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

(*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

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[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.*"

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.
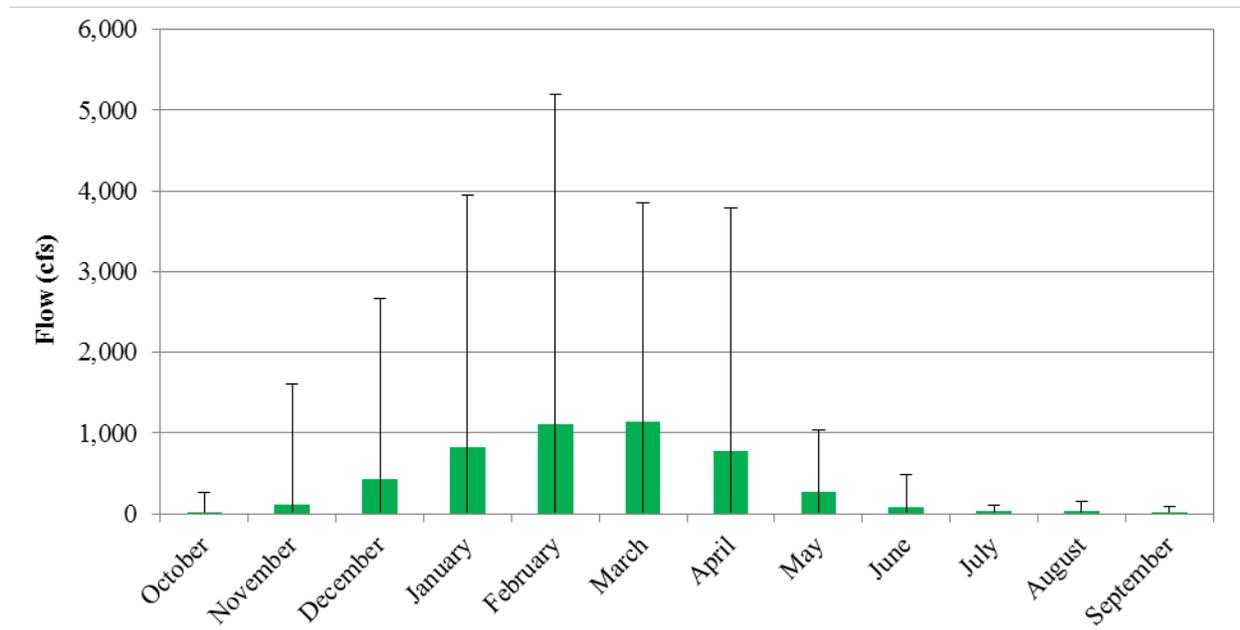

Figure 3.1-1. Mean monthly streamflow for the Bear River near Wheatland gage (USGS Gage 11424000) from WY 1967 through WY 2014.

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.

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.

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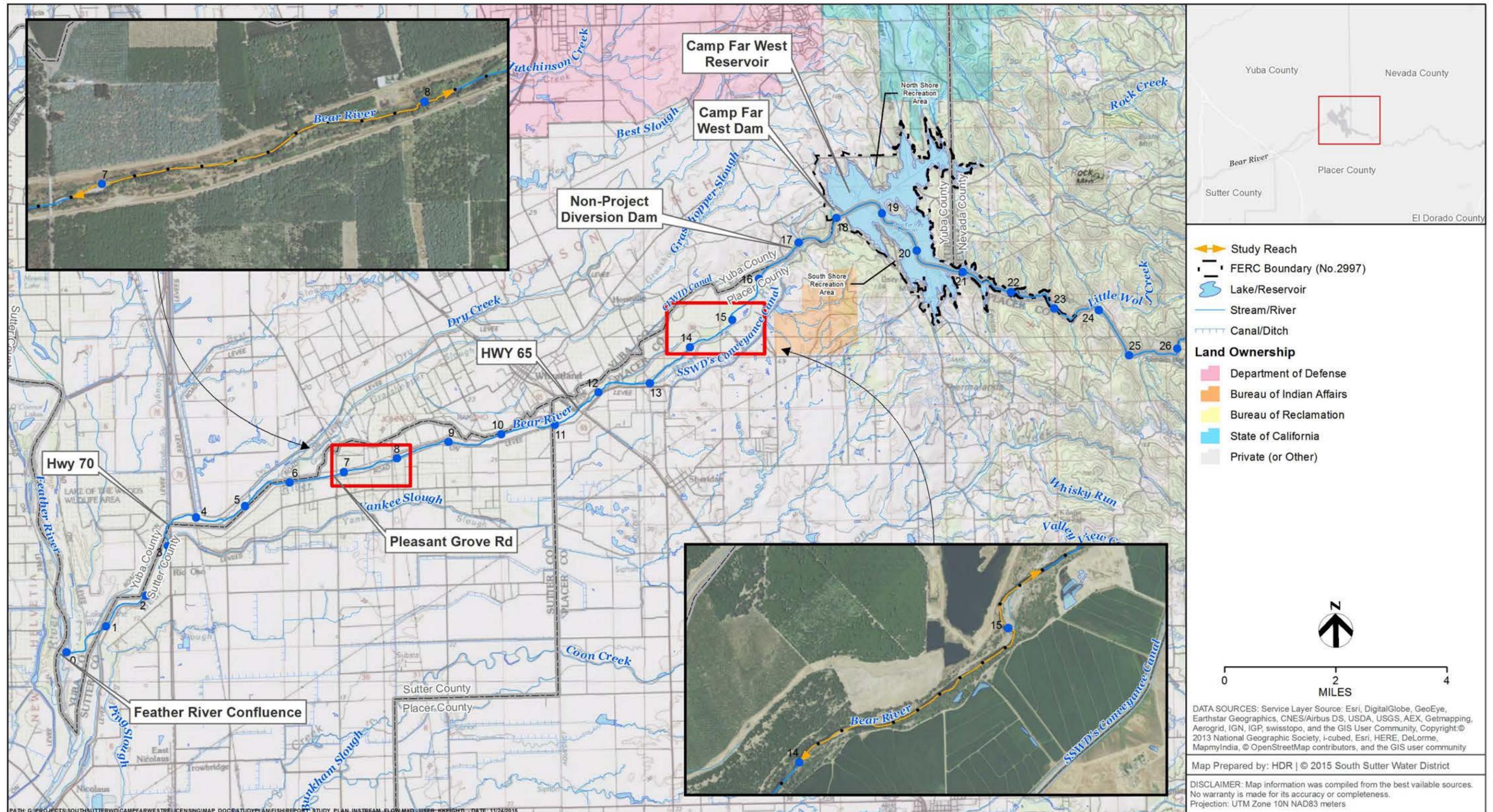
Figure 4.1-1. Study Area of Instream Flow Study.

