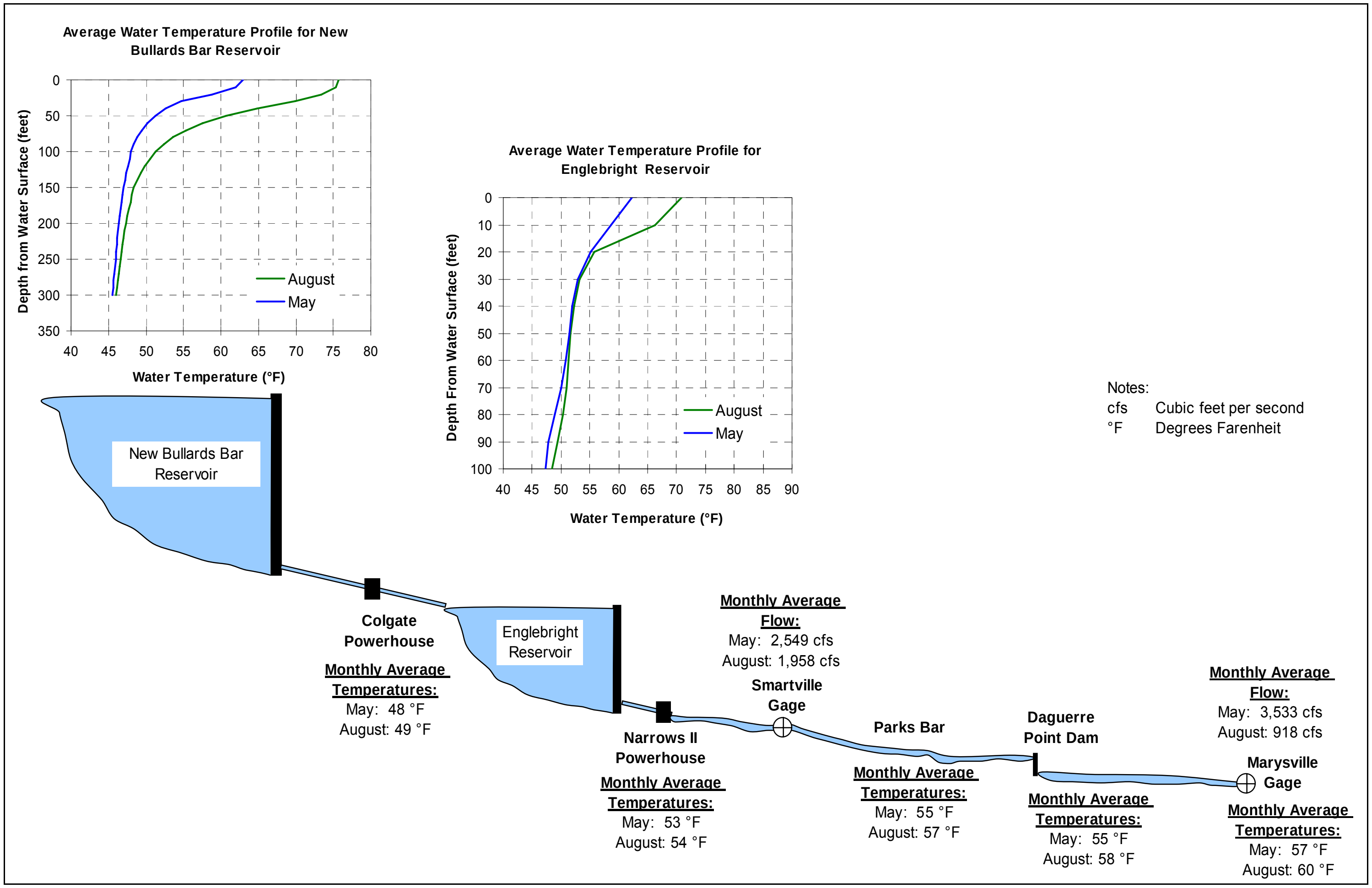

Figure B-1. Average Monthly Water Temperature Profile in the Lower Yuba River for May and August for the Period 1999 to 2004[1]

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[1] Flow data is from U.S. Geological Survey (USGS) gages 11421000 (Marysville) and 11418000 (Smartville). Water temperature data is from YCWA.

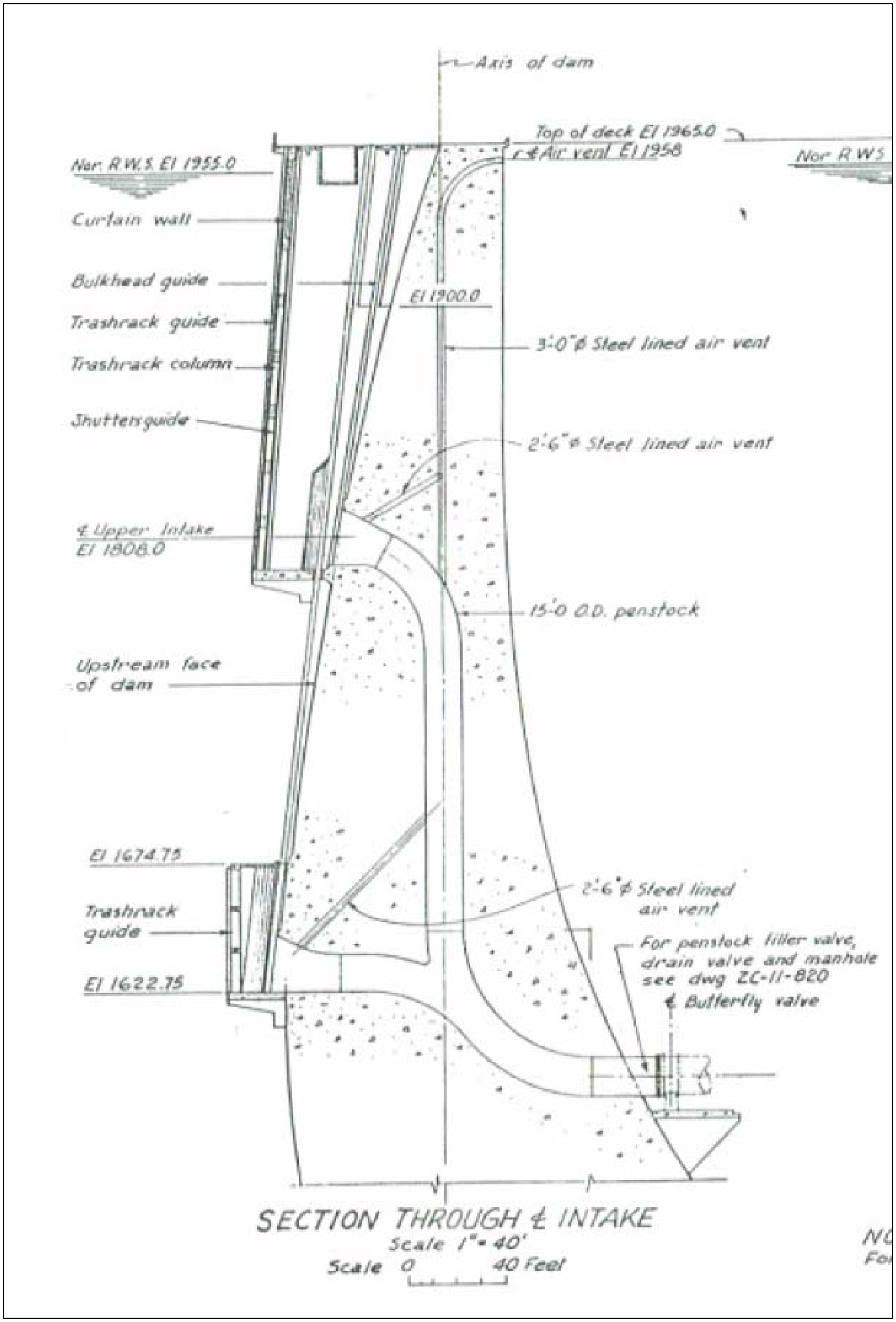

Figure B-2. Section Through New Bullards Bar Dam

Under current operating conditions, the coldwater pool in New Bullards Bar Reservoir is normally not exhausted and coldwater releases are made throughout the year. Current YCWA operating procedures call for use of the low-level outlet throughout the year, as recommended by a temperature advisory committee, which was convened by YCWA in 1993 with representatives from CDFG and USFWS. The low-level outlet has been used for all controlled releases from the dam since September 1993. The minimum pool for operating the low-level outlet is at an elevation of 1,734 feet above msl, 96 feet above the low-level outlet.

Analysis of water temperature profiles in New Bullards Bar Reservoir, for the recorded period of 1990 to 2005, indicate strong seasonal behavior of the water temperature profile within the reservoir (**Figure B-3**). The consistent shape and narrow range of water temperature profiles suggest that temperature in New Bullards Bar Reservoir is primarily controlled by solar radiation and air temperature. The seasonal trends in average monthly water temperature profiles are shown in **Figure B-4** and **Figure B-5**, which shows the warming and cooling cycles of reservoir temperature, respectively.

Additional analysis of the water temperature profiles shows that fluctuations of surface water elevations do not typically impact the water temperature profiles. Available water temperature profiles show surface water elevation variations between 1,818 feet and 1,957 feet above msl, which is equivalent to 440 TAF and 970 TAF of reservoir storage. The consistent monthly water temperature profiles appear to be independent of surface water elevations, over the observed range of elevations.

B.1.1.2 ENGLEBRIGHT RESERVOIR

Recreation activities on Englebright Reservoir are dependent upon a stable reservoir level. Therefore, the active storage in Englebright Reservoir is maintained at a steady elevation of 515 feet (approximately 45 TAF of storage), except during the flood season. As a result, the flow through the Narrows II Powerhouse at Englebright Dam is primarily governed by the water temperature releases from New Colgate Powerhouse, air temperature, and the Middle Yuba and South Yuba rivers' inflow rates and water temperatures. The intake structure at Englebright Dam is located approximately 448 feet above msl.

Analysis of temperature profiles in Englebright Lake, for the period of 1990 to 2005, shows a seasonal behavior of the temperature profiles in the lake (**Figure B-6**). The warming and cooling water temperature cycles in Englebright Lake are shown in **Figure B-7** and **Figure B-8.**

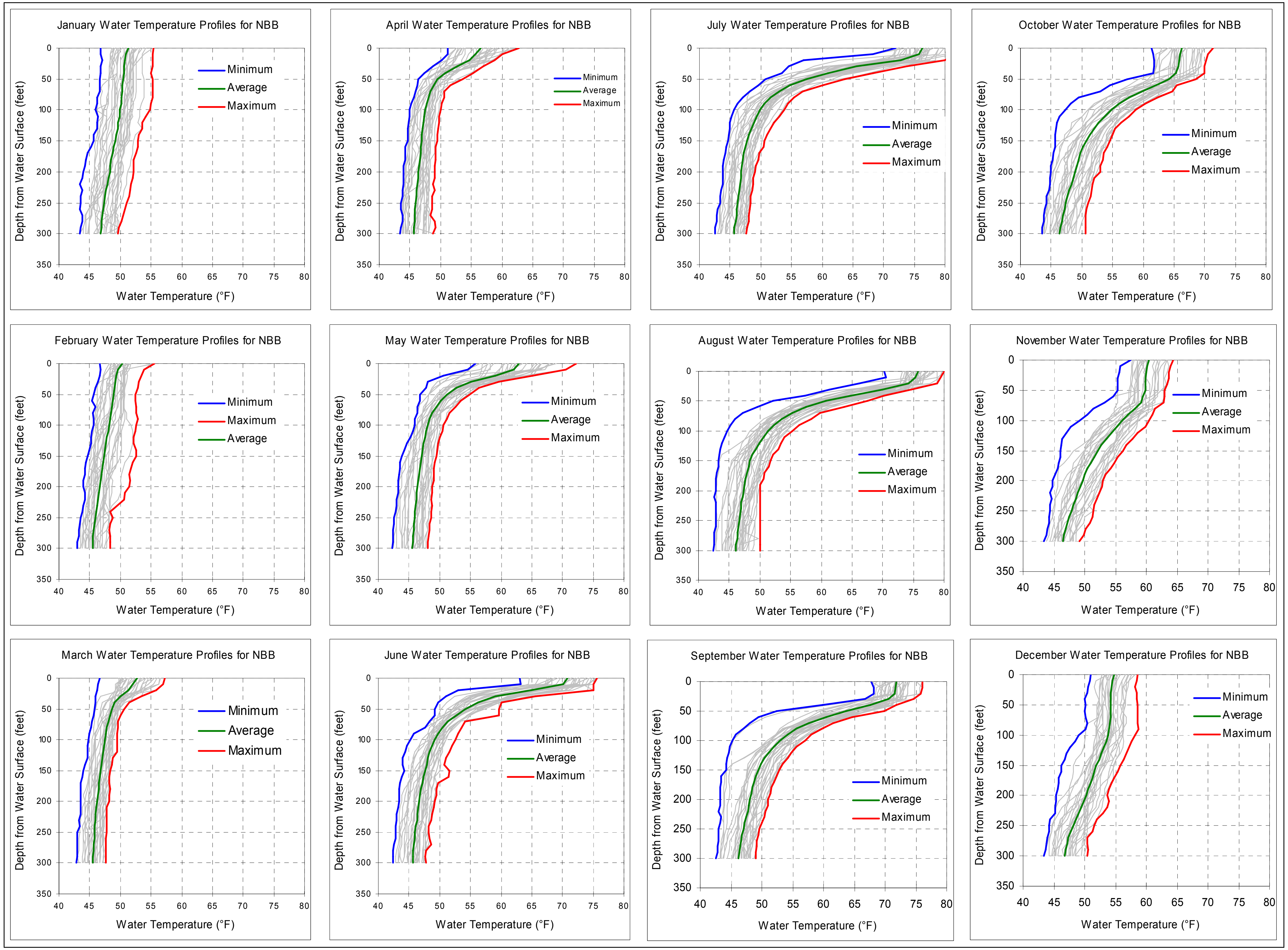

Figure B-3. Monthly Water Temperature Profiles of New Bullards Bar Reservoir

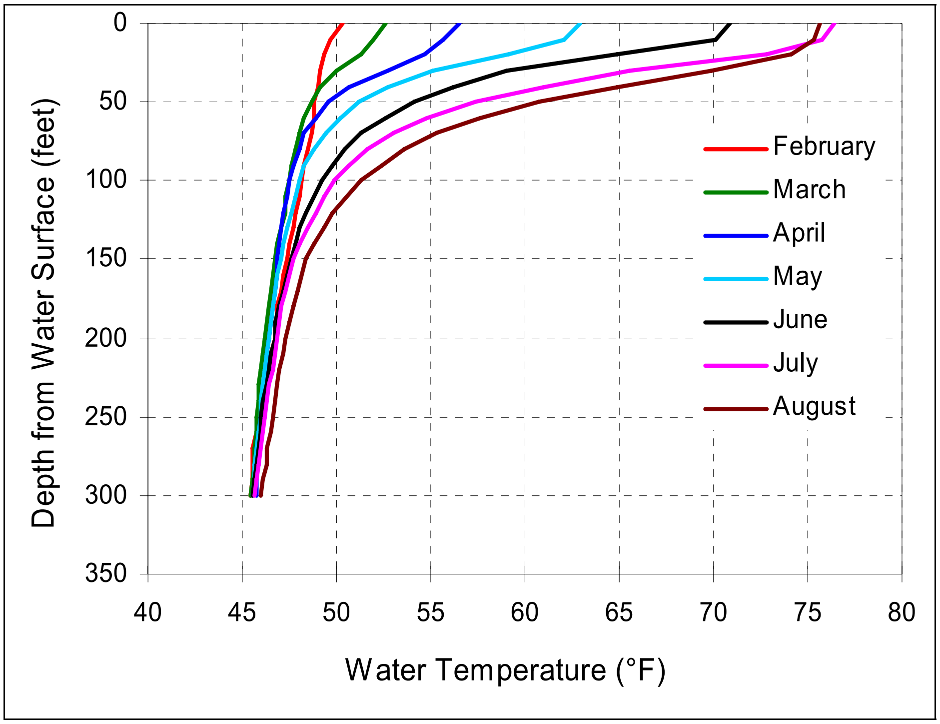

Figure B-4. New Bullards Bar Reservoir Average Monthly Water Temperature Profile, February to August Warming Cycle

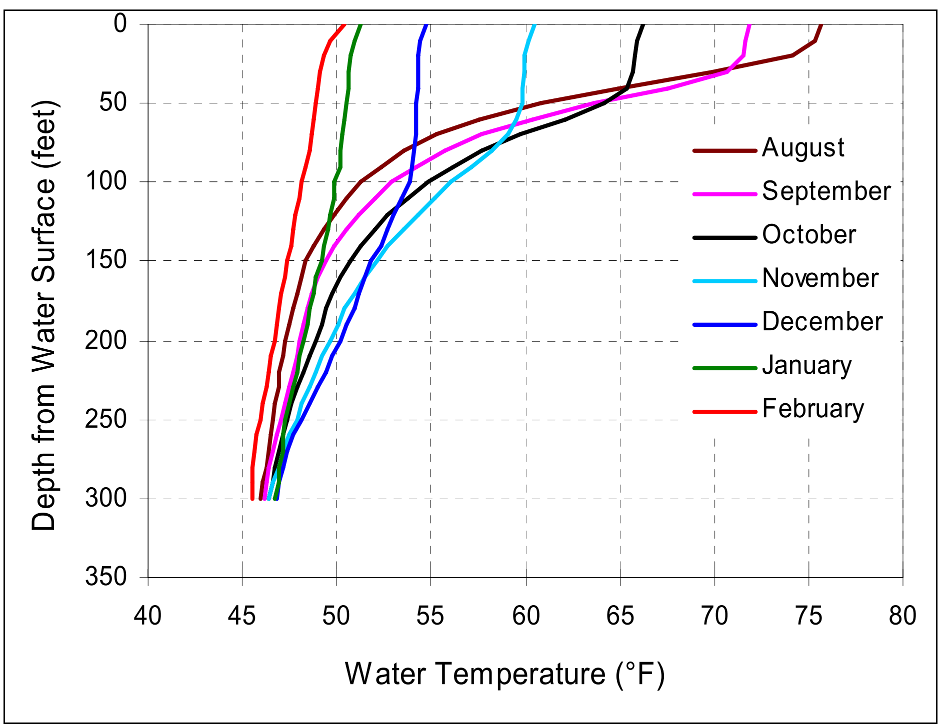

Figure B-5. New Bullards Bar Reservoir Average Monthly Water Temperature Profile, August to February Cooling Cycle

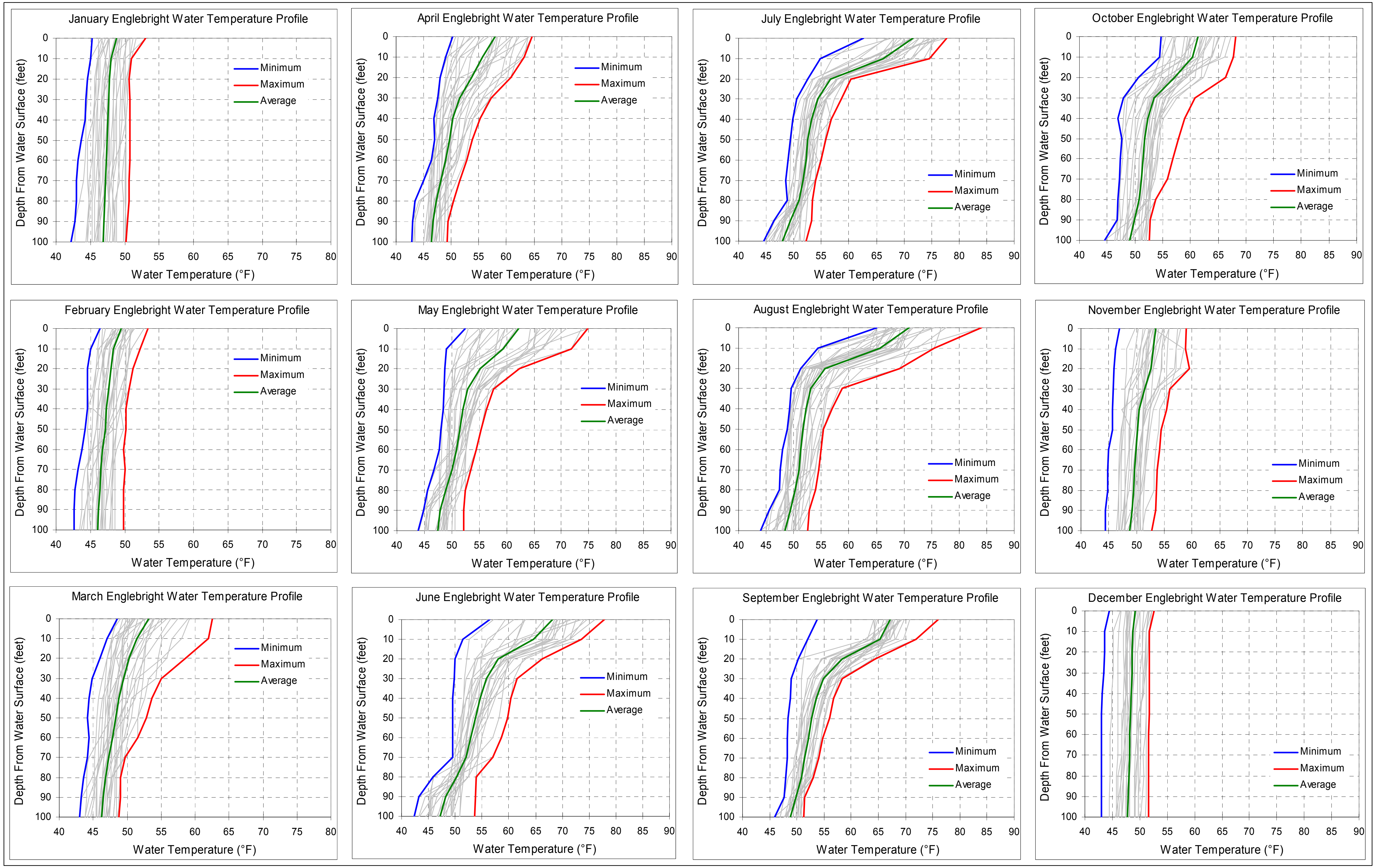

Figure B-6. Monthly Water Temperature Profiles of Englebright Lake

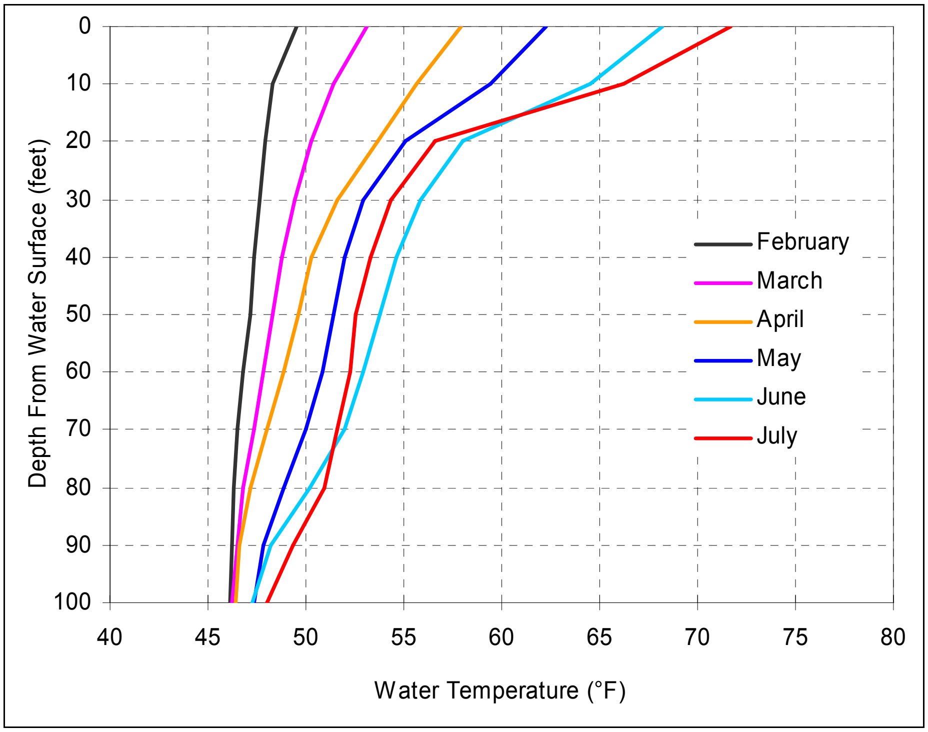

Figure B-7. Englebright Average Monthly Water Temperature Profile, February to August Warming Cycle

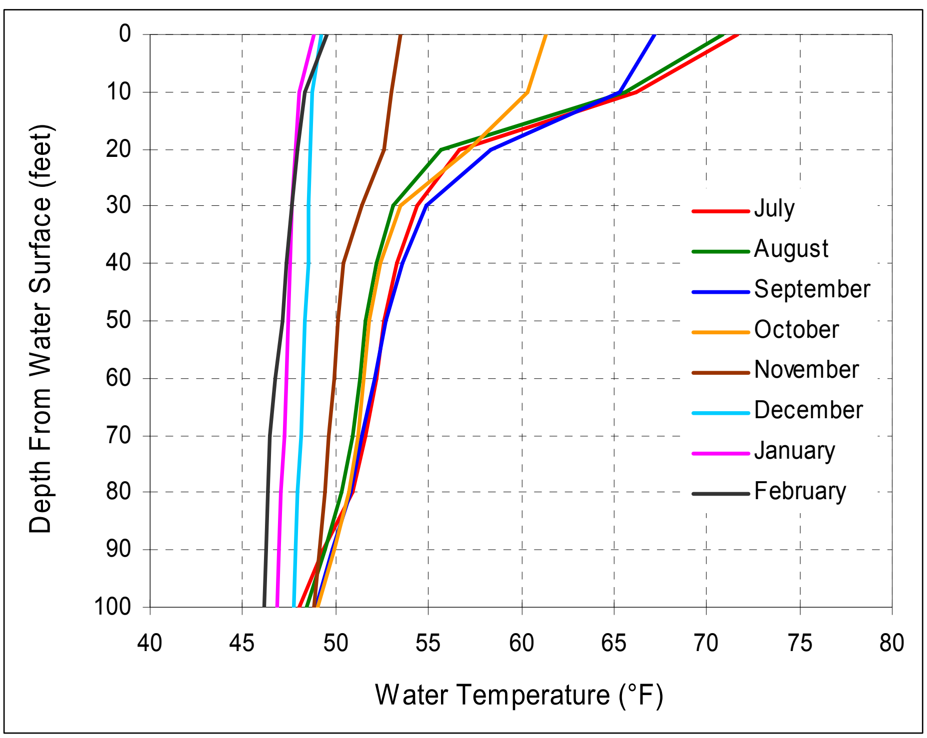

Figure B-8. Englebright Average Monthly Water Temperature Profile, August to February Cooling Cycle

B.1.2 LOWER YUBA RIVER

Figure B-9 shows the monthly average of daily mean water temperatures of the lower Yuba River, at the Marysville Gage, during the three periods, for which water temperature data are available.

- Pre-Yuba project period from 1965 to 1968 (two wet and two below normal years[2])
- Post-Yuba project period from 1974 to 1977 (two wet and two critical years)
- Modified operations in the Yuba Project period from 1993 to 2005[3] (five wet, four above normal, one below normal, one dry, and two critical years)

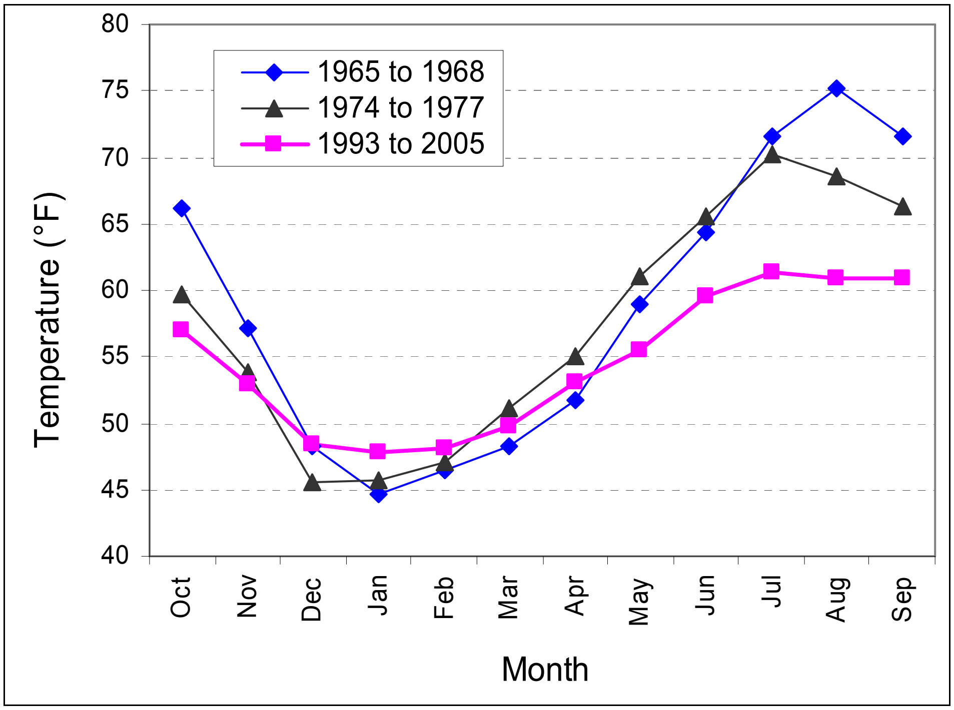

Figure B-9. Monthly Average of Daily Yuba River Water Temperatures at Marysville Gage for Periods of Pre- and Post-Yuba River Development Project

The monthly average of daily mean water temperatures, during the 1974 to 1977 period, also show reductions in summer water temperatures compared to the 1965 to 1968 period, even though the 1974 to 1977 period included the most severe drought (1976-1977) that the Yuba River Basin has experienced in recorded history. This shows the effect of Yuba-project on reducing summer temperature in the Yuba River.

Operation of the Yuba Project was modified in 1993. Therefore, the monthly average water temperatures for the 1993 to 2005 period are more representative of current conditions in the Yuba River. Compared to the period of 1965 to 1968, the monthly averages of daily mean water temperatures were substantially lower during the 1993 to 2005 period, from mid-summer into

[2] Water year types are defined by the Yuba River Index (B-E, *Yuba River Index: Water Year Classifications for Yuba River*, 2000).

[3] Water temperature data is available for 1989 to 2005. However, since September 1993, the low-level outlet of New Bullards Bar Reservoir has consistently been used to release water for power generation at New Colgate Powerhouse to assist in the management of water temperatures in the lower Yuba River.

the fall, with the average August temperature over 10°F lower. The reduction in summer and fall water temperatures was greatly influenced by the continued releases of water from the coldwater pool in New Bullards Bar Reservoir, resulting from the modified operations in the Yuba Project.

B.1.2.1 MECHANISM OF HEAT TRANSFER

For most of the lower Yuba River below Englebright Dam, the river channel is wide and flat, with little or no bank shading. Thus, the entire river channel is exposed to the warm Sacramento Valley air, which produces substantial heat transfer to the water surface. Additionally, water temperatures are influenced by solar radiant heating of the river and riverbed. Many of the Sierra foothill rivers have well defined, moderate to highly incised channels, which provide for low surface width-to-flow ratios. The Yuba River, however, is characterized by a wide, shallow channel (i.e., high surface width-to flow ratio) that receives a substantial amount of solar radiant heating. An aerial photograph of the lower Yuba River at Daguerre Point Dam is shown in **Figure B-10**. As can be seen in the photograph, a substantial portion of the river bottom is covered at very modest flow.

Figure B-10. Photograph of the Yuba River at Daguerre Point Dam Looking Upstream

A cross section of the Yuba River, downstream of Daguerre Point Dam, is presented in **Figure B-11.** Water surface elevations also are plotted within this figure to demonstrate potential water surface elevations over a range of flows (i.e., 250 to 1250 cfs). The figure shows that flow above 500 cfs result in greater surface water width of the river, for each additional increment of flow, compared to flow rates below 500 cfs. Typically, there is a dramatic increase in surface water width once the capacity of the low flow channel is exceeded.

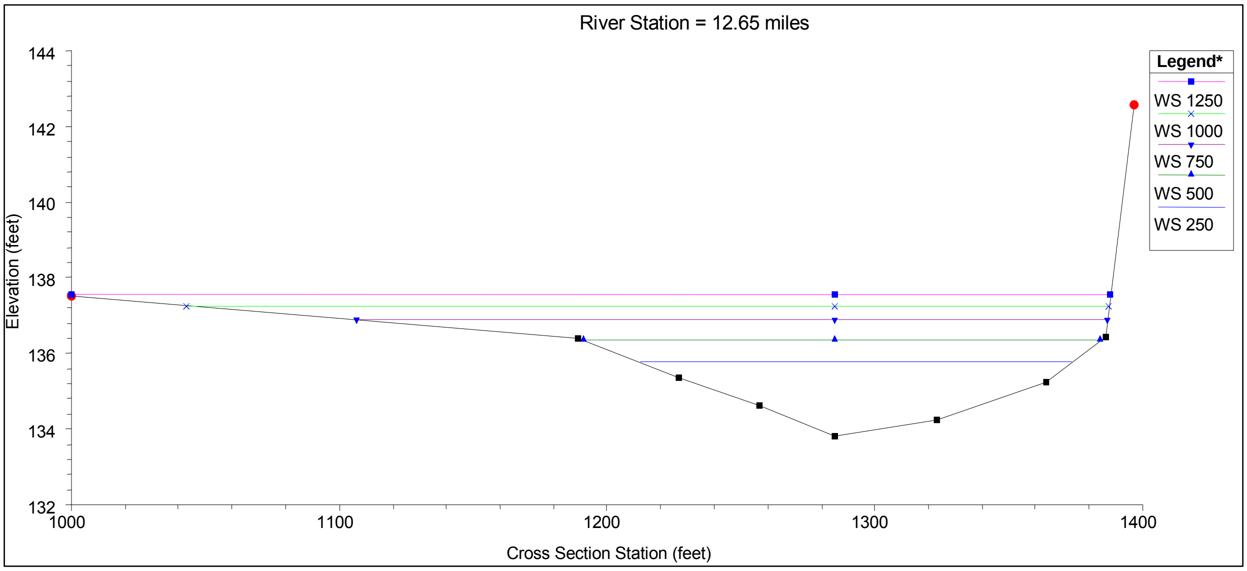

Figure B-11. Yuba River Cross Section at River Mile 12.65 with Flow Stages (e.g., WS 750: Water Surface Elevation at a Flow of 750 cfs)

Figure B-12 shows the range of daily minimum and maximum water temperatures for August 2004. During the summer months, the lower Yuba River experiences a diurnal water temperature variation of approximately 10°F. This extreme diurnal water temperature variation can be mainly attributed to the river geometry and intense warm weather. The mechanism of heat transfer for warming of river water temperatures is governed by air-to-water contact at the water surface and solar radiant heating of the river and riverbed. The air-to-water heat transfer is driven by the difference between the air temperature and the water temperature, and humidity. Solar radiant heating is affected by the time of the year, cloud cover, surface area, water depth, and solar radiation absorption of the riverbed. The lower Yuba River is unprotected from both heating mechanisms and, compared with other foothill rivers, has a greater relative heat load due to its channel geometry. Water temperatures in the lower Yuba River can increase more than 12°F between Englebright Dam and Marysville.

Although significant warming of river temperature occurs in the lower Yuba River, **Figure B-13** shows that considerable warming of cold water releases from New Bullards Bar Dam occurs upstream the Englebright Dam. During the period from March to July, warming upstream of Englebright Dam account for more than 50 percent of the increase in water temperature between New Bullards Bar Dam and Marysville. However, during late summer and fall, August through November, warming in the lower Yuba River, below Englebright Dam, accounts for more than 60 percent of temperature gain between New Bullards Bar Dam and Marysville. Different heat transfer mechanisms control warming of water temperature upstream of Englebright Dam and in the lower Yuba River, which result in seasonal variations of warming rates in the two sections of the river. The rate of warming in Englebright Reservoir is generally controlled by air temperature and solar radiation, and rate and temperature of inflows from Middle and South Yuba rivers. However, the rate of warming in the lower Yuba River is controlled by air temperature and solar radiation, and volume of the flow in the river.

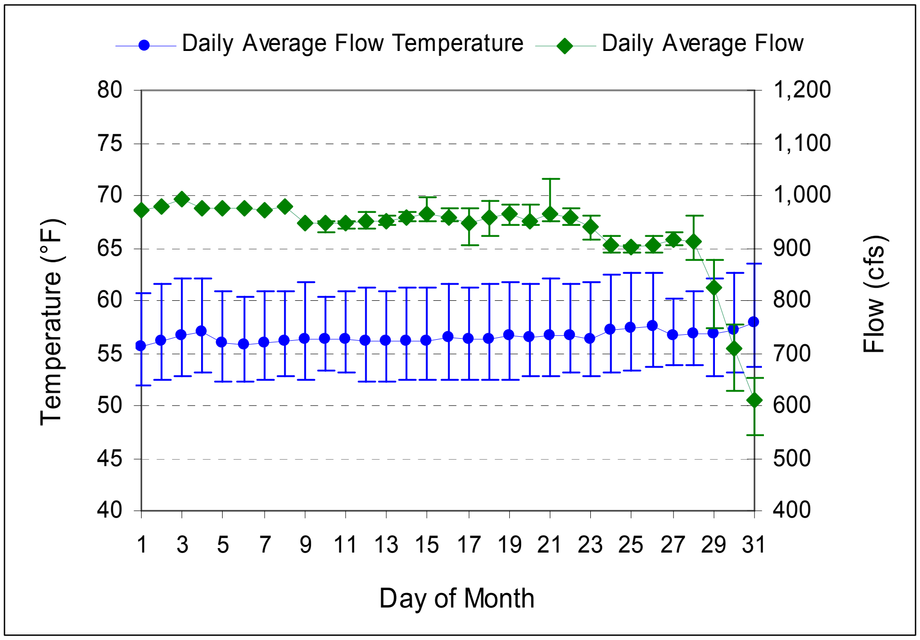

Figure B-12. Lower Yuba River Water Temperature at the Marysville Gage in August 2004

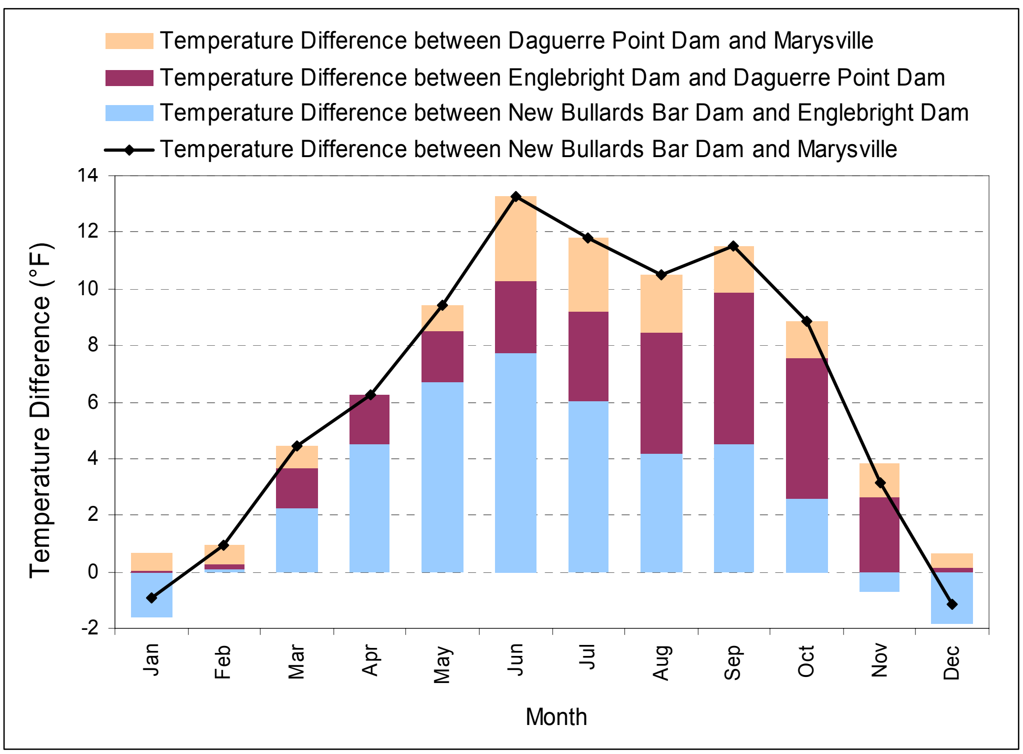

Figure B-13. Average Monthly Water Temperature Differences in the Lower Yuba River (1990 to 2005)

B.2 TEMPERATURE MODELING APPROACH

Temperature models for stream and reservoir applications can be broadly classified as physically based, empirical, or a mix of the two. Physically based models use governing equations for heat transport, flow, and climatic conditions to estimate water temperatures. A physically based model is capable of estimating water temperature under a variety of circumstances that may not be present in the existing system or data set, such as extreme flow conditions or reservoir reoperation. Typically, physically based models are one-dimensional, describing the one-dimensional vertical water temperature profile in a reservoir or the one-dimensional horizontal profile along a stream.

One-dimensional reservoir water temperature models that have previously been used to simulate Central Valley reservoir water temperature profiles include HEC/Reclamation[4], HEC-5Q, WQRRS, and RMA. One-dimensional river water temperature models that have previously been applied to streams in the Central Valley include HEC/Reclamation, HEC-5Q, QUAL2E, WQRRS, and RMA. A disadvantage to using a physically based model is the effort required to build and calibrate the model. In order to simulate a full period of record, meteorological inputs, such as solar radiation and wind, and information about the water temperature for accretions and depletions to the system, are needed. Additionally, atmospheric data is needed for a meaningful prediction.

In contrast, an empirical model (e.g., statistical model) characterizes the statistical relationships between water temperatures and one or more observed characteristic of the system. The simplest example of this type of model is a linear regression relationship between observed flow and water temperature. The advantage of a statistically based model is its ease of use and development. Confidence limits (or error bands) on water temperature results are readily available. However, the model is limited to making predictions regarding future conditions based on available historic data, and such a model cannot evaluate potential outcomes outside of the range of these data. A statistically based water temperature model was used in the 2000 SWRCB Lower Yuba River Hearings (2000 Hearings).

Due to limited available data, statistical water temperature models are used to evaluate the potential impacts of the Proposed Project/Action and alternatives. The statistical models can be used to estimate the effects of different New Bullards Bar Reservoir storage regimes and flow releases, and diversions at Daguerre Point Dam on water temperatures in the lower Yuba River. The statistical models should be used only in a comparative analysis to predict differences in water temperature for a particular action alternative compared to the CEQA No Project Alternative. The statistical models should not be used to predict absolute temperatures in the lower Yuba River.

