	--	--

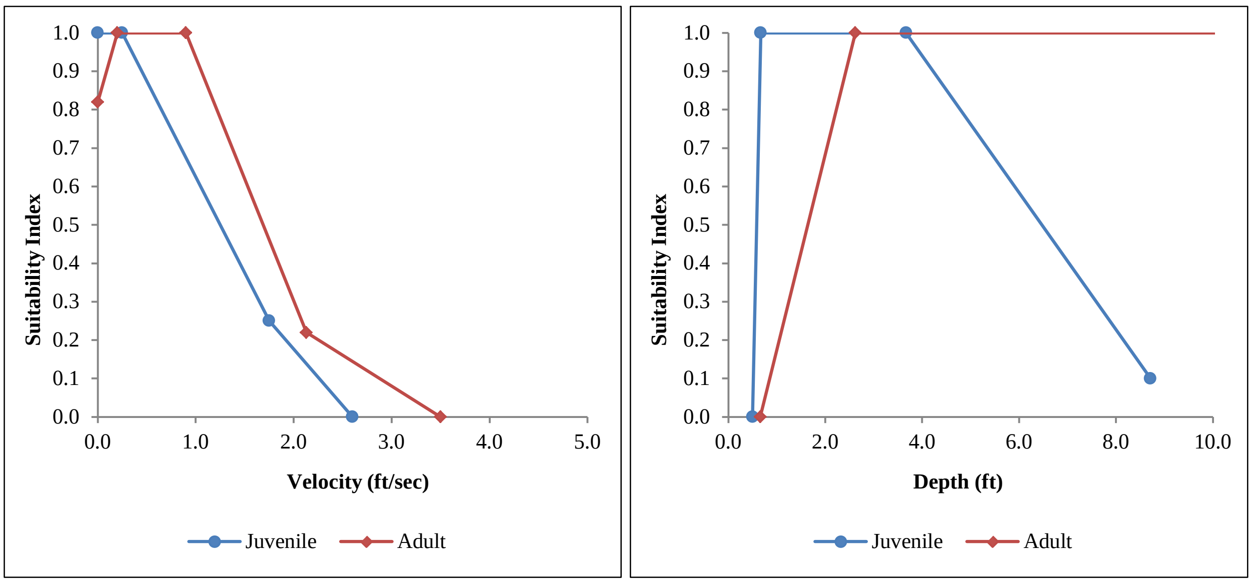

Figure 4.3-2. Hardhead minnow velocity and depth suitability (NID and PG&E 2011).

HSC for velocity and depth will be used for all target species life stages. Substrate and cover criteria will only be applied to the fall-run Chinook salmon HSC. Substrate and cover criteria will not be applied to the adult and juvenile lifestages of hardhead. In general, observations suggest that hardhead do not occupy habitat in stream channels based on substrate but are rather observed over sand-gravel-boulder substrates (Moyle 2002). Hardhead are often observed in the deepest stream habitats available, where the depth of pool or run habitat may act as cover rather than utilizing traditional cover types (i.e., undercut banks, LWM, overhanging vegetation).

Additional species may be modeled based on the results of Study 3.1, *Salmonid Redd Surveys* or Study 3.2, *Stream Fish*.

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4.3.5 Step 5 – Aquatic Habitat Modeling

4.3.5.1 Simulation Flows

A total of 18 discharges will be simulated for each Study site. Habitat suitability and WUA for all target fish species and life stages will be calculated for each simulation flow. WUA is calculated as the product of a composite habitat suitability index at every node in the domain and the area associated with each node. In order to calculate habitat suitability, four data inputs are required: a fish preference file (i.e., HSC), a channel index, depth, and velocity.

Fish preference files contain suitability values (0.0 to 1.0) for velocities, depths, and substrate/cover. A fish preference file is loaded into River2D as a text file. Depth and velocity values are provided from the model once a simulation has converged and is at a steady state. Channel index files are a River2D model file equivalent to a substrate and cover map of the entire model domain.

The WUA calculation will use the standard triple product function which multiplies depth, velocity, and channel index together. Channel index interpolation will be defined using discrete node selection (i.e., nearest node rather than a continuous linear interpolation of the channel index values from surrounding nodes). Discrete node selection is typically applied to substrate classifications such that the original substrate code value is maintained. When cover codes are defined for HSC, a continuous interpolation is applied as a gradient of cover may be best described by the interpolation function.

The sample River2D habitat model output provided below (Table 4.3-4) demonstrates how WUA is calculated at each River2D model node. The depth suitability index (DSI), velocity suitability index (VSI), and the channel index suitability index (CiSI) are multiplied together to obtain a combined suitability index (CbSI). The resulting WUA (in square meters), is a product of the CbSI and the area represented by the node. Total site WUA is the sum of nodal WUA.