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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.

- 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

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.

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[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.

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.

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)

- 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

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

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.

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

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

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.

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

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	--	--

Table 4.3-3.(Continued)

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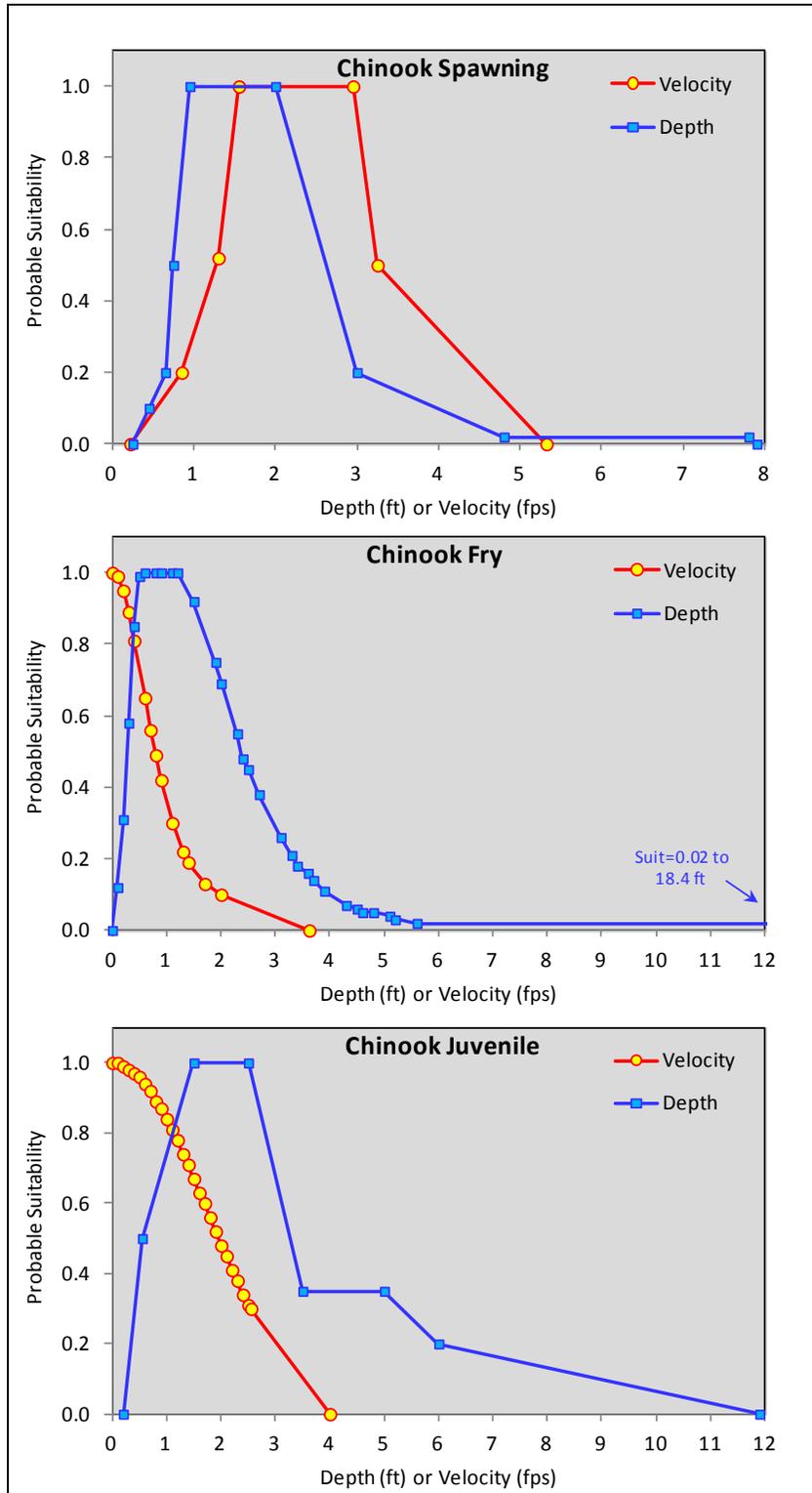
Figure 4.3-1. Depth and velocity HSC curves for spawning, fry, and juvenile fall-run Chinook salmon (YCWA 2013).