B.2.1 PERIOD OF SIMULATION

Monthly simulation of the Sacramento-San Joaquin Delta water system is available for the 72-year period of record. The Yuba Project Model (YPM) is capable of simulating operations of New Bullards Bar and Englebright dams, and flows in the lower Yuba River for the period 1922

[4] HEC (1972) was modified and adapted by J. Rowell to provide temperature simulation capability throughout the Sacramento River basin. This collection of sub-models was ultimately referred to as the "Sacramento River Basin Model" and included Trinity, Whiskeytown, Shasta, Oroville, and Folsom reservoirs; Lewiston, Keswick, Thermalito, and Natoma re-regulating reservoirs; and the Sacramento, Feather, and American rivers. Also see Rowell (1990).

to 2004. However, lack of simulated Delta conditions and simulated through-Delta conveyance capacity for transfers restricts modeling of the lower Yuba River to the 1922 to 1994 period. Thus, temperature modeling for the lower Yuba River is restricted to the 1922 to 1994 period.

Climatic data (e.g., air temperature at Marysville) are required as independent variable(s) in some of the statistical temperature models developed for the lower Yuba River. Historical air temperature data for Marysville is available from 1948 to present. This further restricts the simulation period for temperature modeling using historical monthly air temperature to the 1948 to 1994 period. However, the period of 1922 to 1948 could be included by using historical monthly averages.

B.2.2 TIME STEP

Reservoir storage and flow inputs for the water temperature model are obtained from the YPM. The YPM is run using a monthly time step; therefore, water temperature modeling also is conducted using a monthly time step.

B.2.3 LOCATION

The statistical water temperature model is used to estimate changes in monthly water temperatures of New Colgate releases, Narrows II releases (assumed same as river temperature at the Smartville Gage), Daguerre Point Dam, and Marysville Gage.

B.2.4 CALIBRATION DATA

The data available for calibration of the temperature model is presented in **Table B-1**. More data are available for the period of 1989 to present compared to previous periods, because YCWA is recording water temperature at more locations in the lower Yuba River with greater frequency. The recent data record is more representative of the current operation of the Yuba Project. The water temperature measurement locations in the Yuba River are: New Bullards Bar Reservoir, New Colgate Powerhouse, Englebright Reservoir, Narrows II Powerhouse, Parks Bar, Daguerre Point Dam, and Marysville.

Table B-1. Available Historical Data for Water Temperature Model Calibration

Location	Data Type	Start Date	End Date	Data Type	Frequency
New Colgate PH	Air temperature	1/1/1979	Present	Max, Min	Daily
New Colgate PH	Water temperature	4/6/2000	Present	Max, Min, Avg	Daily
Daguerre	Water temperature	9/1/1999	Present	Obs	Hourly
Deer Creek	Flow	9/1/1969	Present	Avg	Daily
Englebright	Air temperature	1/9/1990	Present	Obs	~Bi-weekly
Englebright	Reservoir profile	1/9/1990	Present	Obs	~Weekly
Englebright	Storage	1/1/1970	Present	Obs	Daily
Marysville	Air temperature	1/1/1951	Present	Max, Min, Obs	Daily
Marysville	Air temperature	July 1948	Present	Max, Min, Avg	Monthly
Marysville	Flow	9/1/1969	Present	Avg	Daily
Marysville	Water temperature	9/16/1999	Present	Obs	Hourly
Marysville	Water temperature	10/1/1989	5/11/1999	Max, Min, Avg	Daily
Narrows II	Water temperature	1/9/1990	Present	Obs	~Weekly
Narrows II	Water temperature	8/24/1999	Present	Max, Min, Avg	Daily
New Bullards Bar	Reservoir profile	1/24/1990	Present	Obs	Monthly
New Bullards Bar	Storage	1/15/1969	Present	Obs	Daily
Parks Bar	Water temperature	9/1/1999	Present	Obs	Hourly
Smartville	Flow	9/1/1969	Present	Avg	Daily
Smartville	Water temperature	9/3/1999	Present	Obs	Hourly

Notes: PH = Powerhouse, Obs = Observation, Max = Maximum, Min = Minimum, Avg = Average

B.3 PREVIOUS STUDIES

Two previous studies have developed water temperature models for the lower Yuba River in 1992 and 2000. The 1992 model was developed to evaluate the Lower Yuba River Fisheries Management Plan proposed by CDFG. The 2000 model was developed for the 2000 Hearings.

B.3.1 1992 WATER TEMPERATURE MODEL OF THE LOWER YUBA RIVER

The development of a water temperature model of the lower Yuba River is reported in *Water Temperature Modeling on the Yuba River* (B-E 1992). The developed temperature model consists of four sub-models:

- ❑ One-dimensional physical model of New Bullards Bar Reservoir (CE-QUAL-R1)
- ❑ Statistical, multiple-linear regression model of New Colgate Powerhouse release temperature, as a function of reservoir temperature and air temperature
- ❑ Statistical multiple linear regression model of water temperature at the Smartville Gage, as a function of New Colgate Powerhouse release temperature and air temperature
- ❑ One-dimensional physical model of the lower Yuba River (HEC-5Q)

The water temperature data used in the study were collected from 1974 through 1977.

B.3.2 2000 ASSESSMENT OF PROPOSED WATER TEMPERATURE REQUIREMENTS

A statistical temperature model was developed for the resumption of the 2000 Hearings. The model development and application is described in *Lower Yuba River: Assessment of Proposed Water Temperature Requirements* (YCWA 2001). Three separate, multivariate linear regression relationships were developed to relate water temperatures in different parts of the system:

- ❑ Narrows II Powerhouse release temperature, as a function of New Colgate Powerhouse release temperature and Marysville air temperature
- ❑ Water temperature at Marysville Gage, as a function of Narrows II Powerhouse release temperature, Marysville air temperature, and the flow at the Marysville Gage.
- ❑ Yuba River temperature at Daguerre Point Dam, as a function of Narrows II Powerhouse release temperature, Marysville air temperature, and the flow at the Marysville Gage.

Solar radiation and ambient air temperature are important factors that affect the flow-water temperature relationship in the lower Yuba River because of the flat geometry of the riverbed. Thus, in developing water temperature relationships, the daily mean air temperatures at Marysville were used as a surrogate for solar radiation, ambient temperature, and other climate-related factors. The relative importance of these controlling factors varies from month to month. Therefore, statistical temperature relationships were established for each month using daily data for that month. The analysis showed that the water temperature at the Marysville Gage is most affected by the Narrows II Powerhouse release temperature and then by the air temperature at Marysville.

Application of the temperature modeling for the 2000 Hearings was based on historical average monthly water temperature of releases from New Colgate Powerhouse (to provide the upstream boundary condition) and historical average monthly air temperature at Marysville.

B.4 PROPOSED TEMPERATURE MODEL

The modeling approach adopted for the Proposed Yuba Accord is to further develop the statistical model developed for the 2000 Hearings. The statistical relationships previously developed for calculating temperatures can be enhanced, through extension of the historical data set used for calibration, to include more recent data. The statistical relationships for the 2000 Hearings were based on historical data collected between 1990 and 1999. Five more years of data now are available.

In addition, under the Yuba Accord Alternative, New Bullards Bar Reservoir storage will be significantly lower in many years. Additional analysis on the effect of reduced reservoir storage on the New Colgate Powerhouse release temperature is needed to understand the impacts of the Proposed Project/Action and alternatives on lower Yuba River temperatures. New Colgate Powerhouse release temperature is an input to the statistical model for calculating the Narrows II Powerhouse release temperatures and, subsequently, the water temperature at Daguerre Point Dam and at the Marysville Gage.

The proposed statistical model consists of five sub-models that can be used to predict water temperature at the following locations:

- New Colgate Powerhouse release
- Narrows II Powerhouse release (assumed to equal the water temperature at the Smartville Gage
- Daguerre Point Dam
- Marysville Gage

B.4.1 NEW COLGATE POWERHOUSE RELEASE TEMPERATURE

The consistent monthly temperature profiles in New Bullards Bar Reservoir (Figure B-3) allows for development of a reasonable estimate of water temperature at New Bullards Bar low-level outlet. The estimated water temperature at the low-level outlet can then be used to estimate release temperature through New Colgate Powerhouse by accounting for water warming through the powerhouse. The temperature model for New Colgate Powerhouse release temperature consists of two components: (1) low-level outlet temperature component and (2) release temperature component.

Model Description

The low-level outlet temperature model assumes an average temperature profile for each month, which is developed using the historical record of temperature profiles in New Bullards Bar Reservoir (Figure B-3). Water temperature at the low-level outlet is estimated from the monthly temperature profile corresponding to the depth of the low-level outlet from the water surface. Depending on the volume of the release, the thickness of the intake zone for the low-level outlet will vary. Water temperature at the low-level outlet is adjusted to account for thickness of intake zone.

The release temperature model uses a multi-linear regression relationship to predict the temperature of the New Colgate Powerhouse water release. This relationship uses three independent variables:

- Estimated average monthly water temperature at New Bullards Bar low-level outlet

- Average monthly release rate from New Colgate powerhouse
- Average monthly air temperature at Marysville

This model accounts for both the warming through the powerhouse and the seasonal variability in low-level outlet temperature. Because water temperature at the low-level outlet is estimated using long-term average monthly temperature profiles, monthly air temperature and release rates are used to account for seasonal variability. Marysville air temperature is used in the relation as a surrogate for climatic conditions.

Model Calibration

The New Colgate release temperature model was developed using data spanning the period of 1994 to present. Data sets prior to 1994 were excluded because it wasn't until after 1994 that all New Colgate releases were made from the low-level outlet at New Bullards Bar Dam. The regression equation for New Colgate release temperature is:

$$NCT = 9.88 + 0.7801 * NBT - 0.000547 * NCR + 0.0401 * Air$$

Where

NCT = Release temperature of New Colgate Powerhouse (°F)
NBT = Estimated water temperature of the low-level outlet at New Bullards Bar Dam (°F)
NCR = Release rate of New Colgate (cfs)
AIR = Air temperature at Marysville (°F)

Comparison between observed and predicted release temperature at New Colgate Powerhouse is shown in **Figure B-14**. The comparison shows a general good performance of the developed model for New Colgate release temperature (**Table B-2**). Although the fit between the observed and predicted is not complete, the observed release temperature falls well within the 99 percentile confidence limits of model predictions. As reported in **Table B-3**, statistical tests confirm the significance of all the parameters used in the temperature equation for New Colgate release.

Table B-2. Performance Statistics for the New Colgate Release Temperature Equation

Statistic	Value
R-Square	0.674
Mean absolute error (°F)	0.69
Standard deviation of error (°F)	0.88

Table B-3. Statistical Significance Tests for the Parameters of the New Colgate Release Temperature Equation

Parameter	P-value[5]
Intercept	3.7 E-03
NBT	2.8 E-23
NCR	2.8 E-08
AIR	1.6 E-06

[5] P-value tests whether each individual variable has a significant contribution to the relationship. If p-value is less than 0.05, then its corresponding variable is a significant predictor in the relationship.

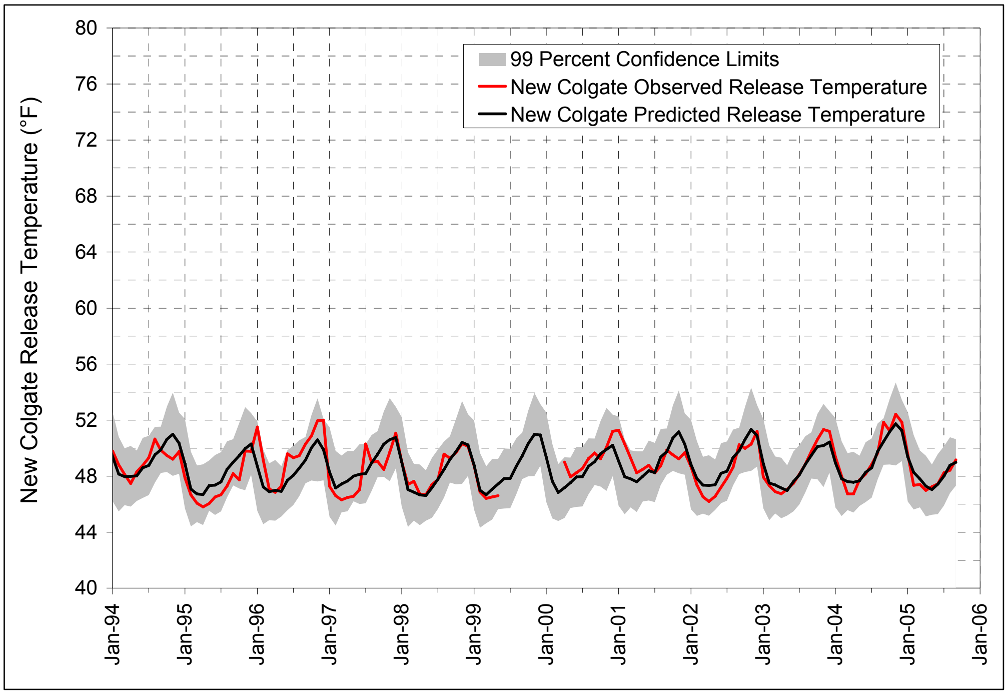

Figure B-14. Predicted and Observed Release Temperature at New Colgate Powerhouse for the Period 1994 to 2005

The coefficients of the regression equation for New Colgate release temperature specifies the sensitivity of release temperature to each independent variable. A one degree increase in release temperature can be caused by an increase in low-level temperature of 1.3 degrees, a decrease in New Colgate release of 1,800 cfs, or a 25-degree increase in average monthly air temperature of at Marysville.

Model Validation

Under the Yuba Accord Alternative, New Bullards Bar Reservoir storage would be significantly lower than the levels experienced in recent years. Therefore, it is important to validate the developed temperature model for New Colgate for reduced reservoir storage conditions. The observed release temperature at New Colgate during the historical low storage conditions of 1976 and 1977 and data for 1981 were used to validate the developed model. **Figure B-15** shows the time series of New Bullards Bar Reservoir storage.

Figure B-16 compares the observed and predicted release temperature for New Colgate during 1976, 1977, and 1981. It should be noted that observed release temperature is only shown for periods when release is made from the low-level outlet at New Bullards Bar Dam. Figure B-16 shows a reasonable match between observed and predicted release temperature. Observed temperature remained largely within the 99 percentile confidence limits of model prediction, except during 1976. Although the prediction error during 1976 was high (3 degrees on average), the model correctly predicted the trend of release temperature. Figure B-16 also shows that model predicted release temperature is generally warmer than the observed release temperature. This can be explained by the fact that New Colgate releases prior to 1994 were generally made from the upper-level outlet at New Bullards Bar Dam, while the low-level outlet is used when reservoir storage is low. This means that during that period cold water pool has been exercised less regularly than in recent years, which can explain the conservative model predictions of release temperature.

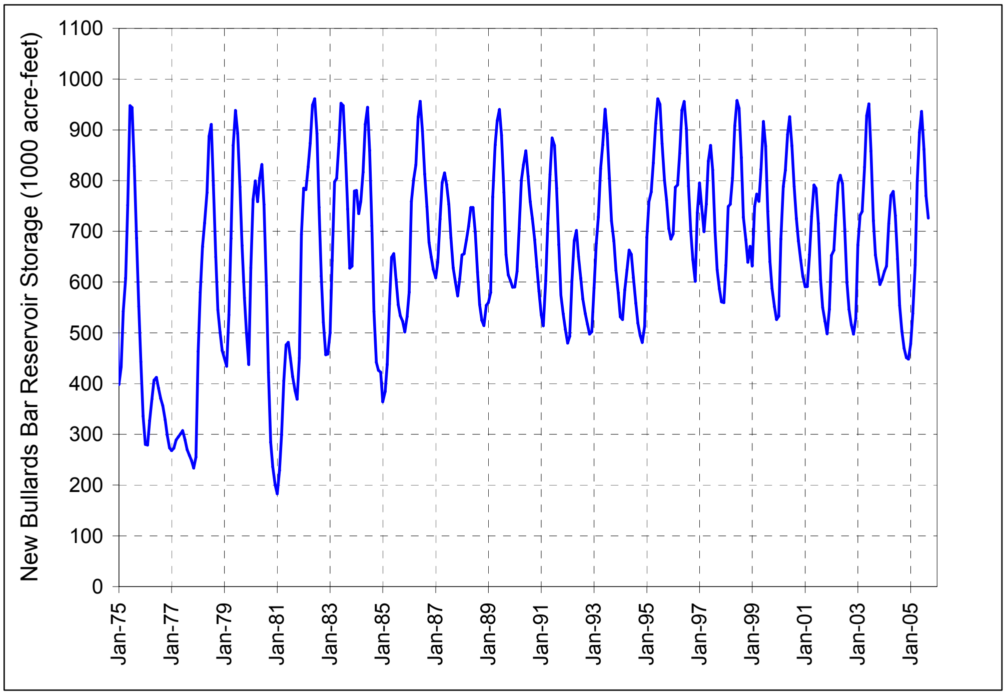

Figure B-15. New Bullards Bar Reservoir Monthly Storage Time Series

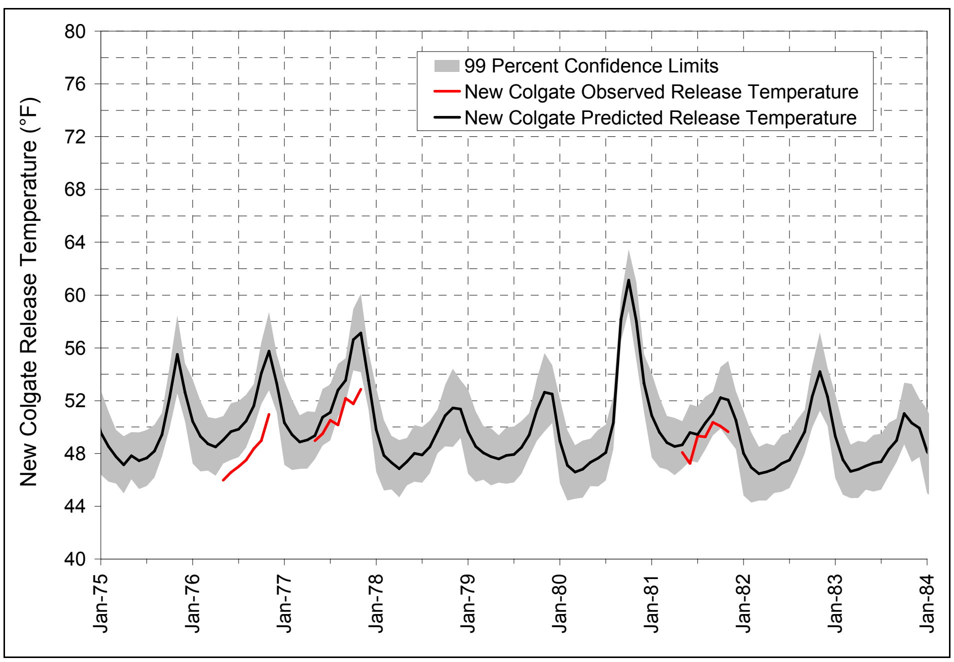

Figure B-16. Validation of New Colgate Release Temperature Model using Observed Release Temperature during 1976, 1977, and 1981[6]

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[6] Observed release temperature is only shown at periods when release is made from the low-level outlet at New Bullards Bar Dam.

Model Comparison to Previous Studies

The statistical temperature model developed for the 2000 Hearings did not include a component to model New Colgate release temperature. However, a temperature model for New Colgate releases was developed in 1992 *(Water Temperature Modeling on the Yuba River, B-E 1992)*. That model used a similar concept to the model developed in this analysis, where temperature in the reservoir is modeled to predict water temperature at the low-level outlet, which is then used to estimate New Colgate release temperature. The main difference between the two approaches is that the 1992 model used a one-dimensional physical model to predict the temperature profile in the reservoir (CE-QUAL-R1), while the approach used in this study used average monthly temperature profiles of the reservoir. Another significant difference is the time step used in each model; the 1992 model used daily time step, while the current model uses monthly time step.

It has been determined that the one-dimensional physical model with daily time steps is not appropriate for the purpose of this analysis. This is primarily due to the large metrological data requirements of the one-dimensional model, which restricts its application over the complete period of analysis. Moreover, the New Colgate release temperature statistical model, developed in this analysis, has demonstrated adequate performance in predicting release temperature.

Impact of Reservoir Geometry on Temperature Profiles

Due to the three-dimensional (3-D) geometry of the New Bullards Bar Reservoir, as the elevation of water surface drops, the thickness of a water layer of certain volume will expand because of reduction in the plan area of the reservoir. This phenomenon could modify the temperature profile in the reservoir. However, analysis of the available historical record of temperature profiles did not support the presence of this effect. The available record of temperature profiles (1990 to 2005) documented surface water elevation variations of 139 feet (between 1,957 and 1,818 feet). Further analysis was undertaken based on conservation of warm water volumes as the reservoir elevation is reduced. Under this assumption, the upper temperature profile becomes elongated. However, changes in the temperature profile and the estimated water temperature at the low-level outlet were not significant compared to the observed variation in water temperature profiles from year to year for any given month. Therefore, distortion of the temperature profiles due to impacts of the reservoir 3-D geometry is not modeled.

B.4.2 NARROWS II POWERHOUSE RELEASE TEMPERATURE

Narrows II Powerhouse release temperature is modeled using a statistical relationship between Narrows II release temperature and temperature and volume of the inflows to Englebright Lake, as well as the effects of solar radiation and heat exchange with the overlaying warm air. This model relates the release temperature of Narrows II Powerhouse to changes in New Bullards Bar operations and to changes in New Colgate release temperature. Since Englebright Reservoir storage is maintained at a steady level during its normal operations, impact of reservoir elevation on release temperature is not modeled.

Model Description

Narrows II Powerhouse release temperature model is a multi-linear regression relationship that uses four independent variables:

- Average monthly New Colgate release temperature
- Average monthly Air temperature at Marysville
- Average monthly Englebright Lake inflows from New Bullards Bar
- Average monthly Englebright Lake inflows from sources other than New Bullards Bar Dam (i.e., Middle Yuba and South Yuba rivers)

Model Calibration

The Narrows II release temperature model is developed using data spanning the period of 1990 to present (data sets prior to 1990 were generally incomplete). The equation for Narrows II release temperature is:

$$N2 = 15.69 + 0.448^{*}\ NCT + 0.236^{*}\ AIR - 0.00064^{*}\ NBI + 0.00056^{*}\ YRI$$

Where

N2 = Release temperature of Narrows II Powerhouse (°F)
NCT = Release temperature of New Colgate Powerhouse (°F)
AIR = Air temperature at Marysville (°F)
NBI = Inflows to Englebright Lake from New Bullards Bar Dam (cfs)
YRI = Inflows to Englebright Lake from Middle Yuba and South Yuba river (cfs)

Comparison between observed and predicted release temperature at Narrows II Powerhouse is shown in **Figure B-17**. The comparison shows a good performance of the developed model for Narrows II release temperature (**Table B-4**). Although the fit between the observed and predicted is not complete, the observed release temperature falls well within the 99 percentile confidence limits of model predictions. In addition, model predictions closely match the seasonal trend in observed release temperature. As reported in **Table B-5**, statistical tests confirm the significance of all the parameters used in the temperature equation for Narrows II release.

The coefficients of the regression equation for Narrows II release temperature specifies the sensitivity of release temperature to each independent variable. A one degree increase in release temperature can be caused by an increase in New Colgate release temperature of 2.2 degrees, an increase in average monthly air temperature of 4.2 degrees at Marysville, a decrease in New Bullards Bar release of 1,600 cfs, or an increase of 1,800 cfs in the inflows from Middle and South Yuba rivers.

It should be noted that the maximum release capacity of New Colgate Powerhouse is about 3,500 cfs. Therefore, the relationships for the reservoir temperature model do not hold for flood control operations that require a release rate greater than 3,500 cfs. However, temperatures in the lower Yuba River are not a concern during flood control operations.

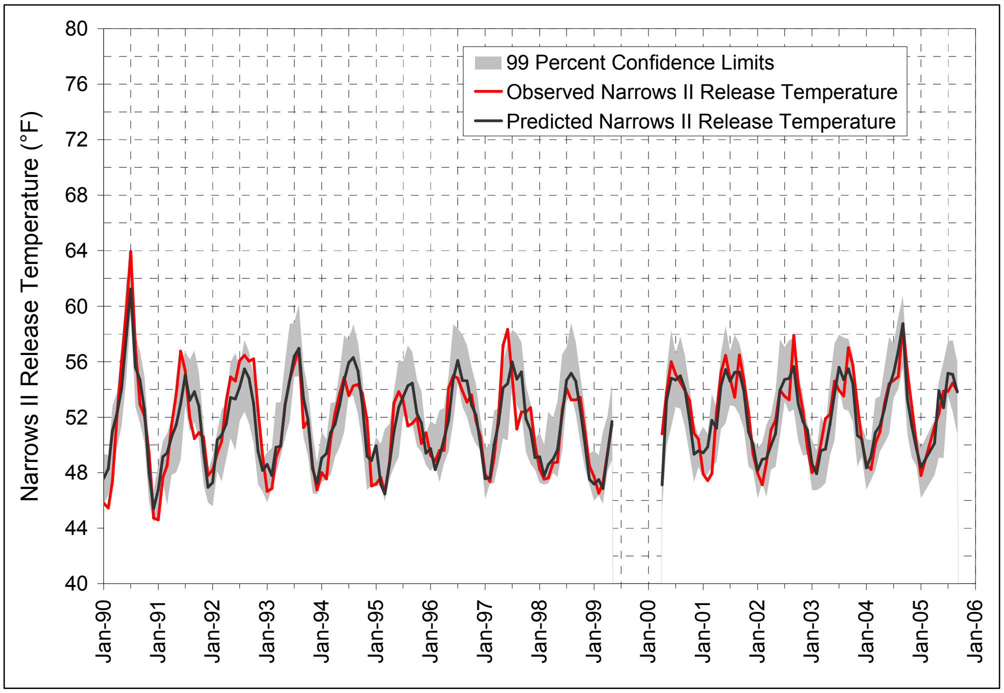

Figure B-17. Predicted and Observed Release Temperature at Narrows II Powerhouse for the period 1990 to 2005 (Calibration Results)

Table B-4. Performance Statistics for the Narrows II Release Temperature Equation

Statistic	Value
R-Square	0.792
Mean absolute error (°F)	1.18
Standard deviation of error (°F)	1.49

Table B-5. Statistical Significance Tests for the Parameters of the Narrows II Release Temperature Equation

Parameter	P-Value[7]
Intercept	3.1 E-08
NCT	5.1 E-14
AIR	3.1 E-53
NBI	2.4 E-06
YRI	6.0E-04

Model Validation

Figure B-18 compares the 1976 to 1984 observed and predicted release temperature for Narrows II. This period of the record is used for validation because it was not part of the calibration data set (1990 to 2005). Note that model predictions are only provided during periods when observed New Colgate release temperature is available.

[7] P-value tests whether each individual variable has a significant contribution to the relationship. If p-value is less than 0.05, then its corresponding variable is a significant predictor in the relationship.

Figure B-18 shows that predicted release temperature reasonable matched the general monthly trend of observed temperature. Although observed temperature fell below the 99 percentile confidence limits of model prediction during some periods, average absolute prediction error for the validation test was about 2.6°F.

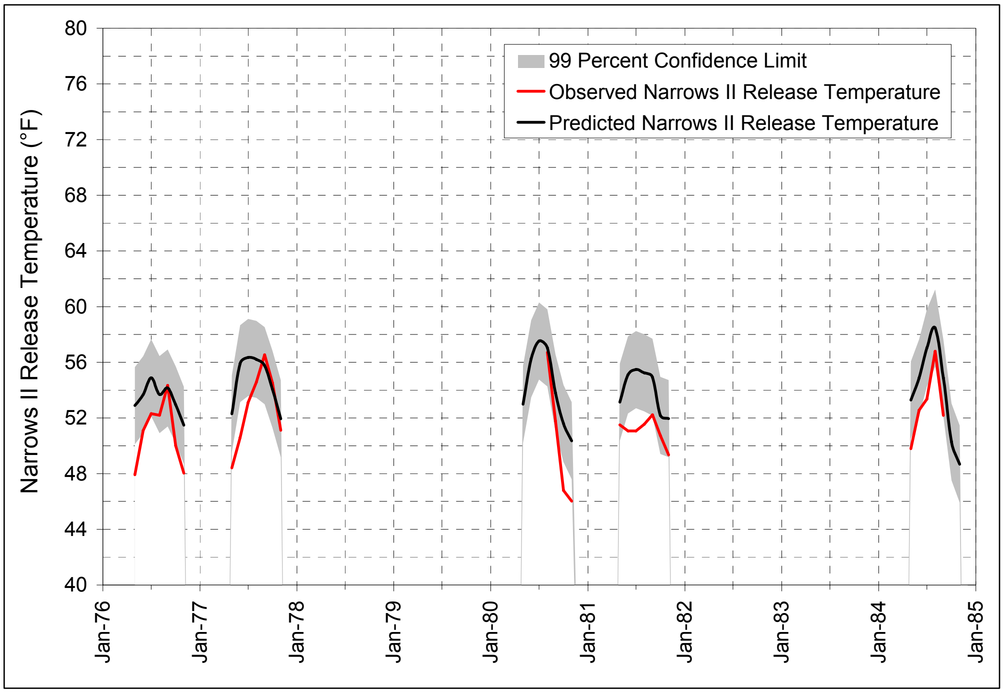

Figure B-18. Validation of Narrows II Release Temperature Model Using Observed Release Temperature at Narrows II Powerhouse for the Period 1976 to 1985

Model Comparison to Previous Studies

Two statistical temperature models were developed previously for water temperature below Englebright Dam: the temperature model for the 2000 Hearings and the temperature model developed in 1992 (*Water Temperature Modeling on the Yuba River, B-E 1992*). All models for water temperature below Englebright Dam, including the one developed in this study, used a multi-linear regression approach. The two previous models used two independent variables: (1) New Colgate release temperature and (2) average monthly air temperature at Marysville. The model developed under this analysis extends the previous two models by including flow terms in the regression equation, in addition to the temperature terms; it uses four independent variables: (1) New Colgate release temperature, (2) average monthly air temperature at Marysville, (3) Englebright Lake inflows from New Bullards Bar, and (4) Englebright Lake inflows from sources other than New Bullards Bar Dam (i.e., Middle Yuba and South Yuba river).

In this study, temperature relation for Narrows II is developed using monthly average temperature and inflows to Englebright Lake to account for detention time in the lake. This agrees with the approach adopted by the 1992 temperature model, where 20-day running average temperature was used to account for the effects of detention in Englebright Lake. In addition to a monthly temperature relation, the 2000 Hearings study also developed daily flow temperature relations, by month, for water temperature below Englebright Dam. These daily relations had noticeably lower R-square values compared to the monthly relation. This again emphasizes the need to account for effects of detention in Englebright Lake.

Inclusion of flow terms into the regression relation has improved the overall performance of the temperature model, where its R-Square improved from 0.64 in the 2000 Hearing model to 0.79 under the new model. This is an additional evidence of the significance of the flow terms in the regression relationship, which has been confirmed by the statistical tests (Table B-5). Moreover, including the flow terms in the regression equation allows for evaluating the impact of changed release pattern in New Bullards Bar Dam on temperature in lower Yuba River.

B.4.3 DAGUERRE POINT DAM WATER TEMPERATURE

Daguerre Point Dam is approximately 12 miles downstream of Englebright Dam. The terrain for this reach of the river varies significantly from a steep, narrow gorge near Englebright Dam to a wide, flat, open area near Daguerre Point. Also, there are multiple accretions and depletions between Englebright Dam and Daguerre Point, including Deer Creek, Dry Creek, and the Yuba River Goldfields. While there is a flow gage at the mouth of Deer Creek, there are limited temperature data for any of these locations and there are no flow gages below Deer Creek, except for the Marysville Gage.

Factors controlling Yuba River temperature at Daguerre Point include temperature of the releases form Englebright Dam and heat exchange in the river, which is affected by both climatic conditions and volume of the flow in the river. The impacts of inflows from Deer Creek on river temperature at Daguerre Point is not modeled because of the scarcity of temperature data for these inflows, in addition to their small volumes compared to the flows in Yuba River.

Model Description

The Daguerre Point Dam temperature model is a multi-linear regression relation that uses three independent variables:

- Narrows II release temperature
- Flow at Smartville
- Air temperature at Marysville

Two separate models are developed and compared for Daguerre Point, a single-relation model and a monthly-relations model. The monthly-relations model estimates water temperature at Daguerre Point using a set of unique coefficients for each month. The monthly relations are developed to assess the relative influence of the independent variable on a monthly basis.

Model Calibration

The Daguerre Point temperature models are developed using data spanning the periods of 1976, 1977, and 2000 to 2005. Additional available data set between 1997 and 2000 was reserved for model validation purposes. Although the temperature models developed in this study use monthly time-steps, calibration of Daguerre Point temperature model is carried-out using daily data. Use of daily data for calibration provides a larger data set for calibration compared to using monthly average data. This is especially important because of the short available temperature record at Daguerre Point. Moreover, because of the short travel time between Englebright Dam and Daguerre Point Dam, using daily data for calibration of models that uses monthly time-steps is considered appropriate.

Observation of the relation between flows and temperature shows a reduction in the influence on water temperature as flows increase, while influence increase for lower flows. Therefore, a linear relationship between flow and temperature will tend to overestimate predicted water temperature at higher flows and underestimate water temperature at low flows. To capture this nonlinear effect a logarithmic relationship between flows and temperature is used in place of the linear relationship. Daguerre Point water temperature representative equation has the form:

$$DGP = A + B^* N2 + C^* AIR + D^* \ln (SMF)$$

Where

DGP = Water temperature at Daguerre Point Dam (°F)
N2 = Release temperature of Narrows II powerhouse (°F)
AIR = Air temperature at Marysville (°F)
SMF = Yuba River Flow at Smartville gage (cfs)
A, B, C, D = Coefficients
Ln ( ) = the natural logarithm

Table B-6 presents the regression coefficients for the two models of Daguerre Point water temperature. **Figure B-19** and **Figure B-20** compare the observed and predicted water temperature at Daguerre Point using the monthly-relations model for the periods 2000 to 2005 and 1976 to 1977, respectively. The comparison shows a good performance of the developed monthly-relation model for Daguerre Point water temperature. The observed water temperatures fall well within the 99 percentile confidence limits of model predictions.

Table B-6. Model Coefficients of Water Temperature at Daguerre Point Dam

	Coefficients			
	A	B	C	D
Single-Relation	37.3	0.353	0.277	-2.636
Monthly-Relations				
January	21.6	0.345	0.170	0.180
February	8.0	0.653	0.179	-0.080
March	15.9	0.708	0.135	-1.030
April	53.2	0.108	0.126	-1.738
May	46.7	0.281	0.183	-2.363
June	57.1	0.271	0.108	-2.836
July	83.9	0.090	0.082	-4.948
August	86.4	0.066	0.037	-4.728
September	83.2	-0.067	0.116	-4.274
October	52.9	0.274	0.135	-2.895
November	2.5	0.877	0.148	-0.585
December	29.6	0.274	0.148	-0.221

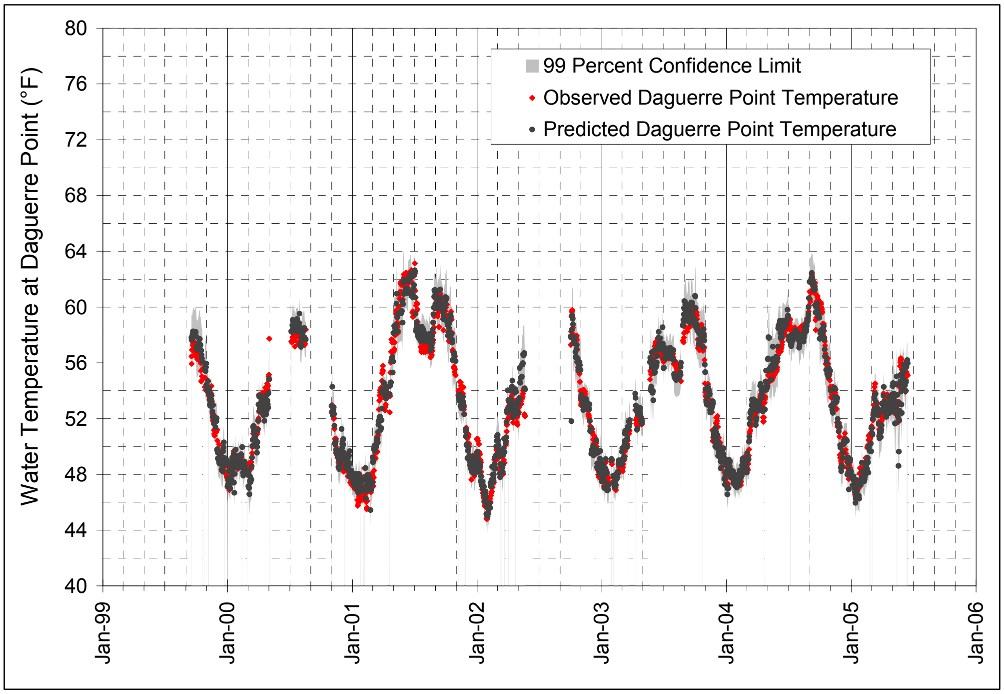

Figure B-19. Predicted and Observed Release Temperature at Daguerre Point Dam for the Period 1999 to 2005 (Calibration Results)

Note: Temperature Predictions are developed using the monthly-relations model.

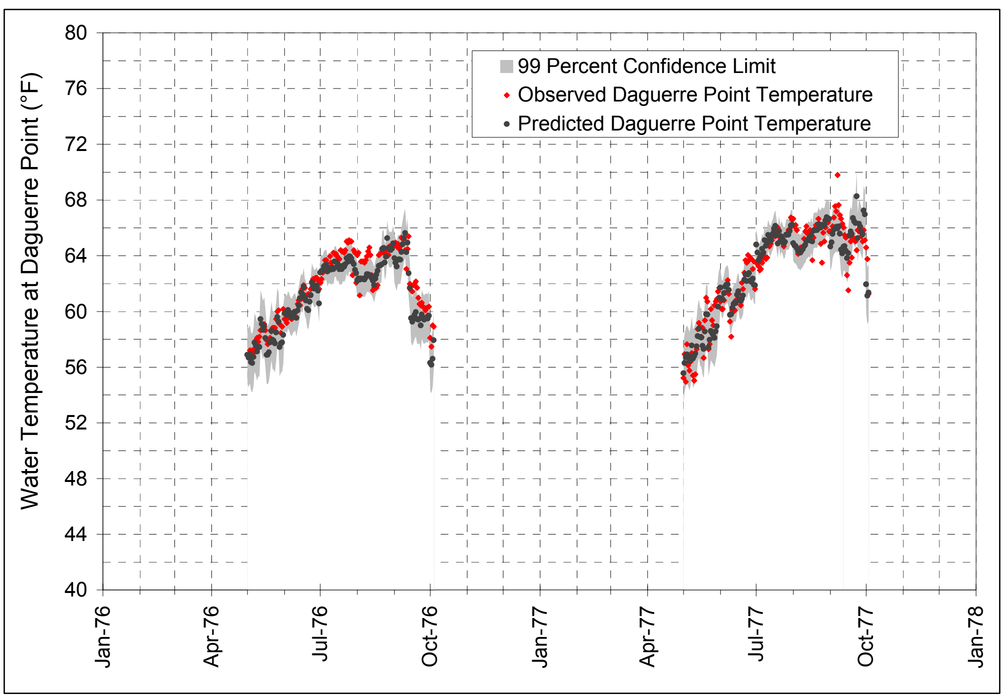

Figure B-20. Predicted and Observed Release Temperature at Daguerre Point Dam for the Period 1976 to 1977 (Calibration Results)

Note: Temperature Predictions are developed using the monthly-relations model.

Table B-7 reports the performance statistics of the developed single-relation and monthly-relation models for Daguerre Point water temperature. Performance statistics show an overall improved performance of the monthly-relations model over the single-relations model. This is caused by the additional degrees of freedom provided in the monthly-relations model, which has a total of 48 coefficients compared to 4 coefficients for the single-relation model. In addition, the monthly-relations model has the ability to capture effects of seasonal controls on river temperature that are not captured by the three independent variables, e.g., inflows from Deer Creek and Dry Creek.

Table B-7. Performance Statistics for the Daguerre Point Dam Water Temperature Models

Statistics	Single-Relation Model	Monthly-Relations Model	Percent Change
R-Square	0.861	0.971	+13%
Mean absolute error (°F)	1.57	0.68	-57%
Standard deviation of error (°F)	1.97	0.90	-54%

The coefficients of the regression equation specify the sensitivity of water temperature to each independent variable. Based on the single-relation model, a one degree increase in water temperature at Daguerre Point can be caused by an increase in release temperature in Narrows II of 2.8°F, an increase in Maysville air temperature of 3.6 °F, or a 46 percent decrease in river flow at Smartville. However, the sensitivity of water temperature to these factors varies from month to month.

Table B-8 shows the results of statistical significance tests for Daguerre Point temperature models. The tests confirm the significance of all the parameters used in the single-relation temperature equation. However, results of the significance test were not consistent for the monthly-relations model. The coefficients corresponding to Marysville air temperature were all significant predicators in the model. On the other hand, the coefficients corresponding to Narrows II release temperatures were insignificant predicators during the months of April, July, and August. The coefficients corresponding to Smartville flows were insignificant predicators during the months of January, February, and December. These monthly coefficients were reported insignificant because the historical record used for calibration showed limited influence of their corresponding variables on river temperature during the specified months.

Model Validation

To validate the developed models for water temperature at Daguerre Point, the data set for the period 1997 to 2000, which was not part of the calibration data set, was used. The validation test was carried-out at monthly time-steps because the developed models will be applied to estimate average monthly temperature in lower Yuba River. **Figure B-21** shows the comparison between the observed and predicted monthly water temperature at Daguerre Point for the period 1997 to 2000. It shows that predicted water temperatures, from both the single-relation and monthly-relations model, reasonably matched the observed temperature. The average absolute prediction errors in the validation test for the single-relation and monthly-relations models are 1.7 °F and 0.8 °F, respectively. This is additional evidence in favor of the monthly-relations model over the single-relation model.

Table B-8. Statistical Significance Tests for the Parameters of the Daguerre Point Dam Water Models

	P-Value[8]			
	A	B	C	D
Single-Relation	1E-237	8.1E-72	0	2E-296
Monthly-Relations				
January	2.1E-15	3.7E-09	1.9E-28	1.3E-01
February	5.5E-03	8.4E-19	2.4E-21	3.4E-01
March	8.4E-09	1.0E-25	6.3E-22	2.8E-18
April	1.5E-21	1.8E-01	5.5E-27	1.2E-19
May	3.9E-58	2.8E-09	9.4E-22	2.2E-50
June	4.0E-78	1.2E-13	9.2E-21	1.5E-72
July	3.8E-76	1.1E-01	3.9E-13	2E-121
August	2.5E-64	3.3E-01	4.0E-03	5E-117
September	8.8E-91	1.3E-02	2.2E-15	1.2E-66
October	1.1E-24	5.0E-05	2.4E-14	5.2E-15
November	4.9E-01	1.0E-26	9.6E-25	6.5E-04
December	3.0E-23	7.2E-09	6.4E-21	1.2E-01

* P-values highlighted in red correspond to coefficients that are statistically insignificant.