Table 4.3-4. Sample section from a nodal attribute file showing habitat suitability and WUA results.

Node	x	Y	Depth (m)	Velocity (mps)	Channel Index	DSI	VSI	CiSI	CbSI	WUA (sq. m)
1	587155.1	124891.8	1.31	0.0982	6	0.52	1	1	0.52	0.1737
2	587154.6	124891.7	1.287	0.0918	1	0.551	1	0.1	0.0551	0.1424
3	587138.7	124888.3	-1.315	0	1	0	0.6	0.1	0	1.2279
4	587155.7	124891.9	1.4099	0.0984	1	0.3927	1	0.1	0.0393	0.1679
5	587156.2	124892	1.5438	0.0926	6	0.3034	1	1	0.3034	0.1834
6	587155.6	124891.4	1.1709	0.1108	6	0.7075	1	1	0.7075	0.4167
7	587142.7	124889.2	-0.224	0	1	0	0.6	0.1	0	1.4058
8	587144.3	124889.5	0.3681	0.0107	1	0.9075	0.6735	0.1	0.0611	1.2983
9	587154.9	124891.2	1.1759	0.1002	6	0.7008	1	1	0.7008	0.447

4.3.7 Step 7 – Effective Habitat Analysis

Building on the spatial habitat suitability results and the site-wide aggregation of WUA, an effective habitat analysis incorporates critical temporal and potentially habitat limiting

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components to the analysis. The analysis applies constraints or limiting factors which, in this Study, will inherently include water availability but will also be focused on water temperature.

Evaluation of habitat availability over time, in combination with spatial habitat suitability results, conveys important information about the effect of changing river conditions on the habitat of fish community. Often, it is the time dependent characteristics of habitat occurrence that ultimately may limit a particular lifestage and therefore control the population (Waddle 2001).

The foundation of the effective habitat analysis is a habitat time series (HTS) for the full period of record. The HTS requires that the WUA function extend from highest mean daily flow in the hydrologic record to the lowest (i.e., 100% to 0% flow exceedance). For the Study, the WUA will be extrapolated to zero percent exceedance in two steps. First, flows will be modeled in River2D to the maximum extent acceptable within model calibration parameters established during model calibration. Second, WUA will be extrapolated from the highest modeled flow in River2D to zero percent exceedance and, extrapolated from the lowest modeled flow to 100 percent exceedance using the following approach.

A non-linear exponential extrapolation equation will be applied to the last three points of each WUA data set. The non-linear option for extrapolation follows the trend of the regression and never completely bottoms out, which is likely the most realistic trend line for WUA. If the non-linear function does not produce results as expected, a flat-line approach will be employed whereby the WUA function is extended at a constant magnitude from the last data point. In some circumstances, it is reasonable to apply the flat-line to habitat as habitat-flow relationships (i.e., HSC) for most species are not documented or well understood at the highest flows observed in a Study site.

The effective habitat model will be calculated using Microsoft® Excel. Several inputs are required. These include:

- Target Species and Lifestages. The analysis will evaluate all species and lifestages identified in Section 4.3.4.
- Periodicity. Lifestage periodicity input to the program enables the program to calculate habitat frequency for only the time of year when the lifestage of interest may be present. Periodicity will be evaluated in accordance with Table 4.3-5.

Table 4.3-5. Target species life stage periodicity.

Life Stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
FALL-RUN CHINOOK SALMON																								
Spawning	X	X																X	X	X	X	X	X	X
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X	X	X										
Fry	X	X	X	X	X	X																	X	X
HARDHEAD MINNOW																								
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Adult	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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- Hydrology. A baseline historical hydrology data set will be developed for use in the HTS. Its development is described below. The Project Base Case hydrologic data set will be used for all analyses. That is, each hydrologic node will be based on existing flows (i.e., the hydrologic regime that would occur under current Project operation) and will be based on the relicensing hydrology database for the period of record ranging from WY 1976 through WY 2014.

Evaluations of habitat over time are typically conducted in the form of a habitat exceedence (i.e., duration) analysis, which is particularly useful for assessing the impacts of alternative flow regimes over the complete range of discharges considered for alternative flow scenarios (Bovee et al. 1998, Waddle 2001). This curve represents the percent of time that a given amount of habitat (in square meters or square feet) is equaled or exceeded during the analysis period. This summarization also allows for the comparison of the available habitat under different flow scenarios at a given Study site.

Habitat exceedance curves are constructed in the same manner as a flow exceedance (i.e., duration) curve, but use habitat values instead of discharges as the ordered data. Although the habitat exceedance curves look like and are based on flow exceedance curves, there is no direct correspondence between the two. For example, the habitat value that is exceeded 90 percent of the time usually does not correspond to the discharge that has the same exceedance probability.