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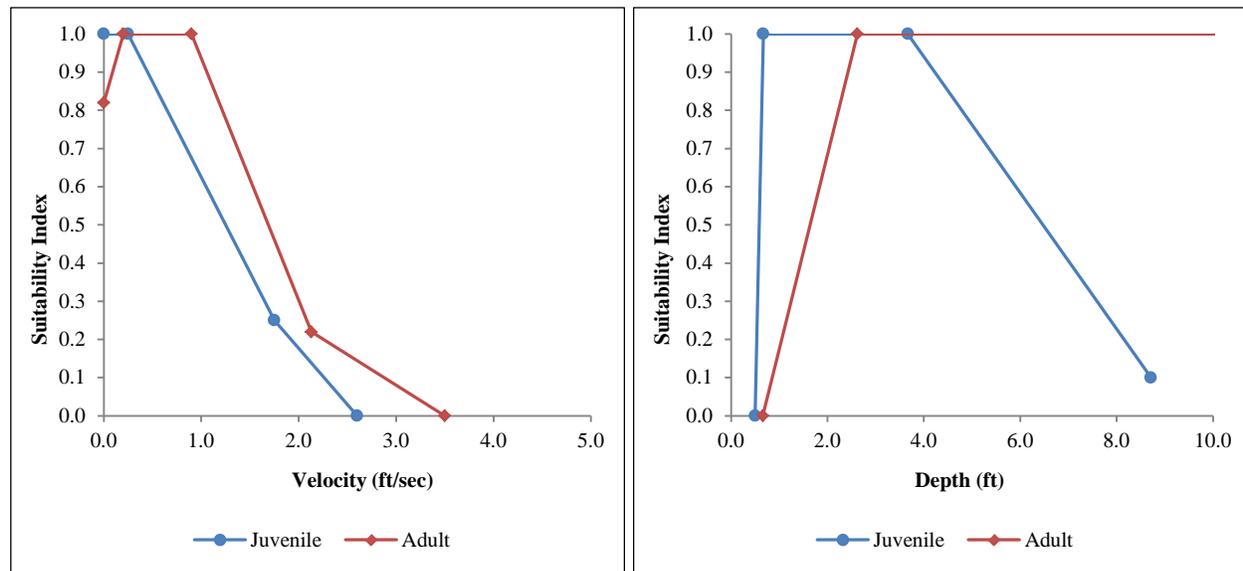
Figure 4.3-2. Hardhead minnow velocity and depth suitability (NID and PG&E 2011).

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*.

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

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	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

- • <u>Hydrology</u>. 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

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).

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.

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Attachment 1
Habitat Mapping Methods

Attachment 1
Study 3.3 – Instream Flow Study
Habitat Mapping Methods

1.0 <u>Introduction</u>

The purpose of the habitat mapping effort is to develop specific, comprehensive, and detailed information on aquatic habitat and channel morphology characteristics of the Bear River downstream of the Project to the confluence with the Feather River. There has been no coordinated approach to habitat map and little is known about the features of the channel and associated habitat. Therefore, there are significant gaps in existing data for the purposes of assessing habitat quantity, quality, and distribution in the stream reaches affected.

SSWD completed some initial habitat mapping and channel characterization prior to filing the NOI and PAD because development of aquatic study plans required a basic understanding of the general physical and biological character of the Bear River. Additional information is needed that extends along the entire Bear River.

2.0 <u>Methods</u>

Habitat mapping generally will follow standard methods similar to those applied in other recent relicensings in California. Habitat will be mapped using ground-based surveys. The River is generally very low gradient and flows through Quaternary alluvium so no reach breaks were noted. It is also confined by levees and highly modified from historical mining, redirection, dredging, diversions, and agricultural development.

The stream longitudinal profile was measured using maps available from Terrain Navigator Pro© (V. 7) software. Distance between contour lines was measured and a longitudinal profile was created. Map-based gradient, while an estimate, is often a good indicator of stream energy and process (Figure 1). The map gradient averages 0.1% and ranges between 0.3% just below the dam to almost flat between RM 13 and 15.5 (2 miles above Highway 65). The slope is fairly consistent throughout the reach.
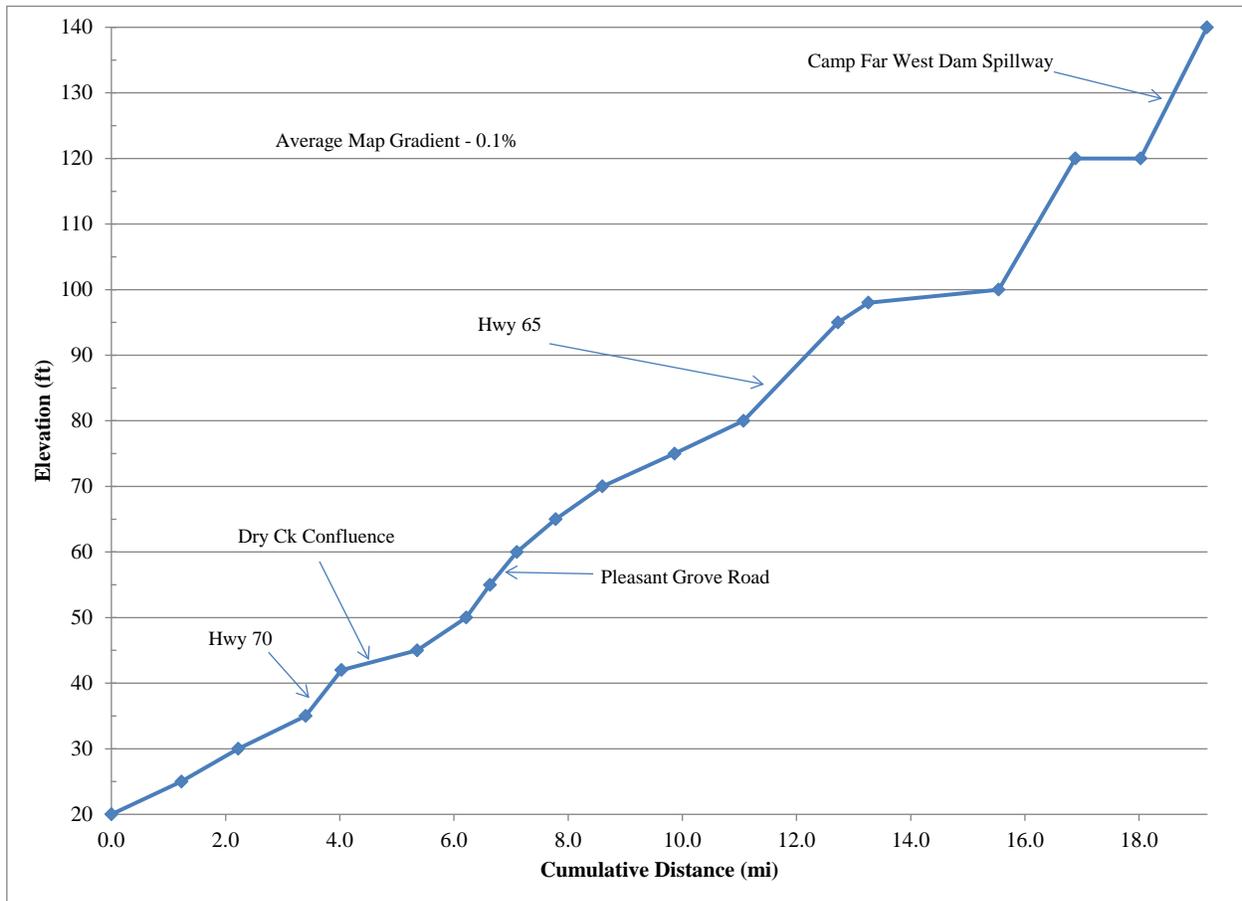
Figure 1. Longitudinal profile (based on 1:24k topographic map) of Bear River from junction with Feather River to Camp Far West Dam.