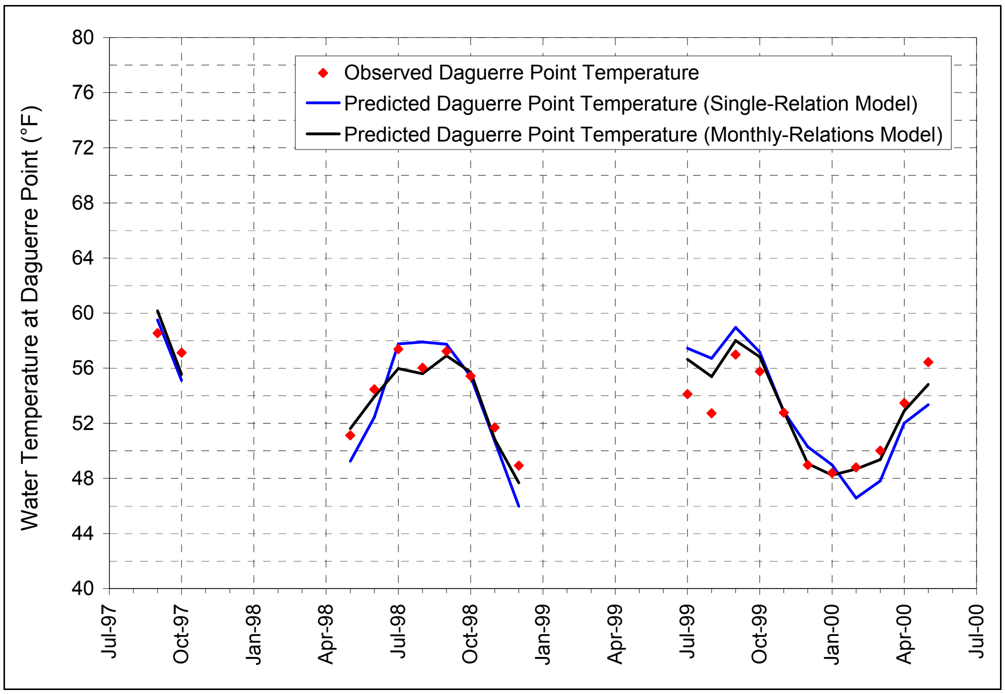

Figure B-21. Predicted and Observed Release Temperature at Daguerre Point Dam for the Period 1997 to 2000 (Validation Results)

Model Comparison to Previous Studies

Two temperature models were developed previously for water temperature at Daguerre Point Dam: (1) the statistical temperature model for the 2000 Hearings and (2) the one-dimensional physical temperature model (HEC-5Q) developed in 1992 (*Water Temperature Modeling on the Yuba River, B-E 1992*). The model developed under this analysis extends the statistical model

[8] P-value tests whether each individual variable has a significant contribution to the relationship. If p-value is less than 0.05, then its corresponding variable is a significant predictor in the relationship.

developed for the 2000 Hearings. The physical approach (HEC-5Q) is not used because of the large data input requirements, which include continuous metrological and flow data, as well as river cross sections information.

Because of the limited calibration data, the 2000 Hearings model developed a regression relationship for temperature at Daguerre Point using river temperature at Marysville, in addition to Marysville air temperature and Yuba River flow at the Marysville Gage. An additional relationship was also developed that replaced Marysville water temperature with release temperature at New Colgate. Similar to the approach used in this analysis, the 2000 Hearings model developed single-relation and monthly-relations models that were calibrated using daily data.

For the purpose of this study, additional five years of continuous daily temperature data is made available at Daguerre Point Dam (2000 to 2005). This additional data set allowed for the development of direct relationship between temperature of releases from Englebright Dam (Narrows II release temperature) and river temperature at Daguerre Point. Additionally, the temperature relationships developed in this study used flow at Smartville as an independent variable in place of flow at Marysville. The relationship between flow and temperature is also changed from a linear to a logarithmic relation to capture the observed behavior of flow and temperature relation in the calibration data set.

B.4.4 WATER TEMPERATURE AT MARYSVILLE GAGE

The Marysville Gage is approximately six miles downstream of Daguerre Point Dam. The river in this reach is relatively wide and flat, with very little cover or shade. There are few accretions or depletions in this reach. While the Yuba Goldfields have an influence on water temperatures, they are relatively high in the reach, and the flow reaches equilibrium with the Goldfield return flow temperature by the time it reaches the Marysville Gage. Therefore, the impact of Goldfield is not explicitly modeled.

Factors controlling Yuba River temperature at Marysville include temperature of the releases form Englebright Dam and heat exchange in the river, which is affected by both climatic conditions and volume of the flow in the river. The volume of the flow in the Yuba River is a function of both Englebright releases and diversions at Daguerre Point Dam.

Model Description

The Marysville water temperature model is a multi-linear regression relation that uses four independent variables:

- Narrows II release temperature
- Air temperature at Marysville
- Flow at Marysville
- Flow at Smartville

Yuba River flows in both Marysville and Smartville are used in order to capture the impacts of water diversions at Daguerre Point Dam. Two separate models are developed and compared for Marysville, a single-relation model and a monthly-relations model. The monthly-relations model estimates water temperature at Marysville using a set of unique coefficients for each month. The monthly relations are developed to assess the relative influence of the independent variable on a monthly basis.

Model Calibration

The Daguerre Point temperature models are developed using data spanning the periods of 1976, 1977, and 2000 to 2005. Additional available data set between 1990 and 2000 was reserved for model validation purposes. Although the temperature models developed in this study use monthly time-steps, calibration of Marysville temperature model is carried-out using daily data because it provides a larger data set for calibration compared to using monthly average data.

Similar to the models developed for Daguerre Point water temperature, a logarithmic relationship between flows and temperature is used. Marysville water temperature representative equation has the form:

$$MAR = A + B^* N2 + C^* AIR + D^* Ln(MRF) + E^* Ln(SMF)$$

Where

MAR = Water temperature at Marysville (°F)
N2 = Release temperature of Narrows II powerhouse (°F)
AIR = Air temperature at Marysville (°F)
MRF = Yuba River Flow at Marysville Gage (cfs)
SMF = Yuba River Flow at Smartville Gage (cfs)
A, B, C, D = Coefficients
Ln ( ) = the natural logarithm

Table B-9 presents the regression coefficients for the two models of Marysville water temperature. **Figure B-22** and **Figure B-23** compare the observed and predicted water temperature at Marysville using the monthly-relations model for the periods 2000 to 2005 and 1976 to 1977, respectively. The comparison shows a good performance of the developed monthly-relations model for Marysville water temperature. The observed water temperatures fall well within the 99 percentile confidence limits of model predictions.

Table B-10 reports the performance statistics of the developed single-relation and monthly-relation models for Marysville water temperature. Performance statistics show an overall improved performance of the monthly-relations model over the single-relations model. This is caused by the additional degrees of freedom provided in the monthly-relations model, which has a total of 60 coefficients compared to 5 coefficients for the single-relation model. In addition, the monthly-relations model has the ability to capture effects of seasonal controls on river temperature that are not captured by the four independent variables.

Table B-9. Model Coefficients of Water Temperature at Marysville

	Coefficients				
	A	B	C	D	E
Single-Relation	47.97	0.197	0.300	-4.873	1.723
Monthly-Relations					
January	2.57	0.778	0.120	0.321	0.033
February	11.12	0.870	0.145	1.662	-3.252
March	16.33	0.843	0.116	1.439	-3.238
April	49.33	-0.144	0.075	-0.493	1.393
May	53.64	0.085	0.237	-3.590	1.203
June	67.63	0.243	0.167	-3.313	-1.161
July	93.21	0.245	0.111	-3.311	-4.139
August	117.53	-0.496	0.099	-4.529	-0.962
September	97.30	-0.173	0.092	-4.380	-0.666
October	63.83	0.202	0.214	-2.454	-2.155
November	3.36	0.842	0.226	0.094	-0.999
December	36.27	0.141	0.141	-0.801	0.683

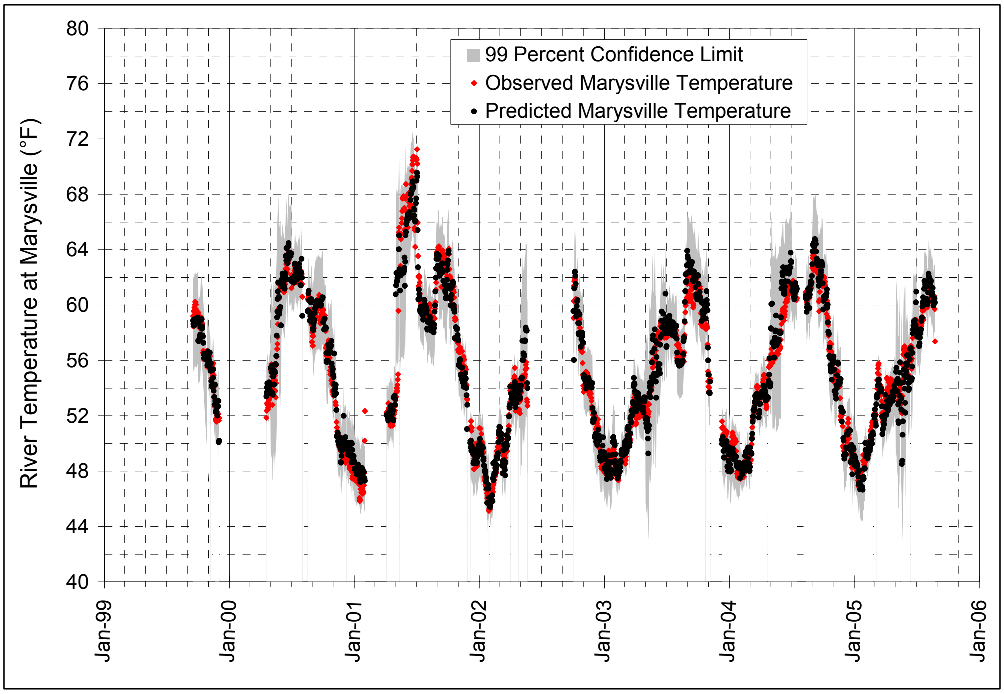

Figure B-22. Predicted and Observed Release Temperature at Marysville for the period 1999 to 2005 (Calibration Results)

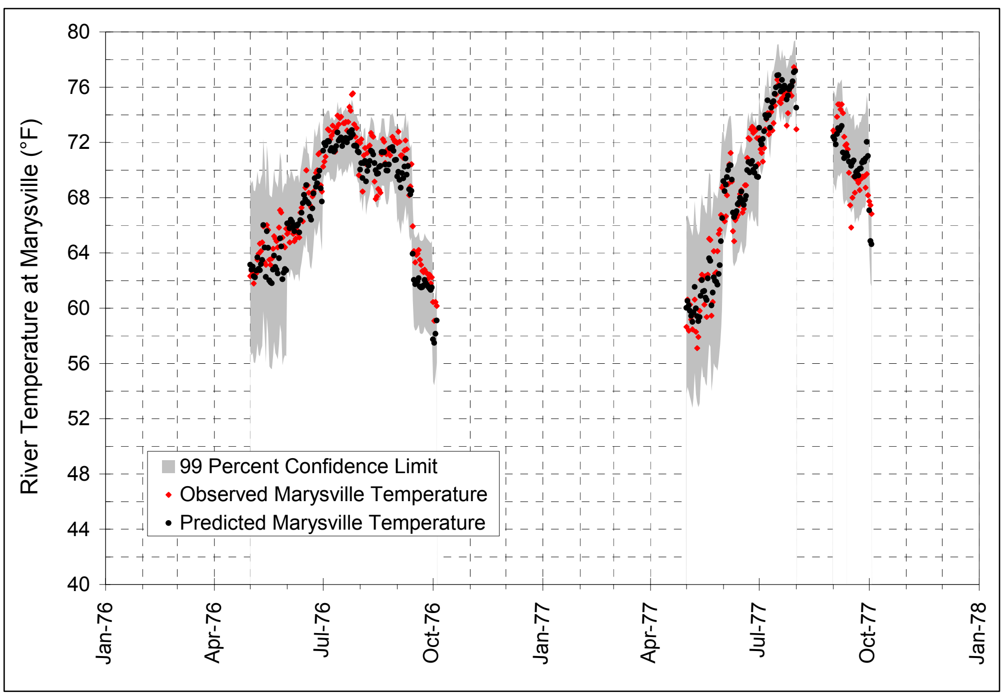

Figure B-23. Predicted and Observed Release Temperature at Marysville for the Period 1976 to 1977 (Calibration Results)

Table B-10. Performance Statistics for the Marysville Water Temperature Models

Statistics	Single-Relation Model	Monthly-Relations Model	Percent Change
R-Square	0.870	0.964	+11%
Mean absolute error (°F)	1.93	0.85	-56%
Standard deviation of error (°F)	2.48	1.26	-49%

The coefficients of the regression equation specify the sensitivity of water temperature to each independent variable. Based on the single-relation model, a one degree increase in water temperature at Marysville can be caused by an increase in release temperature in Narrows II of 5.1°F, an increase in Maysville air temperature of 3.3°F, or a 22 percent decrease in river flow at Marysville. However, the sensitivity of water temperature to these factors varies from month to month.

Table B-11 shows the results of statistical significance tests for Marysville temperature models. The tests confirm the significance of all the parameters used in the single-relation temperature equation. However, results of the significance test were not consistent for the monthly-relations model. Similar to Daguerre Point models, the coefficients corresponding to Marysville air temperature were all significant predicators in the model in all months. On the other hand, the coefficients corresponding to Narrows II release temperatures were insignificant predicators during the months of April and May. The coefficients corresponding to Marysville flows were insignificant predicators during the months of January, April, and November. The coefficients corresponding to Smartville flows were insignificant predicators during the months of January, May, June, August, and September. These monthly coefficients were reported insignificant because the historical record used for calibration showed limited influence of their corresponding variables on river temperature during the specified months.

Table B-11. Statistical Significance Tests for the Parameters of the Marysville Water Temperature Models

	P-Value[9]				
	A	B	C	D	E
Single-Relation	6E-221	1.8E-15	0	1E-186	2.4E-16
Monthly-Relations					
January	6.2E-01	2.6E-09	5.9E-08	4.6E-01	9.4E-01
February	8.9E-05	1.4E-26	7.3E-16	1.5E-05	3.9E-11
March	5.1E-06	1.6E-24	1.8E-19	2.9E-03	9.0E-09
April	6.6E-14	1.5E-01	1.3E-08	1.1E-01	6.6E-05
May	5.0E-34	2.4E-01	1.4E-15	2.7E-06	2.4E-01
June	2.6E-37	4.5E-06	7.1E-22	1.7E-05	3.0E-01
July	7.3E-54	5.8E-04	1.4E-16	3.5E-24	2.0E-15
August	8.8E-52	4.4E-05	3.2E-08	1.9E-32	5.1E-02
September	2.1E-97	6.2E-08	2.2E-09	2.6E-20	2.4E-01
October	1.6E-32	1.7E-03	3.3E-31	9.9E-11	4.3E-07
November	4.7E-01	3.0E-17	5.2E-29	7.3E-01	5.6E-06
December	5.0E-21	1.7E-02	3.5E-13	2.2E-04	7.8E-03
* P-values highlighted in red correspond to coefficients that are statistically insignificant					

[9] P-value tests whether each individual variable has a significant contribution to the relationship. If p-value is less than 0.05, then its corresponding variable is a significant predictor in the relationship.

Model Validation

To validate the developed models for water temperature at Marysville, the data set for the period 1990 to 2000, which was not part of the calibration data set, was used. The validation test was carried-out at monthly time-steps because the developed models will be applied to estimate average monthly temperature in lower Yuba River. **Figure B-24** shows the comparison between the observed and predicted monthly water temperature at Marysville Point for the period 1990 to 2000. It shows that predicted water temperatures, from both the single-relation and monthly-relations model, reasonable matched the observed temperature. The average absolute prediction errors in the validation test for the single-relation and monthly-relations models are 1.9 °F and 1.5 °F, respectively.

Model Comparison to Previous Studies

Two temperature models were developed previously for water temperature at Marysville: (1) the statistical temperature model for the 2000 Hearings and (2) the one-dimensional physical temperature model (HEC-5Q) developed in 1992 (*Water Temperature Modeling on the Yuba River, B-E 1992*). The model developed under this analysis extends the statistical model developed for the 2000 Hearings. The physical approach (HEC-5Q) is not used because of the large data input requirements that restrict the use of the model over the complete simulating period.

The 2000 Hearings model used a regression relationship for temperature at Marysville using release temperature at Englebright Dam, Marysville air temperature, and Yuba River flow at Marysville Gage. Similar to the approach used in this analysis, the 2000 Hearings model developed single-relation and monthly-relations models that were calibrated using daily data.

The model developed for this analysis extends this relationship by adding a fourth independent variable, flow at Smartville. The use of two flow terms in the equation, flows at Marysville and Smartville, allows for capturing the effect of water diversions at Daguerre Point Dam. However, the relationship between flow and temperature has changed from a linear to a logarithmic relation to capture the observed behavior of flow and temperature relation in the calibration data set.

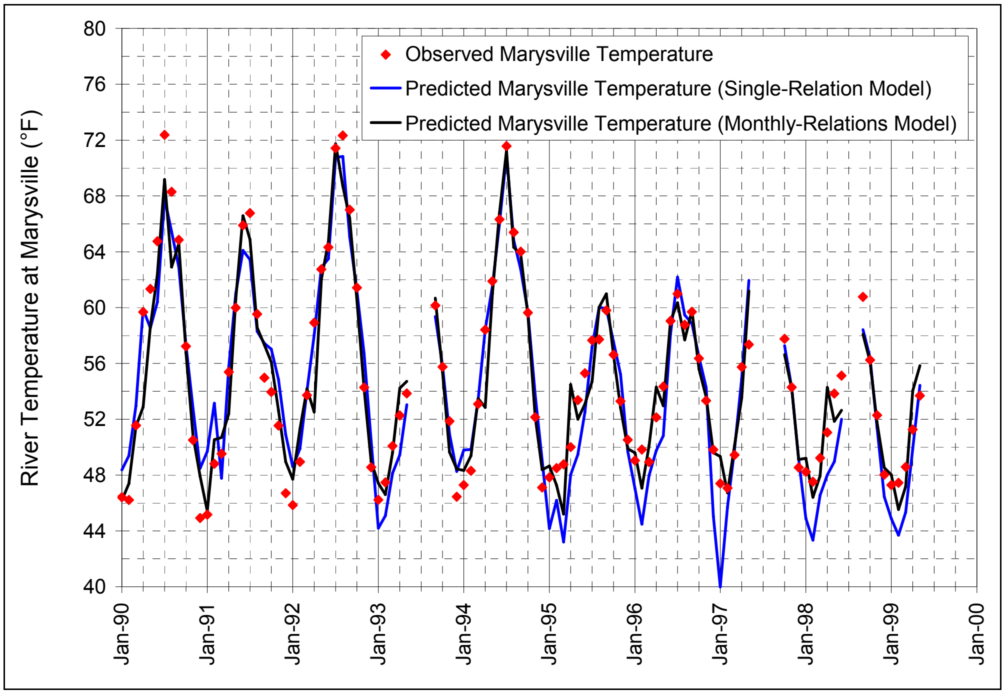

Figure B-24. Predicted and Observed Release Temperature at Marysville for the Period 1990 to 2000 (Calibration Results)

B.4.5 PREDICTION UNCERTAINTY OF TEMPERATURE MODELS

Error margins for the predictions of a certain model are determined by the standard deviation of calculated errors during model calibration. Standard devotions of calibration errors for the four model components for the lower Yuba River are reported in Table B-2, Table B-4, Table B-7, and Table B-10. Error margin corresponding to 99 percent confidence level is:

$$\text{Error Margin} = \pm 2.56 * \text{STD}$$

Where

STD = standard deviation of calibration errors

Because of the linkage between the four components of lower Yuba River temperature model, prediction uncertainty of a certain component is carried over into the other models that depend on its output. **Table B-12** summarizes the prediction uncertainty of lower Yuba River temperature model that also accounts for the carry-over of errors. It should be noted that Table B-12 represents the upper bound on the expected errors of model predictions.

Table B-12. Upper Bound of Prediction Uncertainty of Lower Yuba River Water Temperature Model at 99 Percent Confidence Level

	Single-Relation Model	Monthly-Relations Model
New Colgate Release Temperature Model	± 2.3 °F	-
Narrows II Release Temperature Model	± 4.8 °F	-
Daguerre Point Temperature Model	± 6.7 °F	± 4.0 °F
Marysville Gage Temperature Model	± 8.1 °F	± 4.9 °F

B.5 REFERENCES

Bookman Edmonston Engineering, Inc. 1992. Water Temperature Modeling on the Yuba River.

YCWA. 2001. Lower Yuba River: Assessment of Proposed Water Temperature Requirements. Testimony of Stephen Grinnell, P.E., Yung-Hsin Sun, Ph.D., and Stuart Robertson, P.E. Prepared by Bookman-Edmonston Engineering, Inc.

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APPENDIX E

Attachment 1 to the March 2011
Yuba County Water Agency
Yuba River Development Project
FERC Project No. 2246
ESA/CESA-Listed Salmonids Downstream
of Englebright Dam Study Proposal

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ATTACHMENT 1
TO THE
MARCH 2011 YUBA COUNTY WATER AGENCY
YUBA RIVER DEVELOPMENT PROJECT
FERC PROJECT NO. 2246
ESA/CESA-LISTED SALMONIDS DOWNSTREAM OF ENGLEBRIGHT DAM
STUDY PROPOSAL

AVAILABLE FIELD STUDIES AND DATA COLLECTION REPORTS

CDFG. 1978. *Yuba River Steelhead, Yuba County*. Technical Memorandum, prepared by R. Rogers, CDFG Region 2, Rancho Cordova, California.

During the winter of 1975-76, records of steelhead caught, size, and angling effort in the lower Yuba River were acquired through angler survey questionnaires. All *O. mykiss* 14 in. total length (TL) or longer were considered steelhead, and *O. mykiss* less than 14 in. were considered resident rainbow trout. Monthly catch rates estimates were divided by various assumed harvest rates to devise population estimates. This technical memorandum suggested a reasonable population estimate of 2,000 steelhead, given the methods and assumptions utilized. This technical memorandum also suggested that a good fall-run and winter-run of steelhead occurred, indicating the stocking program of *O. mykiss* during the 1970s had been successful and Yuba River steelhead habitat had improved since completion of New Bullards Bar Dam.

CDFG. 1984. *Yuba River Steelhead Run During Winter of 1976-77*. Technical Memorandum, prepared by R. Rogers, CDFG Region 2, Rancho Cordova, California.

During the winter of 1976-77, CDFG and USFWS conducted trapping for marking and tagging and a creel survey to estimate size and timing of the steelhead spawning run, origin of spawners (wild vs. hatchery), harvest rate and catch rate by anglers. Upstream migrant steelhead were trapped at a weir located on the lower Yuba River 6 miles upstream from the confluence with the Feather River that was fished continuously from September 23, 1976 to March 6, 1977. Each morning and evening steelhead in the trap were marked or tagged, checked for sex, length, general condition, amount of dorsal fin wear, and scale samples were taken before being released upstream. All *O. mykiss* observed were equal to or greater than 16 in. fork length (FL), and were therefore considered to be steelhead rather than resident rainbow trout.

Population estimates based on the Peterson tag-recapture method resulted in an estimate of 494 steelhead in the annual run, although this technical memorandum acknowledged that much of the annual run was not sampled, that sampling was conducted during an extreme drought year, and that an estimate of the normal steelhead run as about 2,000 fish seems reasonable.

Two migration peaks of steelhead was observed, one in October and one in February. Average fork length of 69 males measured was 24.8 in. with a range of 16 to 33 in. Average fork length of 77 females measured was 23.6 in. with a range of 16 to 30 in. From dorsal fin wear, 49% of the steelhead observed were judged to be of hatchery origin, although this technical memorandum stated that designating origin of steelhead according to fin wear is not entirely reliable. From scale analysis, 50% of the fish were judged to be of wild origin, although this technical memorandum also acknowledged that information on the origin of fish (wild vs. hatchery) is inconclusive.

This technical memorandum stated that fishing for steelhead trout on the lower Yuba River has improved considerably since New Bullards Bar Reservoir filled in 1970.

CDFG. 1991. *The Lower Yuba River Fisheries Management Plan Final Report*. The Resources Agency, CDFG, Stream Evaluation Report No. 91-1. February 1991.

Between 1986 and 1988, the California Department of Fish and Game (CDFG) and its contractor (Beak Consultants Inc. 1989) conducted a comprehensive series of detailed studies addressing fish community structure, fish populations, fish passage, flow-habitat relationships, water temperature, water quality, riparian habitat, and diversion impacts. These studies were conducted in four reaches of the lower Yuba River: (1) Narrows Reach extending approximately 2.2 miles below Englebright Dam and downstream of the Narrows 1 and Narrows 2 powerhouses; (2) Garcia Gravel Pit Reach beginning downstream of the Narrows Reach and extending to the DPD located 12.5 miles downstream of Englebright Dam; the (3) DPD Reach extending 7.8 miles to the downstream terminus of the Yuba Goldfield; and (4) the remaining 3.5 miles below the Simpson bridge to the confluence with the Feather River in the town of Marysville. The results of these studies led to the development of CDFG's *The Lower Yuba River Fisheries Management Plan Final Report* in 1991.

Assessment of the fish community structure within the lower Yuba River included the estimation of fish species composition, relative abundance, and distribution parameters using electrofishing and snorkel survey techniques. Both methods were used because of their utility in addressing different informational needs of the study. Snorkeling surveys allowed for the characterization of juvenile salmonid habitat during spring months that were otherwise inaccessible to boat electrofishing, such as shallow near-shore and riffle areas. Electrofishing was conducted primarily to assess those species that were underrepresented in snorkel surveys.

Combined results from the electrofishing and snorkeling surveys resulted in the documentation of 15 fish species in the lower Yuba River. Chinook salmon and steelhead were observed in all river reaches downstream of the Englebright Dam, and were the only fish species observed in the Narrows Reach. Chinook salmon were the most abundant of all fish species in the lower Yuba River representing 49% of total number of fish observed, followed by steelhead/rainbow trout representing 22% of the total number of fish observed.

A total of 1,707 fish were collected by electrofishing with increasing species diversity in the downstream direction. Only Chinook salmon and two other fish species were captured in the Narrows Reach. Diversity was greater in the Garcia Gravel Pit Reach including Chinook salmon, steelhead/rainbow trout, and seven other species. Chinook salmon also were collected in the DPD Reach, although steelhead/rainbow trout were not. Relative abundance estimates from electrofishing indicated Chinook salmon and Sacramento sucker were the most abundant species, comprising 49% and 32% of total electrofishing efforts, respectively. Steelhead/rainbow trout represented less than 1% of lower Yuba River abundance.

A total of 8,815 fish were observed during snorkeling surveys. Chinook salmon and steelhead/rainbow trout were present in all four reaches and were the only fish observed just below Englebright Dam in the Narrows Reach. Snorkel survey abundance estimates suggested that Chinook salmon were the most abundant fish species in the lower Yuba River representing 49% of all fish observed, and steelhead/rainbow trout comprised 22% of total observations.

CDFG (1991) reported that a small spring-run Chinook salmon population historically occurred in the Yuba River but the run virtually disappeared by 1959. As of 1991, a remnant spring-run Chinook salmon population reportedly persisted in the lower Yuba River maintained by fish produced in the lower Yuba river, fish straying from the Feather River, or fish previously and infrequently stocked from the Feather River Hatchery. CDFG (1991) reported that adult spring-run Chinook salmon migrate into the lower Yuba River beginning in March extending into July, spend the summer in deep pools in the Narrows Reach, and spawn from early to mid-September into November. Spring-run Chinook salmon juvenile rearing reportedly occurred in off-channel areas, and emigration occurred as fry within a few weeks of emergence or as larger juveniles as late as June.

CDFG (1991) reported that approximately 200 steelhead/rainbow trout spawned in the lower Yuba River annually prior to 1970. During the 1970s, CDFG annually stocked hatchery steelhead from the Coleman National Fish Hatchery into the lower Yuba River, and by 1975 estimated a run size of about 2,000 fish (CDFG 1991). CDFG stopped stocking steelhead into the lower Yuba River in 1979. CDFG (1991) reported that steelhead enter the lower Yuba River as early as August, migration peaks in October through February, and may extend through March. A run of “half-pounder” steelhead reported occurred from late-June through the winter months. Spawning reportedly occurred from January through April with egg incubation occurring from January through May, with fry emerging between February and June. CDFG (1991) reported that juvenile steelhead reared throughout the year but, unlike Chinook salmon in the lower Yuba River, may spend from one to three years in freshwater before emigrating primarily from March to June. CDFG (1991) indicated that most juvenile steelhead rearing occurred above DPD in the Garcia Gravel Pit Reach.

CDFG (1991) reported that adult Chinook salmon densities were greatest in riffle and deep pool habitats, whereas juvenile Chinook salmon and steelhead/rainbow trout were highest in the fast flowing riffle and run/glide habitats.

Microhabitat use criteria were developed to address habitat-flow relationships in the lower Yuba River for the Chinook salmon spawning, fry, and juvenile rearing lifestages. Substrate criteria used frequency of observation of dominant substrate particle size, whereas water depth and velocity criteria were developed by applying the non-parametric tolerance limits method to the frequency-of-use distribution measurements taken on the lower Yuba River. CDFG (1991) considered spawning gravel resources in Garcia Gravel Pit and DPD reaches of the lower Yuba River to be excellent, and also recommended future habitat improvement including construction of shallow rearing areas and off-channel habitat to increase survival of fry and juveniles.

CDFG (1991) also conducted riparian vegetation mapping of lower Yuba River plant communities within the study area. Three plant communities (blue oak/digger pine woodland, riparian forest, and grassland/agriculture), one topographic feature (hydraulic mine tailings), and one urban region were mapped. Riparian vegetation accounted for 56% of the total lineal shoreline coverage downstream of Englebright Dam.

SWRI, JSA, and BE. 2000. *Hearing Exhibit S-YCWA-19. Expert Testimony on Yuba River Fisheries Issues.* Prepared for the California State Water Resources Control Board Water Rights Hearing on Lower Yuba River February 22-25 and March 6-9, 2000.

The SWRI et al. (2000) document summarized data collection in the lower Yuba River obtained from 1992 through 2000. Since 1992, Jones and Stokes Associates (JSA) biologists conducted fish population surveys in the lower Yuba River used snorkel surveys to determine annual and seasonal patterns of abundance and distribution of juvenile Chinook salmon and steelhead during the spring and summer rearing periods. The SWRI et al. (2000) report stated that in general, juvenile Chinook salmon were observed by snorkeling throughout the river but with higher abundances above DPD. This report suggested that higher abundances above DPD may have been due to larger numbers of spawners, greater amounts of more complex, high quality cover, and lower densities of predators such as striped bass and American shad, which reportedly were restricted to areas below the dam.

Chinook Salmon

The SWRI et al. (2000) report stated that in 1992, beach seining surveys were conducted to measure lengths and weights of juvenile Chinook salmon at several locations in the lower Yuba River upstream and downstream of DPD. Beach seining was conducted at four sites (two upstream and two downstream of DPD) at weekly intervals from April 30, 1992 to June 5, 1992. Weekly measurements of lengths and weights were also taken from emigrating juvenile Chinook salmon at the Hallwood-Cordua fish screen during this period. Major findings of the 1992 surveys were summarized in SWRI et al. (2000) as follows.

- Juvenile salmon in the lower Yuba River exhibited significant growth in 1992. The average fork length at the Parks Bar site increased from 51.0 mm on May 1 to 69.1 mm on May 29, for an average growth rate of approximately 0.65 mm per day. Although accurate estimates of growth were not possible at other sites because of small sample sizes, the average sizes of juvenile on specific sampling dates both upstream and downstream of DPD were consistent with relatively rapid growth based on generalized growth curves for Chinook salmon.
- The seining data indicated a general increase in the size of juvenile Chinook salmon with distance downstream on any given date, possibly reflecting downstream movement of larger fish.
- Emigrating Chinook salmon salvaged at the Hallwood-Cordua fish screen were larger on any given date and encompassed a narrower size range (64.6 mm on April 30 to 77.5 mm on June 4) than Chinook salmon sampled above DPD. Although differences in efficiency existed between beach seining and the fish screen, the larger, more consistent size of emigrating juveniles compared to juveniles sampled in the river is consistent with the general knowledge that smolt migrations begin after the fish reach a certain size.

The SWRI et al. (2000) report stated that in 1993, high flows precluded the use of beach seines, although direct observations of juvenile Chinook salmon during monthly snorkel surveys (March 2, 1993 through August 10, 1993) revealed increases in the average size of juvenile salmon from 30-40 mm in early March, to approximately 60-70 mm by mid-June. Significant numbers of juvenile Chinook salmon continued to rear in the lower Yuba River through August, attaining average sizes of 70-80 mm and maximum sizes up to 120 mm. The apparent slower growth rates, longer residence periods, and later emigration timing in 1993 compared to 1992 were consistent with the hypothesis that emigration readiness is determined, at least in part, by the effects of water temperature of growth and development of young Chinook salmon during the spring rearing period. SWRI et al. (2000) reported that beach seine surveys were again conducted in 1994 at several locations upstream and downstream of DPD. The growth rates and body sizes of juvenile Chinook salmon on specific dates appeared to be similar to those observed in 1992.

SWRI et al. (2000) reported that individual lengths and weights of juvenile Chinook salmon in 1992 and 1994 were used to calculate condition factors. During the 1992 and 1994 surveys, fish were also examined for the presence of outward signs of stress (i.e., physical abnormalities, lesions, parasites). In 1992, juvenile Chinook salmon exhibited good condition factors at all locations throughout the sampling period (average condition factor ranged from 1.01 to 1.21 among all sampling sites and dates). SWRI et al. (2000) suggested that growth conditions were better in 1992 than in 1994. In 1994, average condition factors among all sampling sites and dates ranged from 0.95 to 1.05. No outward signs of stress were observed either in 1992 and 1994.

The SWRI et al. (2000) report stated that based on daily records of the number of Chinook salmon salvaged at the Hallwood-Cordua canal fish screen, the spring emigration period of juvenile salmon can begin as early as mid-April and continue until mid-June. However, it was noted that CDFG had not initiated salvage operations early enough in the season to sufficiently address the overall outmigration period. For the sampling that had been conducted, SWRI et al. (2000) reported that most juvenile Chinook salmon emigrated past DPD in April and May with peak numbers in early to late May. However, of all fish sampled, the median date of emigration past the dam (date when 50% of the total number of fish were collected at the Hallwood-Cordua fish screen) varied from late April to early June and was positively related to average April-May flow measured at the Smartsville gage. The report also stated that, in general, the median date of outmigration was delayed approximately 7-8 days with each 1,000-cfs increase for flows ranging from 400 cfs to 4,000 cfs, and that emigration timing during 1992-1994 continued to follow that relationship.

SWRI et al. (2000) suggested that the relationship between flow and emigration timing may reflect the effect of spring water temperatures on salmon growth rates and readiness to migrate; low water temperatures associated with high flows during the spring rearing period result in slower growth rates and later emigration. Conversely, higher water temperatures associated with lower flows result in higher growth rates and earlier emigration. SWRI et al. (2000) also suggested that observations of extended rearing of juvenile Chinook salmon into the summer months in high-flow years and the consistent size of emigrating juvenile Chinook salmon at the Hallwood-Cordua fish screen also support that relationship.

Steelhead/Rainbow Trout

The SWRI et al. (2000) report stated that since 1992, snorkeling, electrofishing, and angling surveys revealed the presence of large numbers of juvenile steelhead/rainbow trout in the lower Yuba River. This report suggested that the presence of a highly-acclaimed sport fishery, the lack of direct hatchery influence, and the presence of juveniles represented by a number of age classes confirmed that significant natural spawning and rearing of steelhead/rainbow trout occurred in the lower Yuba River. The physical appearance of adults and the presence of seasonal runs and year-round residents suggested that both sea-run (steelhead) and resident rainbow trout existed in the lower Yuba River, although no definitive characteristics had been identified to distinguish young steelhead from resident trout. Therefore, observations presented in the SWRI et al. (2000) report may apply to juveniles of either or both steelhead and resident rainbow trout, as summarized below.

- The primary spawning and rearing habitat for juvenile steelhead/rainbow trout is upstream of DPD. In 1993 and 1994, snorkeling surveys indicated that the population densities and overall abundance of juvenile trout (age 0 and 1+) were substantially higher upstream of DPD, with decreasing abundance downstream of DPD. In 1992, a general increase in the average size of juvenile trout in seine catches from the uppermost to the lowermost monitoring sites suggested a similar distribution pattern.

- Since 1992, a broad range of trout size classes have been observed in the lower Yuba River during spring and summer snorkeling, electrofishing, and angling surveys. Juvenile trout ranging in size from 40-150 mm were commonly observed upstream of DPD. Numerous larger juveniles and resident trout up to 18 inches long were also commonly observed in the mainstem upstream and downstream of DPD.

- The 1999 results of the juvenile steelhead study suggested that the highest abundance of young-of-the-year steelhead occurred above DPD despite suitable flow and water temperatures below the dam. Age 0 (young-of-the-year) trout were clearly shown by the distinct mode in lengths of fish caught by electrofishing (40-100 mm fork length). A preliminary examination of scales indicated that most yearling (age 1+) and older trout were represented by fish greater than 110 mm long, including most if not all of the fish caught by hook and line. The sizes of age 0 and 1+ trout indicated substantial annual growth of steelhead/rainbow trout in the lower Yuba River. Seasonal growth of age 0 trout was evident from repeated sampling of trout in 1992 and 1999, but actual growth rates could not be estimated because of continued recruitment of fry (newly-emerged juveniles) or insufficient sample sizes.

- Approximately 200 juvenile trout in 1992 and 1,100 trout in 1999 were measured, weighed, and examined to determine their general health and condition. All trout appeared healthy and in good physical condition. Like salmon, condition factors for juvenile trout increased with increasing size. In spring 1992, average condition factors for age 0 trout (48-82 mm average fork length) ranged from 1.07 -1.34. In summer 1999, average condition factors for age 0 trout (43-60 mm average fork length) ranged from 0.89-1.03, while those of age 1+ and older trout (156-420 mm fork length) averaged 1.13.

The SWRI et al. (2000) document also developed proposed minimum instream flow requirements which built upon additional information developed since 1992, including fish habitat utilization and detailed analyses of fish habitat-flow relationships and water availability. Development of the proposed instream flow requirements was based primarily on: (1) updated information characterizing Yuba River Basin hydrology and water year type classification; (2) water availability assessments for lower Yuba River instream flows, based on five water year types; (3) updated and additional lower Yuba River fishery information; (4) improved flow-temperature relationships for the lower Yuba River; and (5) a definition of maintaining lower Yuba River fish resources in "good condition."

CDFG. 2002. *Sacramento River Spring-run Chinook Salmon. 2001 Annual Report.* Prepared for the Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. October 2002.

CDFG (2002) summarized information from limited upstream migration surveys conducted during 2001, reconnaissance-level redd surveys conducted during 2001 and 2002, and rotary screw trapping during 2001-2002. CDFG (2002) reported that despite limited information on the population size of spring-run Chinook salmon in the lower Yuba River, data at that time indicated that adult escapement of spring-run Chinook salmon was relatively low and had been greatly reduced from historical levels. Prior to 2001, when CDFG conducted a study to estimate the number of adult spring-run Chinook salmon immigrating into the Yuba River by trapping fish in the fish ladder at DPD, there was almost no specific information on the run timing and size of the population in the lower Yuba River (CDFG 2002). In the 2001 CDFG study, which involved limited sampling of fish ascending the north ladder at DPD, a total of 108 adult Chinook salmon were estimated to have passed the dam between March 1, 2001, and July 31, 2001 (CDFG 2002).

Based upon reconnaissance-level redd surveys conducted by CDFG on the lower Yuba River from the Narrows pool downstream to DPD from August 31 to September 28, 2001, CDFG (2002) reported that the first redd was observed on September 7, 2001, and a total of 288 redds were observed. They also reported that 205 redds were observed in the lower Yuba River during the same time period in 2000. CDFG (2002) suggested that spring- and fall-run Chinook salmon were restricted to spawning in the same reach of the lower Yuba River.

Rotary screw trap operations were conducted during the 2001-2002 season to document the outmigration patterns of juvenile salmonids in the lower Yuba River. Data collected included timing, duration, and size of all Chinook salmon at the time of emigration. Although spring- and fall-run spawning occurred in the same physical location, initial length-frequency data from juveniles captured in the rotary screw trap indicated the presence of both a dominant fall-run and a smaller population of spring-run Chinook salmon CDFG 2002). Spring-run Chinook salmon were determined by size-at-date differences through the operation of the rotary screw trap. A total of 6,719 juveniles classified as spring-run Chinook salmon were captured between November 10, 2001 and May 8, 2002. These juvenile Chinook salmon sized ranged from 26mm FL to 108mm FL.

Lower Yuba River Water Transfer Monitoring Reports 2001 – 2004

The summaries below regarding recent water transfer studies conducted on the lower Yuba River were derived from the following sources:

YCWA and SWRCB. 2001. *Environmental Assessment: Proposed Temporary Transfer of Water From Yuba County Water Agency to DWR, Year 2001*. Prepared for Yuba County Water Agency and the State Water Resources Control Board by EDAW.

YCWA. 2003. *Draft Evaluation of 2002 Yuba River Water Transfers.* Prepared for Yuba County Water Agency by Surface Water Resources, Inc. January 28, 2003.

YCWA. 2005. *Evaluation of the 2004 Yuba River Water Transfers, Draft.* Prepared for Yuba County Water Agency by Surface Water Resources, Inc.

Water transfers and related monitoring studies and evaluations were performed in the lower Yuba River during 2001, 2002, and 2004. The primary fisheries issues evaluated by these studies included: (1) juvenile steelhead downstream movement; (2) adult Chinook salmon immigration and the potential for increased straying of non-native fish into the lower Yuba River; and (3) water temperatures in the lower Yuba River and Feather River.

The 2001 water transfers (172,000 acre-feet) occurred between approximately July 1, 2001 and October 14, 2001. Over a few days, flows increased by about 1,200 cubic feet per second (cfs) and were generally sustained in the lower Yuba River through late August when ramp-down began.

The 2002 water transfers (157,050 acre-feet) occurred from mid-June through mid-September and did not have a definitive ramp-up period. Instead, the relatively high flows that occurred during spring were sustained until initiation of the water transfers. Relatively stable flows of approximately 1,200 to 1,400 cfs at the Marysville gage were maintained through August 16, 2002. The ramp-down period associated with the water transfers began on August 17, 2002 and ended on September 16, 2002.

The 2004 water transfers (100,487 acre-feet) lacked a definitive ramp-up period. The relatively stable high June flows averaged 946 cfs at Marysville and were sustained through the initiation of the transfers (July 1) to the cessation of transfers on August 28, when flows were approximately 970 cfs at Marysville. Although the water transfers continued through September, a short ramp-down period occurred from August 28, 2004 through September 1, 2004, when flows at the Marysville gage were reduced to 531 cfs. Flows remained low and stable during the rest of September, averaging approximately 513 cfs.

Juvenile Steelhead/Rainbow Trout Non-Volitional Downstream Movement

Previous reporting of the water transfer studies used the term steelhead when referring to *O. mykiss* juveniles. However, it is recognized that both anadromous and resident lifehistory strategies of *O. mykiss* have been and continue to be present in the lower Yuba River, and that definitive distinction of juveniles between these lifehistory strategies were not previously conducted. Therefore, the following summaries use the term "steelhead/rainbow trout" when referring to *O. mykiss.*

The 2001 water transfer was characterized by a relatively large, rapid ramp-up period. A week subsequent to the start of the 2001 water transfers, the daily catch at the CDFG Hallwood Boulevard (RM 7) RST increased from less than 10 young-of-the-year (YOY) steelhead/rainbow trout juveniles per day, to more than 450 YOY per day (CDFG unpublished data). The next week, daily catches decreased to about 190 YOY per day and continued to further decrease during the following weeks while the transfers were continuing, but still surpassed catches prior to the water transfers, suggesting that juvenile steelhead/rainbow trout moved from the upstream reaches of the lower Yuba River to areas downstream of Hallwood Boulevard.