This discordance happens because of the normal bell-shaped data relationship between total habitat and discharge (Bovee et al. 1998) whereby the same habitat can be achieved with different flows. Consequently, a given habitat exceedance probability might be related to more than one discharge, and is not explicitly related to the probability of exceedance of specific flows. Habitat exceedance curves and habitat metrics derived from the curves, such as total cumulative daily habitat and area under the curve, can be used to quantify the differences in habitat between baseline and alternative conditions (Hawks Nest Hydro 2015, HDR 2014, Bovee et al. 1998).

Habitat modeling results for this Study will not be weighted by reach length (i.e., habitat type frequency) and will therefore reflect only the habitat contained within each Study site. To quantify the amount of habitat change resulting from one hydrologic scenario to another (e.g., Water Year type or operational change), summary graphics and tables will be created using a metric of the total habitat days, which is analogous to the calculation of the total area under the curve.

As previously mentioned, in addition to water availability, water temperature is the most important limiting factor for fall-run Chinook salmon in the Study Area.

Anadromous salmonid water temperature numeric guidelines developed by the United States Environmental Protection Agency (EPA) (EPA 2003) will be used to examine the suitability of water temperature conditions for fall-run Chinook salmon by Effective Habitat Analysis (EHA). These EPA guidelines are 7-day averages of the daily maxima (7DADM) water temperatures that the EPA claims maintains protection of anadromous salmonids. Although the EPA developed these guidelines based on review of literature describing water temperature-related

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effects on various species of anadromous salmonids, species-specific guidelines were not developed. Table 4.3-6 shows the EPA guidelines for the anadromous salmonid lifestages that will be used in this Study.

Table 4.3-6. EPA water temperature guidelines (EPA 2003) for protection of anadromous salmonids by life stage.

Salmonid Life History Phase Terminology	7-Day Average of the Daily Maxima Guideline (°C)	Protective of:
Adult Migration	≤18°C	Salmon and steelhead migration
Spawning and Egg Incubation	≤13°C	Salmon and steelhead spawning, egg incubation and fry emergence
Juvenile Rearing and Emigration	≤16°C for "core" juvenile rearing;[1] ≤18°C for migration and non-core juvenile rearing	Salmon and steelhead rearing and juvenile migration
Smoltification	≤14°C	Composite criteria for salmon and steelhead smoltification[2]

[1] EPA recommends that for areas of degraded habitat, "*core juvenile rearing*" use covers the downstream extent of low density rearing that currently occurs during the period of maximum summer temperatures (EPA 2003).

[2] EPA establishes a guideline of ≤15°C for salmon smoltification and a guideline of ≤14°C for steelhead smoltification; but for a composite guideline for both species, the steelhead guideline of ≤14°C is applied.

One model run using the Base Case hydrology will be made for each life stage of the target species using the input data sets described above. For each 6-hour time step, there will be an associated water temperature at each node. Daily temperature at each node will be calculated using the 7DADM water temperature. Each nodal temperature value will then be compared to the temperature threshold table for each species and life stage. Threshold values for all species and life stages will be binary, meaning that if the 7DADM water temperature criterion at a given node was exceeded, the habitat will be deemed not effective and assigned a zero value. If the 7DADM nodal temperatures are less than or equal to the threshold temperature, the habitat value associated with the discharge will be maintained.

To show the results of the analysis, EHA charts and tables will be generated showing the unconstrained habitat (i.e., no temperature thresholds applied) and the constrained habitat (i.e., temperature thresholds applied). To quantify the amount of habitat change resulting from the application of temperature thresholds, summary tables will be developed. These tables summarize the percent change between habitat availability with no temperature considerations versus the effective habitat availability with temperature thresholds applied.

5.0 Consistency of Methodology with Generally Accepted Scientific Practices

The Study methods are consistent with the goals, objectives, and methods used in many recent and relevant studies in California using River2D for salmonid habitat (USFWS 2010, 2005 and 1997). The EHA has most recently been used in the Merced River Hydroelectric Project (FERC No. 2179) (MID 2013) relicensing. The Study uses standard data collection and modeling methods for 2D instream flow studies and habitat evaluations (Pasternack 2011, YCWA 2013, Steffler and Blackburn 2002, Waddle 2001, Bovee et al. 1998).

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6.0 Schedule

SSWD anticipates the schedule to complete the Study as follows:

Planning .... October 2016 – June 2017
Collect Data ....October 2016 – October 2017
Hydraulic and Habitat Modeling .... June 2017 – October 2017

The Study information will be included in SSWD's DLA and FLA. If SSWD completes the Study before preparation of the DLA, SSWD will post the information on SSWD's Relicensing Website and issue an e-mail to Relicensing Participants advising them that the report is available.

7.0 Level of Effort and Cost

This Study will incorporate data from SSWD's relicensing Studies 2.1, *Water Temperature Monitoring*; 2.2, *Water Temperature Modeling*; and 3.1, *Salmonid Redd*. The costs for implementation of those studies are not included in this Study's cost. SSWD estimates the costs in 2016 dollars to complete the Study is between $215,000 and $350,000.