Initial field data were collected in June 2015 when discharge was controlled by SSWD at 25 cfs to maximize access and safety during fieldwork and evaluate habitat composition during the seasonal period of greatest habitat heterogeneity. Anticipating habitat based on differences in discharge is too subjective so the habitat calls are made at the survey low-flow. Further mapping will be done in the low flow period of 2016.

2.1   Study Area

Habitat mapping will be completed in the Bear River downstream of the non-Project diversion dam to the confluence with the Feather River. The backwater pond between Camp Far West Dam and the non-Project diversion dam will be noted. In 2015, RM 16.3 to 16.9, 12.1 to 12.4, and 6.4 to 7.1 was mapped in the downstream and upstream direction while wading and walking. The 4.7 mile section between Hwy 65 and the Pleasant Grove Bridge was mapped in the downstream direction while floating inflatable kayaks. Additional mapping will be completed using similar methods. No tributaries will be mapped due to dry channels, vegetation (e.g., no flow, and channels dominated by macrophytes), and private ownership.

2.2.　　　　Meso-Habitat and Channel Classification

A three-tiered habitat mapping classification system developed by Hawkins et al. (1993) will be used to assist in the identification of individual habitat units in the field. Level III categories are generally modified/adopted from McCain et al. (1990). Figure 2 shows the relationship among the three levels. At the broadest level, Level I categorizes habitats as "fast water" and "slow water." In Level II, fast water is subdivided into two categories: turbulent and non-turbulent; slow water is also subdivided into two categories: scour pool and dammed pool.
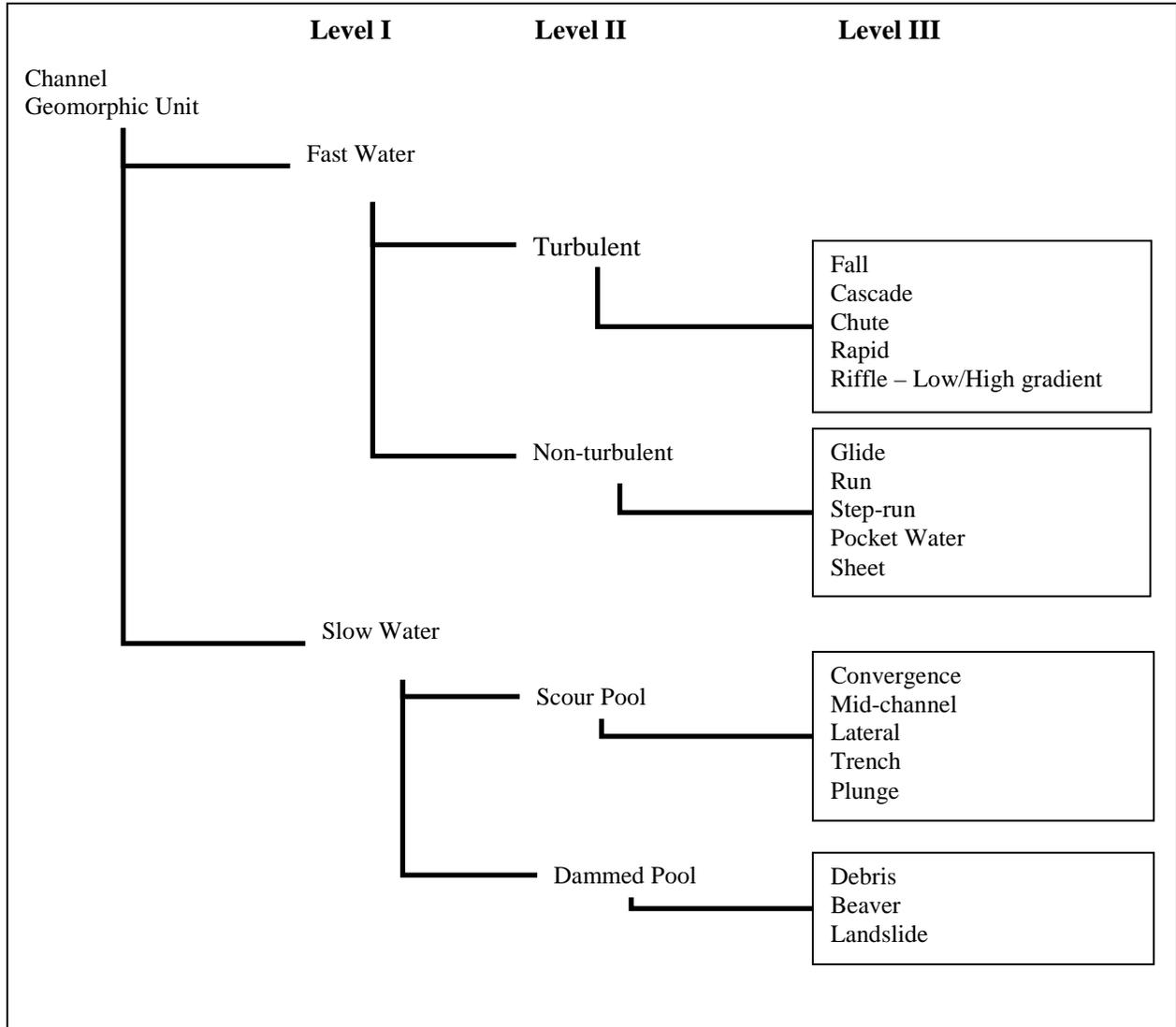
Figure 2. Key to habitat types used in the lower Bear River.