In response to these observations, an instream flow release schedule for the water transfers was created by YCWA, NMFS, USFWS, and CDFG to avoid a rapid increase in flow when the transfers begin, and to minimize or avoid potential impacts on anadromous fish in the lower Yuba River associated with non-volitional downstream movement. During the 2002 and 2004 water transfers, YCWA maintained instream flows in the lower Yuba River at a relatively stable rate in the late spring, with gradual changes in flow rates through initiation of the water transfer. Monitoring data (RST catch data) indicated that the large peak in downstream movement of juvenile steelhead/rainbow trout observed in 2001 did not occur in 2002 or 2004.

Water transfer monitoring in 2001, 2002, and 2004 indicated that the character of the initiation of the water transfers could potentially affect juvenile steelhead/rainbow trout downstream movement. Based upon the substantial differences in juvenile steelhead/rainbow trout downstream movements (RST catch data) noted between the 2001 study, and the 2002 and 2004 studies, it was apparent that the increases in juvenile steelhead/rainbow trout downstream movement associated with the initiation of the 2001 water transfers were avoided due to a more gradual ramping-up of flows that occurred in 2002 and 2004.

Attraction of Non-natal Adult Chinook Salmon in the Lower Yuba River

Water transfer monitoring efforts also studied the potential for the Yuba River water transfers to affect the straying of Feather River hatchery Chinook salmon into the lower Yuba River via decreased water temperatures and increased flow relative to the Feather River. YCWA and CDFG monitoring efforts in 2001, 2002, and 2004 water transfer years indicated that Chinook salmon of hatchery origin ascended the fish ladders at DPD in the lower Yuba River during both the water transfer and non-transfer periods. Chinook salmon of hatchery origin also have been observed ascending the Yuba River in non-transfer years (CDFG unpublished data).

Sampling of adult Chinook salmon via ladder trapping at DPD during 2001 was not sufficient to provide a dataset that could be statistically analyzed, and although 2002 data were statistically analyzed, a number of unexpected procedural difficulties were encountered resulting in low reliability of 2001 and 2002 abundance estimates. However, observations made during these water transfer studies led to the June 2003 installation of a VAKIRiverwatcher system, an infrared detection device, as well as a photographic recorder at DPD.

The use of the VAKI Riverwatcher as a counting device enabled more efficient and reliable monitoring of adipose fin-clipped and non-adipose fin-clipped adult Chinook salmon that immigrated into the lower Yuba River before, during, and after the 2004 water transfer. Estimates were conducted of immigration rates (fish/day), abundance of adipose fin-clipped and non-adipose fin-clipped adult Chinook salmon, and proportions of adipose fin-clipped adult Chinook salmon. The findings of these analyses led to the following general conclusions:

- The temporal distributions of the daily counts of adipose fin-clipped and non-adipose fin-clipped adult Chinook salmon likely were reflections of Chinook salmon adult immigration life stage periodicity, with the relatively abundant fall-run Chinook salmon mostly migrating during the post-transfer period.

- The estimates of the proportions of clipped adult Chinook salmon to the total number of adult Chinook salmon immigrating into the lower Yuba River did not suggest the attraction of non-natal adult Chinook salmon during the 2004 transfer period, because the proportion calculated for the transfer period was not greater than the proportions for the pre-transfer and post-transfer periods.

- Multivariate time series analyses indicated that the immigration rates of non-adipose fin clipped and adipose-fin clipped Chinook salmon in 2004 were not significantly associated with: (1) attraction flows, defined as the difference between lower Yuba River and Feather River flows; or (2) attraction water temperatures, defined as the difference between lower Yuba River and Feather River water temperatures.

JSA. 2003, 2007, and 2008. *Lower Yuba River Redd Dewatering and Fry Stranding Monitoring and Evaluation Plan.* November 2003. *Lower Yuba River Redd Dewatering and Fry Stranding Study 2007 Annual Report* (JSA 2007) and *Lower Yuba River Redd Dewatering and Fry Stranding Study 2008 Annual Report* (JSA 2008).

In D-1644, the SWRCB in 2001 directed YCWA to submit a plan, in consultation with USFWS, NMFS, and CDFG that describes the scope and duration of future flow fluctuation studies to verify that Chinook salmon and steelhead redds are being adequately protected from dewatering with implementation of D-1644 criteria (JSA 1992). In RD-1644, the SWRCB in 2003 readopted this requirement. After various comments and revisions, the March 2002 Plan (Plan) was approved by the SWRCB on April 17, 2002. Phase I of the Plan was undertaken in 2002, and implementation of Phase II of the Plan continues.

These studies combine habitat mapping, field surveys, and information on the timing and distribution of fry rearing in the lower Yuba River to evaluate the effectiveness of D-1644 flow fluctuation and reduction criteria in protecting Chinook salmon and steelhead/rainbow trout fry. Two studies were conducted and summarized in the 2007 and 2008 *Lower Yuba River Redd Dewatering and Fry Stranding Annual Reports* (JSA 2007, 2008) to the SWRCB.

The first *Lower Yuba River Redd Dewatering and Fry Stranding Study* was conducted in April 2007 to evaluate bar and off-channel stranding of juvenile salmonids associated with a flow reduction of 1,300-900 cfs (at Smartsville) at a ramping rate of 100 cfs per hour. Bar stranding was again evaluated in June with a temporary flow reduction of 1,600-1,300 cfs at a rate of 100 cfs per hour. Snorkel surveys were conducted between Rose Bar and the Highway 20 Bridge in the lower Yuba River. During the April 5, 2007 drawdown, field crews observed 8 stranded salmon fry in the interstitial spaces of substrates on bar slopes (perpendicular to shoreline) ranging from 0.5 to 5.5%. No stranded fish were observed during surveys conducted on June 18, 2007. The presence of both juvenile Chinook salmon and steelhead/rainbow trout were confirmed in shallow, near-shore areas adjacent to the study sites, suggesting that the risk of bar stranding is greatly reduced by June. Following April 5, 2007 flow reductions, a total of 11,100 juvenile Chinook salmon were found in 20 isolated off-channel habitats. Most (93%) of the isolated juveniles were newly emerged and exhibited a length ranging from 30 to 50 mm.

An update *Lower Yuba River Redd Dewatering and Fry Stranding Study* was subsequently conducted from May 29, 2008 through June 4, 2008 with a scheduled flow reduction on June 1, 2008. Two of the three potential stranding locations had changed since the 2007 study. A total of 7 stranded trout fry (ranging between 30-35mm) were observed in the interstitial spaces of substrates on bar slopes (perpendicular to shoreline) ranging from 2.0 to 5.7%. Following the June 1, 2008 flow reductions, 266 juvenile salmonids were isolated in 6 off-channel sites. JSA (2008) suggested that the preliminary findings indicated that juvenile steelhead/rainbow trout fry may be less vulnerable to off-channel stranding than juvenile Chinook salmon because of their more restricted distribution and inability to access off-channel areas under late spring flow conditions. Long-term monitoring of several isolated off-channel sites confirmed that some sites can support juvenile salmonids for long periods and even produce favorable summer rearing conditions.

In accordance with the *Lower Yuba River Redd Dewatering and Fry Stranding Monitoring and Evaluation Plan* (2003), YCWA and JSA will continue to monitor and evaluate stranding risk and flow-habitat relationships for off-channel stranding. Future actions will include the following : (1) continued evaluation of the effects of time of day (night versus day) on stranding risk of juveniles; (2) inspection of interstitial habitats along the river margins to determine the presence of young fry before bar stranding evaluations; (3) evaluation of the effects of higher ramping rates (>100 cfs per hour) on stranding risk of larger fry and juveniles; (4) continued evaluation of the relationship between flow range and the number, area, and distribution of off-channel sites that become disconnected from the main river; (5) evaluation of the effect of peak winter and spring flows on the incidence of off-channel stranding; and (6) continued monitoring of habitat conditions and survival of Chinook salmon and steelhead/rainbow trout in selected off-channel monitoring sites where stranding is frequently observed.

Massa, D. 2004. *Yuba River Juvenile Chinook Salmon (Oncorhynchus tshawytscha), and Juvenile Central Valley Steelhead Trout (Oncorhynchus mykiss), Life History Survey: Annual Data Report 2003-2004.* California Department of Fish and Game Annual Report, Sacramento Valley & Central Sierra Region, Rancho Cordova, CA.

This study was conducted to continue development of baseline information for the Central Valley Project Improvements Act's (CVPIA), Anadromous Fish Restoration Program (AFRP) for juvenile Chinook salmon and steelhead/rainbow trout life history strategies on the lower Yuba River. Data were collected to determine the timing and duration of downstream emigration, abundance and/or relative abundance, and to monitor the condition and size of outmigrating juvenile Chinook salmon and steelhead/rainbow trout. Emigrating juvenile Chinook salmon were coded-wire tagged (CWT) in an effort to enumerate and determine the relative contribution to adult escapement on the lower Yuba River.

Juvenile Chinook salmon and steelhead trout were captured using a rotary screw trap (RST) with an eight-foot diameter cone placed in the lower Yuba River located approximately 6 miles east of the city of Marysville, adjacent to the south end of Hallwood Boulevard. Except during extraordinarily high water flows or during periods of excessive debris, the trap was fished 24-hours-per-day, seven-days-a-week from October 15, 2003 through June 17, 2004 following its installation on October 1, 2003.

Twenty-one species of fish were captured in the RST including a total of 307,297 juvenile Chinook salmon. Steelhead/rainbow trout were captured less frequently and totaled 590 fish during the October – June trapping period. This study revealed that peak catches of juvenile Chinook salmon on the lower Yuba River occur between December and March, which is approximately one month earlier than observed during previous monitoring efforts. Over 67,000 juvenile Chinook salmon were captured during the first two weeks of December 2003, and captures remained high until mid-March 2004. A total of 21,396 captured fry for the month of March 2003 signified the conclusion of peak emigration for juvenile Chinook salmon. Massa (2004) suggested that three runs of Chinook salmon (spring-, fall-, and late-fall run) were identified by modal distributions of captures at the RST. Spring-run Chinook salmon were first observed on November 1, 2003, followed by fall-run observations in December 2003, and late-fall run during mid-April 2004. Fall-run Chinook represented the majority of juveniles captured in the lower Yuba River. Coded Wire Tagging (CWT) began November 26, 2003 and ended June 15, 2004 with the majority of tagging occurring during peak emigration between December 9, 2003 and March 18, 2004. Of the 307,397 total juvenile Chinook salmon captured in the RST, 185,305 juvenile Chinook salmon were successfully injected with a CWT and adipose-fin clipped prior to release.

Kozlowski, J.F. 2004. *Summer Distribution, Abundance, and Movements of Rainbow Trout (Oncorhynchus mykiss) and other Fishes in the Lower Yuba River, California*. UC Davis Thesis.

Kozlowski (2004) conducted electrofishing (early-July and late-August), two mid-channel snorkel surveys (late-July and early-September), and river margin surveys (mid-August) just prior to the second electrofishing period during 2000. In addition, he reviewed 1999-2000 salvage data for the Hallwood-Cordua canal, a diversion canal located at DPD, and 1999-2001 trapping data for the Hallwood rotary screw trap (RST) near Hallwood Boulevard. These surveys were conducted to assess the distribution, abundance, and movement of steelhead/rainbow trout and other species below Englebright Dam.

The study focused on the portion of the lower Yuba River between Marysville and the Narrows within the following four reaches: (1) the Simpson Lane Bridge (about RM 3.2) to the Yuba Goldfields (about RM 8.3); (2) the western boundary of the Yuba Goldfields (about RM 8.3) to DPD (about RM 11.5); (3) upstream from DPD (about RM 11.5) to the upstream side of Long Bar (about RM 16.2); and (4) Highway 20 (about RM 16.2) to the downstream side of the Narrows (about RM 22.2).

Backpack electrofishing and snorkel survey data collection methods were used to estimate distribution and abundance population parameters for various life stages of steelhead/rainbow trout, as well as assess the aquatic community composition in the lower Yuba River. Fish screen salvage at DPD and rotary screw trapping methods were used to assess fish movements within the lower Yuba River, including above and below DPD. Age-0, juvenile, and adult summer distribution, abundance and movements were investigated between 1999 and 2000.

During the study a total of at least 12 species were observed including Chinook salmon and steelhead/rainbow trout. Kozlowski (2004) found higher abundances of juvenile and adult steelhead/rainbow trout above DPD, relative to downstream of DPD. Chinook salmon occurrence and abundance increased throughout the summer.

Kozlowski (2004) observed age-0 and adult steelhead/rainbow trout throughout the entire study area, with highest densities in upstream habitats and declining densities with increasing distance from the Narrows. Total numbers of juvenile and adult steelhead/rainbow trout observed below DPD accounted for 18 to 26% of the total number of steelhead/rainbow trout observed in the study area. The distribution of age-0 steelhead/rainbow trout observed appeared to be related to the distribution of spawning adults. The majority of redds observed during snorkel surveying occurred in the upstream reach between Long Bar and the Narrows during winter and spring 2000.

Some age-0 steelhead/rainbow trout dispersed downstream soon after emerging, beginning in July and August, and continued throughout the year (Kozlowski 2004). Salvage data at the Hallwood-Cordua fish screen suggested that most juvenile fish initiated their downstream movements immediately preceding and following a new moon, indicating the presence of lunar periodicity in the timing or outmigration patterns in the lower Yuba River (Kozlowski 2004).

Kozlowski (2004) stated that flow and temperature did not appear to cause age-0 steelhead/rainbow trout to initiate these downstream movements since these factors varied little or not at all during the duration of the summer. Similarly, water temperatures remained within the range preferred by steelhead/rainbow trout throughout the study area and did not vary substantially among reaches. As a result, the distributional pattern of steelhead/rainbow trout in the study area could not be explained by differences in water temperatures in the lower Yuba River.

Kozlowski (2004) found that the density of age-0 steelhead/rainbow trout was positively correlated to median substrate size of the upstream reach suggesting suitable rearing habitat for this life stage in the lower Yuba River. Juvenile and adult steelhead/rainbow trout were observed in greater numbers in pool habitats, and identified more frequently downstream of the Narrows, than in run habitats. Kozlowski (2004) suggested that results of this study indicated a relatively higher degree of habitat complexity, suitable for various life stages, in the reaches just below the Narrows compared to farther downstream. This includes greater occurrence of pools-type microhabitat suitable for juvenile and adult steelhead/rainbow rearing and holding, as well as small boulders and cobbles preferred by the age-0 emerging life stage.

Growth of age-0 steelhead/rainbow trout in the lower Yuba River was relatively slow throughout the summer, averaging between 47.9 mm (July 3 2000 - July 14, 2000) and 56.5 mm (August 25, 2000 – September 11, 2000) during the summer (Kozlowski 2004). The mean size observed in the lower Yuba River during this study was reportedly smaller than the August mean fork length (70 mm) reported by Cavallo et al. (2003; as cited in Kozlowski 2004) for age-0 rainbow trout in the low flow channel of the lower Feather River, and the lower American River in July (82 mm) reported by Snider and Titus (1994) but may be due to the presence of sampling biases inherent to electrofishing and snorkeling or seining methods. In a comparison of sampling methodology for this study, Koslowski (2004) suggested that snorkeling methods underestimated age-0 steelhead/rainbow trout numbers at sites where electrofishing yielded relatively high catches, but appeared to be a better estimator of fish density at sites where electrofishing yielded low numbers and was attributed to steelhead/rainbow trout fleeing sampling sites rather than hiding in the substrate as the electrofishing crew sampled the river margin.

Massa, D. and C. McKibbin. 2005. *Yuba River Juvenile Chinook Salmon (Oncorhynchus tshawytscha), and Juvenile Central Valley Steelhead Trout (Oncorhynchus mykiss), Life History Survey: Annual Data Report 2004-2005.* California Department of Fish and Game Annual Report, Sacramento Valley & Central Sierra Region, Rancho Cordova, CA.

Massa and McKibbin (2005) is a continuation of the Life History Surveys for the annual period extending from 2004-2005. Juvenile Chinook salmon and steelhead/rainbow trout were captured using two rotary screw traps (RST) with an eight-foot diameter cone placed in the lower Yuba River approximately 6 miles east of the city of Marysville, adjacent to the south end of Hallwood Boulevard. Except during extraordinarily high water flows or during periods of excessive debris, the traps were fished 24 hours per day, 7 days a week from October 21, 2004 through June 27, 2005 (Trap 1) and from April 26, 2005 to June 20, 2005 (Trap 2).

Twenty-two species of fish were captured in the RST including a total of 285,034 juvenile Chinook salmon. Steelhead/rainbow trout were captured less frequently and totaled 614 fish during the trapping periods. Massa and McKibbin (2005) suggested that peak catches of juvenile Chinook salmon on the lower Yuba River were observed later in the calendar year than in the previous 2003-2004 season, but were consistent with observations from earlier monitoring efforts (1999-2002).

Massa and McKibbins (2005) suggested that three runs of juvenile Chinook salmon (spring-, fall-, and late-fall run) were identified by modal distributions of captures at the RST. Fall-run Chinook represented the majority of juveniles captured in the lower Yuba River. CWT began November 29, 2004 and ended June 7, 2005 with the majority of tagging occurring during peak emigration between early January 2005 and late February 2005. Of the 285,034 total juvenile Chinook salmon captured in the RST, 242,774 juvenile Chinook salmon were successfully injected with a CWT and adipose-fin clipped prior to release.

JSA. 2006. *2003 Fall-run Chinook salmon spawning escapement in the Yuba River*. Prepared for Yuba County Water Agency by Jones and Stokes Associates, Inc.

JSA (2006) reported that annual surveys of Chinook salmon carcasses have been conducted on the lower Yuba River since 1953 to estimate fall-run Chinook salmon (*Oncorhynchus tshawytscha*) spawning escapement (i.e., the number of salmon that return to spawn each year). They reported that CDFG has conducted annual surveys of Chinook salmon carcasses on the lower Yuba River from 1953 to 1989, but suspended its surveys because of budget cuts. In response, YCWA with the assistance of JSA in 1991, conducted subsequent escapement surveys through 2003. CDFG assisted JSA from 1992 through 1994. In 2002 and 2003, additional funding was provided by the California Department of Water Resources (CDWR) and the Pacific States Marine Fisheries Commission (PSMFC) to ensure a complete search for tagged hatchery strays. The main objective of the annual carcass surveys was to estimate annual spawning escapement of fall-run Chinook salmon in the lower Yuba River downstream of Englebright Dam.

JSA (2006) reported an estimate of 28,897 Chinook salmon spawned in the lower Yuba River based on surveys conducted during 2003. JSA (2006) reported that the average spawning escapement for 1996–2003 was estimated to be 24,563 fish, which was substantially higher than the average of 13,809 for the preceding period between 1972–1995 representing the post–New Bullards Bar Reservoir period. Overall, average spawning escapement for the pre- and post-reservoir periods (1953–1971 and 1972–2003) was 12,906 and 16,050 fish, respectively.

Grover, A. and B. Kormos. (undated). *The 2006 Central Valley Chinook Age Specific Run Size Estimates*. Scale Aging Program, California Department of Fish and Game 475 Aviation Blvd, Suite 130 Santa Rosa, CA 95403

Through scale aging, this study produced age-structured hatchery and natural escapement estimates for all principal reaches and runs of Chinook salmon (*Oncorhynchus tshawytscha*) in the Central Valley. Digital imaging and reading techniques were used, and a modified maximum likelihood estimator based on the work of Kimura and Chikuni (1987; as cited in Grover and Kormos undated) was utilized. This method uses known, aged CWT salmon scale samples in conjunction with those of unknown aged (non-CWT) fish to create bias-corrected age proportions from which age-specific run size estimates were made. Grover and Kormos (undated) reported that preliminary results showed that there are differences between the age structure of hatchery and natural escapement. In addition, they indicated that there are age structure differences among the Chinook lifehistory types present in the Central Valley. Results from this study indicated that in the lower Yuba River about 4.5% of the 2006 total escapement was comprised of 2 year old Chinook salmon, 16% were age 3, and 79.5% were age 4.

Grover, A. and B. Kormos. (undated). *The 2007 Central Valley Chinook Age Specific Run Size Estimates.* Scale Aging Program, California Department of Fish and Game 475 Aviation Blvd, Suite 130 Santa Rosa, CA 95403

Results from the 2007 evaluation utilized the same methods and procedures described for the 2006 evaluation (presented above). Grover and Kormos (undated) stated that there are differences between the age structure of hatchery and natural escapement, and among the Chinook life history types present in the Central Valley. Results from this study indicated that in the lower Yuba River about 3% of the 2007 total escapement was comprised of 2 year old Chinook salmon, 36% were age 3, 59% were age 4, and 1.6% were age 5.

NMFS. 2007. *Biological Opinion on the Operation of Englebright and Daguerre Point Dam on the Yuba River, California.* File Number 151422-SWR-2006-SA00071:MET (PCTS # 2007/01232). November 21, 2007.

In November 2007, NMFS issued a BO on the operation of USACE's facilities on the Yuba River, including DPD and Englebright Dam. Central Valley spring-run Chinook salmon and Central Valley steelhead passage at DPD was addressed in the BO, although NMFS (2007) stated that a final preferred alternative was not identified to alleviate passage impediment issues at DPD. The BO did not address project effects on the threatened southern-DPS of North American green sturgeon.

According to NMFS (2007), infrared and videographic sampling at ladders located at DPD since 2003 has provided more robust estimates of spring-run Chinook salmon numbers migrating into the lower Yuba River. NMFS (2007) reported preliminary estimates of adult spring-run Chinook salmon ascending DPD as 1,250 in 2003, 431 in 2004, 1,019 in 2005, 217 in 2006, and 242 in 2007. However, NMFS (2007) considered these numbers to be preliminary, minimum estimates, because periodic problems with the sampling equipment resulted in periods when fish ascending the ladders were not counted, so it is likely that the actual numbers are higher than those reported. NMFS (2007) observed that the detection of adipose fin clips on some of these fish indicated that they were hatchery strays, most likely from the Feather River Hatchery, and that the short time period in which this sampling has been conducted, coupled with the salmon's three to four year life cycle made it difficult to determine decisive trends in the spring-run Chinook salmon population. While the data from 2006 and 2007 indicate a reduction in total abundance, passage in May (the primary spring-run migration month) of 2007 was the highest detected in that month since the sampling has been conducted (NMFS 2007).

Based on infrared and videographic sampling at both DPD fish ladders since 2003, NMFS (2007) reported that minimum, preliminary estimates of the number of steelhead ascending DPD were 170 in 2003, 762 in 2004, 356 in 2005, 150 in 2006, and 511 in 2007. Additionally, because steelhead can be similar in size to many other species of fish in the Yuba River, only those inferred images that were backed up by photographic images clearly showing that the fish was a steelhead were included in the counts (NMFS 2007). Therefore, NMFS (2007) stated that it is likely that the actual numbers of steelhead passing DPD were higher than those reported. The data indicated that through the first half of the month of July 2007, upstream adult steelhead passage at DPD was the highest since the device was installed in 2003, although determination of decisive trends in the Yuba River steelhead population was difficult at that time (NMFS 2007).

Massa, D. 2008. *Lower Yuba River Chinook Salmon Escapement Survey: October 2007 – January 2008.* California Department of Fish and Game Annual Report, North Central Region, Chico, CA.

This report presents results of Chinook salmon spawning escapement surveys during 2007 to 2008, as well as summary information from preceding years. Massa (2008) reported that although escapement surveys were conducted on the lower Yuba River to estimate the number of returning adult Chinook salmon since 1953, previous estimates were infrequent and unlike more recent surveys (1994, 1996-2006), because methods were not consistent from year to year. Survey duration and area of sampling varied, resulting in data that were statistically inappropriate for trend analysis.

Massa (2008) estimated 2,604 Chinook salmon (2,423 adult and 81 grilse) spawned in the lower Yuba River survey area during the period of October 2, 2007 to January 3, 2008. This estimate was the lowest observed in twelve consecutive years, and was less than a third of the escapement estimate reported for 2006 (8,231 fish).

Separate estimates could not be created for each of the six survey reaches due to low sample size, although previous surveys have suggested that the majority of spawning occurs above DPD (JSA 2006; Massa 2006; Massa 2007). Approximately 70% of the returning escapement in 2006 utilized the area between the Narrows pool and DPD (Massa 2007). Massa (2008) stated that although it is difficult to accurately determine time of spawning from carcass recovery dates, spring-run carcasses, as identified through CWT recovery, were recovered between October 3, 2007 and October 16, 2007. As observed in 2005, all spring-run Chinook salmon recoveries were from the Feather River Hatchery. A single fall-run recovery also originated from the Feather River Hatchery. No recoveries were observed from the CDFG's wild-tagging operation (*Lower Yuba River Life History Investigation*) during this survey. As observed in 2005 and 2006, the majority of Feather River Hatchery strays were from plants transported far from their natal hatchery, mostly to San Pablo Bay via the Wickland Oil net pens (Massa 2008).

Beginning in 2005, the Feather River Hatchery began tagging early arriving (May/June) spring-run Chinook salmon with floy tags and releasing these fish to the river. Incidentally, two of these floy-tagged Feather River spring-run Chinook salmon have been collected during escapement surveys on the lower Yuba River - one in 2006 and one in 2007 (Massa 2008).

Scale samples were collected at random from October 2, 2007 through January 3, 2008. As a result of low overall sample numbers, an attempt was made to collect scales from all fresh carcasses encountered. A total of 346 samples were collected.

Annual population abundance estimates of Chinook salmon for the Sacramento-San Joaquin River system, including the lower Yuba River, have been complied by the CDFG Fisheries Branch Anadromous Resource Assessment Unit and presented as an independent dataset in GrandTab. The GrandTab report is a compilation of sources estimating the late-fall, winter, spring, and fall-run Chinook salmon populations for all streams surveyed in the Central Valley and are based on counts of fish entering hatcheries, migrating past dams, annual carcass surveys, live fish counts, and ground and aerial redd surveys. Population estimate sources for GrandTab include: (1) CDFG; (2) USFWS; (3) CDWR; (4) the East Bay Municipal Utilities District; (5) PG&E; and (6) the Fisheries Foundation of California. Fall-run Chinook salmon have been monitored since 1952, spring-run Chinook salmon since 1960, and late-fall and winter Chinook salmon runs since 1970.

Zimmerman, C., G. Edwards, and K. Perry. 2009. *Maternal origin and Migratory History of Steelhead and Rainbow Trout Captured in Rivers of the Central Valley, California.* Trans. of the Amer. Fish. Soc. 138:280-291. February 23, 2009.

Zimmerman et al. (2009) stated that the treatment of sympatric life history forms as single populations exhibiting polyphenism or as reproductively isolated populations has profound implications in decisions related to protection and recovery of species (Zimmerman and Reeves 2000; McEwan 2001; as cited in Zimmerman et al. 2009). Zimmerman et al. (2009) analyzed otolith strontium:calcium (Sr:Ca) ratios to determine maternal origin (anadromous vs. non-anadromous) and migratory history (anadromous vs. non-anadromous) of *O. mykiss* collected in Central Valley rivers between 2001 and 2007, including the lower Yuba River.

Fish were captured by various sampling techniques including beach seining, rotary screw trapping, electrofishing, carcass surveying, and hook and line.

A total of 964 otoliths were examined to determine age, maternal origin, and migratory history. Age-0 fish were collected from only three sites: Deer Creek, lower Yuba River, and Calaveras River. Zimmerman et al. (2009) found that age and length composition of samples varied among locations, and that mean length-at-age varied among locations. They determined mean fork length of steelhead and rainbow trout collected from the lower Yuba River as age-0 (68mm ± 24mm), age-1 (228mm ± 2mm), age-2 (271mm ± 24mm), age-3 (348mm ± 25mm), and age-4 (424mm ± 29mm).

Of the 964 otoliths examined from Central Valley streams, 224 were classified as steelhead progeny and 740 were classified as progeny of rainbow trout females. The proportion of steelhead progeny in the lower Yuba River (about 13%) was intermediate to the other rivers examined (Sacramento, Deer Creek, Calaveras, Stanislaus, Tuolumne, and Merced), which ranged from 4% in the Merced River to 74% in Deer Creek (Zimmerman et al. 2009).

Mitchell, W.T. 2010. *Age, Growth, and Life History of Steelhead Rainbow Trout (Oncorhynchus mykiss) in the Lower Yuba River, California.* ICF International. March 2010.

Steelhead/rainbow trout age structure, life history, stock composition, origin, and growth in the lower Yuba River were analyzed using scales, which is an effective method for determining these life history characteristics, as well as the relationships between growth, life history variation, and recruitment (Mitchell 2010). Scales from 787 juvenile and adult steelhead/rainbow trout were collected in the lower Yuba River from 1998 to 2007. Most fish were collected by trapping, angling, and electrofishing. Upstream migrants were captured at DPD between November 11, 2000 and March 12, 2001. The remainder of sampling was conducted opportunistically via hook-and-line angling from 2004 to 2007.

Scales were taken from 142 age 0+ and age 1+ steelhead/rainbow trout collected by electrofishing during July to September 1999 and July to August 2000. Sampled fish averaged 107 mm FL and ranged from 68 to 198 mm FL. Of 467 juvenile and adult steelhead rainbow trout collected by angling between September 1998 and June 2007, only four fish were identified as steelhead and ranged in length from 438 to 559 mm FL. Scales taken from 71 juvenile and adult steelhead/rainbow trout trapped in the fish ladder at DPD from November 1, 2000 through March 28, 2001averaged 401 mm FL and ranged from 220 to 720 mm FL, with ten fish identified as steelhead and ranging in length from 453 to 720 mm FL (Mitchell 2010).

Scale analysis indicates the presence of at least four age categories for steelhead/rainbow trout in the lower Yuba River that spent 1, 2, or 3 years in freshwater and 1 year at sea before spawning. Mitchell (2010) does not report any steelhead/rainbow trout spending more than 1 year at sea before returning to spawn. Two of the 14 steelhead sampled were returning to spawn for a second time. A relatively higher proportion of age-3/1 were reported.

Results from Mitchell (2010) indicate steelhead/rainbow trout in the lower Yuba River are exhibiting a predominately residential life history pattern. He found that only 14% of samples gathered from DPD, and 1% from angling were anadromous steelhead adults. Based on scale analysis, nearly all fish had spent 1 to 4 winters in freshwater with no evidence of ocean residence (Mitchell 2010).

Mitchell (2010) reported that back-calculation of fork length (FL) showed substantial variability in size and growth for steelhead/rainbow trout juvenile age classes (0+ and 1+ fry). Late summer emerging 0+fry were smaller (<70mm FL) than average (108mm FL) by the end of their first winter, while early spring emergers were generally larger than average by the end of winter. Age 1+ juveniles grew 146mm in length following their first winter, reaching an average FL of approximately 265mm by the end of their second winter. Analysis of scale growth patterns indicate a period of accelerated growth during the spring peaking in the summer months, and followed by decelerated growth in the fall and winter. Following the second winter, steelhead/rainbow trout in the lower Yuba River exhibit reduced annual growth in length with continued growth in mass until reaching reproductive age. Additionally, more rapid juvenile and adult steelhead/rainbow trout growth occurred in the lower Yuba River compared to the lower Sacramento River and Klamath River steelhead/rainbow trout, with comparable growth rates to steelhead/rainbow trout in the upper Sacramento River (Mitchell 2010).

Garza, J.C., and D.E. Pearse. (undated). *Population Genetic Structure of Oncorhynchus mykiss in the California Central Valley.* Final report for California Department of Fish and Game Contract # PO485303. University of California, Santa Cruz and NOAA Southwest Fisheries Science Center.

Garza and Pearse (undated) reported that genotype data was collected from 18 highly variable microsatellite molecular markers in more than 1,600 fish from the Central Valley region sampled by CDFG biologists, as well as a sample of adult steelhead from Battle Creek sampled by the USFWS. Analyses of these data examined population structure within the region, relationships between populations above and below barriers to anadromy, relationships of Central Valley populations with coastal steelhead populations, and population genetic diversity.

The analysis in Garza and Pearse (undated) focused on 17 initial “population” samples, comprised of fish sampled from the Kings, Tuolumne, Stanislaus, Calaveras, American, Yuba, Feather, Butte, Deer, Battle, and McCloud river sub-basins. Additional analyses were conducted with data from the same microsatellite markers in rainbow trout hatchery stocks and steelhead from coastal and California Central Valley populations. These analyses examined whether specific fish are, or are descended, from hatchery strains used in local stocking efforts, as well as providing biogeographic context for the Central Valley regional results. Garza and Pearse (undated) reported that in general, all naturally-spawned populations within the Central Valley basin were closely related, regardless of whether they were sampled above or below a known barrier to anadromy. This is due to some combination of pre-impoundment historic shared ancestry, downstream migration and, possibly, limited, anthropogenic, upstream migration. However, lower genetic diversity in above-barrier populations indicates a lack of substantial genetic input upstream and highlights lower effective population sizes for above-barrier populations. In contrast to coastal steelhead, close relationships were not found between populations above and below barriers within the same sub-basin. Instead, above-barrier populations clustered with one another and below-barrier populations clustered with one another in all tree analyses. The consistent clustering of the above-barrier populations with one another, and their position in the California-wide trees, indicate that they are likely to most accurately represent the ancestral population genetic structure of steelhead in the Central Valley (Garza and Pearse undated).

Garza and Pearse (undated) also identified possible heterogeneity between samples from different tributaries of the upper Yuba and Feather rivers, although Linkage (gametic phase) Disequilibrium (LD) was lower in these populations. Other than in the Nimbus Hatchery sample, only one other fish, in the lower Yuba River population, was identified as a hatchery fish with high confidence. In fact, the salient characteristic of population structure for Central Valley *O. mykiss* inferred from this study is that the populations of naturally-spawning fish sampled here are all closely related, regardless of whether they are currently above or below barriers to anadromy. This indicates that hatchery rainbow trout planted above dams in the region have not replaced *O. mykiss* populations trapped upstream of dam construction, fish commonly referred to as residualized steelhead (Garza and Pearse undated).

Garza and Pearse (undated) stated that these results indicate smaller effective size in above-barrier populations, which is consistent with the expectation of decreased upstream migration and the lost influx of new genes through migration. This situation will lead to gradual genetic erosion, which can contribute to eventual population extirpation (Srikwan and Woodruff 2000 as cited in Garza and Pearse undated). Facilitating upstream migration might help to alleviate such eventual genetic effects, but may also counteract the potential adaptation of above-barrier populations that is expected because of the strong selection against downstream migration in such populations (Garza and Pearse undated).

Garza and Pearse (undated) stated that efforts to integrate above-barrier populations with those below dams to increase overall effective size of steelhead populations and reestablish historical connectivity should also proceed with great caution, as these fish have been under very strong selection against anadromy since dam construction. The consequences of such integration are not known, but could range from beneficial increases in genetic diversity and effective size, to decreased fitness of hybrids and various ecological interactions such as competition or direct predation (Garza and Pearse undated).

OTHER RELEVANT DOCUMENTS

CDFG. 1993. *Restoring Central Valley streams: A plan for action*. The Resources Agency, CDFG, Sacramento, California. November 1993.

The CDFG (1993) report assessed the condition of Central Valley anadromous fish habitat and associated riparian wetlands, and set priorities for taking actions to restore and protect aquatic ecosystems that support fish and wildlife and to protect threatened and endangered species. Priorities were identified to guide future efforts toward restoration. On the lower Yuba River, priority actions included installing fish screens on lower Yuba River diversions, improving spawning and rearing habitat, and protecting and managing riparian habitat. Recommendations for administrative actions to improve anadromous fish habitat in the lower Yuba River also included specific stream flow recommendations which were consistent with the CDFG (1991) report titled *The Lower Yuba River Fisheries Management Plan Final Report*. The recommendations also included target water temperatures, although no specific water temperature studies, flow-temperature relationships, or water temperature availability studies were presented.

Busby, P.J., T.C. Wainwright & G.J. Bryant. 1996. *Status review of West Coast steelhead from Washington, Idaho, Oregon, and California*. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-27. 261 pp.

The NMFS Biological Review Team (BRT) prepared a Status review of West Coast steelhead from Washington, Idaho, Oregon, and California which presented environmental and biological information concerning steelhead populations in Washington, Idaho, Oregon, and California. The BRT identified 15 steelhead ESUs throughout the region of evaluation, 12 of which include coastal forms including the Central Valley, and 3 of which include inland forms.

Within the Central Valley, the Yuba Rivers and others (i.e., the American, Feather, and possibly the upper Sacramento and Mokelumne rivers), were identified as have naturally spawning populations (CDFG 1995 as cited in Busby et al. 1996), but have had substantial hatchery influence and their ancestry was not clearly known. Genetic data was the primary evidence considered for the reproductive isolation criterion, supplemented by inferences about barriers to migration created by natural geographic features.

This document reported conclusions reached by the BRT for determining whether the listing of west coast steelhead under the ESA would be warranted. The BRT reported that few detailed studies existed on the relationship between resident and anadromous O. mykiss in the same location, but that each of the ESUs included multiple spawning and resident populations of O. mykiss. Additionally, genetic studies generally show that rainbow trout and steelhead from the same area may share a common gene pool. The BRT reports that progeny of nonanadromous O. mykiss can be anadromous, and that anadromous O. mykiss can produce nonanadromous progeny, however, evidence exists to suggest substantial genetic divergence between resident and anadromous fish in areas where resident populations have been isolated by long-standing natural barriers.

The BRT reported the status of native natural steelhead in the Yuba River as unknown, although the population appeared to be stable and supporting a fishery (McEwan and Jackson 1996 as cited in Busby et al. 1996) likely due to influence by Feather River Hatchery fish. The BRT also concluded that the Central Valley steelhead ESU was in danger of extinction, and that introgression from hatchery fish may be a concern in the Yuba River and throughout the Central Valley.

Biologists familiar with the stock of the Yuba River steelhead suggest that almost no natural production of steelhead occurs on the Yuba River (Hallock 1989 as cited in Busby et al. 1996). However, Busby et al. 1996 also identified two areas of scientific uncertainty regarding natural reproducing including as deficiency of recent run-size estimates for natural steelhead stocks, and uncertainty in determining which populations to include in the ESU considering that there was substantial question regarding the genetic heritage of natural populations in the Central Valley.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1996. *Historical and present distribution of Chinook salmon in the Central Valley Drainage of California.* In: Sierra Nevada Ecosystem Project, Final Report to Congress, vol. 111, Assessments, Commissioned Reports, and Background Information (University of California, Davis, Centers for Water and Wildland Resources, 1996).

This report summarized historical accounts of spring-run Chinook salmon populations, including the Yuba River. Yoshiyama et al. (1996) reported that prior to the impacts associated with gold mining, dam construction, and water diversions, large numbers of spring-run Chinook salmon were taken by miners and Native Americans as far upstream as Downieville on the North Yuba River. During the construction of the original Bullards Bar Dam (1921 - 1924), numerous Chinook salmon congregated and died below the dam. Due to their presence high in the watershed, Yoshiyama et al. (1996) concluded that these fish were spring-run Chinook salmon. In addition, this report indicated that prior to the construction of Englebright Dam, CDFG fisheries biologists observed large numbers of steelhead spawning in the uppermost reaches of the Yuba River and its tributaries.

CDFG. 1996. *Steelhead Restoration and Management Plan for California.* Prepared by D. McEwan and T. Jackson. Inland Fisheries Division, Sacramento, CA.

CDFG developed the *Steelhead Restoration and Management Plan for California* (Steelhead Plan) in 1996 as a component of the SB 2261 program. As mandated by *The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 (SB 2261),* a policy of the State of California is to significantly increase the natural production of salmon and steelhead, and directed CDFG to develop a program that strives to double naturally spawning anadromous fish populations by the year 2000.

CDFG (1996) reported that the Yuba River historically supported the largest, naturally-reproducing, persistent population of steelhead in the Central Valley, and that wild stocks in the Sacramento River system are mostly confined to upper Sacramento River tributaries such as Antelope, Deer, and Mill creeks and the Yuba River. This report, referencing CDFG (1991), stated that the lower Yuba River maintained natural production, and was managed by CDFG as a naturally sustained population. CDFG (1996) reported that the run size for the Yuba River in 1984 was estimated to be about 2,000 steelhead (CDFG 1984 as cited in CDFG 1996).

This report stated that as of 1996, the status of the Yuba River steelhead population was unknown, although it appeared to be stable and continued to support a steelhead fishery, and that the Yuba River was essentially the only wild steelhead fishery remaining in the Central Valley. This report, referencing CDFG (1991), reported that the lower Yuba River was annually stocked with 27,270 to 217,378 yearling steelhead from the Coleman National Fish Hatchery between 1970 to 1979, and that as of 1996 it was unknown whether the steelhead stock was of native origin or was derived from the planting of Coleman National Fish Hatchery fish. Although no specific water temperature studies, flow-temperature relationship evaluations, or water temperature availability studies were presented, CDFG (1996) suggested that low flows and elevated water temperatures resulting from water diversions had affected the anadromous populations of the lower Yuba River.

The CDFG (1996) report recommended that efforts should continue to seek adequate flows and temperatures, and implement restoration actions for the lower Yuba River. This report also stated that CDFG should continue to manage the lower Yuba River as a wild steelhead fishery, and recommended that hatchery steelhead not be planted in the lower Yuba River.

NMFS. 1997. *Status review update for West Coast steelhead from Washington, Idaho, Oregon, and California.* Memorandum date 7 July 1997 from the Biological Review Team to the National Marine Fisheries Service Northwest Regional Office. Online at http://www.nwr.noaa.gov/1salmon/salmesa/pubs/sru970707.pdf

This report summarizes conclusions of the NMFS Biological Review Team (BRT) regarding the Central California Coast, South-Central California Coast, Southern California, Central Valley, Upper Columbia River, and the Snake River Basin ESUs. The west coast steelhead biological review team (BRT), convened by NMFS, reviewed comments and new data received from federal, state, and tribal agencies, nine west coast fisheries scientists, and the public solicited in response to the proposed rule, Busby et al. 1996 Status Review for West Coast Steelhead from Washington, Idaho, Oregon, and California August 1996.

The BRT notes new information from CDFG, including some additional counts of juvenile steelhead in the mainstem San Joaquin River and the Stanislaus River, and noted additional information on the distribution of steelhead in the San Joaquin System (Yoshiyama et al. 1996 as cited in NMFS 1997). However, the BRT determined that for the Central Valley ESU, no new information was provided that was sufficient to estimate population trends. No changes were made to the geographic delineation of the Central Valley steelhead ESU, ESU distribution, population-trends, or to the assessment of Central Valley steelhead ESU risk of extinction. Additionally, the BRT concluded that any ESU identified in geographic region of California's Central Valley would almost certainly be considered at risk of extinction. The BRT recognized that native steelhead may no longer exist in many streams in the Central Valley and that under some ESU configurations, identification of any native, naturally-spawning fish of ESA concern may be difficult.