8.0 References Cited

Bovee, K., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor and J. Henriksen. 1998. Stream habitat analysis using the instream flow incremental methodology. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD-1998-0004.

California Department of Fish and Game (CDFG). 1991. Draft Report: Lower Bear River Instream Flow and Temperature Recommendations. pp. 80.

California Department of Fish and Wildlife. Unpublished. Stocking and fish survey records at Camp Far West Reservoir. Provided by Sean Hoobler on 7/3/2015.

Curtis, J.A., L.E. Flint, C.N. Alpers, and S.M. Yarnell. 2005. Conceptual model of sediment processes in the upper Yuba river watershed, Sierra Nevada, CA. USGS Staff Published Research. Paper 482.

Hawks Nest Hydro LL, 2015. Aquatic Habitat Use Instream Flow Study. Hawks Nest Hydroelectric Project. FERC No. 2512. Prepared by HDR Engineering, 2015.

HDR. 2014. Gila River Fish Habitat Study, Gila, NM. Prepared for the New Mexico Interstate Stream Commission.

Kelsey, H.M., R. Lamberson, and M.A. Madej. 1987. Stochastic model for the long-term transport of stored sediment in a river channel. Water Resources Research, Vol. 23, No. 9, pp 1738-1750.

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Merced Irrigation District, 2013. Instream Flow (PHABSIM) Downstream of Crocker-Huffman Dam. Merced River Hydroelectric Project. FERC No. 2179. Prepared by HDR Engineering, 2013.Moyle, P.B. 2002. Inland Fish of California, 2nd Edition. University of California Press, Berkeley, California.

National Oceanic & Atmospheric Administration (NOAA). 2015. United States Interagency Elevation Inventory. Available online: <https://coast.noaa.gov/inventory> . Accessed February 4, 2016. Last updated 2015. NOAA's Ocean Service, Office for Coastal Management (OCM), Charleston, SC.

Nevada Irrigation District and Pacific Gas and Electric Company (NID and PG&E). 2011. Instream Flow. Technical Memorandum 3-2. Yuba Bear-Drum Spaulding Project, FERC Project Nos. 2266-096 and 2310-173. HDR Engineering, Sacramento, CA.

Pasternack G.B. 2011. 2D Modeling and Ecohydraulic Analysis. Land, Air, and Water Resources, University of California at Davis. pp.158.

Placer County. 2012. Placer Legacy Program Summary. Available online: <http://www.placer.ca.gov/bos/District2/~/media/bos/dist2/documents/PlacerLegacyReport2010_11.ashx>. Accessed: August 24, 2015.

Rantz, S.E. 1982. Measurement and computation of stream flow: Volume 1. Measurements of stage and discharge. USGS Water Supply Paper 2175.

South Sutter Water District (SSWD). 1988. Garden Bar Dam and Reservoir Water Power Project, FERC No. 5222, Application for license before Federal Energy Regulation Commission, January 1988.

Steffler, P. M. and J. Blackburn. 2002. River2D: Two-dimensional depth averaged model of river hydrodynamics and fish habitat. Introduction to depth averaged modeling and user's manual. Edmonton, University of Alberta.

Thomas, J.A., and K.D. Bovee. 1993. Application and Testing of a Procedure to Evaluate Transferability of Habitat Suitability Criteria. Regulated Rivers: Research and Management. 8(3): 285-294.

United States Environmental Protection Agency (EPA). 2003. USEPA Region *10 Guidance for Pacific Northwest. State and Tribal Temperature Water Quality Standards.* EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA.

United States Fish and Wildlife Service (USFWS). 2010. Flow-Habitat Relationships for Juvenile Fall/Spring-Run Chinook Salmon and Steelhead/Rainbow Trout Rearing in the Yuba River. pp. 294.

______. 2005. Monitoring of Restoration Projects in the Merced River using 2-Dimensional Modeling Methodology. 106 pp.

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______. 1997. Identification of the instream flow requirements for fall-run Chinook salmon spawning in the Merced River. Ecological Services, Instream Flow Assessments Branch. Merced River Final Report. pp. 69.

Waddle, T. and P. Steffler. 2002. R2D_Mesh. Mesh Generation Program for River2D Two Dimensional Depth Averaged Finite Element. Introduction to Mesh Generation and User's Manual. U.S. Geological Survey.

Waddle, T.J., ed. 2001. PHABSIM for Windows: User's Manual and Exercises. Fort Collins, CO. U.S. Geological Survey. 288 pp.

Yuba County Water Agency (YCWA). 2013. Technical Memorandum 7-10. Instream Flow Downstream of Englebright Dam. Yuba River Development Project. FERC Project No. 2246.

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