Habitat mapping will use methods developed by Hawkins et al. (1993), McCain et al. (1990) and Flosi and Reynolds (1994). Each distinct habitat unit will be numbered consecutively in the direction of travel during the day of the mapping and for an individual section. Different days or sections will also be numbered consecutively beginning with Habitat Mapping Unit 1 (HMU1)

and later combined with previous mapping for data analysis. Habitat type descriptions are listed in Table 1. Any pools created by vegetation, beavers, artificial berms, or other strong downstream control will be noted. Additional data (length, width, height, and function) will be collected for concentrations of giant cane (*Arundo donax*). The base map of the Bear River will be loaded onto a mobile device (e.g., tablet or laptop) and be utilized along with data collection software that can collect features (e.g., polygons, lines, areas, points) from an external GPS source. All cane concentrations will be collected with a differential GPS antenna capable of 1 meter or better accuracy.

Table 1. Habitat types to be used in mapping for the South Sutter Water District Bear River (Adapted from McCain et al. 1990, Armantrout 1998, Payne 1992, McMahon et al. 1996, and Hawkins et al. 1993).

I. Fast Water:			Riffles, rapid, shallow stream sections with steep water surface gradient.
	A. Turbulent:		Channel units having swift current, high channel roughness (large substrate), steep gradient, and non-laminar flow and characterized by surface turbulence.
		1. Fall:	Steep vertical drop in water surface elevation. Generally not modelable.
		2. Cascade:	Series of alternating small falls and shallow pools; substrate usually bedrock and boulders. Gradient high (more than 4%). Generally not modelable.
		3. Chute:	Narrow, confined channel with rapid, relatively unobstructed flow and bedrock substrate.
		4. Rapid:	Deeper stream section with considerable surface agitation and swift current; large boulder and standing waves often present. Generally not modelable.
		5. Riffles:	Shallow, lower-gradient channel units with moderate current velocity and some partially exposed substrate (usually cobble). • Low gradient — Shallow with swift flowing, turbulent water. Partially exposed substrate dominated by cobble. Gradient moderate (less than 4%). • High gradient — moderately deep with swift flowing, turbulent water. Partially exposed substrate dominated by boulder. Gradient steep (greater than 4%). Generally not modelable.
	B. Non-turbulent:		Channel units having low channel roughness, moderate gradient, laminar flow, and lack of surface turbulence.
		1. Sheet:	Shallow water flowing over smooth bedrock.
		2. Run / Glide:	Shallow (glide) to deep (run) water flowing over a variety of different substrates.
		3. Step Run	A sequence of runs separated by short riffle steps. Substrates are usually cobble and boulder dominated.
		4. Pocket Water:	Swift flowing water with large boulder or bedrock obstructions creating eddies, small backwater, or scour holes. Gradient low to moderate.
II. Slow Water:			Pools; slow, deep stream sections with nearly flat water surface gradient.
	A. Scour Pool:		Formed by scouring action of current.
		1. Trench:	Formed by scouring of bedrock.
		2. Mid-channel:	Formed by channel constriction or downstream hydraulic control.
		3. Convergence	Formed where two stream channels meet.
		4. Lateral:	Formed where flow is deflected by a partial channel obstruction (streambank, rootwad, log, or boulder).
		5. Plunge:	Formed by water dropping vertically over channel obstruction.
	B. Dammed Pool:		Water impounded by channel blockage.
		1. Debris:	Formed by rootwads and logs.
		2. Beaver:	Formed by beaver dam.
		3. Landslide:	Formed by large boulders.
		4. Backwater:	Formed by obstructions along banks (Recorded as a comment or note to mapping).
		5. Abandoned Channel:	Formed along main channel, usually associated with gravel bars (Not part of the main active channel - Recorded as a comment or note to mapping).

2.3   Habitat Mapping

Ground habitat mapping will be conducted on foot by teams of two individuals. Habitat units will be designated using the habitat types described in Table 1. Habitat units will be separately identified where the unit length is at least equal to the active channel width (McCain et al. 1990, Flosi and Reynolds 1994), or if the unit is otherwise distinctive. Figure 2 is a copy of the field form used for the mapping. Teams record the length and width of each habitat type unit using a laser range finder. Mapping will be contiguous (i.e., each habitat unit abuts the next unit, except for split channels, which will have the length measured but individual habitat units within each split will not be mapped but may be identified). The beginning and ending of the mapped section, and every fifth mapped unit, and every tenth characterized habitat unit, will have Global Positioning System (GPS) reading recorded in UTM NAD83 datum; locations may also be added to the field laptop as described above in Section 2.2 for identifying giant cane concentrations. Table 2 provides the definitions and description of the data to be collected that would be entered in Figure 3.