CDFG. 1998. *A Status Review of the Spring-Run Chinook Salmon (Oncorhynchus tshawytscha) in the Sacramento River Drainage***.** Candidate Species Status Report 98-01. CDFG, Sacramento, CA.

This status report was prepared in response to a petition to list Sacramento River spring-run Chinook salmon as an endangered species pursuant to the California Endangered Species Act (Fish and Game Code Sections 2050 *et seq*.). Based on information available to CDFG at that time, and in consideration of existing and future proposed actions affecting spring-run Chinook salmon, CDFG (1998) concluded spring-run Chinook salmon to be threatened.

Regarding the lower Yuba River, this report suggested that spring-run Chinook salmon populations may be hybridized to some degree with fall-run Chinook salmon due to lack of spatial separation of spawning habitat. CDFG (1998) suggested measures to improve habitat and survival of spring-run Chinook salmon in the lower Yuba River, including: (1) supplement flows with water acquired from willing sellers; (2) reduce flow fluctuations; (3) maintain adequate instream flows for temperature control; (4) screen all diversions to meet CDFG and National Marine Fisheries Services (NMFS) criteria; (5) improve fish bypass at water diversions; (6) improve adult and juvenile passage at DPD; (7) maintain and improve riparian habitat; (8) operate reservoirs to provide adequate water temperatures; (9) evaluation of the feasibility of removal of Englebright Dam to re-introduce spring-run Chinook salmon to their historic range; and (10) changing CDFG fishing regulations to prevent take of adult spring-run Chinook salmon during upstream migration.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grand, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. *Status review of Chinook salmon from Washington, Idaho, Oregon, and California*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

This document reports results of the comprehensive ESA status review of Chinook salmon from Washington, Oregon, California, and Idaho. To provide a context for evaluating these populations of Chinook salmon, biological and ecological information for Chinook salmon in British Columbia, Alaska, and Asia were also considered. NMFS formed a team of scientists with diverse backgrounds in salmon biology to conduct this review. This Biological Review Team (BRT) for Chinook salmon included fisheries scientists, and federal and state agencies.

The BRT addressed issues related to the definition of Distinct Population Segments, population abundance, and causes of decline for Chinook salmon. Ecoregions delineated in this report include those geographic areas throughout the broad distribution of Chinook salmon, including California's Central Valley. The BRT analyzed regional variations in life-history, ecology, and genetic information as part of the assessment regarding California Central Valley Chinook salmon. The report includes discussion and conclusions specific to Central Valley spring-run and fall-run ESU's found in the Sacramento, Feather, and Yuba rivers.

NMFS (2007) reports that historically, spring-run Chinook salmon were predominant throughout the Central Valley, occupying the upper and middle reaches (450-1,600 m in elevation) of several rivers including Yuba, Feather, and Sacramento rivers, with smaller populations in most other tributaries with sufficient cold-water flow to maintain spring-run adults through the summer prior to spawning (Stone 1874, Rutter 1904, and Clark 1929 as cited in NMFS 2007). CDFG (1965) as cited in NMFS (2007), reported spring-run Chinook salmon to be extinct in the Yuba, American, Mokelumne, Stanislaus, Tuolumne, Merced, and San Joaquin Rivers. However, populations of spring-run Chinook salmon in the Sacramento and Yuba rivers were identified as being at a moderate risk of extinction (Nehlsen et al. 1991 as cited in NMFS 2007).

Calkins et al. (1940) estimated abundance at 55,595 fish in the Sacramento River Basin during the period 1931-39 (NMFS 2007). In the early 1960s, adult escapement was estimated to be 327,000, predominantly in the mainstem Sacramento River (187,000), but with substantial populations in the Feather (50,000), American (36,000), and Yuba (22,000) Rivers and in Battle Creek (21,000); remaining escapement was scattered among numerous tributaries (CDFG 1965 as cited in NMFS 2007).

NMFS. 1998. *Endangered and threatened species: Threatened status for two ESUs of steelhead in Washington, Oregon, and California*. Federal Register [Docket No. 980225046-8060-02, 19 March 1998] 63(53):13347.

NMFS filed a final rule, notice of determination regarding the listing of two *O. mykiss* ESUs as threatened under the Endangered Species Act (ESA) located in Washington, Oregon, and California (Lower Columbia River) and including the Central Valley. The Central Valley, California steelhead ESU occupies the Sacramento and San Joaquin Rivers and their tributaries. NMFS (1998) has identified only naturally spawned populations of steelhead (and their progeny) residing below naturally and man-made impassable barriers (e.g., impassable waterfalls and dams) as threatened.

The BRT identified long-term declines in abundance, small population sizes in the Sacramento River, and the high risk of interbreeding between hatchery and naturally spawned steelhead as major concerns for steelhead in this ESU. Addition, the BRT emphasized the significant loss of historic habitat, degradation of remaining habitat from water diversions, reduction in water quality and other factors, and the lack of monitoring data on abundance as other important risk factors for this ESU. During the examination of the relationship between hatchery and natural populations of steelhead assessed whether any hatchery populations are essential for their recovery. At this time, no hatchery populations are deemed essential for recovery (and hence listed) in either of the two listed ESUs. At this

time, NMFS is listing only anadromous life forms of *O. mykiss*. NMFS(1998) concluded that Central Valley steelhead warrant listing as a threatened species at this time but may be reconsidered if new information indicates a substantial change in the biological status of this ESU or the direction of restoration efforts in the Central Valley.

YCWA. 2000. *Draft Environmental Evaluation Report, Yuba County Water Agency, Yuba River Development Project* (FERC No. 2246). Prepared by Yuba County Water Agency, Surface Water Resources Inc., and Jones and Stokes Associates. December 2000.

An Environmental Evaluation Report was prepared to address potential effects of the operation of Yuba River Development Project (YRDP) on anadromous salmonids in the lower Yuba River below Englebright Dam. The report was prepared in response to the listing of steelhead as threatened in March 1998, the listing of spring-run Chinook salmon in September 1999, and designation of critical habitat in February 2000. The report evaluated potential flow and water temperature related effects, and compared instream conditions prior to the completion of New Bullards Bar Dam in 1970, and since that time. In addition, the report listed several conservation measures being undertaken as part of YRDP operations in the lower Yuba River.

Yoshiyama, R., E. Gerstung, F. Fisher, and P. Moyle. 2001. *Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California*. In Contributions to the Biology of Central Valley Salmonids, California Fish and Game, Bulletin 179, Volume 1. Salmonid Symposium, Bodega Bay, California. October 22-24, 1997, Randall Brown, editor.

This report characterized historic distributions of Chinook salmon throughout the Central Valley of California and states that both spring- and fall-run Chinook salmon historically occurred in the Yuba River watershed.

Yoshiyama et al. (2001) reported that salmon were caught in the North Fork Yuba River by PG&E workers in the Bullards Bar area during the 1898–1911 period of operation of the Yuba Powerhouse Project, and that salmon ascended in “considerable numbers” up to Bullards Bar Dam during its period of construction (1921–1924). This report stated that there were no natural barriers above the Bullards Bar Dam site, so Chinook salmon and

steelhead presumably had been able to ascend a considerable distance up the North Fork Yuba River, potentially as far as Downieville at the mouth of the Downie River (CDFG file records as cited in Yoshiyama et al. 2001). This report further suggested that: (1) there were no natural obstructions from Downieville upstream to Sierra City, where Salmon Creek enters, spring-run Chinook salmon and steelhead most likely were able to traverse that distance; (2) spring-run Chinook salmon and steelhead probably ascended the higher-gradient reaches up to about two miles above the juncture of Salmon Creek; and (3) the absolute upstream limit on the North Fork Yuba River would have been Loves Falls for spring-run Chinook salmon and steelhead.

This report stated that in the Middle Fork Yuba River, there were no significant natural obstructions except for a 10-foot falls in the lower reach, and Chinook salmon possibly had access to a considerable portion of the Middle Fork Yuba River. Both Chinook salmon and steelhead were observed in the lower part of the Middle Fork Yuba River, near where the North Fork Yuba River joins, during a CDFG survey in 1938 (CDFG unpublished data as cited in Yoshiyama et al. 2001). Steelhead were found as far upstream as the mouth of Bloody Run Creek (CDFG unpublished data as cited in Yoshiyama et al. 2001). Whether Chinook salmon also reached that far remains conjectural. Yoshiyama et al. (2001) concluded that direct information was lacking and it was uncertain if many salmon were able to surmount the 10-foot falls on the lower river, and they conservatively considered the falls located 1.5 mi. above the mouth as the effective upstream limit of salmon in the Middle Fork Yuba River.

Yoshiyama et al. (2001) reported that little is known of the original distribution of salmon in the South Fork Yuba River where the Chinook salmon population was severely depressed and upstream access was obstructed by dams when CDFG began surveys in the 1930s. There were records of salmon occurring within one to two miles upstream of the mouth of the South Fork Yuba River (DFG unpublished data as cited in Yoshiyama et al. 2001). A substantial cascade with at least a 12-foot drop, located one-half mile below the juncture of Humbug Creek (CRA 1972; Stanley and Holbek 1984; as cited in Yoshiyama et al. 2001), may have posed a significant obstruction to salmon migration, but it was not necessarily a complete barrier. However, Yoshiyama et al. (2001) categorized the cascade below Humbug

Creek as essentially the historical upstream limit of salmon during most years of natural streamflows. They also stated that steelhead were known to have ascended the South Fork Yuba River as far as the juncture of Poorman Creek near the present town of Washington (CDFG unpublished data as cited in Yoshiyama et al. 2001), and perhaps some spring-run Chinook salmon historically also reached that point.

CDWR and USACE. 2003a. *Daguerre Point Dam Fish Passage Improvement Project 2002 Fisheries Studies – Analysis of Potential Benefits to Salmon and Steelhead from Improved Fish Passage at Daguerre Point Dam*. Prepared for CDWR and USACE by ENTRIX, Inc. and J. Monroe. March 2003.

The purpose of this report was to examine available data on habitat conditions, flow, passage, and spawning above and below DPD to assist in the analysis of potential benefits or impacts of improved passage at the dam prior to selection of an alternative concept(s) for consideration in the environmental review process. The report included a review of available data from CDFG, USFWS, JSA, and other sources. It also incorporated field observations of river habitat conditions made by ENTRIX, Inc. (ENTRIX) in September of 2002 (ENTRIX and J. Munroe 2003 as cited in CDWR and USACE 2003). The report described channel morphology, spawning habitat suitability, historical and potential habitat use by species, water temperature, hydrology, as well as discussions regarding conceptual benefits and impacts for different fish passage alternatives.

CDWR and USACE. 2003b. *Daguerre Point dam fish passage improvement project 2002 water resources studies.* Prepared for CDWR and USACE by ENTRIX, Inc. June 2003.

The purpose of this report was to summarize and analyze the available hydrologic (including groundwater and flooding), hydraulic, and sediment data for the lower Yuba River. This report characterized the conditions on the river, including hydrology (groundwater and surface water), flow hydraulics, sediment transport, and flooding as part of the DPD Fish Passage Improvement Project.

USACE. 2003. *Daguerre Point Dam Fish Passage Improvement Project – Alternative Concepts Evaluation.* Prepared for ENTRIX, Inc. by W. Rodgers, Inc. September 2003.

USACE (2003) focused conceptually on improving fish passage for native anadromous fish species at DPD while maintaining water interests and flood management. Project alternative feasibility was assessed with consideration given to fisheries benefits and limitations, environmental impacts, sediment/mercury containment, water supply impacts, operation and maintenance requirements, engineering and construction demands, and economics.

YCWA. 2003. *Initial Study/Proposed Mitigated Negative Declaration for the Narrows 2 Powerplant Flow Bypass System Project*. November 2003.

The Initial Study (YCWA 2003) addressed the environmental impacts of construction and operation of a synchronous full-flow bypass at YCWA's Narrows 2 Powerplant. Prior to implementation of the Narrows 2 Powerplant Full-flow Bypass System, the Narrows 2 Powerplant did not allow the full-flow capacity to be bypassed during non-operation. Even a brief loss of power resulted in a substantial loss of river flow. YCWA (2003) suggested that any facility shutdowns, particularly those occurring during the warm and dry summer months, could result in flow and temperature conditions in the lower Yuba River potentially detrimental to fish by increasing water temperatures in the river above physiologically suitable levels, or reducing flow magnitude to levels that could result in redd dewatering or juvenile stranding.

The primary objectives of the Narrows 2 Powerplant Full-flow Bypass System Project were to: (1) maintain more stable releases from the Narrows 2 Powerplant during emergency and maintenance shutdowns at the same flow rate as was being discharged before the shutdown occurred; and (2) make the flow fluctuation and reduction criteria stated in YCWA's FERC License No. 2246 more protective of downstream fish species than the criteria that were previously stated in that license. Detailed information on the population status, lifestages, general population trends, and critical habitat for Central Valley spring-run Chinook salmon and Central Valley steelhead in the lower Yuba was provided in Appendix B to the IS/MND.

Since the issuance of the SWRCB Yuba Accord Water Rights Decision (D-1644) in March 2008, a full-flow bypass structure has been installed on the Narrows 2 hydropower facility which will essentially eliminate the potential for detrimental flow and temperature

fluctuations to occur in the lower Yuba River associated with maintenance and operation of the Narrows 2 Powerplant.

YCWA, FERC, and NMFS. 2003. *Biological Assessment, Yuba River Development Project* (FERC No. 2246) Proposed License Amendment. Prepared for Yuba County Water Agency, Federal Energy Regulatory Commission, and National Marine Fisheries Services by Surface Water Resources, Inc.

This Biological Assessment addressed a proposed amendment to the Federal Power Act (FPA) license for Project No. 2246 issued to the YCWA by the Federal Power Commission (FPC). Pursuant to 50 CFR 402.11, YCWA filed with the Federal Energy Regulatory Commission (FERC), a definitive proposal to amend the license to: (1) authorize YCWA to construct and operate a synchronous full-flow bypass (bypass) at YCWA's Narrows II Powerhouse; and (2) revise the license's flow reduction and fluctuation criteria.

This Biological Assessment concluded that the Proposed Action generally will improve conditions for Central Valley spring-run Chinook salmon and steelhead in the lower Yuba River by largely eliminating adverse effects on those species resulting from unplanned outages at the Narrows 2 Powerhouse; the primary element of the Proposed Action that will have this effect is the installation of a synchronous full-flow bypass at the Narrows II Powerhouse. Biological effects of short-term outages were expected to be eliminated by providing essentially simultaneous restoration of flows. Biological effects of long-term outages on spring-run Chinook salmon and steelhead were expected to be eliminated by allowing YCWA to bypass almost the entire river flow without generating electricity.

CALFED and YCWA. 2005. *Draft Implementation Plan for the Lower Yuba River Anadromous Fish Habitat Restoration: Multi-Agency Plan to Direct Near-Term Implementation of Prioritized Restoration and Enhancement Actions and Studies to Achieve Long-Term Ecosystem and Watershed Management Goals.* Prepared by Lower Yuba River Fisheries Technical Working Group. Funded by CALFED and Yuba County Water Agency. October 2005.

The purpose and goal of the CALFED and YCWA (2005) report was to facilitate the implementation of prioritized actions and studies that intended to protect, enhance, and

restore: (1) the Yuba River aquatic and riparian habitats; (2) the key processes that create and maintain these habitats; and (3) the anadromous fish species that use such habitats.

The report described abiotic (geomorphology, water flow, and water temperature) and biotic (habitat, species-specific profile and population status) conditions in the lower Yuba River watershed to provide a technical basis for the development of species-specific conceptual models to assess how physical conditions may be affecting the anadromous fish species of primary management concern (i.e., spring- and fall-run Chinook salmon, steelhead, green sturgeon, American shad and striped bass). The conceptual models prioritized potential life-stage specific stressors that may negatively affect fish survival, growth or other critical lifecycle processes.

CALFED and YCWA (2005) identified major factors (directly flow-related) influencing the status of naturally-spawning spring-run Chinook salmon and steelhead in the lower Yuba River including: (1) restricted flow-dependent habitat availability; (2) limited habitat complexity and diversity; (3) elevated water temperatures; and (4) flow fluctuations. Major factors (not directly flow-related) influencing the status of naturally-spawning spring-run Chinook salmon and steelhead in the Yuba River were identified as: (1) blockage of historic spawning habitat resulting from the construction of the Englebright Dam in 1941, which has implications for the spatial structure of the populations; (2) impaired adult upstream passage at DPD; (3) unsuitable spawning substrate in the uppermost area (i.e., Englebright Dam to the Narrows) of the lower Yuba River; (4) limited riparian habitats, riverine aquatic habitats for salmonid rearing, and natural river function and morphology; and (5) impaired juvenile downstream passage at DPD.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. *Updated status of federally listed ESUs of West Coast salmon and steelhead.* U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

This report summarizes biological information updated from the 1999 status review for the 26 ESUs of listed salmon and steelhead, and one candidate ESU (lower Columbia coho salmon), and presents the team's conclusions regarding the current risk status of the these ESUs. The status of the Central Valley spring-run Chinook salmon ESU, which includes populations found on the Yuba River, was formally assessed during a coastwide status review (Myers et al. 1998). In June 1999, a BRT convened to update the status of this ESU by summarizing information and comments received since the 1997 status review and presenting BRT conclusions concerning four deferred Central Valley Chinook salmon ESUs (NMFS 1999). The Good et al. (2005) Biological Review Team (BRT) consisted of scientists from the NMFS Northwest and Southwest Fisheries Science Centers, and supplemented by experts on particular species from NMFS and other federal agencies

Good et al. (2005) suggests that previous status reviews were focused primarily on risk assessments, and (apart from the discussion of resident fish in steelhead ESUs) did not consider issues associated with the geographic boundaries, artificial propagation, or non-anadromous resident forms of ESUs. These issues, as well as hatchery information from the Salmon and Steelhead Hatchery Assessment Group (SSHAG), and updated stock histories and biological information for every hatchery population, were further reviewed by Good et al. (2005) to obtain a better understanding of the nature and role of hatcheries associated with each listed ESU and to facilitate conclusions about the ESU/DPS status of resident fish.

Good et al. (2005) reports that of the numerous populations of Central Valley spring-run Chinook salmon once inhabiting Sierra Nevada streams, only the Feather River and Yuba River populations remain. The BRT indicates that little is known about the status of the spring-run Chinook salmon population on the Yuba River, other than that it appears to be small (Good et al. 2005).

The Feather and Yuba rivers contain populations that are thought to be significantly influenced by the Feather River Hatchery spring-run Chinook salmon stock. The Feather River Hatchery spring-run Chinook salmon program releases its production far downstream of the hatchery, causing high rates of straying (CDFG 2001a). The BRT suggests there is concern that Central Valley fall-run and spring-run Chinook salmon have hybridized, and that the Feather River Central Valley spring-run Chinook salmon population is depends on Feather River Hatchery production (Good et al. 2005). The BRT reports the Feather River Hatchery stocks as a major threat to the genetic integrity of the remaining wild, spring-run Chinook salmon populations.

Good et al. (2005) indicates that Yuba River spring-run Chinook salmon, Feather River Hatchery spring-run Chinook salmon, and putative Feather River natural spring-run Chinook salmon, were categorized into a large cluster composed mostly of natural- and hatchery-origin fall-run Chinook salmon. In the original Chinook salmon status review conducted by Myers et al. (1998), a majority of the BRT members concluded that the Central Valley spring-run Chinook salmon ESU was in danger of extinction (Good et al. 2005). Listing of this ESU was deferred, and in the status review update conducted by NMFS (1999), the BRT majority shifted to the view that this ESU was not in danger of extinction, but was likely to become endangered in the foreseeable future (Good et al. 2005). A major reason for this shift was data indicating that a large run of spring-run Chinook salmon on Butte Creek in 1998 was naturally produced, rather than strays from Feather River Hatchery. Naturally spawning spring-run Chinook salmon in the Feather River were included in the listing, but the Feather River Hatchery stock of spring-run Chinook salmon was excluded. Little is known about the status of the spring-run Chinook salmon population on the Yuba River, other than that it appears to be small.

NMFS. 2005. *Preliminary Biological Opinion Based on Review of the Proposed Yuba River Development Project License Amendment for Federal Energy Regulatory Commission License No. 2246, Located on the Yuba River in Yuba County, California, and Its Effects on Threatened Central Valley Spring-Run Chinook Salmon (Oncorhynchus Tshawytscha) and Central Valley Steelhead (O. Mykiss), in Accordance With Section 7 of the Endangered Species Act of 1973, As Amended.* November 4, 2005.

NMFS issued a preliminary biological opinion (BO) to FERC which analyzed the potential effects of the proposed Yuba River Development Plan License Amendment (FERC License No. 2246) on threatened Central Valley spring-run Chinook salmon and Central Valley steelhead. Subsequent to the completion of this BO, the action area was proposed for designation as critical habitat for these two fish species, as well as for the southern-DPS of North America green sturgeon. A final rule designating critical habitat was published September 2, 2005 (70 FR 52488) and became effective January 2, 2006. Therefore the NMFS (2005) Preliminary BO as a final BO considering effects of the Yuba River Development Plan on Central Valley spring-run Chinook salmon and Central Valley

steelhead, and as a conference opinion considering project effects on the Southern-DPS of North American green sturgeon.

NMFS (2005) provided a review of available information that generally described life history characteristics for lower Yuba River threatened species. NMFS (2005) reported that a loss of habitat and altered instream flow conditions were the primary factors affecting the status of critical habitat for spring-run Chinook salmon. Additionally, NMFS (2005) reported that predation by striped bass and largemouth bass may be exacerbated by the alteration of natural flow regimes and structures.

Gard, M. 2007. *Flow-habitat relationships for spring and fall-run Chinook salmon and steelhead/rainbow trout spawning in the Yuba River.* Draft report prepared by the Energy Planning and Instream Flow Branch of the USFWS, Sacramento, CA. April 19, 2007.

This draft report presented flow-habitat relationships for spring- and fall-run Chinook salmon and steelhead/rainbow trout spawning in the lower Yuba River. This draft report used the 2-dimensional hydraulic model River2D and habitat suitability criteria (HSC) developed for the lower Yuba River from data collected during 2000 – 2004. Representatives of YCWA, PG&E, and UC Davis submitted comments on this draft report, requesting necessary revisions to the hydraulic model, and particularly to the HSC development. Although the report was revised in March 2008, The issues raised in the comments remain unresolved.

Lindley, S., R. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. *Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin.* San Francisco Estuary & Watershed Science Volume 5: California Bay-Delta Authority Science Program and the John Muir Institute of the Environment.

This report provided a framework to assess the viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin basin, and included some information regarding the Yuba River. Lindley et al. (2007) reported that adult Chinook salmon expressing the phenotypic timing of adult immigration associated with spring-run Chinook salmon persisted and spawned in the lower Yuba River below the Englebright Dam,

and that the lower Yuba River is among the last Central Valley floor tributaries supporting populations of naturally-spawning spring-run Chinook salmon and steelhead. They reported that in the long-term, the Yuba River has high potential for maintaining suitable anadromous salmonid habitat, despite the expected long-term climate warming, and that under the expected climate warming scenario of about 5°C by the year 2100, substantial salmonid habitat would be lost in the Central Valley, with the Yuba River being one of the only Central Valley tributaries with significant amounts of habitat remaining.

YCWA. 2007. *Draft Environmental Impact Report/Environmental Impact Statement for the Proposed Lower Yuba River Accord.* Prepared for the Department of Water Resources, Bureau of Reclamation and Yuba County Water Agency by HDR|SWRI. June 2007.

The Draft EIR/EIS for the Proposed Lower Yuba River Accord provided a comprehensive compilation of existing information regarding the aquatic resources of the lower Yuba River, as well as descriptions of the development of the Yuba Accord flow schedules and impact evaluation. The Fisheries Chapter of the Draft EIR/EIS consisted of 411 pages, with over 15,000 pages of related model output in the Appendices. Provided below is a brief summary of the most relevant information presented in YCWA (2007) regarding population characteristics of spring-run Chinook salmon and steelhead, and development of the Yuba Accord flow schedules.

Population Characteristics

The spring-run Chinook salmon spawning period extends from September through November, while the embryo incubation life stage generally extends from September to March. Limited redd surveys during late-August and September conducted by CDFG have detected spawning activities beginning during the first or second week of September. They have not detected a bimodal distribution of spawning activities (i.e., a distinct spring-run spawning period followed by a distinct fall-run Chinook salmon spawning period) but instead have detected a slow build-up of spawning activities starting in early September and transitioning into the main fall-run spawning period.

Spring-run Chinook salmon juveniles are believed to rear in the lower Yuba River year-round. In general, juvenile Chinook salmon have been observed throughout the lower Yuba River, but with higher abundances above DPD. This may be due to larger numbers of spawners, greater amounts of more complex, high-quality cover, and lower densities of predators such as striped bass and American shad, which reportedly are restricted to areas below DPD (YCWA 2007).

The spring-run Chinook salmon smolt emigration period is believed to extend from November through June, although based on CDFG's run-specific determinations, the vast majority (approximately 94 percent) of spring-run Chinook salmon were captured as post-emergent fry during November and December, with a relatively small percentage (nearly 6 percent) of individuals remaining in the lower Yuba River and captured as YOY from January through March. Only 0.6 percent of the juvenile Chinook salmon identified as spring-run were captured during April, 0.1 percent during May, and none were captured during June (YCWA 2007).

Steelhead adult immigration and holding in the lower Yuba River extends from August through March (YCWA 2007). Spawning generally extends from January through April, primarily occurring in reaches upstream of DPD. The embryo incubation life stage generally extends from January through May. Juvenile steelhead/rainbow trout are believed to rear in the lower Yuba River year-round.

Steelhead/rainbow trout juveniles have been observed moving downstream past the lower portion of the lower Yuba River during spring and summer months. However, at least some of this downstream movement may be associated with the pattern of flows in the river. Based upon the substantial differences in juvenile steelhead/rainbow trout downstream movements (RST catch data) noted between the 2001 study, and the 2002 and 2004 studies, it is apparent that the increases in juvenile steelhead downstream movement associated with the initiation of the 2001 water transfers were avoided due to a more gradual ramping-up of flows that occurred in 2002 and 2004. The steelhead smolt emigration period is believed to extend from October through May (YCWA 2007).

Yuba Accord Flow Schedules

Development of the flow schedules and the three agreements that comprise the Yuba Accord was a collaborative process that took place over a period of approximately two and a half years. The flow schedules were developed by a Technical Team of biologists representing YCWA, the NGOs, CDFG, NMFS, and USFWS with the express goal of optimizing fisheries conditions in the lower Yuba River. During development of the flow regime for the Yuba Accord, extensive stressor analyses were undertaken which principally considered steelhead, spring-run Chinook salmon, and fall-run Chinook salmon.

A suite of six flow schedules, plus Conference Year rules for 1-in-100 critically dry years, were developed and are based on water availability, including inflow into New Bullards Bar Reservoir and reservoir carry-over storage. In addition to the biological and other science-based considerations, one of the Technical Team's objectives was to maximize the probability of occurrence of the higher flow schedules (1 and 2) while minimizing the probability of occurrence of the very low flow schedules (6 and Conference Year). Based on computer simulation model results, the estimated predicted probabilities of occurrence over the 78-year period of hydrologic record indicate that the two most optimum flow schedules (1 and 2) would be achieved nearly 80 percent of the time.

To support the impact analyses conducted for the Yuba Accord EIR/EIS, hydrologic modeling was used to simulate potential changes in flows and water temperatures in the lower Yuba River that would be expected to occur as a result of implementing the Yuba Accord. The fisheries analyses utilized several methodologies to evaluate project-related impacts, including: (1) a flow-duration assessment; (2) evaluation of flow dependent spawning habitat availability expressed as weighted usable area; and (3) utilization of available data on flow and water temperature relationships to determine the cumulative probabilistic distribution of water temperatures for each month at a given river location.

A statistical water temperature model was developed to evaluate the potential impacts of the alternatives considered in the Yuba Accord EIR/EIS. The statistical model was used to estimate the effects of various New Bullards Bar Reservoir storage regimes, flow releases, and diversions at DPD on water temperatures in the lower Yuba River.

Water temperature evaluations conducted for the Yuba Accord EIR/EIS indicated that Yuba River water temperatures generally remain suitable for all life stages of spring-run Chinook salmon and steelhead with implementation of the Yuba Accord flow schedules. Water temperatures generally remained below 58°F year-round (including summer months) at Smartsville, and generally remain below 60°F year-round at DPD. At Marysville, water temperatures generally remain below 60°F from October through May, and generally remain below 65°F from June through September.

Gard, M. 2008a. *Flow-Habitat Relationships for Juvenile Spring/Fall-Run Chinook Salmon and Steelhead/Rainbow Trout Rearing in the Yuba River.* Draft report prepared by the Energy Planning and Instream Flow Branch of the USFWS, Sacramento, CA.

This draft report presented flow-habitat relationships for spring- and fall-run Chinook salmon and steelhead/rainbow trout juvenile rearing in the lower Yuba River. This draft report used the 2-Dimensional hydraulic model River2D and habitat suitability criteria (HSC) developed for the lower Yuba River from data collected during 2003 – 2005. Representatives of YCWA, PG&E, and UC Davis submitted comments on the draft report requesting necessary revisions to the hydraulic model and HSC development. These comments have not been addressed to date.

Gard, M. 2008b. *Sensitivity Analysis for Flow-Habitat Relationships for Steelhead/Rainbow Trout Spawning in the Yuba River.* Draft report prepared by the Energy Planning and Instream Flow Branch of the USFWS, Sacramento, CA.

This draft report presented a sensitivity analysis that was conducted to examine the effects of alternative criteria on flow-habitat relationships and biological validation for steelhead/rainbow trout spawning in the lower Yuba River. This draft report did not resolve the comments made by representatives of YCWA, PG&E and UC Davis on the Gard 2007 draft report.

Gard, M. 2008c. *Relationships Between Flow Fluctuations and Redd Dewatering and Juvenile Stranding for Chinook Salmon and Steelhead/Rainbow Trout in the Yuba River.* Draft report prepared by the Energy Planning and Instream Flow Branch of the USFWS, Sacramento, CA.

This draft report presented potential relationships between lower Yuba River flow fluctuations and Chinook salmon and steelhead/rainbow trout redd dewatering and juvenile entrapment stranding. These relationships were presented as the percentages of spawning habitat dewatered and area stranded with different flow reductions. The draft report assumed that juvenile salmon would be stranded if the depth at the stranding point is less than the minimum depth at which Gard (2008a) found juvenile salmon during juvenile habitat suitability data collection, and that there would be insufficient intra-gravel flow through a redd if the mean water column velocity at the redd was less than the lowest velocity at which Gard (2007) found a salmonid redd in the lower Yuba River. YCWA has provided comments on this draft report.

NMFS. 2009. *Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon, and the Distinct Population Segment of Central Valley Steelhead.* National Marine Fisheries Service, Southwest Regional Office, Sacramento, California. October 2009.

The NMFS (2009) Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon, and the Distinct Population Segment of Central Valley Steelhead ("Draft Recovery Plan") recognizes the importance and potential to increase spring-run Chinook salmon and steelhead populations in the lower Yuba River. The Draft Recovery Plan (NMFS 2009) established three priority levels to help guide recovery efforts for watersheds that are currently occupied, and are referred to as Core 1, 2, and 3 populations. Core 1 Populations are highest priority, have a known ability or potential to support viable populations, and have the capacity to respond to recovery actions. Spring-run Chinook salmon and steelhead in the lower Yuba River are Core 1 populations. Core 1 populations form the foundation of the recovery strategy, and should be the first focus of an overall recovery effort (NMFS 2009).

The Draft Recovery Plan (NMFS 2009) states that *"…many of the processes and conditions that are necessary to support a viable independent population of spring-run Chinook salmon can be improved with provision of appropriate instream flow regimes, water temperatures, and habitat availability. Continued implementation of the Yuba Accord is expected to address these factors and considerably improve conditions in the lower Yuba River*".

The lower Yuba River, downstream of Englebright Dam, was characterized as having a high potential to support viable populations of spring-run Chinook salmon and steelhead, primarily because: (1) the river supports persistent populations of spring-run Chinook salmon and steelhead; (2) flow and water temperature conditions are generally suitable to support all life stage requirements; (3) the river does not have a hatchery on it; (4) spawning habitat availability does not appear to be limiting; and (5) there is high habitat restoration potential (NMFS 2009).

The Draft Plan (NMFS 2009) states, that in order to secure a viable independent population of spring-run Chinook salmon, and to secure the extant population and promote a viable population of steelhead in the lower Yuba River, several key near-term and long-term habitat restoration actions were identified, including the following:

- Continued implementation of the Yuba Accord flow schedules to provide suitable habitat (flow and water temperature) conditions for all life stages
- Improvements to adult salmonid upstream passage at DPD
- Improvements to juvenile salmonid downstream passage at DPD
- Implementation of a spawning gravel augmentation program in the uppermost reach (i.e., Englebright Dam to the Narrows) of the lower Yuba River
- Improvements to riparian habitats for juvenile salmonid rearing
- Creation and restoration of side-channel habitats to increase the quantity and quality of off-channel rearing (and spawning) areas
- Implementation of projects to increase floodplain habitat availability to improve habitat conditions for juvenile rearing

The Draft Plan (NMFS 2009) identified the following Priority 1 recovery actions for the Yuba River: (1) develop and implement a phased approach to salmon reintroduction planning to recolonize historic habitats above Englebright Dam; and (2) improve spawning habitat in the lower Yuba River by gravel restoration program below Englebright Dam and improve rearing habitat by increasing floodplain habitat availability.

Comments on the Draft Recovery Plan (NMFS 2009), including issues specific to the lower Yuba River and the Yuba River Watershed, have been provided to NMFS. FR (51553-51555) states that all comments received by the due date will be considered before NMFS' decision whether to adopt a final recovery plan. NMFS (74 FR 51553) specifically states that it will consider and address all substantive comments received during the comment period. A Final Recovery Plan has not yet been issued.

CDFG and PG&E. 2009. *Draft Habitat Expansion Agreement for Central Valley Spring-Run Chinook Salmon and California Central Valley Steelhead.* November 2009.

PG&E and CDWR entered into the *Habitat Expansion Agreement for Central Valley Spring-Run Chinook Salmon and California Central Valley Steelhead* (HEA) effective November 20, 2007, with multiple government and non-government entities including American Rivers, Arthur G. Baggett, Jr., CDFG, U.S. Department of Agriculture Forest Service, NMFS, USFWS, and the State Water Contractors. The overall goal of the HEA is to expand the amount of habitat with the physical characteristics necessary to support spawning, rearing and adult holding of spring-run Chinook salmon (and steelhead) in the Sacramento River Basin. Specifically, the Habitat Expansion Threshold (HET) is to expand spawning, rearing and adult habitat sufficiently to accommodate an annual estimated net increase of 2,000 to 3,000 spring-run Chinook salmon for spawning in the Sacramento River Basin. The HET is focused on spring-run Chinook salmon as the priority species, because expansion of habitat for spring-run Chinook salmon typically accommodates steelhead as well (CDFG and PG&E 2009). The intent of the HEA is to create "permanent" solutions to problems which provide benefits through the term duration of a typical FERC license (i.e., up to 50 years).

Substantial efforts have been undertaken to identify, develop and consider the relative merits of habitat restoration actions in the lower Yuba River. The need for, identification of, and relative merits of the actions to expand habitat and accomplish the goals of the Oroville FERC Relicensing HEA regarding biological, physical and operational considerations pertinent to the lower Yuba River were presented in a report as Appendix G to the Draft

HEA during early November 2009. The lower Yuba River has been designated as having a high potential to meet the HEA goals and thresholds. A Final HEA has not yet been adopted.

ONGOING DATA COLLECTION, MONITORING AND EVALUATION ACTIVITIES

LOWER YUBA RIVER ACCORD MONITORING AND EVALUATION PROGRAM

The Yuba Accord River Management Team (RMT) is comprised of representatives of YCWA, NMFS, USFWS, CDFG, PG&E, CDWR, and the non-governmental organizations (NGOs) that are parties to the Fisheries Agreement of the Yuba Accord (South Yuba River Citizens League, Trout Unlimited, Friends of the River, The Bay Institute). The RMT, in collaboration with representatives from University of California at Davis and the Pacific States Marine Fisheries Commission, has developed a Monitoring and Evaluation Program (M&E Program) to guide the efficient expenditure of approximately $6 million to evaluate the effects of implementation of the Yuba Accord on the aquatic resources of the lower Yuba River over the period extending from 2008 to 2016. Monitoring and data from implementation of the M&E Program will be complied into annual reports and available at the RMT website www.yubaaccordrmt.com. The M&E Program embraces a monitoring-based adaptive management approach to increase the effectiveness of, and to address the scientific uncertainty associated with, specific monitoring and study activities, and restoration actions. Within the framework of this M&E Program, the RMT retains the flexibility to revise monitoring actions to address specific issues or obtain additional information. In addition, the parties to the Fisheries Agreement of the Yuba Accord intended that the monitoring and data collection activities implemented via the M&E Program will produce a useful database for the proceedings of the Federal Energy Regulatory Commission (FERC) regarding the relicensing of YCWA's Yuba River Development Project.

In addition to monitoring and evaluation of the fish community, the fisheries evaluations in this M&E Program focus on steelhead/rainbow trout and the two principal Chinook salmon runs that are known to use the lower Yuba River (i.e., fall-run and spring-run[1,2] Chinook salmon), although evaluations of Chinook salmon exhibiting the phenotypic characterization of lifestage

[1] Federally listed as threatened.
[2] State listed as threatened.

periodicities associated with late fall-run Chinook salmon also are included[3]. Regarding steelhead/rainbow trout, the physical appearance of adults and the presence of seasonal runs and year-round residents indicate that both sea-run (steelhead[1]) and resident rainbow trout exist in the lower Yuba River. Thus, it is recognized that both anadromous and resident lifehistory strategies of *O. mykiss* have been and continue to be present in the lower Yuba River, resulting in the use of the term "steelhead/rainbow trout" when referring to *O. mykiss* in this document.

The primary purpose of the M&E Program is to provide the monitoring data necessary to evaluate whether implementation of the Yuba Accord will maintain fish resources (i.e., the fish community including native fish and non-native fish) of the lower Yuba River in good condition, and will maintain viable anadromous salmonid populations. The "Viable Salmonid Population" (VSP) concept was developed by McElhany et al. (2000; as cited in the M&E Program) in order to facilitate establishment of Evolutionarily Significant Unit (ESU)-level delisting goals and to assist in recovery planning by identifying key parameters related to population viability. Four key parameters were identified by McElhaney et al. (2000; as cited in the M&E Program) as the key to evaluating population viability status, including: (1) abundance; (2) productivity; (3) diversity; and (4) spatial structure. McElhaney et al. (2000; as cited in the M&E Program) interchangeably use the term population growth rate (i.e., productivity over the entire life cycle) and productivity. Good et al. (2007; as cited in the M&E Program) used the term productivity when describing this VSP parameter, which also is the term used for this parameter in the Yuba Accord M&E Program.

Abundance is an important determinant of risk, both by itself and in relationship to other factors (McElhaney et al. 2000 as cited in the M&E Program). Small populations are at a greater risk for extinction than larger populations because risks that affect the population dynamics operate differently on small populations than in large populations. A variety of risks are associated with the dynamics of small populations, including directional effects (i.e., density dependence - compensatory and depensatory), and random effects (i.e., demographic stochasticity, environmental stochasticity, and catastrophic events).

[3] Although late fall-run Chinook salmon populations occur primarily in the Sacramento River (CDFG Website 2007), use of the lower Yuba River by late fall-run Chinook salmon has been reported to occur (D. Massa, CDFG, pers. comm.; M. Tucker, NMFS, pers. comm.). When the various studies addressing steelhead and spring-run and fall-run Chinook salmon are conducted, the collected data will be analyzed to examine Chinook salmon exhibiting phenotypic characterizations of late fall-run Chinook salmon.

The parameter of productivity and factors that affect productivity provide information on how well a population is "performing" in the habitats it occupies during the life cycle (McElhaney et al. 2000 as cited in the M&E Program). Productivity and related attributes are indicators of a population's performance in response to its environment and environmental change and variability. Intrinsic productivity (the maximum production expected for a population sufficiently small relative to its resource supply not to experience density dependence), the intensity of density dependence, and stage-specific productivity (productivity realized over a particular part of the life cycle) are useful in assessing productivity of a population.

Diversity refers to the distribution of traits within and among populations, and these traits range in scale from DNA sequence variation at single genes to complex life-history traits (McElhaney et al. 2000 as cited in the M&E Program). Traits can be completely genetic or vary do to a combination of genetics and environmental factors. Diversity in traits is an important parameter because: (1) diversity allows a species to use a wide array of environments; (2) diversity protects a species against short-term spatial and temporal changes in its environment; and (3) genetic diversity provides the raw material for surviving long-term environmental changes (McElhaney et al. 2000 as cited in the M&E Program). Some of the varying traits include run timing, spawning timing, age structure, outmigration timing, etc. Straying and gene flow strongly influence patterns of diversity within and among populations (McElhaney et al. 2000 as cited in the M&E Program).

Spatial structure reflects how abundance is distributed among available or potentially available habitats, and how it can affect overall extinction risk and evolutionary processes that may alter a population's ability to respond to environmental change. A population's spatial structure encompasses the geographic distribution of that population, as well as the processes that generate or affect that distribution (McElhaney et al. 2000 as cited in the M&E Program). A population's spatial structure depends fundamentally on habitat quality, spatial configuration, and dynamics as well as the dispersal characteristics of individuals in the population. Potentially suitable but unused habitat is an indication of the potential for population growth.

In the Yuba Accord M&E Program, performance indicators associated with each of the VSP parameters (Abundance, Productivity, Diversity and Spatial Structure) and analytical steps ("analytics") to address each of these performance indicators are provided separately for the adult and juvenile lifestages of the anadromous salmonids (including spring-run Chinook salmon and steelhead) in the lower Yuba River. In addition, each section includes examinations of potential relationships between measures of VSP parameters, and flows and water temperatures resulting from implementation of the Yuba Accord. Data for the analytics associated with the performance indicators for the VSP parameters, and for examination of potential relationships between measures of VSP parameters and flows and water temperatures are obtained from the specific sampling protocols and procedures. The RMT has developed the following Protocols and Procedures in accordance with the Yuba Accord M&E Program:

1) Flow and Water Temperature Monitoring
2) Topographic Mapping (Digital Elevation Model) – *physical habitat assessment*
3) Substrate and Cover Mapping – *spawning/juvenile rearing habitat characterization*
4) 2-D Hydrodynamic Modeling – *physical habitat dynamics and availability*
5) Mesohabitat Classification – *physical habitat characterization*
6) Riparian Vegetation Mapping – *juvenile rearing habitat characterization*
7) Acoustic Tagging and Tracking – *Chinook salmon immigration and holding*
8) VAKI Riverwatcher Monitoring – *adult immigration, temporal distribution*
9) Redd Surveys – *spawning spatial and temporal distribution, habitat utilization*
10) Carcass Surveys – *spawning stock escapement estimation*
11) Snorkel Surveys – *juvenile rearing, spatial/temporal distribution, habitat utilization*
12) Rotary Screw Trapping – *juvenile emigration, temporal distribution*
13) Genetic Sampling and Characterization – *Chinook salmon run differentiation*
14) Otolith Sampling and Characterization – *natal stream origin, growth, age, and size*

Each of the Yuba Accord M&E Program Protocols and Procedures prepared by the Yuba Accord RMT are summarized below. Detailed descriptions of each of the Protocols and Procedures may be referenced at www.yubaaccordrmt.com.

1) Flow and Water Temperature Monitoring

The lower Yuba River Accord consists of a Fisheries Agreement that requires YCWA to comply with the Yuba Accord flow schedules. In addition to simply documenting the flows and water temperatures in the lower Yuba River associated with implementation of the Yuba Accord, the overarching goal of the flow and water temperature monitoring is to provide the data to identify and evaluate potential relationships between flows and water temperatures with fish population/community responses, measures of Viable Salmonid Population parameters, and aquatic habitat attributes.

Flow and water temperature monitoring is considered to be a long-term effort to track in-river water temperature conditions over time with the implementation of the Yuba Accord. Water temperature monitoring is anticipated to be conducted annually for at least five years, from 2008/2009 through 2013/2014. The RMT will review the data and reports on an annual basis, and determine whether the overall duration of the water temperature monitoring study plan should be modified.

In the lower Yuba River, water temperature data loggers are deployed in the main channel at the following stations: (1) at Simpson Lane (RM 3); (2) at Marysville (RM 6); (3) at Walnut Avenue (RM 8.1); (4) at DPD (RM 11.4); (5) upstream of DPD (RM 13.2); (6) downstream of Dry Creek (RM 13.3); (7) at Long Bar (RM 16.0); (8) at Parks Bar (RM 17.4); (9) downstream of Deer Creek (RM 22.7); (10) downstream of Narrows 2 Powerhouse at Smartsville (RM 23.6); and (11)in Narrows 2 Powerhouse Penstock (RM 23.9)

In the Feather River, thermographs are deployed at the following stations: (1) one mile upstream of the Yuba River confluence (RM +1); (2) the left (east) bank at the Yuba River confluence (RM 0); and (3) the right (west) bank at the Yuba River confluence (RM 0).

Streamflow gages in the lower Yuba River are located at the following locations: (1) Smartsville downstream of Narrows 2 (USGS 11419000; PG&E NY28); and (2) Marysville (USGS 11421000).

Stream water temperatures in the Feather and lower Yuba rivers are monitored using StowAway Tidbits (Onset Computer Corporation) water temperature recorders that have 12-bit resolution with a minimum accuracy of +/- 0.2° C. All temperature data loggers are programmed to record water temperatures at 15 minute intervals. Redundant water temperature loggers are installed at each site as close as possible to the primary recorders.

Water temperature recorders are secured in the channel by a cable to a root mass, tree trunk, or man-made structure, or secured using embedded rebar where necessary. A GPS coordinate is taken and recorded at each installation point, along with other points that may be useful for retrieving the recorder (i.e., point lacks a distinct trail for access). Photographs are taken of each site, including recorder installation configuration.

The loggers are retrieved at approximately monthly intervals to check their status and download new data. During each visit, water temperature data are downloaded into an optic shuttle or directly to a personal computer. Prior to each download of the water temperature data, a National Institute of Standards and Technology (NIST) traceable digital thermometer is used to measure the water temperature at the recorder, and compared to the last logger reading to check for accuracy drift of the recorder. Only after the raw water temperature data is downloaded and safely backed-up is the optic shuttle cleared or data used. Data recorded for each site visit includes: (1) date; (2) time; (3) station ID; (4) field team; (5) air temperature; (6) water temperature (NIST); (7) current weather; (8) site notes (i.e., vandalism, logger replacement, etc); (9) download file name; (10) backup file name; (11) GPS coordinates (first visit); and (12) photo numbers (first visit or when appropriate).

Concurrent with in-river data retrieval activities each month, electronic records of flow data recorded at Smartsville and Marysville is obtained from the California Data Exchange (http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=YRS) and/or from YCWA. These data are saved into the flow and water temperature monitoring database for use during preparation of the annual reports.

2) Topographic Mapping (Digital Elevation Model)

The overarching goal of the Topographic Mapping and Digital Elevation Model (DEM) Protocol and Procedure is to provide a highly detailed dataset to be used in the assessments of physical habitat, and in the identification and evaluation of potential relationships between flows and water temperatures with fish population/community responses and aquatic habitat attributes. Methods to obtain the data necessary to develop a detailed topographic map of the lower Yuba River include both airborne Light Detection And Ranging (LIDAR) mapping of the terrestrial river corridor and boat-based echo-sounding of the submerged river channel.

Lower Yuba River LIDAR data was acquired on September 21, 2008. On that day, the Yuba River discharge at Smartsville was constant at 860 cfs, Deer Creek was at 3 cfs, and Marysville was at 622 cfs. Bathymetric data was acquired on multiple dates: August 19, 20, 22, 25, and 26, 2008; September 16, 17, 18, and 19, 2008; March 4-6, 2009; May 6, 15, 20, 2009.

The topographic map of the lower Yuba River was completed during April 2010.

The study area for this protocol and procedure is the river corridor of the lower Yuba River extending from Englebright Dam to the confluence of the Yuba and Feather rivers (near Marysville, California).

After the flight, data was directly processed and reduced to obtain a detailed "bare earth" only dataset with a vertical accuracy of approximately 0.15-m, which is the level of resolution prescribed by the rigorous Class 1 standard. The spatial resolution for this protocol is 1 point every 0.738-m (1 pt per ~2 ft). The LIDAR survey also yielded the intensity of the LIDAR return signal at each point, rasterized to yield a black and white image of the river corridor, which serves as a base map for GIS and was used to construct a polygon shapefile of the water's edge. Data points from the LIDAR survey were imported into ArcGIS to create a DEM of the terrestrial land around the river using a standard TIN-based approach with breaklines and additional quality assurance measures.

The 2008-2009 mapping used multiple echo-sounders deployed simultaneously across the bow of the boat. A customized aluminum jet-boat was outfitted with up to five Odom Hydrotrack survey-grade fathometers (each with a 3,200-kHz transducer) and a TSS 335B motion sensor that adjusted for roll/pitch of the vessel. Position data for the fathometers was collected using real-time kinematic (RTK) GPS receiving corrections by radio from an on-site base station located on one of the pre-established benchmarks. These benchmarks were established by long-duration static surveys with an RTK GPS and then waiting to obtain "ultra precise" solutions through NOAA's Online Positioning User Service (OPUS).

Where depth permitted, the boat made cross sections on a approximate 3-m interval and performed six longitudinal transects approximately evenly spaced across the channel. To account for the water surface slope and its changes through time, Mini Troll 400 vented pressure transducers (In-situ, Inc., Fort Collins, CO) were placed in the river along the survey area and their elevations were surveyed using RTK GPS. An algorithm was used to interpolate water surface slopes based on the distance between the pressure transducers.

Position data was recorded every 1-s, and a radial filter was applied in post-processing to the boat-based data to obtain 0.6-m spacing between points, achieving the goal of obtaining bathymetric data at a resolution of 1 point per m^2 along the boat tracks.

To create the topographic map, the following items were obtained through data collection: LIDAR flight and data file tiling scheme polygon shapefile, LIDAR data coverage polygon shapefile, LIDAR intensity images (all returns), LIDAR ground-return point file (ASCII format), boat-based echo-sounder/RTKGPS point file filtered to 2-foot spacing, total station point data.

3) Substrate and Cover Mapping

Fluvial processes that are important for the lower Yuba River are influenced by a suite of hydrogeomorphic variables including channel topography, flows, substrate, and cover. A restricted amount of substrate and cover information exists for some sites on the lower Yuba River since the floods of 2006.

The objectives of the Substrate and Cover Mapping Protocol and Procedure are to: (1) produce a substrate map of the lower Yuba River; and (2) produce a cover map of the lower Yuba River. Each of these maps will then be used for a number of specific analytics in the M&E Program which includes activities such as characterization of microhabitat and mesohabitat conditions (including their spatial diversity) as well as assessment of dynamic fluvial processes and design of habitat rehabilitation projects.

Substrate and cover mapping is planned to occur during September 2010 because relatively low flows and high visibility conditions are expected to occur at that time.

The Substrate and Cover mapping Protocol and Procedure study area extends from Englebright Dam to the confluence with the lower Feather River. 2D hydrodynamic modeling of the lower Yuba River has yielded a wetted area boundary for a flow of 4,000 cfs at Smartsville, which will be converted to an ArcGIS polygon shapefile and uploaded into GPS units used by the mapping team. Substrate and cover will only be mapped in this domain. Because flow at the time of mapping will be <4,000 cfs, some of the mapping area will be on land and some underwater.

Regardless of whether the crew is on land or in water, the crew will start at Englebright Dam and work downstream one section at a time. In each section, the crew will map the substrate and cover by making three passes of the wetted channel and three passes of the terrestrial land. Each pass will consist of the following activities: (1) an initial pass to get an overview of the conditions in the section; (2) going back to the top and then mapping substrate polygons on the way down; and (3) going back to the top and then mapping all cover as points, lines, or polygons according to cover classification.

Crew members will create point, line, or polygon features of all substrates and cover features of interest using handheld differential GPS units (sub-meter accuracy) by plotting GPS coordinates while walking, driving, or boating around the perimeter of a feature. The procedure for mapping on land involves doing the three passes by walking or using an ATV, depending on accessibility for an ATV in each section and how rough the surface is for moving faster than walking speed on an ATV.

Substrate

A pre-established method for performing observational reconnaissance of the lower Yuba River substrate already exists for the salmonid redd surveys. Crew members have been trained to cover the whole submerged domain by scanning the river from the shore to the middle of the river, working downstream in a kayak. Side channels in the survey area are observed by walking. This method will be used for mapping substrate and cover. Surveyors will wear polarized sunglasses during walking or driving surveys, and use transparent bottom buckets while boating in shallow water areas. Deepwater surveys will be conducted via underwater video, snorkel, SCUBA, or other methods pending results of field-tested techniques during the spring through summer 2010.

Handheld GPS units require that each substrate polygon be larger than 5x5 m^2 to be accurately mapped, so that will be the minimum size of a substrate or cover patch recorded. However, if a substrate polygon has more than one substrate size class present in it with an area >10%, then the minimum polygon size will be 10x10 m^2. This constraint represents the consensus for balancing effort and cost relative to the needs of the dataset for analytic application.

Regardless of whether the crew is on land or in water, substrate classification categories will be used to make a "facies" map of the surficial pattern of substrate, with each area of a homogeneous substrate type mapped as a polygon. For each substrate polygon, the observer will estimate the percent of area composed of each substrate size class to the nearest 10% value, only recording those with >10% contribution. For a substrate polygon, a GPS data dictionary file accompanying the coordinates will identify the substrate classes present and the percent of each substrate class to the nearest 10%. Substrate classification categories include: (1) bedrock (no alluvium); (2) boulder field (D>256); (3) large cobble (128<D<256); (4) cobble (90<D< 128); (5) medium gravel/small cobble (32<D<90); (6) fine gravel (2<D<32); (7) sand (0.0625<D<2); and (8) silt/clay (D<0.0625).

Cover

For individual wood elements, length and mid-point diameter will be obtained using a tape measure and tree caliper, with recorded accuracies of ±5 cm and ±2 cm, respectively. Origins should be identified as bank erosion when roots are present, as cut or placed when evident by visual inspection, as limb breakage when the large wood piece could be matched up with a nearby scar on a riparian tree, and as unknown in all other cases.

For boulders, diameter should be measured with a tape measure and the angularity designated as angular (i.e., having sharp edges), well-rounded, or unknown. The following classification will be used to characterize cover on the lower Yuba River: (1) wood log (≥3 m long by ≥10 cm diameter); (2) wood jam (≥3 m); (3) boulder (>3 m); (4) boulder cluster (>3 m); (5) undercut bank (>3 m); (6) submerged aquatic (>3 m); (7) wetted channel woody vegetation (> 3 m long by >1 m above substrate); (8) overhanging riparian vegetation (> 3 m in longest dimension and >1 m above substrate); and (9) human detritus by name (car, cement block, refrigerator, and other items. ≥3-m long by ≥10-cm diameter).

4) 2-D Hydrodynamic Modeling

Two-dimensional (2D) numerical models solve vertically integrated conservation of momentum and mass equations using a finite element, finite difference, or finite volume computation method to acquire local water depth and depth-averaged 2D velocity vectors at each node in a computational mesh. These models further add the ability to consider full lateral and longitudinal variability down to the sub-meter scale, including effects of alternate bars, transverse bars, islands, and boulder complexes, but require highly detailed topographic maps of channels and floodplains. Four different 2D numerical models have been used on the lower Yuba River, including FLO-2D, RIVER2D, FESWMS, and SRH-2D. SRH-2D is a relatively new model that spans many of the capabilities of FLO-2D, RIVER2D and FESWMS, but it is more computationally efficient and numerically stable, so it can be used to simulate long river segments in very high resolution.

Presently, the Yuba Accord RMT is using SRH-2D to simulate hydraulics for the entire lower Yuba River downstream of the Highway 20 Bridge with 1-m intermodal spacing. To achieve this more efficiently, the lower Yuba River has been divided into three reaches: (1) Highway 20 Bridge to DPD; (2) DPD to the USGS Marysville gaging station; and (3) USGS Marysville gaging station to the confluence of the Yuba and Feather rivers. SRH-2D models of each reach are being run concurrently. Presently, the model is being run at variable discharges to test the model against available data. Subsequently, 4 flows between 700 and 4,500 cfs (at the Smartsville gage) will be simulated.

SRH-2D uses a flexible mesh that may contain arbitrarily shaped cells. A hybrid mesh may achieve the best compromise between solution accuracy and computing demand. SRH-2D adopts very robust and stable numerical schemes with a seamless wetting-drying algorithm. The resultant outcome is that few tuning parameters are needed to obtain the final solution.

SRH-2D was evolved from SRH-W which had the additional capability of watershed runoff modeling. Many features are improved from SRH-W. As described by the USBR Technical Service Center, Sedimentation and River Hydraulics Group website (http://www.usbr.gov/pmts/sediment/model/srh2d/index.html), SRH-2D features include: (1) 2D depth-averaged dynamic wave equations (standard St. Venant equations) are solved with the finite-volume numerical method; (2) steady state (with constant discharge) or unsteady flows (with flow hydrograph) may be simulated; (3) an implicit scheme is used for time integration to achieve solution robustness and efficiency; (4) an unstructured, arbitrarily-shaped mesh is used which includes the structured quadrilateral mesh, the purely triangular mesh, a combination of the two, or a Cartesian or raster mesh; (5) all flow regimes (i.e., subcritical, transcritical, and supercritical flows) may be simulated simultaneously without the need for special treatments; (6) robust and seamless wetting-drying algorithm; and (7) solved variables include water surface elevation, water depth, and depth-averaged velocity.

5) Mesohabitat Classification

The M&E Program recognizes that the processes creating microhabitat are dynamic and spatially diverse, and management of a river that undergoes periodic planform changes requires more than a static depiction of microhabitat conditions. Consequently, “mesohabitat” is defined as the interdependent set of microhabitat variables (depth, velocity, substrate, cover, and hyporheic parameters) over a discernible landform known as a morphological unit (i.e., scour pool, riffle, and lateral bar) associated with a specific magnitude of flow. Mesohabitats typically occur at a spatial scale of approximately 0.5 to 10 times the length scale of channel width. This spatial scale directly ties to the fluvial processes responsible for channel dynamics and thus enables a mechanistic understanding of how fluvial dynamics drives spatial structure.

Morphological units evaluated at a meso-scale can be used to explain fluvial-ecological relations and may therefore be good indicators of fish utilization patterns. The goals of the Mesohabitat Classification Protocol and Procedure are to: (1) identify mesohabitat units throughout the lower Yuba River; (2) evaluate the quality, number, size and distribution of mesohabitats for various lifestages of adult and juvenile anadromous salmonids; and (3) evaluate the maintenance of watershed processes in the lower Yuba River.

Mesohabitat characterization is planned to begin during summer of 2010 and be completed the same year.

The proposed study area for this project is the lower Yuba River from Englebright Dam to the confluence of the Yuba and Feather rivers (near Marysville, California).

This Protocol and Procedure emphasizes a GIS-based analysis of existing data layers for developing the classification, and then uses field-based reconnaissance for QA/QC and ground truthing of the classification. The key data layers required to perform GIS-based characterization of morphological units are: (1) a DEM of the river corridor; (2) a water's edge shapefile and associated digital water surface elevation model for each discharge at which mesohabitats will be characterized (the model may be obtained by overlaying the edge shapefile onto the DEM and extracting the ground elevations along the water's edge); (3) a derived water depth map made by subtracting the DEM from the water surface elevation model; and (4) aerial photography of the river at each discharge of interest.

Descriptions of the objective and numeric criteria used to delineate morphologic units incorporate concepts provided by Montgomery and Buffington (1997) and Thomson et al. (2001) (see www.yubaaccordrmt.com. for additional descriptions). Morphological units to be identified in the lower Yuba River may include the following: (1) forced pool; (2) pool; (3) chute; (4) run; (5) glide; (6) riffle entrance; (7) riffle; (8) recirculation; (9) backwater; and (10) medial bar.

Once the morphological unit classification and map is complete, a site reconnaissance will be performed by a team of two people to check the quality of the map in delineating the in-channel units. Upon arriving at a site by truck or boat, the crew will start at one end and systematically work along the river, wading or boating into each morphological unit and confirm that the depth and velocity criteria used to delineate the unit are met. Field-based delineation confirmation will consist of making 10 depth measurements using a graduated pole, and 10 water velocity measurements, using a velocity meter, at points randomly scattered around the unit. Resultant values will be compared to the criteria.

If field observations reveal a systematic error in the delineation of a specific unit, then the handheld GPS will be used to re-map the individual polygon by walking or boating around the perimeter and tracing the correct extent. Revised polygons will be imported into GIS to replace the faulty ones and boundaries of surrounding polygons will be amended to mesh with the revised boundary lines.

The definitions of the mesohabitats will be taken from the correspondingly named morphological units. Mesohabitat maps will be developed for forced pools, pools, secondary channels, backwaters, recirculations, chutes, riffles, riffle entrances, runs, and glides, using the appropriate shoreline shapefile and depth raster map.

6) Riparian Vegetation Mapping

The RMT is undertaking, collaborating or observing several riparian mapping and analysis efforts on the Yuba River below Englebright.

The California Department of Fish and Game (CDFG) mapped all riparian habitats of the Central Valley starting in the 1977. This mapping effort used large categories of vegetation type (e.g., forest, shrub, herbaceous and bare gravel bar), and would be useful to assess large changes of riparian habitat over the last 20-30 years. Known as the Katibah maps after the principal investigator, these resources are reported to exist in CDFG archives as scanned images of variable quality spatial rectification. Licensee has not been able to obtain these.

CDFG is currently mapping riparian habitats throughout the Central Valley at a similar scale as the Katibah maps, but following the National Vegetation Classification Standard and the California Vegetation Manual. A GIS layer of these maps for the lower Yuba River up to Highway 20 is expected to be available in 2011 (Diana Hixon, pers comm.).

A riparian mapping project has been initiated by the RMT. The RMT has used Light Detection and Ranging (LiDAR) data for the entire riparian corridor up to Highway 20 to yield a map of riparian structure (i.e., height and density). The RMT plans to use ground data from CDFG with the LiDAR data to develop stand classifications following the California Vegetation Manual, yet one scale finer than that being produced by CDFG. This effort is targeted for completion in late 2010.

In addition, the RMT in conjunction with University of California at Davis and YCWA have developed a topographic map and two-dimensional hydrodynamic model of the Yuba River downstream of Englebright Dam as a basis for integrating and understanding riparian trends.

Also, an analysis of historic aerial photographs and maps of the lower Yuba dating from 1906 through 1998 will be undertaken as a joint project between the Yuba County Water Agency and the RMT. That effort should be completed by summer 2011.

Depending on the products that result from these various ongoing study efforts, the RMT may undertake additional riparian data collection effort for the Yuba River downstream of Englebright Dam.

7) Acoustic Tagging and Tracking Surveys

The Acoustic Tagging and Tracking Protocol and Procedure consists of acoustic-tagging immigrating adult Chinook salmon and monitoring their distribution and movement in the lower Yuba River. Chinook salmon acoustic tagging will be conducted in conjunction with the Genetic Sampling and Characterization Protocol and Procedure.

Goals of the Acoustic Tagging and Tracking Protocol and Procedure include: (1) examination of habitat utilization of upstream migrating and spawning Chinook salmon exhibiting the run timing characteristics of spring-run Chinook salmon; (2) examination of the spatial and temporal distributions of holding spring-run Chinook salmon from spring through fall, and potential relationships with variable flow and water temperature regimes; (3) comparison of differential spatial and temporal distributions of immigrating and holding spring-run and fall-run Chinook salmon, and potential relationships with variable flow and water temperature regimes; and (4) examination of differential spatial and temporal distributions of spring- and fall-run Chinook salmon spawning (in conjunction with Chinook salmon redd surveys) and potential relationships with flow and water temperature regimes.

The adult spring-run Chinook salmon Acoustic Tagging and Tracking Survey is anticipated to be a multi-year effort. Acoustic tagging and tracking of 30 immigrating adult spring-run Chinook salmon occurred in the lower Yuba River from Englebright Dam downstream to the Yuba River and Feather River confluence from May to November 2009. During 2010, attempts will be made to tag 30 adult spring-run Chinook salmon during May and possibly into June, and for comparative purposes 30 adult fall-run Chinook salmon will be tagged during fall (October 2010). The RMT will review the data and reports annually, and will determine the overall duration of the acoustic tagging study.

Acoustic tagging of immigrating adult Chinook salmon will occur in the lower Yuba River downstream of DPD to the Yuba River and Feather River confluence. Adult Chinook salmon will be captured using hook-and-line sampling. Therefore, the exact location(s) for acoustic tagging will vary depending upon the specific locations of individual captures.

If an adult Chinook salmon is deemed to be sufficiently healthy for tagging, the fish will be placed in a CO_2 solution for anesthetization, and the following measurements and data will be recorded: (1) fork length (mm); (2) total length (mm); (3) body depth (mm); (4) sex (male or female); (5) adipose fin presence (Yes or No); (6) description and photograph of any visible parasites, fungi, lesions, or other signs of disease or injury, including potential hooking injuries; and (7) acoustic tag ID (serial) number of the tag that will be implanted into the fish.

After data collection, VEMCO V13-1L acoustic tags, programmed to have a "kill switch" and turn off after a pre-determined amount of time (i.e., 7 months) so that the tags do not interfere with other acoustic tagging studies after the tagged fishes have died, will be inserted into the fish. The esophageal insertion method will be used, where acoustic tags are inserted into the stomachs of spring-run Chinook salmon. Esophageal insertion will be used because surgery is not required, results in reduced tag loss and reduced changes in swimming behavior (due to the tag being placed near the center of the fish's gravity) compared to external tagging, and a relatively short recovery time is required prior to releasing the fish (Demco et al. 2003 as cited in the M&E Program).

After tagging, a caudal fin-clip will be taken for genetic sampling (refer to Genetic Sampling and Characterization Protocol and Procedure for more information). A floy tag will be implanted in the subdural region near the dorsal fin of the fish for identification during carcass surveys. After the fish is measured, acoustic-tagged, sampled for genetics, and floy-tagged, the fish will be immediately released back into the river where the water is relatively calm and the fish can be observed.

Monitoring for acoustic-tagged spring-run Chinook salmon will occur on the lower Yuba River from Englebright Dam to the Yuba River and Feather River confluence through the use of acoustic hydrophones currently in place (J. Nelson, CDFG, 2008, pers. comm.). As of February 2009, there are 16 hydrophones located throughout the lower Yuba River, with an additional hydrophone planned to be installed at the downstream end of the Narrows. Monitoring for tag pings may also occur outside the lower Yuba River if tagged Chinook salmon move into other rivers such as the lower Feather River. Static receiver hydrophones will operate continuously year-round and data will be obtained at least every other month by CDFG (The Heritage and Wild Trout and the Steelhead Management and Recovery Programs). Data will be sent to the RMT's lead biologist from the RMT acoustic-tagged spring-run Chinook salmon every other month.

In addition to fixed-station hydrophones (i.e., static receivers), mobile tracking surveys will be conducted to monitor acoustic-tagged spring-run Chinook from Englebright Dam to the Yuba River and Feather River confluence via jet boat or walking and use of a hydrophone. A jet boat will be used to survey from the Yuba River and Feather River confluence to the bottom of the Narrows. Surveyors will track acoustic tagged Chinook salmon from the Narrows Pool to Deer Creek and from Englebright Dam to Deer Creek by walking. Surveyors will only survey reaches that they deem safe between Englebright Dam and Narrows Pool. One omni-directional and one directional hydrophone will be used in conjunction with an acoustic receiver for the mobile tracking surveys. When an acoustically tagged fish is detected, the location will be recorded using a GPS unit.

Mobile tracking surveys will begin during mid-May, or soon after tagged fish are released. From below the Narrows to the Yuba River and Feather River confluence, mobile tracking surveys will be conducted every week. Mobile tracking surveys from below Englebright Dam to the bottom of the Narrows Reach also will be completed weekly if possible.

Prior to initiation of the acoustic tagging survey, acoustic tags will be placed in various habitat types in the lower Yuba River, and mobile tracking surveys will be conducted to test the ability of detecting tag pings in the various habitat types. Mobile tracking techniques will be refined as necessary to maximize the detection of acoustic tags in all habitat types in the lower Yuba River.

8) VAKI Riverwatcher Monitoring

Fish passage monitoring on the lower Yuba River is conducted using two VAKI Riverwatcher systems, in conjunction with digital photography located in the north and south fish ladders at DPD. The data collected by the VAKI Riverwatcher systems for Chinook salmon and steelhead will be used in conjunction with data from redd surveys, carcass surveys, and angler surveys. The combined datasets will be used to generate abundance estimates, help evaluate habitat use, and examine trends in fish passage.

Goals of the VAKI Riverwatcher monitoring include: (1) estimate the abundance of spring-run, fall-run, and late fall-run Chinook salmon and steelhead above DPD; (2) examine the temporal distribution of immigration of the total run, and natural origin spring-run, fall-run, and late fall-run Chinook salmon and steelhead immigrating past DPD; (3) examine the size structure of salmonids using length-frequency distributions; (4) examine the age structure of salmonids by examining the modalities of length-frequency distributions; (5) examine the annual and multi-year trends in timing of immigrating salmonids past DPD; (6) examine the annual and multi-year trends in timing of different sizes of immigrating salmonids past DPD; (7) use VAKI Riverwatcher data in conjunction with redd survey data to estimate the abundance of steelhead below DPD; and (8) use VAKI Riverwatcher data in conjunction with water temperature and flow data to evaluate potential relationships between water temperatures and flows, and the timing of adult salmonid immigration.

Both of the VAKI Riverwatcher systems are operated year-round for monitoring fish migration in the lower Yuba River. The VAKI Riverwatcher system began operation during 2003, and is anticipated to be operated continuously at least through 2014.

The VAKI Riverwatcher system records both silhouettes and electronic images of each fish passage event. By capturing silhouettes and images, fish passage can be accurately monitored even in under turbid conditions. Data for each fish passage event is downloaded directly to an on-site PC for further analysis.

Data collection for individual fish passage events are automatically recorded by the VAKI Riverwatcher systems. Each data record is reviewed by personnel to: (1) identify the fish species; (2) examine if Chinook salmon have an adipose fin, and (3) identify non-fish passage events (i.e., debris). The VAKI Riverwatcher systems record the time/date of each fish passage event, the upstream or downstream direction of passage, the speed of the fish moving through the system (m/sec), the fish's body depth (mm), and logs water temperature every hour. The body depth of a fish is converted to a length measurement (cm) by the program software (Winari v. 4.16) utilizing a body length-to-depth ratio. The morphometric body ratios were obtained by measuring 36 fall-run Chinook salmon in 2003 and 119 fall-run Chinook salmon in 2005 from the Feather River Hatchery and 168 steelhead from the lower Yuba River (D. Massa, CDFG, pers. comm. 2009). To maximize the accuracy of passage estimates generated by the VAKI Riverwatcher systems, a full-time technician will be employed to monitor the systems and minimize system off-line events.

9) Redd Surveys

Redd counts have been used widely to estimate or provide indices of adult salmonid escapement or abundance, and examine the spatial and temporal distribution of spawning adult salmonids. In addition, data pertaining to redd location and size will be obtained to develop indices of redd superimposition using GIS analyses for the Chinook salmon runs and steelhead/rainbow trout in the lower Yuba River.

Goals of the redd surveys conducted in the lower Yuba River include: (1) evaluate and compare the spatial and temporal distribution of redds and redd superimposition over the spawning seasons for the Chinook salmon runs and steelhead/rainbow trout spawning in the lower Yuba River; (2) compare the magnitude (and seasonal trends) of lower Yuba River flows and water temperatures with the spatial and temporal distribution of redds (and rates of redd superimposition) for the Chinook salmon runs and steelhead/rainbow trout; (3) estimate the total annual abundance of adult fall-run Chinook salmon and steelhead/rainbow trout in conjunction with angler surveys and VAKI Riverwatcher data; and (4) establish a long-term data set to be used to evaluate habitat utilization by the Chinook salmon runs and steelhead/rainbow trout in the lower Yuba River under variable biotic and abiotic conditions.

Reconnaissance-level redd surveys will be conducted during August to document the initiation of spawning activity in the lower Yuba River. The 2008-2009 and 2009-2010 redd surveys were conducted weekly beginning the week after a redd was first observed during the reconnaissance-level redd survey through the portion of the season encompassing the majority of Chinook salmon spawning activity. Prior redd and carcass surveys indicate that the majority of Chinook salmon spawning activity occurs through December, with reduced amounts of Chinook salmon spawning continuing through late-March, and steelhead/rainbow trout spawning extending through April. From the 2008-2009 pilot redd survey data and a simulation approach, a weekly sampling frequency was found to result in the most precise and accurate (least biased) estimates of spawning activity. Therefore, weekly redd surveys will be conducted from the initiation of spawning activity until May each year beginning during the 2010-2011 redd survey and subsequent surveys.

Approximately 20.9 mi. of the 24 mi. of total length of the lower Yuba River will be surveyed during the redd surveys. About 0.7 mi. of the lower Yuba River located immediately below the first set of riffles downstream of Deer Creek to the top of Narrows Pool will not be surveyed due to rugged and dangerous conditions in the steep canyon known as the Narrows. Additionally, an approximate 2 mi. section of the lower Yuba River from Simpson Lane Bridge to the confluence with the Feather River will not be regularly surveyed because redds have not been observed during past surveys. This section of the river will be surveyed once during peak Chinook salmon spawning to ascertain that this section is, in fact, not being utilized for spawning.

Several species of fish exist in the lower Yuba River known to construct redds including Chinook salmon, steelhead/rainbow trout, Sacramento sucker (*Catostomus occidentallis*), and Pacific lamprey (*Lampetra tridentata*). Visual differentiation between steelhead/rainbow trout redds and Sacramento sucker, and Pacific lamprey spawning nests is of concern because these three species clean the gravel during spawning. Sacramento suckers do not typically spawn until late-March and April, and are generally visible during their spawning season.

Steelhead/rainbow trout redds are generally easy to distinguish, because they create a noticeable pit and tail spill in the gravel during redd construction. The Oregon Department of Fish and Wildlife (1999; as cited in the M&E Program) distinguish lamprey spawning nests and steelhead/rainbow trout redds using redd/nest dimension measurements. A steelhead/rainbow trout redd is distinguished by a longer length than width and the tailings are evenly distributed downstream by the current. Lamprey spawning nests generally have a neat and round appearance, with a conical bowl. The unique characteristic of a lamprey spawning nest is the placement of the tailings upstream from the nest. Lamprey excavate their spawning nests by sucking onto the gravel and then depositing it outside the nest.

Species-specific redd identification will be conducted by comparing the physical dimensions and locations for all known redds (i.e., redds which were positively identified with one species or another building or guarding them). During the redd surveys, each redd observed with an adult building or guarding them will be measured, and the species identified and recorded. Result from the 2008-2009 and 2009-2010 redd surveys in the lower Yuba River indicated that lamprey were observed spawning in late-March and early-April in the most downstream sampling reach of the lower Yuba River, where sand was the subdominant substrate.

The 2010-2011 redd surveys, and any subsequent surveys, will be conducted using two catarafts rather than the four kayaks used during the 2008-2009 and 2009-2010 redd surveys. Each surveyor, wearing polarized sunglasses, will scan the river from the shore to the middle of the river, working downstream. Side channels in the survey area may require walking. Visibility will be measured using a secchi disk at the top of the survey section.

Deep water surveys will be conducted during the 2010-2011 redd survey period in addition to the surveys conducted by cataraft. The specific methods employed for the deep-water surveys are being field tested during the winter and late-summer of 2010.

For each new redd observed throughout the sampling season, the following data will be recorded: (1) a GPS (Trimble GeoExplorer XT) location taken at the center of the redd's pit with a unique identifying number (i.e., Date + plus redd number; i.e. 082908-001); (2) total dimensional area (using a GPS) for areas appearing to contain multiple redds with no clear boundaries (i.e., mass aggregate spawning); (3) habitat type (i.e., pool, riffle, run, or glide); (4) substrate composition of ambient habitat based on substrate size immediately upstream of the pit; (5) redd species identification; (6) number of fish observed on the redd; (7) location information (i.e., side channel or main channel); (8) comments regarding observable redd superimposition (i.e., redd overlap); and (9) any additional comments.

The path undertaken by each surveyor down the river will be recorded using Garmin GPSMAP 60Cx GPS units to document specific locations of the river surveyed. The GPS (Trimble GeoExploerXT) and a data dictionary will be used to ensure redds counted during the previous survey weeks are not double-counted. In addition, surveyors will mark each redd at the pit with a painted rock. Redd area measurements will be conducted to examine redd superimposition throughout the lower Yuba River for the Chinook salmon runs and steelhead/rainbow trout.

At each fresh redd located, measurements of mean water column velocity, “nose velocity” (i.e., fish focal point water velocity, which is the water velocity at an observed fish’s position or, when a fish is not observed actively preparing a redd, at the predetermined distance of 0.5 ft above the undisturbed streambed), total water depth and visual estimates of substrate composition will be made to approximate habitat conditions prior to gravel disturbance caused during redd construction. All measurements will be made 0.5 ft upstream of the leading edge of the pit along the mid-line of the redd, unless field personnel determine that measurements adjacent to the mid-point of the pit are more representative of undisturbed conditions for that specific location. The specific location of the measurements will be recorded on the data sheet.

Redd substrate composition will be visually estimated as percentage composition (to the nearest 10 percent) of each of eight size categories. Prior to conducting the steelhead/rainbow trout redd surveys, the field survey crews will become familiar with visual substrate size estimation by having undergone training by visually estimating substrate size, then comparing those estimates to results obtained by passing those substrate elements through a gravel template. Visual estimation of substrate sizes will be along the B axis of the substrate elements.

10) Carcass Surveys

The carcass surveys use a mark and recapture technique to estimate the abundance of spawning adult Chinook salmon. The annual abundance estimates are essential for monitoring trends in population size. In addition, biological data is collected from observed Chinook salmon carcasses (i.e., length, sex, spawning status, genetic tissue samples, scales, otoliths, and coded wire-tags) to monitor the populations.

Goals of the annual carcass surveys in conjunction with data collected from the VAKI Riverwatcher, and acoustic tagging survey include: (1) use the genetic tissue samples collected during the carcass survey and the acoustic tagging survey to differentiate spring-run and fall-run Chinook salmon; (2) use the coded-wire tags and otoliths collected to determine the origin of Chinook salmon (i.e., hatchery-origin, natural-origin and river of origin); (3) estimate the total, weekly, monthly and seasonal abundances of spring-run and fall-run Chinook salmon; (4) estimate the abundance of natural-origin and hatchery-origin spring-run and fall-run adult Chinook salmon; (5) use length data to examine the size structure of the spring-run and fall-run Chinook salmon populations; (6) use scale samples to examine the age structure of the spring-run and fall-run Chinook salmon populations; and (7) examine multi-year trends in the annual run sizes of spring-run and fall-run Chinook salmon (i.e., total population, hatchery-origin and natural-origin).

The annual Chinook salmon carcass surveys will be a long-term monitoring effort of the lower Yuba River spring-run and fall-run adult Chinook salmon populations. A consistent carcass survey methodology has been employed in the lower Yuba River since the mid-1990s (Massa 2008). Annual Chinook salmon carcass surveys will occur from the beginning of the spawning season (September) through the end of the spawning season (late-January). Begin and end dates of the annual carcass survey will vary depending on when Chinook salmon redds are observed and when the recapture rate of tagged carcasses in January approaches zero. Field reconnaissance teams begin to monitor Chinook salmon spawning during August. The first carcass survey will begin about 10 to 14 days after the first Chinook salmon redds are observed.

The study area for the carcass survey is the lower Yuba River extending from the Englebright Dam downstream to the Simpson Lane Bridge. The study area is divided into three survey reaches: (1) Narrows Pool to Highway 20 Bridge; (2) Highway 20 Bridge to DPD; and (3) DPD to Simpson Lane Bridge. All survey reaches will be surveyed once a week.

The weekly carcass survey will be conducted by a crew of 4-6 people and will be executed via jet boat and walking. Two crews will be utilized to collect scale samples, tissue samples, otoliths and heads for coded-wire tag recovery (i.e., 2008/2009 through 2013/2014).

During the weekly carcass survey, personnel will collect, count, and record data for: (1) fresh carcasses (carcass with red or pink gills, or at least one clear eye); (2) non-fresh carcasses (no clear eyes and gills are not red or pink); and (3) tagged carcasses. All observed non-fresh carcasses and adipose fin-clipped carcasses will be counted and chopped in half to prevent recounting during subsequent surveys. Tagged carcasses (recaptures from previous surveys) will be counted and chopped. Fresh carcasses that have an adipose fin will be counted and tagged. All carcasses will be released into the river. Fresh adult carcass data will be used in the Schaefer mark-recapture model (Schaefer 1951 as cited in the M&E Program) with modifications referenced to Taylor (1974; as cited in the M&E Program) to estimate abundance. Abundance will be estimated weekly throughout the annual spawning period, and annually.

11) Snorkel Surveys

The overall goal of the Snorkel Surveys Protocol and Procedure is to study anadromous salmonid diversity and habitat occurrence, in addition to observing community composition in the lower Yuba River. This Protocol and Procedure evaluates abiotic variables affecting fish diversity and habitat occurrence including external forces (i.e., daily cycle, time of year, flow, and fluvial landform structure), and internal responses to specific combinations of the external forces (i.e., spatial pattern of water depth and mesohabitat pattern).

It is anticipated that 2 years of snorkel surveys will be conducted, beginning during winter of 2011. Sampling months will be selected so that all juvenile salmonid life stages will be present in the river during the course of snorkeling activities, however, it may be prudent to continue sampling through the duration of summer. The study area for the snorkel surveys is the lower Yuba River from Englebright Dam to the confluence of the Yuba and Feather rivers (near Marysville, California). This study length includes a diverse assemblage of mesohabitat types as indicated by observed riffle habitat spacing at approximately 4-7 bankful widths in most gravel-bed rivers. The rapids in the Narrows will not be sampled due to potential safety issues.

The specific sampling design continues to undergo refinement by the RMT. However, at this time, it is anticipated that a morphological unit (up to 9 in-channel types and 3-5 edge types) oriented sampling strategy, stratified by river reach (up to 8 reaches based on geomorphic principles) will be employed. The objective of the survey sampling design is to obtain a strong geographical distribution suitable for longitudinal analysis. Prior to each sampling survey, specific localities will be identified using GIS and uploaded to Trimble GPS units for easy field location.

Divers will evaluate visibility in the lower Yuba River by taking NTU measurements before sampling each day to determine if surveying is warranted. For each day of sampling, "effective visibility' will be measured using a standard "4" lure and measured maximum distance for underwater identification of parr marks.

Surveys will be conducted with three people in the river and a fourth on the river bank. A second bank recorder may be necessary for units with high densities of fish. Channel units will be surveyed by divers daily beginning at the downstream end of the channel unit working towards the upstream end of the channel unit whenever possible. This includes working in an upstream direction along channel margins in swift areas. In deep, high velocity areas of the river where snorkelers are physically unable to snorkel upstream, they will survey the area by drifting downstream 3 abreast. In some areas of the river, it may be impossible to conduct snorkel surveys in either direction due to water velocity and in river hazards (i.e., rapids, rocks). In these non-sampled areas, probability statistics may need to be applied. Fish that are disturbed during the survey (i.e., swimming away and/or seeking refuge) will not be considered to be exhibiting normal behavior. When undisturbed fish are located, snorkelers will first take a still image using their mask-integrated digital camera.

Snorkeling effort will not be uniform in all channel units because the lower Yuba River ranges in width from 10-100 m. Snorkelers will maintain "lanes" during surveys, spaced so that they are 3 m apart. Snorkelers are responsible for surveying the area 1.5 m on either side of their path through the river. The snorkeler closest to the bank should maintain a distance 1.5 m from the bank and is responsible for surveying the area from the bank to an imaginary line 3 m from the bank. Backwater habitats and off-channel pools will be visually sampled by the nearest surveyor.

Snorkelers will identify species and life stage, estimate fish length, and measure water depth that the fish is observed in. Fish length will be estimated in 20-mm size increments (i.e., 30-50 mm, 50-70 mm, etc.), which is believed to be the smallest interval that trained divers can distinguish. When a group of fish is observed, and it is not possible to characterize them all individually, then counts of the number of fish in habitat "patches" (defined by the area of riverbed that can be effectively observed by a single diver) will be made. A colored weight (large washers, fishing leads) with attached numbered tag will be placed on the bed to mark the location of either a single fish being observed or the central location of a group of fish too numerous to identify each one. Once the entire channel unit has been surveyed, two divers will walk or drift back downstream with a Trimble GPS to relocate and record the GPS location for all bed tags identified during the snorkel survey in order to be able to characterize water depth, water velocity, proximity to cover, and other geomorphic features. The area of non-sampled channel resulting from excessive water velocity will be quantified at a representative snorkeling discharge, or range of discharges, and subsequently classified as "swimmable" and "unswimmable" areas, as part of the M&E Program 2D Hydrodynamic Model of the lower Yuba River. The resulting two multi-feature GIS vector polygons will be intersected with the M&E Program Mesohabitat Map, as appropriate for that discharge, and used to determine the relative abundances of non-sampled mesohabitat at the lower Yuba River and study-site-only spatial scales.

12) Rotary Screw Trapping

Rotary Screw Traps (RSTs) are anchored at a fixed point in the stream channel and intercept a portion of the juveniles, smolts, or fry of juvenile salmonids migrating downstream, as well as other fishes, utilizing the force of moving water over baffles inside the cone to rotate. RSTs provide valuable information such as the presence/absence of migrating life-stages, determination of age and size at migration, condition, timing, species, and genetic characteristics (Volkhardt et al. 2007 as cited in the M&E Program).

Goals of the rotary screw trapping include: (1) document the (juvenile) fish community composition in the lower Yuba River; (2) estimate and examine trends in the weekly, monthly, seasonal and annual abundances of emigrating juvenile Chinook salmon and steelhead/rainbow trout from above DPD and the lower Yuba River; (3) estimate the number of juvenile spring-run Chinook salmon and steelhead/rainbow trout that rear during the summer and emigrate in the fall from DPD and the lower Yuba River; (4) examine the influence of lower Yuba River flows and water temperature on the timing of juvenile Chinook salmon and steelhead/rainbow trout emigration; (5) evaluate time-period specific size structure during juvenile Chinook salmon and steelhead/rainbow trout emigration; and (6) document the seasonal presence of developmental phases (i.e., yolk-sac fry, fry, parr, silvery parr, and smolt) of juvenile Chinook salmon and steelhead/rainbow trout.