STREAM HABITAT TYPING SURVEY DATA (Camp Far West - South Sutter Water District)

Data Sheet # _____

Stream/Reach/Subreach:_____   Page _____ of _____

Team: _____   Date _____

UTM: _____NAD 83 (Habitat unit No_____)   PM _____   Map Gradient:_____

Habitat Unit #																				
Habitat Type [1]	FALL	CAS	CHU	RAP	FALL	CAS	CHU	RAP	FALL	CAS	CHU	RAP	FALL	CAS	CHU	RAP	FALL	CAS	CHU	RAP
	HGR	LGR	GLI	RUN	HGR	LGR	GLI	RUN	HGR	LGR	GLI	RUN	HGR	LGR	GLI	RUN	HGR	LGR	GLI	RUN
	STEP	POW	SHT	COP	STEP	POW	SHT	COP	STEP	POW	SHT	COP	STEP	POW	SHT	COP	STEP	POW	SHT	COP
*note if dammed pool	MCP	LAP	TRP	PLP	MCP	LAP	TRP	PLP	MCP	LAP	TRP	PLP	MCP	LAP	TRP	PLP	MCP	LAP	TRP	PLP
Length (ft)																				
Est. Avg. Width (ft)																				
Est. Avg. Pool Depth (ft)																				
Max. Pool Depth (ft)																				
Pooltail Embedded %																				
Significant Cover?[2]	INSIGNIF		BLDR		INSIGNIF		BLDR		INSIGNIF		BLDR		INSIGNIF		BLDR		INSIGNIF		BLDR	
	VEG		WOOD		VEG		WOOD		VEG		WOOD		VEG		WOOD		VEG		WOOD	

SUBSTRATE COMPOSITION

Dominant	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB					
Substrate	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT					
Subdominant	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB					
Substrate	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT					
Dominant	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB	BED	BLD	COB					
Bank Substrate	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT	GRV	SND	SLT					

Length of LB and RB Exposed Banks (feet)																				
Confinement [4]																				
Unit Flagged/ Labeled? (Y/N)																				
Tributary Inflow in cfs																				
Landmarks or photos																				

	#	Diameter class	Length class	#	Diameter class	Length class	#	Diameter class	Length class	#	Diameter class	Length class	#	Diameter class	Length class
Large Woody Debris [5] within bankful width															
No. of LWD Pieces within wetted width															
Fish Migration Barrier [6] (y/n)?															
Giant Cane Accumulation (length, width, ht)															
Giant cane function															
Comments / Observations: Fish? Wildlife? Amphibs? Backwater or side chan. amphib habitat? Riparian? Landmarks, Photo #s, Etc.															

[1] **FALL** = Falls, **CAS** = Cascade, **CHU** = Chute, **RAP** = Rapid, **GLI** = Glide, **RUN** = Run, **STEP** = Step Run, **HGR** = High Gradient Riffle (>4%), **LGR** = Low Gradient Riffle, **POW** = Pocket Water, **SHT** = Sheetflow ;

Pools: COP = Convergence, **MCP** = mid-channel pool, **LAP** = Lateral, **TRP** = Trench, **PLP** = Plunge

The minimum unit length should be 1x active channel width, unless there is something notable or unique about it.

[2] Note if cover is a significant or dominant feature of the unit:

(e.g., logs in stream, lots of boulders, >25% surface area has instream or low overhanging vegetation, etc.)   Q/C initials:

[4] Channel Confinement: **1**=Confined Shallow; **2**=Confined Deep; **3**=Moderate Confined (<2x wetted channel width); **4**=Unconfined (>= 2 wetted channel widths)

[5] Criteria for LWD is:any downed wood at least partially within bankful width of channel, exceeding 3' length, minimum diameter of 4" at the large end

Size classes: 4-**12"**, 12-**24"**, 24-**36"**,or 36"**+ x** 3-**25'**, 25-**50'**, 50-**75'**, 75'**+** (ie. 4 | 25 = 4-12", 25-50').

Key pieces (longer than 1/2 bankful, or modify channel morph or hab) mapped on IPAD incl. l, d at large end, rootwad?, jam?, function.

[6] Waterfalls, high velocity chutes or cascades at approx bankful flows. NOTE VERTICAL DROP and IF CONDITIONAL or PERMANENT

Notes regarding access points (road condition, bridge crossings, trails, etc.)

Figure 3. Field form used for ground-based habitat mapping.

Table 2. Description of data collected during habitat mapping.