RST sampling has been conducted seasonally on the lower Yuba River from 1999 to 2005 and year-round from 2006 to 2009. RST sampling has been temporarily suspended until the logistics associated with implementing a trapping device at or upstream of DPD have been resolved, in order to obtain comparable data between upstream and downstream locations for focused evaluations. It is anticipated that additional sampling will be conducted commencing in 2011, and may be conducted in subsequent years pending results, as evaluated by the RMT.

The RSTs are fished year-round, with the survey period defined as October 1 through September 31. Interruptions of sampling effort within a particular survey period due to, for example, excessive debris or high streamflow, is recorded and justified.

The M&E Program Rotary Screw Trapping activities have utilized a set of three RSTs near Hallwood Boulevard (approximately 0.5 mi. upstream of Hallwood Boulevard at RM 7.5). A fourth trap is intended for use upstream of DPD, although, the exact location has not been chosen. Two of the RSTs at the Hallwood Boulevard location are conically shaped with a cone diameter of 8 feet. The two 8-ft RSTs (RST 1 and RST 2) are fished in tandem and tethered to a rock anchor and set approximately 100 feet downstream of the 5-ft RST. The third RST at the Hallwood Boulevard location has a cone diameter of 5 feet, tethered by an earth anchor situated toward the downstream end of a large gravel bar.

A field crew of two to three technicians service the RSTs at least once per day to document their operational status, remove trapped fish from the live box, estimate rotation speed, remove debris, and record water temperature (°C), velocity (feet per second), and turbidity (NTUs). During periods of excessive algae growth (June-October), high debris loads, or high river flow events the RSTs will be serviced at least twice per day to keep them rotating continuously and reduce fish mortality.

Captured fish are processed on the bank of the river. Juvenile steelhead/rainbow trout and Chinook salmon are processed before other fish species and are kept in separate buckets for mark-recapture tests. Estimates of species abundance, weight (0.1 g), and fork length (mm) are made. Captured steelhead/rainbow trout and Chinook salmon are additionally assigned life-stage index values and run designation. Mark-recapture tests are performed approximately weekly for juvenile steelhead/rainbow trout and juvenile Chinook salmon once captured numbers equal or exceed the pre-specified target number (1000), or 5 days have elapsed, whichever comes first. A minimum of 300 juvenile Chinook salmon or steelhead/rainbow trout are needed for the efficiency tests. Fish are marked with Bismarck Brown powder on the day prior to release, held overnight, and released the next day. All recaptured fish in each of the RSTs are measured for fork length (mm), weighed (0.1 g), and assigned a life-stage index value. Trap efficiency is estimated using data collected during the seven days after a group of efficiency test fish is released. Marked fish are released 625 meters upstream from the trapping location and uniformly across the river for random dispersal. Capture efficiency tests will be performed throughout the year whenever catch of juvenile Chinook salmon or steelhead/rainbow trout in the RST is sufficient.

13) Genetic Sampling and Characterization

A genetic analysis of phenotypic spring-run Chinook salmon collected in the lower Yuba River will help identify the amount of introgression among spring-run and fall-run Chinook salmon, and source populations for phenotypic spring-run Chinook salmon that currently exist in the lower Yuba River. Additional monitoring such as Acoustic Tagging and Tracking and Carcass Surveying is ongoing, and will provide additional information regarding the current extent of reproductive isolation between spring-run and fall-run Chinook salmon in the lower Yuba River.

Goals of the Genetic Sampling and Characterization Protocol and Procedure are to use tissue samples to: (1) identify the genetic composition of lower Yuba River phenotypic fall-run and spring-run Chinook salmon; and (2) examine genetic differentiation between fall-run and spring-run Chinook salmon in the lower Yuba River.

Adult Chinook salmon genetic sampling began during May 2009, when 43 adult phenotypic spring-run Chinook salmon were sampled. Sampling also is being conducted during the May/June 2010 Acoustic Tagging and Tracking surveys, and during the 2010 fall Carcass Surveys (September through December). Additional sampling may be conducted during subsequent years, pending the RMT's review of the results from previous and planned sampling.

Genetic sampling will occur during the acoustic tagging and tracking survey of immigrating adult spring-run Chinook salmon (May/June) and during Chinook salmon carcass surveys (September through December). Genetic sampling of Chinook salmon carcasses will occur throughout the carcass surveys, beginning in September (targeting spring-run Chinook salmon) and continuing through late December (targeting fall-run Chinook salmon).

For the purpose of genetic sampling of adult Chinook salmon, the study area extends from the downstream terminus of the Narrows to the confluence of the lower Yuba River and the Feather River near Marysville, California.

Genetic sampling of live adult phenotypic spring-run Chinook salmon will occur on the lower Yuba River downstream of DPD. Tissue samples will be obtained from adult phenotypic spring-run Chinook salmon during acoustic tagging and tracking surveys. Therefore, the exact location(s) for genetic sampling will vary depending upon the specific locations of individual captures. Genetic sampling also will be conducted during the

Chinook salmon carcass surveys, in survey reaches including: (1) Narrows pool to Highway 20 Bridge; (2) Highway 20 Bridge to DPD; and (3) DPD to Simpson Lane Bridge.

Guidelines for genetic sample collection provided by the NOAA Southwest Fisheries Science Center's Santa Cruz laboratory (refer to Attachment 2 of the M&E Program Genetic Sampling and Characterization Protocol and Procedure), as well as additional guidelines provided by the CDFG (refer to Attachment 3 of the M&E Program Genetic Sampling Protocol and Procedure), will be used to collect data and genetic samples from all live adult Chinook salmon and Fresh (i.e., pink or red gills or at least one clean eye) Chinook salmon carcasses. Genetic analyses are conducted by the NOAA Southwest Fisheries Science Center's Santa Cruz laboratory.

Scales are additionally collected as part of the M&E Programs Genetic Sampling and Characterization Protocol and Procedure for age assessment. If possible, all observed fresh Chinook salmon carcasses will have scale samples and associated data collected. For the CDFG Age Scale Program, a minimum goal of 550 scale samples is needed for each run of Chinook salmon being sampled (Kormos 2007 as cited in the M&E Program). In addition, scale samples are needed for all coded-wire tagged fish and all grilse. Scale samples are collected from a preferred scale area located on the left side of the fish. A diagonal section of 20-30 scales are taken from the posterior insertion of the dorsal fin and just slightly above the lateral line.

14) Otolith Sampling and Characterization

The Otolith Sampling and Characterization Protocol and Procedure will identify whether adults spawning on the Yuba River were originally born and reared in the lower Yuba River or whether they are strays to the lower Yuba River. The use of $^{87}Sr/^{86}Sr$ isotopic data permits the identification of whether individuals are of natural or hatchery origin, as well as their specific source of origin (e.g., Feather River Hatchery vs. Coleman National Fish Hatchery).

The Yuba River has an $^{87}Sr/^{86}Sr$ value of 0.7082 (Barnett-Johnson et al. 2008 as cited in the M&E Program). This relatively high ratio is distinct among other tributaries to the Sacramento River. Wild and hatchery-origin fish from the Feather River are likely sources of strays due to proximity to the lower Yuba River and are isotopically distinguishable from the lower Yuba River and each other, as are other potential sources of strays.

Goals of the Otolith Survey include: (1) determining the origin of Chinook salmon in the lower Yuba River (i.e., hatchery-origin, natural-origin and river of origin); and (2) evaluating the contribution of Chinook salmon naturally produced in the Yuba River to the returning spawning population.

Otolith sampling was conducted during 2009-2010 and will again be conducted during 2010-2011. The need for additional years of sampling will be determined pending the RMT's review of the results from previous and planned sampling. Otoliths are collected during the annual Chinook salmon carcass surveys as part of the long-term monitoring effort of the lower Yuba River spring-run and fall-run adult Chinook salmon populations. Annual Chinook salmon carcass surveys and otolith sampling occur from the beginning of the spawning season (September) through the end of the spawning season (late-January). Begin and end dates of the annual carcass survey will vary depending on when Chinook salmon redds are observed and when the recapture rate of tagged carcasses in January approaches zero.

In the field, otoliths are removed from all fresh non-adipose fin-clipped Chinook salmon carcasses. In addition, otoliths are removed from all of the heads collected from adipose fin-clipped carcasses in the laboratory unless a sub-sampling procedure (as described below) is required due to high carcass numbers. A "flip top" approach for removing otoliths is used so the fresh non-adipose fin-clipped fresh carcasses can be tagged for the mark-recapture study. A detailed description of this procedure is provided in the M&E Program Carcass Survey Protocol and Procedure.

The Otolith Sampling and Characterization Protocol and Procedure analyzes a minimum of 100 temporally stratified otoliths to reflect the distribution of spawners to the lower Yuba River and acquire a reasonable estimate of straying. Sample numbers may be increased to better constrain estimates as demonstrated during the 2009 Otolith Survey. Otolith survey results will be linked to the M&E Program Genetic Sampling analysis (spring- vs. fall-run Chinook salmon determination).

All fresh Chinook salmon carcasses were sampled during the 2009 carcass survey, with the exception of October 21, 2009 when sub-sampling methods were used because of a large sample size. Watershed-level composition estimate was attained by creating a 'Rand' variable in excel to assign a random number to each otolith sample. Samples were subsequently sorted in ascending order, and the first 120 samples used in analysis. The additional 20 samples were saved in case any of the initial 120 samples were compromised during the preparation process, or were required for later analysis.

Samples collected on October 21, 2009 were sub-sampled at a ratio 1:5 in the field. To ensure than these sub-samples were not underestimated in the watershed-level composition estimate, and to account for a greater representation of carcasses on that day that were not sampled, 4 “dummy” variables was created for each of samples collected, which represented the fish not sampled. The “dummy” variable was included in the original 'Rand' subsample. In the instance where a “dummy” variable was selected as part of the subsample, a collected otolith sampled from a carcass that day was substituted.

Otolith microchemistry analysis is performed via a contract with the Barnett-Johnson Fisheries and Otolith Laboratory at the University of California, Santa Cruz. Otolith microchemistry analyses conducted are expected to be similar to those used by Barnett-Johnson et al. (2007 and 2008; as cited in the M&E Program). The microchemistry analysis assessed the concentration of heavy and light Strontium isotopes, ^{87}Sr and ^{86}Sr respectively, because Sr substitutes for Ca in the otoliths carbonate matrix and can be extracted at daily growth increments. The technique analyses the ^{87}S /^{86}Sr isotopic ratios that identify natal freshwater habitat, small-scale movement patterns and timing of migration into freshwater from the ocean based on water chemistry or foodwebs disparities among habitats. In addition to otolith microchemistry analyses, efforts are underway to plan activities associated with otolith microstructure analyses to examine discrete daily growth increments deposited throughout the life of the fish.

OTHER DATA COLLECTION AND MONITORING PROGRAMS

CDFG Scale Aging Program

CDFG uses scales to estimate salmonid size at age, and obtain information on the age structure of the annual Chinook salmon runs in the Central Valley, including the lower Yuba River. Scale sampling occurs at hatcheries and on CDFG escapement surveys to reflect spatial and temporal differences in age structure among fish.

Goals of CDFG's Scale-Age Program include: (1) examining age structure and the variation in the age structure of the total (hatchery and natural origin) and of natural origin spring-run and fall-run Chinook salmon; and (2) estimating sex composition by age for the total (hatchery and natural origin) population and of natural origin adults, and determine the variability in sex composition of the adult population (by age) for spring-run and fall-run Chinook salmon.

Lower Yuba River Chinook salmon escapement surveys are conducted each year (see above). Scale samples are collected annually from October through January in the lower Yuba River. Results from the 2006-2007 and 2007-2008 are reported above (see Grover and Kormos undated).

Scale samples are collected from fresh Chinook salmon carcasses for age determination and cohort reconstruction through cooperation with the Ocean Salmon Project. The sample design was selected to achieve a non-biased estimate of age structure for the specific portion of the population where escapement estimates are made without respect to known or unknown age fish. Almost all of the adipose fin clipped fish from hatcheries are scale sampled to provide a reference collection of as many known age scales as possible. In hatcheries, samples are collected at a constant rate throughout the entire spawning period keeping track of the "random" age sample and the additional "non-random" known age samples. During carcass surveys, samples are collected at a constant rate as fish suitable for sampling are encountered. Because of the high sample rate for known age scales at hatcheries and the difficulty of sampling on spawning grounds, non-random samples are generally not taken from adipose fin clipped carcasses.

A skin patch containing between 20-30 scales is removed from the scale pocket located posterior of the last dorsal fin ray, and above the lateral line. Each skin patch is placed in an individual envelope containing: (1) unique sample code; (2) date; (3) location; (4) fork length; (5) sex; (6) ad-clip status; and (7) head tag number if available. Scale envelopes are placed in a dry storage area for later processing by the Ocean Salmon Project's scale aging team. State of the art mounting, digital imaging and digital reading techniques are currently used to examine age structures or patterns. Individual ages are determined from scales by counting winter annuli. Annuli can be identified as bands of closely spaced or broken circuli. Scale samples are read by an individual experienced reader and field biological data (sex and length) are taken into consideration only after the initial evaluation of age by the reader.

CDFG Angler Surveys

In 1998, the CDFG created the Central Valley Salmon and Steelhead Harvest Monitoring Project. The goal of this program is to estimate the number of adult Chinook salmon and steelhead resulting from natural production in Central Valley rivers and streams including: (1) determining annual estimates of the total in-river harvest of salmon and steelhead; and (2) provide limited harvest data on other anadromous and resident sport fish species. . According to CDFG's current Freshwater Sport Fishing Regulations, the lower Yuba River is closed to salmon fishing.

River sections for the lower Yuba River are surveyed year round (D. Massa, CDFG, pers. comm., 2009) Two river sections have been previously surveyed by the Central Valley Angler Survey on the Yuba River including: (1) Marysville to DPD; and (2) DPD to 1 mile upstream of the Highway 20 Bridge. All sample sections were surveyed eight randomly-selected days per month; four weekdays and four weekend days. Weekdays and weekend days were placed in separate strata due to the increase in angling effort commonly associated with weekend days.

The Yuba River is surveyed via kayak, so the angler count and interview data are collected in tandem as the surveyor travels downstream with the current. Start time and launch location are randomized using a random number generator. All data collected is linked to a unique number series assigned to the Central Valley tributaries of the Sacramento River that represent river miles.

Field data required to calculate angler use and catch estimates include hourly counts, angler counts, and angler interviews. During the angler count, time and location of anglers is collected, as well as parameters for angler effort such as the number of boats, the number of boat or shore anglers, and the start and finish times. An interview of all anglers observed during the angler count is preferable. However, if not feasible than every n^{th} angler is interviewed. Data collected during each interview includes: (1) angler location by river mile; (2) fishing method (boat or shore); (3) number of hours fished to the nearest quarter-hour; (4) number of anglers in group; (5) target species; (6) zip code; (7) whether the trip was completed; and (8) the number of fish kept and/or released by species.

Length is used to differentiate between steelhead and rainbow trout. All rainbow trout 16" or greater are considered to be steelhead. Rainbow trout less than 16" are recorded as rainbow trout. For, steelhead/rainbow trout, striped bass, and sturgeon, fish are measured to the nearest ½ centimeter and inspected for any marks or tags. All steelhead caught are inspected for the presence of an adipose fin. A steelhead missing an adipose fin indicated the fish was of possible hatchery origin.

YCWA Lower Yuba River Redd Dewatering and Fry Stranding Monitoring and Evaluation

In D-1644, the SWRCB in 2001 directed YCWA to submit a plan, in consultation with USFWS, NMFS, and CDFG that describes the scope and duration of future flow fluctuation studies to verify that Chinook salmon and steelhead redds are being adequately protected from dewatering with implementation of D-1644 criteria (JSA 1992). In RD-1644, the SWRCB in 2003 readopted this requirement. After various comments and revisions, the March 2002 Plan (Plan) was approved by the SWRCB on April 17, 2002. Phase I of the Plan was undertaken in 2002, and implementation of Phase II of the Plan continues.

Studies associated with the Plan combine habitat mapping, field surveys, and information on the timing and distribution of fry rearing in the lower Yuba River to evaluate the effectiveness of D-1644 flow fluctuation and reduction criteria in protecting Chinook salmon and steelhead/rainbow trout fry. Goals of YCWA Lower Yuba River Redd Dewatering and Fry Stranding Monitoring and Evaluation include: (1) determine the potential magnitude of redd dewatering in relation to the timing and magnitude of flow fluctuations and reductions; (2) determine the potential magnitude of fry stranding in relation to the timing, magnitude, and rate of flow fluctuations and reductions; (3) evaluate the effectiveness of flow fluctuation and reduction criteria in protecting redds and fry; and (4) recommend additional measures to protect redds and fry from flow fluctuations and reductions, if warranted.

Two studies were conducted and summarized in the 2007 and 2008 *Lower Yuba River Redd Dewatering and Fry Stranding Annual Reports* (JSA 2007, 2008) to the SWRCB (see the Available Field Studies and Data Collection Reports section of this document).

In accordance with the *Lower Yuba River Redd Dewatering and Fry Stranding Monitoring and Evaluation Plan* (2003), YCWA and JSA will continue to monitor and evaluate stranding risk and flow-habitat relationships for off-channel stranding. Future actions will include the following: (1) continued evaluation of the effects of time of day (night versus day) on stranding risk of juveniles; (2) inspection of interstitial habitats along the river margins to determine the presence of young fry before bar stranding evaluations; (3) evaluation of the effects of higher ramping rates (>100 cfs per hour) on stranding risk of larger fry and juveniles; (4) continued evaluation of the relationship between flow range and the number, area, and distribution of off-channel sites that become disconnected from the main river; (5) evaluation of the effect of peak winter and spring flows on the incidence of off-channel stranding; and (6) continued monitoring of habitat conditions and survival of Chinook salmon and steelhead/rainbow trout in selected off-channel monitoring sites where stranding is frequently observed.

CDFG Steelhead/Rainbow Trout Acoustic Tagging and Tracking Survey

This is a multi-year study to monitor the movement patterns of wild juvenile and adult steelhead/rainbow trout in the lower Yuba River by CDFG (The Heritage and Wild Trout and the Steelhead Management and Recovery Programs). Utilizing acoustical tags and instream hydrophones, this project will track tagged trout movements, habitat selection, and evaluate tracking techniques over multiple seasons and flow conditions. The goal of this program is to develop understanding regarding the movement of steelhead/rainbow trout to help agencies better manage the trout populations on the lower Yuba River, thus providing anglers with a continued sport fishing opportunity for wild resident/anadromous trout in the Central Valley.

Monitoring for acoustic-tagged spring-run Chinook salmon occurs on the lower Yuba River from Englebright Dam to the Yuba River and Feather River confluence through the use of acoustic hydrophones currently in place (J. Nelson, CDFG, 2008, pers. comm.). As of February 2009, there are 16 hydrophones located throughout the lower Yuba River. Static receiver hydrophones will operate continuously year-round and data will be obtained at least every other month by CDFG.

Wild juvenile and adult steelhead/rainbow trout are captured using hook-and-line sampling, and acoustic tags are inserted into the fish. The exact location(s) for acoustic tagging will vary depending upon the specific locations of individual captures.

In addition to fixed-station hydrophones (i.e., static receivers), mobile tracking surveys are conducted. When an acoustically tagged fish is detected, the location is recorded using a GPS unit.

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APPENDIX D
Voluntary Conservation Measures

This Appendix Includes:

- Gravel/Cobble Augmentation Implementation Plan (GAIP) for the Englebright Dam Reach of the Lower Yuba River, CA
- Lower Yuba River Large Woody Material Management Plan

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Gravel/Cobble Augmentation Implementation Plan (GAIP) for the Englebright Dam Reach of the Lower Yuba River, CA

(photo of proposed gravel augmentation location)

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OVERVIEW

The purpose of this report is to thoroughly document a plan for implementing a gravel/cobble augmentation program below Englebright Dam and to address its biogeomorphic impact on the lower Yuba River. As described below, Englebright Dam plays a crucial role in protecting the downstream region from being overwhelmed by sedimentary mining waste debris still being eroded off hillsides and stored in long sections of the channel network upstream. Most of the active lower Yuba River also still has tens of millions of cubic yards of sedimentary mining waste debris in it that pre-date Englebright Dam and are still being re-worked as part of a highly dynamic, meandering gravel-bed river. However, the reach between Englebright Dam and the confluence with Deer Creek is now almost devoid of river-rounded gravel and cobble necessary for salmon spawning. In particular, spring-run Chinook salmon that historically went far upstream would substantially benefit from a gravel/cobble augmentation program below Englebright Dam. Yet the critical reach is in a narrow canyon that is difficult to access and manage, let alone place thousands of tons of coarse sediment into. Numerous issues have to be considered and addressed. That effort is facilitated by the existence of many studies of the river in recent years that form the basis for understanding the status and challenges ahead for the river.

This report covers topics related to preliminary planning efforts, pre-project characterization of the reach in question, design development for the specific 2010 next-phase pilot project, and long-term planning. Section 1 is an overview of the literature that describes what is already known about the river leading to a geomorphic and biological nexus for the action necessary to rehabilitate the river with respect to the impact of Englebright Dam. Section 2 explains what gravel/cobble augmentation is and how it may be implemented. Specific constraints and opportunities associated with the possible use of each method below Englebright Dam are described, including how specific methods affect site selection and project goals. Section 3 presents the pre-project characterization of the Englebright Dam Reach. That includes a summary of available data and information, a new estimation of the gravel/cobble deficit for the reach, 2D hydrodynamic modeling and analysis of results, and a conception of how the reach works in its baseline condition. Section 4 presents the details of the concept for how to get gravel to the river bed in the remote canyon. The recommended method involves sluicing gravel and cobble to the river. Section 5 explains and tests design concepts, objectives, and methods for the opportunity to place gravel in 2010 to yield immediate, preferred salmon spawning physical habitat. Section 6 describes a long-term plan for monitoring the outcome of the 2010 pilot project and then what actions should be taken thereafter to continue to rehabilitate gravel/cobble storage and enhance salmonid spawning habitat in the reach with additional augmentations over time.

1. LOWER YUBA RIVER BACKGROUND

The 3,490-km^2 Yuba River basin has hot, dry summers and cool, wet winters. Relative to other Sierra basins, the Yuba has among the highest mean annual precipitation (>1,500 mm), so it has been used for hydropower, water supply, flood regulation, gold mining and sediment control (James 2005). During the Gold Rush (mid- to late 1800's), hillsides were hydraulically mined until several court decisions first outlawed the practice, then reinstated it with restrictions and taxes instituted to construct and pay for dams such as Daguerre Point Dam and Englebright Dam. These dams were designed to prevent the transport of hydraulic mining debris to the valley, thus lowering the risk of flooding. However, hydraulic mining never returned to the levels of the 1800's (Gilbert, 1917). Englebright Dam is located at 39°14'23.37"N, 121°16'8.75"W (Yuba River mile 23.9 upstream from confluence with the Feather River) in a narrow bedrock canyon on the Yuba River in northern California. Streamflow is recorded at the United States Geological Survey Smartville gage (#11418000) 0.5 km downstream of Englebright Dam. The gage's statistical bankful discharge 1971-2004 was 5620 cfs (159.2 $m^3 s^{-1}$), which matches field indicators (tops of active medial bars and positioning of bank vegetation) for the bankful discharge in Timbuctoo Bend. Given that the Middle and South Yuba tributaries lack large reservoirs, winter storms and spring snowmelt produce floods that overtop Englebright Dam. The Lower Yuba River (LYR) is ~38 km (24 mi) long from Englebright to the junction with the Feather. The Englebright Dam Reach (EDR) extends from Englebright down to the confluence with Deer Creek (Fig. 1.1).

1.1. LYR Geomorphic History

No records are known to exist describing river conditions in the canyon that Englebright sits in prior to placer gold mining in the mid-Nineteenth century. During the era of placer gold mining, Malay Camp on the northern bank of the Yuba close to the confluence of Deer Creek served as a base of operations for miners working Landers Bar, an alluvial deposit in the canyon nearby. The historical records of the existence of this camp and placer-mining site proves that coarse sediment was stored in the canyon prior to hydraulic mining in a large enough quantity to produce emergent alluvial bars.

During the period of hydraulic gold mining, vast quantities of sand, gravel, and cobble entered the Yuba River (Gilbert, 1917) and deposited throughout the system (Fig. 1.2). This human impact completely transformed the river. Historical photos from 1909 and 1937 document that the canyon was filled with alluvial sediment with an assemblage of river features including riffles (Pasternack et al., 2010). Conditions downstream of the canyon during that period were described by James et al., (2009). Even though Daguerre Point Dam was built on the valley floor in 1906 (at Yuba River mile 11.4 upstream from confluence with the Feather River) to prevent the transport of hydraulic mining debris, it is too small to block sediment migration during floods.

Englebright Dam (capacity of just 82.6 million m^3) was constructed in 1941 to serve as an additional, highly effective barrier to the hydraulic-mining waste material continuing to move down to the Central Valley. Thereafter, photos show that the amount of alluvium in the entire lower Yuba River, including the canyon, decreased (Pasternack et al., 2010). At the Marysville gaging station, the river incised ~20' from 1905-1979, while 0.5 mi downstream of the Highway 20 bridge it incised ~35' over the same period (Beak Consultants, Inc., 1989). These landform adjustments are still on-going. For example, Pasternack (2008) estimated that ~605,000 yds^3 of sediment (primarily gravel and cobble) were exported out of Timbuctoo Bend from 1999 to 2006. Further investigations of landform and sediment-storage changes are on-going, and the early indications are that they will show significant dynamism well beyond what was presumed by Beak Consultants, Inc (1989).

The reported changes conform with the expected, natural response of a river to blockage of downstream sediment passage (e.g. Williams and Wolman, 1984). For most rivers, such geomorphic changes represent a harmful human impact on a river, but in this case of pre-existing, unnatural snuffing of the river corridor by mining debris, the dam is actually *restoring* the river toward its historical geomorphic condition, in the truest meaning of the term- to go back to the pre-existing state prior to hydraulic gold mining. Hydraulic mining is the primary disturbance to the Yuba River. Going back in this case means evacuating much of the waste debris associated with that historic practice. Abatement of the downstream effects of sediment derived from uplands through the use of dams is an accepted practice for watershed rehabilitation (Shields, in press). On the LYR, there is strong evidence that Englebright Dam has helped to evacuate sediment without hurting important channel processes. For example, despite the evidence that Timbuctoo Bend is undergoing significant sediment export and river-corridor incision, White et al. (2010) reported that eight riffles persisted in the same locations over the last 26 years (likely back much further). Most of these persistent riffles are positioned in the locally wide areas in the valley, while intervening pools are located at valley constrictions. Thus, incision and sediment export do not necessary translate into harmful degradation of fluvial landforms. In Timbuctoo Bend, the existence of undular valley walls preserves riffle-pool morphology in the face of on-going geomorphic change. Given the vast quantity of waste material still present in the upper system and the ability of many unhealed hillsides to generate more, Englebright Dam continues to serve as an important protection for the environment of the LYR.

Confounding the natural response of the river to the restorative impact of Englebright, the Yuba River has been subjected to harmful in-channel human activities that further altered it. The greatest impact came from dredgers processing and re-processing most of the alluvium in the river valley in the search for residual gold and to control the river (James et al., 2009). First, there was the formation of the ~10,000 acre Yuba Goldfields in the ancestral migration belt. Then there was the relocation of the river to the valley's northern edge and its isolation from the Goldfields by large "training berms" of piled-up dredger spoils. Dredger-spoil training berms also exist further upstream in Timbuctoo Bend away from the Goldfields (Fig. 1.3); these berms provide no flood-control benefit.

Although no training berms exist in the canyon downstream of Englebright Dam, mechanized gold mining facilitated by a bulldozer beginning ~1960 (Fig. 1.4) completely reworked the alluvial deposits in the vicinity of the confluence with Deer Creek, changing the river's form there (Pasternack et al., 2010). Prior to mechanized mining, glide-riffle transitions were gradual, enabling fish to select among a diverse range of local hydraulic conditions. Bulldozer debris constricted the channel significantly, induced abrupt hydraulic transitioning, and caused the main riffle at the apex of the bar to degrade into a chute. In addition, mining operations evacuated the majority of alluvium at the mouth of Deer Creek. On top of these impacts, the 1997 flood caused angular hillside rocks and “shot rock” debris from the canyon bottom to be deposited on top of the hydraulic-mining alluvium in the canyon.

At present, the Yuba River downstream of Englebright Dam continues to change in response to the complex assemblage of natural processes and human impacts. The legacy of hydraulic mining is the first and foremost impact to the system, relative to the pre-existing condition. Englebright Dam blocks further impacts from upstream mining waste and is directing the river on a trajectory toward restoration of the pre-existing landform. Daguerre Point Dam serves as a stabilizer in the system, providing a base level for how far incision can go between it and Englebright Dam. Mechanized re-working of alluvium and associated channelization have dictated the lateral bounds of what the river can do now and also impact the diversity and distribution of river-corridor landforms.

In summary, the fluvial geomorphology of the Yuba River is so unique that it is crucial to evaluate it on its own terms and not apply simple generations and concepts from other rivers with dams. Hydraulic mining, dredger re-processing of the valley floor, mechanized in-channel mining, upstream watershed management choices, and dams all combine to yield a system that requires careful investigation before making conclusions about how the fluvial geomorphology works and what restoration opportunities exist. Recent studies have helped clarify the current status of the river and more investigations are on-going.

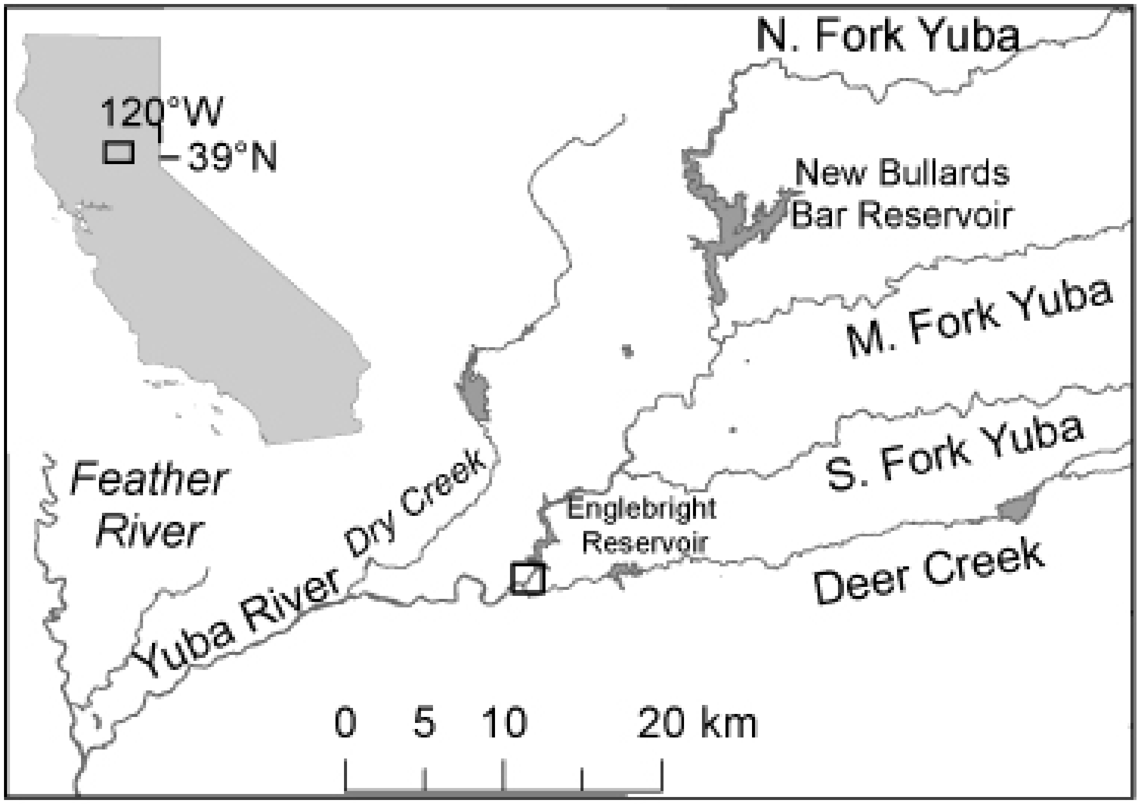

Figure 1.1. Location map of the Englebright Dam Reach (black box) in the Yuba catchment.

Figure 1.2. 1905 photo of the LYR near Parks Bar taken by G.K. Bilbert (http://libraryphoto.cr.usgs.gov/photo_all.htm).

Figure 1.3. Dredger forming high tailings berm out of a mining-waste point bar at Rose Bar on 10/21/1937. (Photo from the California Transportation State Archive).

Figure 1.4. Photo of a gold mining operation on Sinoro Bar circa 1960. (Photo courtest of Ralph Mullican).

1.2. LYR Salmonids History

1.2.1. Historical Population Accounts

The spring run of Chinook salmon (SRCS) is a federally threatened species that is differentiated by the time at which adults migrate from the ocean to freshwater systems (Yoshiyama et al. 1996). There are no quantitative estimates for pristine, historic salmonid populations on the Yuba River prior to hydraulic gold mining, let alone isolating just SRCS, but Yoshiyama et al. (1996) reported historic accounts suggesting a large population, possibly in the hundreds of thousands. For example, they cite Chamberlain and Wells (1879) as stating that the Yuba was so full of salmon that Indians speared them “by the hundred”. However, during hydraulic gold mining much water was diverted away and the river valley was allowed to fill 20-80’ high with mine tailings. A first-hand account of a miner at Long Bar in the valley stated that the miner’s diet primarily consisted of pancakes and there is no mention of fish at all (Lecouvreur, 1906). Yoshiyama et al. (1996) reported accounts of the construction of Bullards Bar Dam in 1921-1924 in which it was stated that so many salmon were blocked at the construction location that their carcasses had to be burned. SRCS and steelhead both were known to migrate far up into the North and Middle Yuba Rivers and several miles up into the South Yuba before reaching potentially impassable waterfalls. However, much of the spawning habitat in the upper watershed was badly degraded by mining debris, sand, and turbidity. If the SRCS population was in the hundreds of thousands of fish, then the riffles in the canyon where Englebright Dam is located would likely have been used by part of that large population during the mining era and early 20th century. However, relative to the total abundance, this number of fish spawning in the canyon may not have drawn the attention of naturalists at the time, especially given the difficulty of getting to that area.

During the latter half of the 20th century, Yuba River salmonid populations were estimated quantitatively (Fig. 1.5), but it is still difficult to isolate SRCS numbers. Yoshiyama et al. (1996) cite several estimates of the fall-run Chinook salmon population, but provide no enumeration of SRCS. They cite John Nelson as reporting that fall- and spring-run populations are mixed and that these mixed fish are now present in “minimal numbers”. CDFG (1991) enumerates the annual estimate of fall-run Chinook salmon, with a range of 1000 in 1957 to 39,000 in 1982. For SRCS, CDFG (1991) states that a remnant population exists and that it is composed of some in-river natural reproduction, strays from the Feather River, and restocked, hatchery-reared fish. Restocking of fingerlings and yearlings was done in 1980. CDFG (1991) reported that 20 pairs of Chinook salmon were observed to spawn at the Narrows powerhouse in autumn 1986 and due to passage barriers in the autumn, it was decided that these were SRCS that migrated during high spring flows. CDFG stopped conducting annual escapement surveys in 1989. No survey was done in 1990. The Yuba County Water Agency (YCWA) sponsored Jones and Stokes, Inc. to perform escapement surveys using the CDFG methodology for 1991-2004.

For 2005-2007 CDFG took over the effort again, but beginning in 2008 the responsibility shifted to the Yuba Accord River Management Team (RMT) as part of its new Monitoring and Evaluation Plan. The RMT's 2008 escapement and redd reports used temporal modalities associated with fresh carcass observations and frequencies of redd observations to try to differentiate spring- and fall-run Chinook salmon. However, it was not possible to obtain a clear distinction and all data were analyzed together. In all of these modern enumerations, abundance estimates did not isolate SRCS or the subpopulation of all Chinook in the EDR; carcass counts were not made in the EDR due to challenging accessibility.

For March 2007 through February 2008, the RMT operated a Vaki RiverWatcher video monitoring system on both fish ladders at Daguerre Point Dam (~12 miles downstream of the EDR). This system scans the side-view projected area of each fish and takes a color photo of each fish. From these data, staff counts the number of fish that pass and use characteristic morphometrics to identify the species of each fish (for ~70% of individuals). Of the 1,324 Chinook that were observed, 336 (25%) passed in March-August, which is the period that SRCS likely migrate.

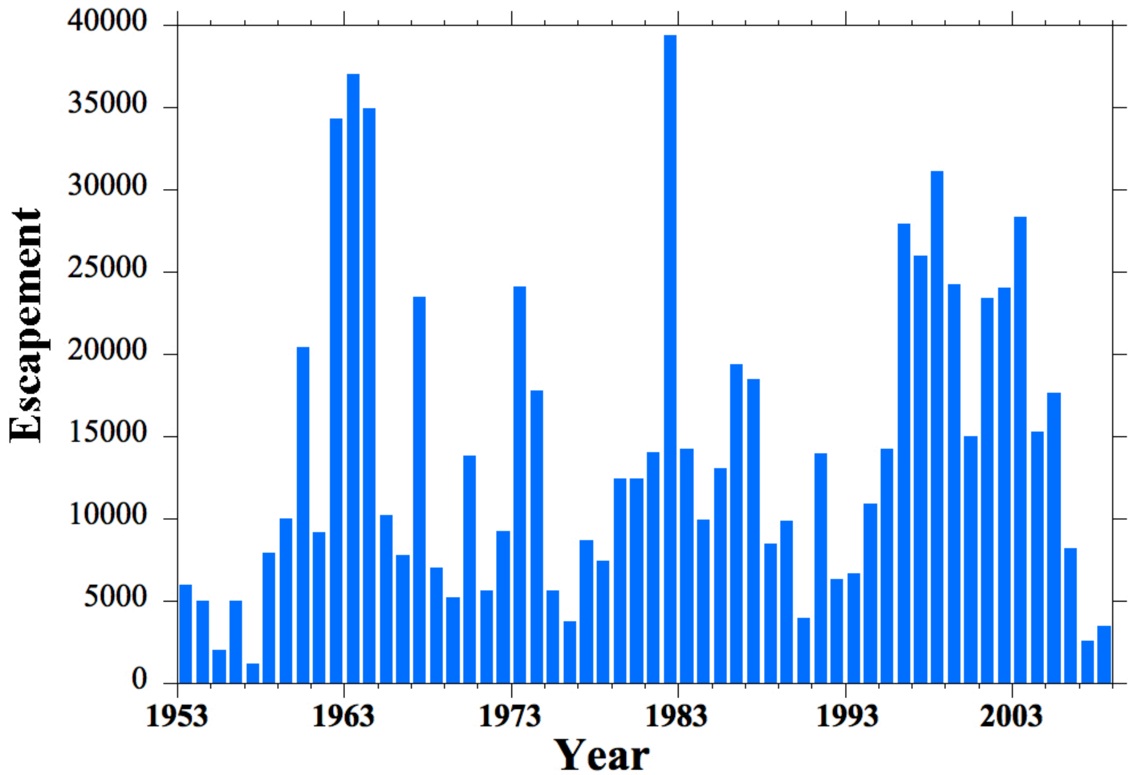

Figure 1.5. Adult Chinook salmon abundance for the LYR based on carcass surveys and coded-wire tagging.

1.2.2. Physical Habitat Conditions

Physical habitat units in rivers are defined as zones with characteristic attributes where organisms perform ecological functions, which are the ways in which organisms interact with each other and their surroundings. Common attributes of physical habitat include substrate type, water depth, water velocity, water temperature, cover objects, and shading. The quantity and quality of physical habitat are critical factors that can limit the size of fish populations. The assemblage of these attributes stem from the interaction among hydrologic, hydraulic, and geomorphic processes. As a result, when processes are altered or degraded by human intervention, then physical habitat will likely be degraded too. In turn, that decreases the size of fish populations.

Physical habitat conditions related to salmonids downstream of Englebright Dam have been studied over the years. With respect to the spawning life stage, Fulton (2008) investigated salmon spawning habitat conditions in the canyon below Englebright Dam and found the conditions to be very poor to nonexistent. No rounded river gravels/cobbles are present in the canyon between Englebright Dam and Sinoro Bar by the confluence with Deer Creek other than a small amount injected artificially in November 2007. For the whole lower Yuba River, Beak Consultants, Inc (1989) states:

> "The spawning gravel resources in the river are considered to be excellent based on the abundance of suitable gravels, particularly in the Garcia Gravel Pit and Daguerre Point Dam reaches. The tremendous volumes of gravel remaining in the river as a result of hydraulic mining make it unlikely that spawning gravel will be in short supply in the foreseeable future. Armoring of the channel bed is possible, but has not developed to date, probably due to periodic flushing by floods comparable to the 1986 event."

Similarly, Pasternack (2008) reported that:

> In Timbuctoo Bend "…there is adequate physical habitat to support spawning of Chinook salmon and steelhead trout in their present population size. Furthermore, all of the preferred morphological units in the *[Timbuctoo Bend Reach]* TBR have a lot of unutilized area and adequate substrates to serve larger populations."

With respect to rearing life stages, Beak Consultants, Inc (1989) states that:

> "The Daguerre Point Dam and Garcia Gravel Pit reaches contribute most of the *[Weighted Usable Area]* WUA, and substantially more than the Simpson Lane Reach; The Narrows Reach contributes little fry habitat… Total WUA for juveniles is highest in the Daguerre Point Darn and Garcia Gravel Pit reaches… The Simpson Lane Reach contributes a small amount of WUA, while The Narrows Reach provides virtually no juvenile habitat."

Adult migration is presently under study by the RMT, but there are some pre-existing observations. Adult SRCS are commonly observed holding in pools in the canyon below Englebright Dam, in the pools in Timbuctoo Bend, and in the pool below Daguerre Point Dam. In September 2007, UC Davis graduate student Aaron Fulton observed SRCS attempting to dig redds and spawn on bedrock covered with a thin veneer of angular gravel, causing them injury. Acoustic tracking of adult SRCS in 2009 by the RMT showed that some individuals migrate into and out of the canyon until September at which point they stop migrating and attempt to spawn between Englebright Dam and the highway 20 bridge.

1.3. LYR Geomorphology-Salmonids Nexus

Two key conclusions from this review of previous knowledge are that most of the lower Yuba River is still geomorphically dynamic and that the river possesses a diversity of in-channel physical habitats, even if some types are not as abundant as would be optimal for restoring the size of fish populations that likely existed in the Yuba River prior to the onset of hydraulic gold mining. Hydraulic mining snuffed the river and its floodplain with a vast, homogenous mix of mining waste. Since Englebright Dam blocked that, channel complexity and habitat diversity has been re-emerging, and that process continues. The extent to which it can continue is impacted by the role of the training berms and the degraded state of the entire Yuba Goldfields, both of which are beyond the scope of actions related specifically to the impact of Englebright Dam, which is the focus of this report. The glaring problem in the system associated with this dam is the status of SRCS spawning in the EDR.