Stream/Reach	Note on every data sheet
Team	Note initials
UTM	Get UTM every 5th unit (NAD 83) - note if at top or bottom or unit
PM & Map Gradient	Note parent material in assessed reach from geologic map; measure gradient from Terrain Nav Pro (office, before or after).
Habitat Unit #	Numbered sequentially, usually from downstream to upstream. Note if this is not the case
Habitat Type	Circle one of the choices, or write something else in if necessary (e.g., "marsh")
Length (ft)	Measured in feet, with hip chain. Clean up your string periodically
Estimated Average Width (ft)	Average width of entire unit, estimated by eye, periodically checking your estimates with a stadia rod or tape. Usually this is bankfull, but in this regulated system, bankfull is hard to describe. Define the "low-flow active channel" where there is hydraulic connectivity with the low flow channel. The boundary is usually marked by a distinctive change to vegetation more dominated by upland species.
Estimated Average Pool Depth (ft)	Where practical, take some measurements across the channel to help develop your estimate. Particularly interested in whether most of the pool is greater than 3 ft deep or not.
Estimated Maximum Pool Depth (ft)	Measure where practical. Estimate otherwise
Pooltail Embedded	Degree to which gravel or larger substrates are vertically embedded in sand or smaller substrates.
Significant Cover?	Is cover a dominant feature of the unit? Or is it just a bit of veg overhang on the edges, and some boulder substrate?
Dominant Substrate	Dominant particle size, by area. Silt, Sand (<2mm or 1/8"), Gravel (2-64mm or 1/8-2.5"), Cobble (64-256mm or 2.5-10"), Boulder (>0"), Bedrock
Subdominant Substrate	Next most dominant particle size, by area
Dominant Bank Substrate	Dominant particle size, by area. Silt, Sand (<2mm or 1/8"), Gravel (2-64mm or 1/8-2.5"), Cobble (64-256mm or 2.5-10"), Boulder (>10"), Bedrock - for the bank.
Bank Erosion (ft)	If stream banks are exposed and actively eroding and provided sediment to the active stream channel, quantify the total length on both the right and left banks (cumulative distance) as you are walking along and total in this column.
Confinement	Channel Confinement: 1=Confined Shallow (<4'); 2=Confined Deep (>4'); 3=Moderate Confined (<2x wetted channel width); 4=Unconfined (≥2 wetted channel widths)
Tributary Inflow in cfs	Estimate trib inflow, and get water temperature of the trib and mainstem upstream of it. GPS the location.
Unit Flagged/Labeled (Y/N)	Flag units frequently, near a unit boundary, indicating up and downstream unit numbers. Label with metal tags a little less frequently. Frequency depends on length of units. Think about a year from now, how far would you like to hike up and downstream with a group of stakeholders, looking for positive identification of which habitat unit you were in? Generally marking every 5 units is a good idea, but it really depends on how long the units are.
Landmarks	Note if landmarks are near unit, to help relocate it. e.g., trib confluences, roads, bridges, trails, unique rock formations or bedrock outcrops, large trees of an atypical species, man-made structures or quasi permanent debris, campgrounds, waterfalls, old car bodies, etc. "Big rock" or "tall tree" are not very helpful. GPS whenever possible and convenient, particularly if it has been awhile since you were at a good landmark. River Left or River Right is looking downstream.
Large Woody Debris (all or part within bankfull)	Note all of it along the way, by habitat unit number. "All pieces of wood lying within the bankfull width of the channel that exceed 3' length, and 4" diameter at the large end. Wood must be both downed, and with a portion lying within the bankfull channel, and dead or dying to be considered LWD. Divide into average size classes, and tally the total number of LWD pieces in each size class." Size classes we will use are maximum diameters of 4-12 inches, 12-24, 24-36, or >36 inches. Lengths are 3-25, 25-50, 50-75 and >75 feet. These are total lengths, not just length in the channel. KEY LWD has to measure 1/2 bankfull width or longer or longer to be counted, so which length classes you might use are dependent on stream width (e.g., a 30ft wide stream would only use classes from 10-25ft on up, because the log would have to be at least 15ft to be counted). Additional key pieces may also be deposited in such a manner that alters channel morphology and/or aquatic habitat such as trapping sediment or altering flow pattern. Put key pieces on IPAD and add length, diameter at large end, if it has a root wad, and if it is part of a jam
Large Woody Debris (in wetted width)	Separate category: the number of pieces found within the wetted width
Fish Migration Barrier?	Note significant waterfalls or high velocity chutes, or any weirs or other man-made obstacles. Be sure to GPS it.
Giant cane accumulations	Estimate length, width, and height of giant cane accumulation. Place location on IPAD. Note function: creates backwater, forces pool/scour, traps and sorts sediment, creates side channel, or other (give description).
Comments/Observations	
Fish? Wildlife? Amphibians? Backwater or side channel amphibian habitat? Riparian? Etc.	Did you see some adult or juvenile fish? Idea of species? Any wildlife, such as deer, otters, amphibians, etc. that the wildlife biologists would be interested in? Are there wet backwater or side channel areas, especially with nearby or overhanging cover, that provides good habitat for amphibians, that the amphibian biologists might want to consider for TES species surveys? If you find good amphibian habitat, GPS it. Is the riparian vegetation notably lush, or wide, or are you in a marsh area?
QA/QC	Non-notetaker checks all columns and boxes after sheet is full to make sure everything is filled out.

The habitat attributes defined in Table 2 were quantified and recorded for each unit mapped. Two levels of ground-based mapping occurred:

- "Fully mapped" units which include quantified variables such as bankfull width, pool depth, substrate, large woody debris (LWD), substrate and bank material, etc. (Figure 2, Table 2)

- "Characterized" units which note the meso-habitat type, length, maximum pool depth, and some with photographs and/or comments of notable details such as the existence of frogs, access and mining activity.

- Along the entire length: LWD will be tallied, key LWD pieces will be marked on the IPAD, giant cane accumulations will be marked on the IPAD.

Habitat frequency will be based on the total length of each habitat type as a percentage of the entire length mapped.

Crews will identify potential barriers to upstream anadromous fish movement using professional judgment and used handheld GPS units to record the locations. Significant tributary junctions and potential fish passage barriers will be noted within the habitat unit in which they occur.

Photographs will be taken of each fully mapped and at many characterized habitat units, generally from the bank or center of channel looking upstream. Occasionally, photos may need to be taken from the banks or from the top of the unit looking downstream, but these differences will be noted. Photographs will be organized into a Word document and labeled with the original unit number; within the reach it was mapped. Summaries of the field data will be entered into an Excel data workbook and data will be summarized into tables and charts and provided electronically.

Prior to mapping, the USGS gage at Highway 65 was visited to determine the level of the water at a 1.5 and 2.5 year return frequency. These are return intervals generally associated with bankfull discharge in unregulated systems. However, in a regulated system, the low flow active channel is important hydrologically because the releases from the diversion dam control timing and volume. Since Camp Far West has no sluice gates, Bear River is also subject to higher and more frequent floods than generally seen in other regulated systems. The stage of the 1.5 and 2.5 year frequency floods was noted at the gage site and used in many of the habitat unit measurements to get an idea of where the frequent flood flows were reaching.

Constructed and natural levees have created an incised channel wherein the 1.5 yr. recurrence interval flows (6.45 ft. staff gage, 2,656 cfs, Figure 4) will flood the entire river plain. Figures 5, 6, and 7 show the low flow active channel (about 4.16 staff gage, 916 cfs), the 1.5 yr. stage (6.45 ft. staff gage, 2,656 cfs), and 2.5 yr. recurrence interval (11.45 staff gage, 7,894 cfs).

Recurrence Interval 1.5 yr = 2,656 cfs = 6.45 ft
Recurrence Interval 2.5 yr = 7,894 cfs = 11.45 ft
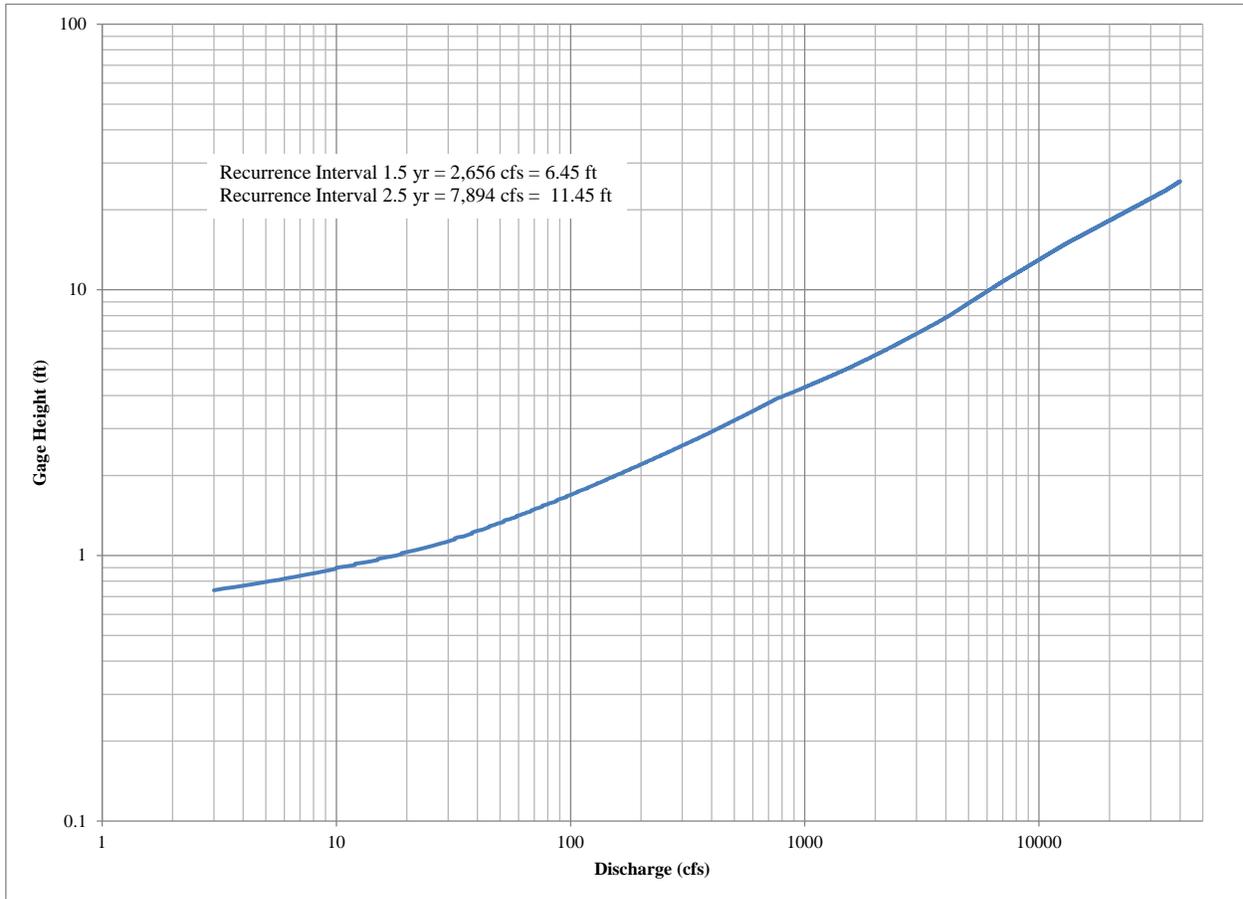
Figure 4. Rating curve for USGS Gage 11424000 near Wheatland at Highway 65 (RM 11.5) based on regulated flow data 1964-2015.

Figure 5. Bear River near Wheatland (RM 11.5, USGS gage 1142400). Stadia rod is being held at the "low flow active channel" where the vegetation transitions from hydric to more terrestrial types. Rough estimate of staff gage elevation is 4.16 ft. (916 cfs). Flow at gage on date of measurement (6-10-15) was 26 cfs.

Figure 6. Bear River near Wheatland (RM 11.5, USGS gage 1142400). Stadia rod is being held at the 1.5 yr. recurrence interval at staff gage elevation of 6.45 ft. (2,656 cfs).

Figure 7.   Bear River near Wheatland (RM 11.5, USGS gage 1142400). Stadia rod is being held at the 2.5 yr. recurrence interval at staff gage elevation of 11.45 ft. (7,894 cfs).

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Attachment 1
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January 2017