The dramatic decline in SRCS in California has been attributed to dams, as they block up to ~80% of historic spawning habitat. Based on life history, impassable high dams have hurt the spawning life stage of adult SRCS the most, because spawning is the purpose behind the migration of SRCS to Sierran headwaters. Under a regulated flow regime, SRCS migrate to bedrock reaches at the base of large dams and hold in pools supplied with cold sub-thermocline water releases. On the Yuba holding occurs below Daguerre Point Dam and to a lesser extent below Englebright Dam (Fig. 1.6), but once it is time to spawn, SRCS move upstream into the canyon. Therefore, whether they provided historically preferred physical spawning habitat or not (and for the Yuba the evidence is that they did), bedrock reaches at the base of large dams play a key role in SRCS viability under the current regime of impassable dams.

If SRCS cannot spawn in sufficient numbers, then physical habitats supporting their subsequent life stages downstream are irrelevant. There is no question that Englebright Dam is a complete barrier to fish migration upstream and gravel/cobble transport downstream. Any effort to reinstate SRCS presence upstream of Englebright Dam would take significant time to figure out, implement, and evaluate its effectiveness. If such an effort were undertaken, it would still be critical to sustain existing populations below the dam using well-proven methods until passage efforts were equally well demonstrated in the watershed. To achieve usable, preferred SRCS spawning habitat in the canyon, it is necessary to resolve the lack of river-rounded gravels/cobbles there. At this time and for the foreseeable future, only the canyon is in need of a gravel/cobble supply to offset the impact of Englebright Dam.

Figure 1.6. Photo of SRCS holding in bedrock/boulder section of the LYR near the mouth of Deer Creek (photo courtesy of Ralph Mullican).

2. GRAVEL/COBBLE AUGMENTATION

The key negative impact of Englebright Dam on the lower Yuba River is the loss of a mixture of gravel- and cobble-sized river-rounded rocks in the canyon between Englebright Dam and the confluence with Deer Creek, which is necessary to support SRCS spawning there. This reach is known as the Englebright Dam Reach (EDR). Fulton (2008) investigated physical habitat in the uppermost third of the EDR and found that suitable hydraulics for salmon spawning were present there, but needed substrates were absent (Fig. 2.1). Subsequent modeling of the entire EDR showed that the same holds true for the entire reach- there are areas of good hydraulics, but they lack the needed river-rounded gravel and cobble mixture (Pasternack, 2008a). Thus, the solution to this problem is to implement a procedure known as gravel/cobble augmentation (Wheaton et al. 2004a; Pasternack, 2008b).

Figure 2.1. Photo of the EDR below Narrows 1 showing the dominance of shot rock on the banks. The wetted channel is devoid of river-rounded gravel and cobble in this area.

2.1. Gravel/Cobble Augmentation Defined

Gravel/cobble augmentation (aka gravel/cobble injection) is defined as the piling up of coarse sediment (usually a mixture of gravel and cobble ranging in size from 0.3-4 inches (8-100 mm) in diameter) within or along a river (Wheaton et al., 2004a).

*The **geomorphic goal** of gravel/cobble augmentation is to reinstate interdecadal, sustainable sediment transport downstream of a dam during floods, which is necessary to support and maintain diverse morphological units, such as riffles, pools, point bars, and backwaters* (Pasternack, 2008b).

*The **ecological goal** of gravel/cobble augmentation that yields self-sustainable morphological units is to have the associated assemblages of physical attributes that are preferred for each of the freshwater life stages of salmonids* (Pasternack, 2008b).

Pasternack (2008b) explains the pros and cons of gravel/cobble augmentation relative to other methods of river rehabilitation in support of salmon spawning. It is important to understand that achieving the geomorphic goal does not mean that the ecological goal will be achieved too. It has frequently been observed that when gravel is injected into a river, it just settles into the bottom of a deep in-channel pit or pool, never to be re-entrained. Unless a reach is investigated for its hydrogeomorphic mechanisms of fluvial landform maintenance, then there is no basis to an assumption that ecological benefits will necessary be achieved from successful redistribution of injected coarse sediment. This is the concept of “process-based” river restoration (Beechie et al., 2010). Any action may or may not work, depending on whether its usage has been placed into the context of the fluvial mechanisms at work in the system. Augmentation of flow or gravel/cobble in the absence of an understanding of processes and impacts is a gamble of unknown value or harm (Pasternack, 2008b).

When performing gravel/cobble augmentation it is often possible to place the material into the wetted channel according a specific design capable of yielding immediate salmon spawning habitat (Wheaton et al., 2004b; Elkins et al., 2007). It can be beneficial to add large wood and boulders during construction to form hydraulic structures in symphony with the gravel/cobble placement (Wheaton et al., 2004c). Together, these diverse elements are shaped (but not hard-wired) to provide adult holding habitat proximal to high-quality spawning habitat, further enhance spawning habitat with complex gravel oxygenation and shading conditions, and furnish early rearing habitat before fish migrate or are flushed downstream. Depending on site history and the specific goals and methods of such efforts, this approach of blending gravel/cobble placement and hydraulic structure construction can dramatically enhance or rehabilitate morphological units and sub-unit hydraulic complexity for a reach below a dam (Elkins et al., 2007). By coupling that with a long-term gravel/cobble injection program at the base of a dam and evaluation of the flow regime, a comprehensive framework for rehabilitating and managing a regulated river can be achieved (Pasternack 2008b). Such a framework for river rehabilitation is hierarchical, because it incorporates a) microhabitat diversity to provide preferred local conditions to support different life stages of existing populations, b) geomorphically sound mesohabitats that provides more and larger organized areas to grow populations, and c) flow variability and injections of gravel to provide the physical inputs necessary for geomorphic dynamics that renew and sustain a gravel-bed river.

2.2. LYR Pilot Gravel/Cobble Augmentation

The United States Army Corps of Engineers (The Corps), UC Davis, and USFWS collaborated on an experimental gravel/cobble injection below Englebright Dam (in the pool below the Narrows II powerhouse) in November 2007. The purpose of this experiment was to find out if and where gravel/cobble would deposit in the EDR and thus gain insight into the efficacy of gravel/cobble injection as a habitat enhancement tool for spring-run Chinook salmon in the EDR. The basic study design involved injecting gravel/cobble during low flow in autumn of 2007 and then waiting for high flows in subsequent water years to move it. Then it would be possible to track where those materials went.

Five hundred short tons of triple washed river gravel/cobble was purchased from a nearby quarry downstream. Based on bucket tests in a quarry, Merz et al. (2006) reported a dry bulk density of gravel/cobble to be ~0.722 yds^3 per short ton for a Mokelumne River quarry. Using this estimate, a total of 361 yds^3 of gravel/cobble was available to be injected in the EDR. The material was trucked in ahead of time and piled on top of the gravel parking lot at the Narrows II powerhouse (Fig. 2.2). Gravel/cobble injection took place on November 29, 2007 beginning at 9:30 am and finishing by 3:00 pm (Fig. 2.3). A TB 135 truck-mounted gravel conveyor was used to reach out over the river and inject gravel into the Narrows II pool. A single small loader was used to transfer piled gravel/cobble into the hopper, but it turned out that not all the gravel/cobble could be fully injected during the single allotted day using that one loader. Consequently, a small amount ended up being incorporated into the parking lot, instead of going into the river (Fig. 2.4). Using a tape measure, the volume of gravel/cobble left behind on the parking lot, in between boulders on the edge of the lot, and spilled over the side was estimated to be ~34 yds^3. Thus, ~327 yds^3 of gravel and cobble was placed into the river.

As the material was being placed into the river, ~400 painted, magnetized tracer stones were put into the hopper with the gravel/cobble to facilitate tracking. Those tracers are thus integrated all throughout the in-river gravel/cobble pile. Those stones are traceable using a magnetic locator, but any rounded gravel that is found downstream in the EDR must be coming from this source, because there is virtually no other such material in this reach.

Pasternack (2009) investigated the status of the injected gravel/cobble after two winters, and some interesting lessons were evident. Although the two intervening winters were relatively dry (Fig. 2.5), some transport did take place. Of the 327 yds^3 that was successfully injected to the river, only ~3 yds^3 moved during the period when flow was ≤ 8014 cfs. After a flood with a peak flow of 15381 cfs, a total of ~75 yds^3 moved. That amount includes the ~3 yds^3 that was moved prior to that, so that means that ~252 yds^3 remained in the gravel/cobble injection pile in the Narrows II pool as of July 1, 2009. For the 2010 water year, the peak discharge occurred in June 5, 2010 and it was only 6928 cfs.

Preliminary observations of Chinook salmon redds in 2009-2010 by the RMT found that 120 redds were located in the EDR between September 7, 2009 and February

22, 2010. This response to limited gravel injection indicates that if more gravel was present, a population of SRCS could be accommodated.

Figure 2.2. 500 short tons of gravel/cobble prior to injection into the Narrows II pool.

Figure 2.3. Gravel injection on November 29, 2007. Gravel pile is located in zone of aeration downstream of the Narrows II powerhouse.

Figure 2.4. Photo of stockpiled gravel/cobble left on the parking area and hillside after the 2007 pilot injection.

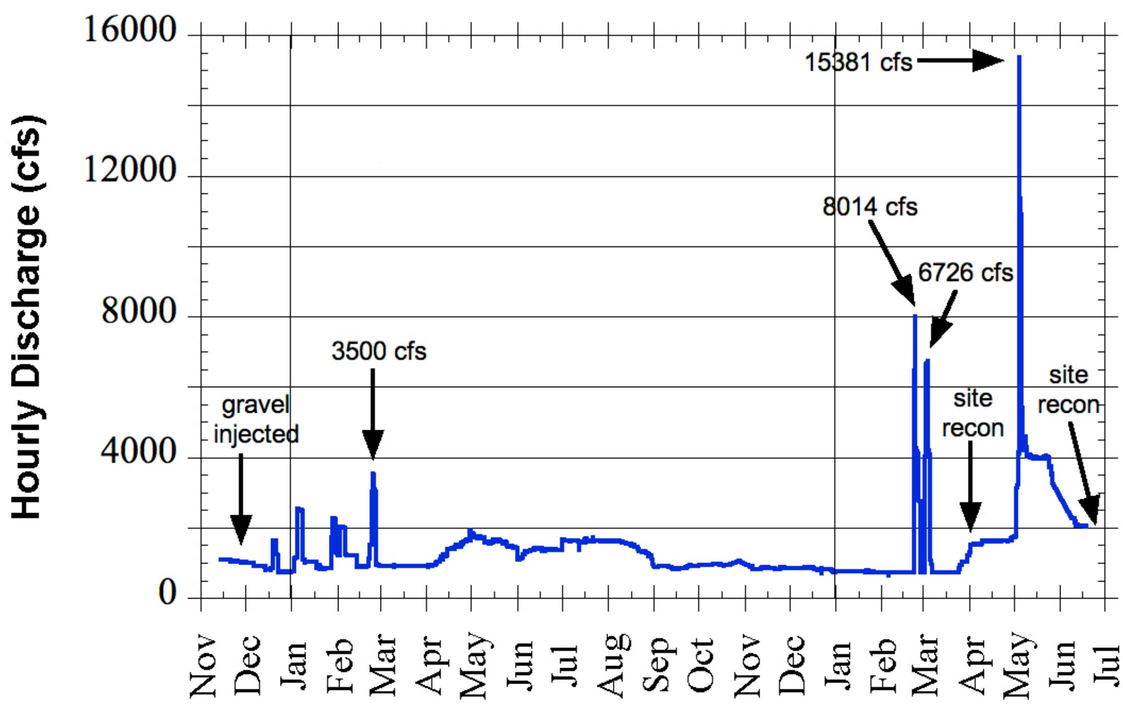

Figure 2.5. EDR Hydrograph of 2008-2009 water years showing flow peaks and the timing of key activities.

2.3. Methods for Gravel/Cobble Augmentation

Once a decision is made to perform gravel/cobble augmentation relative to other possible actions (Pasternack, 2008b), then it is necessary to determine how to implement it. Several reports have analyzed different methods for implementing gravel/cobble augmentation downstream of dams on rivers. Kimball (2003) described methods, limitations, horizontal placement distance, discharge rate, and the price per ton for 1,000 tons of gravel/cobble placed using helicopters, cable ways, and various conveyor belt systems (portable, truck-mounted, crane mounted and attached to dump truck). Bunte (2004) took a different approach and focused on the diverse river forms made with gravel/cobble-augmentation deposits through active construction and “passive” injection. Those included hydraulic structures, big flat plateaus of gravel, supplementation and lengthening of existing riffles (either upstream or downstream of crest), long riffles with 1-3 crests, artificial spawning channels, complex river patterns, filling of pools, bar shaping, spot fixing. She also covered placement of emergent deposits for future flood redistribution, including dumping along the streambank and construction of ephemeral wing dams directing flow into irrigation diversion canals (Bunte, 2004). Sawyer et al. (2009) reported a thorough analysis of the opportunities and constraints of using front loaders to place gravel/cobble according to a detailed design.

The environmental assessment report for the 2007 pilot gravel/cobble injection analyzed three methods of gravel/cobble augmentation (USACE, 2007). For the remote canyon downstream of Englebright Dam, there is a tremendous challenge to get down to the water’s edge in the section where gravel is needed most. The alternatives considered were road construction, helicopter, and truck-mounted conveyor belt.

2.3.1. Road Construction and Gravel Placement

The first method assessed by USACE (2007) was gravel/cobble placement by hauling material in 10-ton and 20-ton trucks down to the river’s edge, pouring it along the edge, and distributing it with front loaders. However, the EDR has not had a road down to the water’s edge since the 1997 flood destroyed the previous one there. The elevation of the river's water surface at 855 cfs is ~292' (NAVD88 datum), whereas the elevation of the end of the existing road at the Narrows II facility is ~353'. The vertical drop of 61' takes place over a horizontal distance of just ~100', so the slope is 0.5 (50%). As a result, the road would have to be steep with switchbacks. It would be unlikely for 20-ton trucks to negotiate the switchbacks, so delivery would be limited to 10-ton trucks or front loaders. Moreover, to construct a new road would require importing a large quantity of road fill materials. USACE (2007) raised a serious concern about the risk of these materials eroding by rain, landslide, or flood, which would cause harmful mud, sand, and angular crushed rock to enter the river and integrate into the bed material. USACE (2007) also indicated that it would be extremely costly and environmentally harmful to remove a temporary road after gravel/cobble augmentation. It is not possible to remove a road off a steep rocky hillside without causing debris to be left behind risking water quality and river-substrate problems. Further considerations in 2010 raised the concern over possibly having to excavate the end of the road in the channel, which could cause water quality problems. Also, the permitting process for road construction would take a long time, precluding gravel/cobble augmentation in 2010 and possibly 2011.

Assuming that a road was constructed and gravel/cobble were to be placed by front loaders, then a suite of concerns related to these machines come into consideration (Sawyer et al., 2009). Extra care would be necessary to avoid oil or gas leaks out of the machinery (a problem known from other efforts). There is also a limitation in matching grading plans in that front loaders cannot go into water deeper than ~2-2.5' or else the transmission can be flooded, ruining the machine (another problem known to have happened in the past on another river). Finally, front loaders cause a high level of turbidity as they drive over the river bed, which can be a water quality problem. For all the above reasons, the method of direct gravel/cobble placement commonly used on the American, Mokelumne, and Trinity Rivers in California is not preferable.

2.3.2. Helicopter Delivery

The second method assessed by USACE (2007) was helicopter delivery. This can be the only means possible for extremely remote locations. However, this approach is the most expensive method, it has a slow delivery rate (depending on how far the stockpile is from the placement site), and it involves highly risky helicopter flying in the presence of power lines and in a narrow canyon with variable winds.

2.3.3. Truck-Mounted Conveyor Belt

The third method assessed by USACE (2007), which was ultimately used in the 2007 pilot project, was a truck-mounted conveyor belt. For this approach, a 135' long conveyor belt mounted onto a truck is fully extended and rotated perpendicular to the truck so that its end is over the river. With a ~100-120' bank width, this length is just sufficient to get material into the Narrows II pool. Material is fed into a hopper using a small 0.5- to 1-ton front loader, and then a feeder with a conveyor belt lifts the material up and onto the truck-mounted belt that delivers it out over the water. By pouring the gravel/cobble into a deep pool, particle breakage is avoided. The experience with using this method in 2007 was highly positive. The only lesson learned from the 2007 pilot project that would enhance future usage of this method was that gravel/cobble injection would have been faster if two loaders had been used instead of one.

Unfortunately, there are two serious problems with using the truck-mounted conveyor belt approach in 2010 and beyond below Englebright Dam. First, given the geometry of the road, hillside, channel, and Narrows II powerhouse, the area of the wetted channel suitable for injection that is within the 135' length of the conveyor belt is very limited. Gravel/cobble is not permitted to be injected up against the powerhouse and any pile cannot interfere with the immediate outflow jet issuing from the powerhouse. The Narrows II pool is ~15' deep, but much of it is not reachable with the conveyor belt. Based on visual appearance at the end of the injection in 2007, the gravel/cobble pile was ~ 11' high off the bed. Given some more rotation capability and making the water even shallower, it looked like a total amount of <1000 tons could be stored in the pool by this method. The gravel/cobble deficit for the EDR (to be enumerated below in section 3) is one to two orders of magnitude higher than that, making this approach inadequate for the need.

Second, there is a proven concern of gravel/cobble injected into the Narrow II pool depositing into the shallow area between the Narrows II and Narrows I powerhouses (Pasternack, 2009). The gravel/cobble injected in 2007 fractionated by size during transport in 2008-2010, such that coarser material deposited on the first bedrock plateau and finer material deposited further downstream. Spawning has been observed on the shallow coarser material on the bedrock plateau. A potential exists in emergency situations where gravel may be de-watered.

When Fulton (2008) and Pasternack (2008a) evaluated the scour potential in the Narrows II pool for different sized floods, they assumed that the gravel/cobble would be in a blanket at the bottom of the pool, not standing ~11' high in a loose conical pile. They had no knowledge at the time of their efforts in 2005-2006 how gravel/cobble augmentation might be done at remote Englebright Dam, so they made a basic assumption about it. As a result, they studied a very different situation from what ended up happening. For the case of a blanket fill on the bed, they predicted that any flood capable of scouring the bottom of this deep pool would easily transport the material beyond the Narrows I powerhouse. The reason is that the intervening channel area consists of a bedrock plateau that is narrower and shallower over the whole flow range, so that focuses flow into the fastest, most scouring jet of water possible for the EDR. Based on 2D modeling, it was demonstrated that any flow that could scour gravel/cobble off the bed of the deep pool would definitely be able to transport it beyond the Narrows I facility.

In fact, the actual conditions associated with the 2007 pilot (and any such gravel/cobble augmentation using the truck-mounted conveyor belt) as well as the flow regime that occurred in 2009 were quite different from what had been investigated. Not only was the gravel/cobble piled high unlike in the model simulations, but another important factor not considered was that the Narrows I powerhouse was releasing 500 cfs perpendicular to the channel during the 2009 peak flow overtopping Englebright Dam. Fulton (2008) did not have a topographic map all the way down to Narrows I for his model study and did not investigate the impact of a flow jetting across the riverbed at that location. Conceptually, such a jet would be expected to dramatically reduce bedload transport past that location.

Thanks to the use of a real-world pilot experiment, Pasternack (2009) observed that the 2009 flood of 15381 cfs scoured off the top ~23% of the 2007 pile. None of the eroded material made it past the Narrows I powerhouse. Instead, it deposited in the nooks in bedrock fractures and behind boulders and bedrock outcrops in a narrow band down the length of the area between the two powerhouses. In autumn 2009 Chinook salmonids were observed by RMT staff to be spawning on that material.

Pasternack (2009) provides a thorough evaluation of what happened and the consequence is that injection of a large amount of gravel/cobble into the Narrows II pool would certainly yield deposits in the area between the powerhouses that is at risk for annual dewatering in September-November. Given that the entire EDR is lacking in gravel/cobble, there are other areas where gravel could be introduced downstream of Narrows I, thereby avoiding the problem if channel dewatering. At a later time it might be worthwhile to revisit the issues related to gravel augmentation upstream of the Narrows I powerhouse to determine any conditions under which gravel/cobble could be added there to expand total habitat capacity and gravel/cobble storage in the reach.

2.3.4. Dumping Gravel/Cobble off Roadside

Although not discussed in USACE (2007), another option is that gravel/cobble may be added to a stream by dumping it off a truck down a hillside to the stream bank or into a stream (Bunte, 2004). This approach has been used on Clear Creek, Trinity River, and the upper Sacramento River. It is very inexpensive and fast. However, this approach only serves geomorphic and ecologic goals if the material avoids breakage and actually becomes entrained into the river. Normally that requires a flood to achieve, which could be years to decades before it happens, precluding ecological benefits. For the hillside below Englebright Dam, the only section accessible by truck is between Narrows I and II powerhouses raising the potential problem of material depositing on the bed at risk of dewatering. Also, the hillside is composed of large boulders, shot rock, and bedrock, so dumping material there would cause a lot of breakage. Angular gravel/cobble harms adult spawners. Finally, there are so many nooks in the material on the hillside that it is most likely that the material would be absorbed into those recesses and locked away. Dramatically more material would have to be placed to offset that problem, and even then it is unclear that the material would ever deposit where desired. A thorough, process-based analysis would be required, but the technical challenges of such an assessment yield high uncertainty.

2.3.5. Cableway Delivery

For steep canyons it is possible to build a cableway high across the canyon and drop gravel down into the river. By having one end of the cableway at a higher elevation than the other, it is possible for the weight of gravel/cobble to carry the load down over the river. After dumping to out, then one winches the container back up. Kimball (2003) reported details and costs. For the canyon below Englebright Dam, the problem is that the only place to stockpile gravel and install/operate a cable way would be in the area between Narrows I and II facilities. As discussed before, this area has a risk of gravel/cobble dewatering in September and October making it unsuitable for gravel/cobble augmentation at this time. Also, gravel/cobble placement is limited to a single cross-section, and for that cross-section there is little control over how and where gravel is place in the river. These factors make this method unsuitable for the EDR for 2010 and likely beyond.

2.3.6. Gravel/Cobble Sluicing

According to Pittman and Matthews (2007) and Kimball (2003), gravel/cobble sluicing involves drawing water up from a source and into an 8" diameter "Yelomine" flexible pipe where gravel/cobble is added from the top to produce a water-sediment slurry that is then piped down to a site for directed placement by 1-2 operators. The amount of water used to do the sluicing depends on the pipe and pump configuration, and is typically 1000-1500 gallons per minutes, which is 2.23-3.34 cfs. The best way to get the water is to locate the water pump(s) at the source-water's edge and then push the water uphill in a 6-8" pipe. The pump cannot draw water vertically up to it more than 30', but if the pump is placed at the water's edge it can push the water vertically much farther as needed to get to the top of the a hill where the gravel/cobble is added.

Normally, it takes five people to operate the system- one person operating the water pump at the water source, one person in a loader bringing gravel to the feeder, one person operating the feeder to prevent clogs and coordinate communications, and two people at the nozzle directing gravel placement and adding pipe as needed to move downstream periodically. This approach is particularly notable for its minimal construction footprint. The main cost is in the upfront purchase of expensive piping, so it largely depends on how far water and the water/sediment slurry has to be pumped. Once the pipes are purchased, they may be used for several years, and the more sediment that is injected, the lower the cost per ton. Also, it may be possible to permanently fix the pipes for annual injections, thereby reducing the labor cost of setting up and taking down the system each year.

Using the sluicing method, the rate of gravel/cobble injection is ~100-300 tons per day, all depending on how frequently the system clogs. This is slow relative to gravel placement by truck-mounted conveyor (~500 tons per day) or truck/front loaders (~1000 tons per day). Indeed, clogs at pipe joints are a likely occurrence and are factored into operations. The primary factors that cause them are 1) low local head, 2) dense packing of 4-6” clasts, and 3) long, flat “finger” shaped rocks that fit through 5-6” sieve openings, but are much longer than that. Once in the pipe finger rocks can turn perpendicular and jam in a coupling. When a jam happens, operations stop, the location of the jam is determined (usually in a coupling), the coupling is broken to release the jam, a new coupling installed, and then operations continue. The steeper the descent (speeding flux), the more continuous the slurry flow (preventing deposition in the pipe), and the finer the sediment mixture (reducing the size of finger rocks), the less clogging will occur. Grain breakage in the pipe has not been evident in any noticeable amount, but the sediment does abrade the pipe, especially at bends. The typical lifetime of a pipe section at a bend has not been reported. Having extra pipe segments on hand is important for long-duration sluicing operations.

In terms of the gravel/cobble placement into the river, the approach with sluicing is to start at the water’s edge, build across the river, and then work downstream. At the outlet of the system, gravel/cobble goes into a rigid pipe supported by floating, air-filled barrels. The outlet is manually directed to the placement spot with the aid of ropes as needed. Using this approach, it is possible to place gravel/cobble according to a sophisticated design with a few constraints. As the operators work their way out into the channel, they must add additional pipe to reach new areas. Pipe in the river lies on the bed. Given the weight of the pipe sections and the need to manually couple them, the pipes have to be placed in shallow water. That limits the depth of water that pipes may be placed into to depths of < ~2-2.5'. As a result, front slopes up to the riffle crest have to be relatively steep. Back slopes can be lower, because ambient river velocity aids distribution of the sediment slurry in a blanket downstream. This approach has been used on the lower Stanislaus River and Clear Creek, with favorable reports in both cases. Given its remoteness and steepness, the canyon below Englebright Dam is a strong candidate for gravel/cobble sluicing.

3. PRE-PROJECT CHARACTERIZATION OF THE EDR

The spatial focus of this gravel/cobble augmentation implementation plan is the Englebright Dam Reach (EDR) of the lower Yuba River, which has been identified to be the area of the river below Englebright Dam that has been impacted by the dam requiring action (Beak Consultants, 1989; Pasternack, 2008a; Pasternack et al., 2010). The next step is to perform a pre-project characterization that documents the baseline conditions of the EDR. This involves reviewing the available data and information for the reach to yield a conceptual model that captures the processes playing central roles in shaping fluvial landforms in the EDR. Broad based information related to the entire watershed helps guide an understanding of the processes relevant to the focal reach, but ultimately what is needed is an understanding of the mechanistic physical process active in the reach today and potentially active through rehabilitation actions. Thus, the effort involves a process-based approach to the problem by nesting different spatial and temporal scales of investigation.

3.1. EDR Literature Summary

Because the EDR is remote, it has not been nearly as well studied as the rest of the lower Yuba River, but it has received some investigation. As described earlier, Beak Consultants, Inc (1989) performed studies in the EDR, including fish habitat mapping, fish community characterization, and implementation of the Instream Flow Incremental Methodology (IFIM) for evaluating stage-dependent physical habitat (using 6 cross-sections in “The Narrows”, which includes the EDR and the subsequent 1.8-km long gorge). In 1999, the terrestrial land in the EDR was topographically mapped by contractors working for The Corps by aerial photogrammetry, but the river’s bathymetry in the reach was not mapped. From 2003-2008 the U.S. Fish and Wildlife Service collaborated with the Watershed Hydrology and Geomorphology Lab at UC Davis to compare and contrast conditions in the EDR and those in Timbuctoo Bend. The reports that presented data and information on EDR were Fulton (2008), Pasternack (2008a), and Pasternack et al. (2010).

3.2. EDR Existing Data and Analyses

There does exist some data for the EDR. Key data include a bathymetric survey and digital elevation model of the reach (Fig. 3.1), substrate pebble counts, water surface elevation observations for flows ranging from 800-91400 cfs, georeferenced historical aerial photos, and observations of Chinook salmon attempting to spawn on bedrock. At the time that Fulton (2008) performed his 2D modeling analysis in 2005-2006 to assess flow-habitat relations, sediment entrainment, and geomorphic processes, available data were limited to just the reach between the Narrows II pool and the Narrows I powerhouse. Subsequently, Pasternack (2008a) did do a few 2D model simulations of the EDR using a newer software program suitable for that length of canyon. Pasternack et al. (2010) reported a detailed historical aerial photo analysis of the EDR focusing on the history and status of Sinoro Bar in the vicinity of the confluence with Deer Creek. Finally, Pasternack (2009) did reconnaissance of the EDR to map the movement of injected gravel and cobble out of the Narrows II pool and quantify a sediment budget for that material.

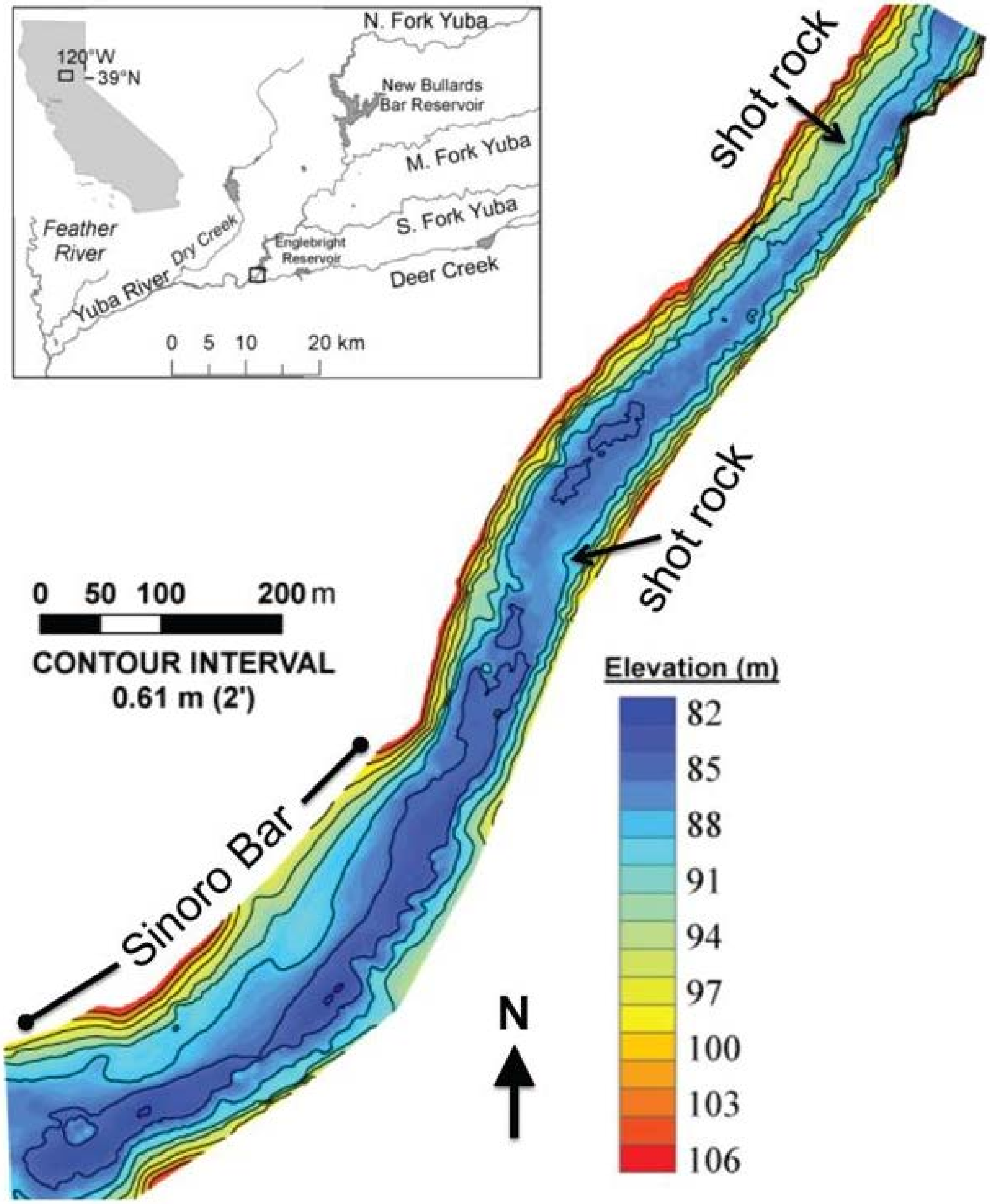

Figure 3.1. EDR topographic map showing locations of existing shot rock deposits. Inset map shows location of study site within the Yuba River basin and within California.

3.3. EDR Gravel/Cobble Deficit

The EDR is mostly devoid of any river-rounded gravel/cobble. This material is the basic building block of alluvial morphological units for the LYR. It is the necessary substrate for SRCS spawning. That leads to the following question:

How much gravel/cobble is needed in the EDR to rehabilitate ecological functionality?

To answer this question it needs to be recognized that different volumes of material would be required to achieve different combinations of geomorphic and ecologic functions. Let us define a placement volume (PV) as

$$PV = \alpha \bullet A \bullet D$$

where A is the plan-view wetted channel area (m^2), D is average depth (m) at spawning flow, and α is a non-dimensional depth scaling factor. A simple approach would be to fill in the entire wetted channel for a typical low autumnal spawning discharge to form one large, flat spawning riffle. Completely filling in the wetted channel in this way would involve assigning α=1, so PV=A•D. This amount would displace the water up, making it shallower and faster, due to a significant decrease in cross-sectional area. However, past studies have all concluded that large, flat spawning riffles do not work. Adult SRCS spawners need deep holding habitat for over-summer holding, local holding refugia proximal to red locations for rest during spawning activity, and locations with hydraulic complexity (presumably because it promotes better hyporheic flow).

Based on many years of experience with designing diverse spawning habitat rehabilitation projects, Pasternack (2008b) reported that for rehabilitating a small riffle of ~50-500’ length, a value of α=0.8 is appropriate. At this scale the focus is just on a single riffle crest and the presumption is that morphological unit diversity exists at a larger scale outside of this one riffle site. For a long reach for which a diversity of morphological units would need to be created, a value of α=0.5 is more appropriate. This value is lower, because riffle crests are the highest points by definition, so constructing a reach with other morphological unit types involves using less volume than that for a riffle crest. As a result, for an intermediate length scale between a site and a reach, an intermediate value of $0.5<\alpha<0.8$ would be appropriate. Although there is no formal scientific proof of these values, they provide a simple, low-cost method of estimating gravel/cobble needs. This provides a reasonable starting point for thorough analysis and design development.

To apply the above method for use in the EDR, the variables A and D were estimated using the SRH-2D model simulation for 855 cfs for three separate sub-reaches and the amount was totaled (Table 3.1). The volume-to-tonnage conversion of Merz et al. (2006) was applied (see section 2.2 above). The total amount of material to eliminate the deficit for the EDR is estimated to be 63,077 short tons (45,510 yds^3). To account for uncertainty, a higher estimate using $\alpha = 0.8$ was also generated, which yielded an estimate of 100,923 short tons (72,816 yds^3). These numbers bound the likely intermediate amount of storage that would be appropriate for the EDR.

Because the reach widens downstream, the largest component is associated with the area downstream of the gaging station rapid. However, that area has been heavily impacted by mechanized gold mining and would greatly benefit from an independent river rehabilitation effort to take advantage of the opportunity to fix Sinoro Bar, which is beyond the scope of the gravel/cobble augmentation plan required to account for the impacts of Englebright Dam. Also, material placed upstream in the narrower part of the canyon is expected to migrate downstream anyway, addressing the gravel deficit in the vicinity of Sinoro Bar over time. Recognizing that the section between the Narrows II and Narrows I facilities has other uncertainties with operations, the relevant area of gravel addition is therefore the area between the Narrows I facility and the top of the rapid downstream of the gaging station.

The recommended long-term gravel storage volume for the section between the Narrows I powerhouse and the rapid downstream of the gaging station is 15,949 to 25,518 short tons.

The exact value may be determined in future design development and evaluation. The idea would be to augment gravel into the appropriate area of the EDR until this amount of gravel storage is achieved. Then, as floods transport material out of the area, more additions would return the storage amount to the total level.

Table 3.1. Estimated gravel/cobble deficit for the EDR to have a diverse assemblage of morphological units (excludes any independent action related to rehabilitating Sinoro Bar). Assumes $\alpha = 0.5$.

subreach	A (ft^2)	D (ft)	volume (ft^3)	volume (yds^3)	short tons
Narrows II to I	61107	4.313	131777	4881	6765
Narrows I to top of rapid	117373	5.294	310686	11507	**15949**
bottom of rapid to end	306193	5.136	786304	29122	40364
total			1228767	45510	63077

Table 3.2. Maximum estimated gravel/cobble fill associated with $\alpha = 0.8$.

subreach	A (ft^2)	D (ft)	volume (ft^3)	volume (yds^3)	short tons
Narrows II to I	61107	4.313	210844	7809	10823
Narrows I to top of rapid	117373	5.294	497098	18411	**25518**
bottom of rapid to end	306193	5.136	1258086	46596	64582

3.4. EDR SRH 2D Model

Two-dimensional (depth-averaged) hydrodynamic models have existed for decades and are used to study a variety of hydrogeomorphic processes. Recently, their use in regulated river rehabilitation emphasizing spawning habitat rehabilitation by gravel placement has been evaluated (Pasternack et al., 2004, 2006; Wheaton et al., 2004a; Elkins et al., 2007). Two-dimensional models have also been applied to better understand the relative benefits of active river rehabilitation versus flow regime modification on regulated rivers.

The U.S. Bureau of Reclamation created and maintains a 2D model called Sedimentation and River Hydraulics 2D (SRH) that is freely available to the public. SRH is highly efficient in its computations and is also highly stable in performing wetting and drying, which is a common problem of other 2D models. The way it has been programmed, it is highly automated. Thus, it is now possible to make 2D models of dramatically larger river segments than before, while retaining the same high resolution desired for characterizing microhabitat.

Apart from characterizing the spatial pattern of hydraulics in the EDR, SRH 2D was to answer two specific questions:

1) *what the spatial pattern of hydraulic habitat for Chinook spawning at 855 and 4500 cfs?*
2) *what is the spatial pattern of gravel/cobble erosion potential for flows ranging from 855 to 96100 cfs?*

The former question addresses the need to determine the extent to which the inadequacy of spawning habitat is due solely to the lack of spawning substrate or whether it is a combination of more microhabitat factors. The latter question seeks to understand the stage-dependent hydrogeomorphic processes responsible for scour and deposition in the EDR, given its unique pattern of channel nonuniformity.

3.4.1. EDR 2D Model Setup

As part of this planning effort, the SRH 2D model of the EDR reported by Pasternack (2008a) was updated to the latest software version and used again. To maintain computational efficiency, three different computational meshes were used, each with an intermodal spacing of ~3' in the wetted area. For low-flow conditions, the original mesh from Pasternack (2008a) was used for flows <5000 cfs. This mesh covered the whole canyon width with ~3' internodal spacing in the channel and up to 6' internodal spacing along the edge. The wetted area for the low flow runs were all within the mesh elements with ~3' internodal spacing. A mid-flow mesh was made for flows 5000-30000 cfs. A high-flow mesh was made for flows 30000-96100 cfs. A higher flow mesh may always be used to run a lower flow, but it takes longer to run than using the appropriate lower flow mesh. Creating a new EDR mesh takes only ~1-2 hours compared with models running for 3-7 days, so making a mesh that is optimal for a given flow is worth the small time and effort.

Table 3.1 reports the stage-discharge relation estimated for the exit cross-section of the model reach as well as the constant Manning's n roughness parameter used and the constant eddy viscosity coefficient used for turbulence closure. For all simulations, 500 cfs was pushed into the river from the bank at the location of Narrows I and all remaining flow came from the upstream boundary in the Narrows II pool. Unfortunately, the stage-discharge relation for the end of the reach was not directly observed, but was estimated by linear slope interpolation based on the water surface elevation (WSE) values at the exit and at the Smartville gaging station observed at 855 cfs. The one test of the accuracy of this approach was obtained by surveying the photo-based evidence of the water line for the 88600 cfs flow occurring on 12/31/2005 (photo and land access for surveying graciously donated by local landowner Ralph Mullican). The two observed WSE's for that flood were 309.71' and 310.77', so the predicted value of 309.58' is reasonable, given the uncertainty in the field observations (especially the higher value, which was measured at a spot up on the side of a large boulder). Ideally, a water level recorder ought to be installed and maintained at the confluence with Deer Creek in support of future investigations.

The chosen constant Manning's n value is more certain as it was based on 2D model calibrations performed by Fulton (2008) for the same wide range of flows. Manning's n does not decrease with increasing stage in the EDR or Timbuctoo Bend, which is consistent with the concept that as flow increases, large roughness elements become active and maintain the overall roughness of the reach, even as grain-scale roughness and riffle-undulation form roughness become less important.

No velocity validation data exists for the EDR at this time, but WSE data is available over the full range of flows from Fulton (2008). Analysis of model performance with WSE indicated that it was within the normal range typical of 2D models. Extensive velocity validation has been performed for this model for the LYR between Hammon Grove Park and Hallwood Road, with the resulting metrics equaling or exceeding the performance of 2D models of other rivers (Barker et al., 2010). Velocity validation has also been done for Timbuctoo Bend (Moir and Pasternack, 2008; Pasternack, 2008) as well as for bedrock and boulder/cobble reaches of the upper South Yuba between Spaulding Dam and Washington, CA (Pasternack, unpublished data). All evidence indicates that the model is suitable and valid for the EDR.

Table 3.3. SRH 2D model inputs and parameters for the discharges simulated.

Q (cfs)	exit WSE	Manning's n	eddy viscosity coefficient
855	283.65	0.032	0.6
1590	284.86	0.032	0.6
4500	287.80	0.032	0.6
10000	291.16	0.032	0.6
15400	293.58	0.032	0.6
30000	298.38	0.032	0.6
50500	303.14	0.032	0.6
88600	309.58	0.032	0.6
96100	310.65	0.032	0.6

3.4.2. Microhabitat Prediction Method

Hydraulic habitat quality predictions for Chinook spawning were made by extrapolating 2D model depth and velocity results through independent habitat suitability curves. No bioverified habitat suitability curves (HSC) for depth, velocity, substrate, or cover for salmonid life stages are accepted by stakeholders on the LYR. Beak Consultants, Inc (1989) collected observations of depths and velocities for a typically small number of redds for that era and generated "utilization-based" curves. They compared their curves to those for the lower Mokelumne River available at that time and found a lot of similarities. CDFG (1991) published utilization-based curves for the lower Mokelumne River and in recent years these curves have been shown to perform very well at predicting Chinook spawning preference and avoidance for baseline and post-rehabilitation conditions (Pasternack, 2008b; Elkins et al., 2007). These Mokelumne curves were tested for use in Timbuctoo Bend on the LYR by Pasternack (2008a) and found to pass all bioverification tests. Other curves based on logistic regression proposed by the USFWS in recent years have not passed the same rigorous tests and remain controversial. Consequently, the bioverified curves used by Pasternack (2008a) were applied in this study.

A global habitat suitability index (GHSI) was calculated as the geometric mean of the depth and velocity indices (Pasternack et al., 2004). To account for uncertainty SRH-2D model predictions, GHSI values were lumped into broad classes, with GHSI = 0 as non-habitat, 0 < GHSI < 0.2 as very poor quality, 0.2 < GHSI < 0.4 as low quality, 0.4 < GHSI < 0.6 as medium quality, and 0.6 < GHSI < 1.0 as high quality hydraulic habitat (pasternack, 2008a). In bioverificaiton, it turned out that only the medium and high quality habitat classes proved to be preferred in terms of being utilized by spawners more than their percent availability, while the remaining classes were all avoided. Therefore, an even further simplification may be made by lumping GHSI into classes of 0-0.4 and 0.4-1.0. This reduces the possibility of error down to just misclassifications across this threshold.

3.4.3. Sediment Transport Regime Prediction Method

To evaluate gravel/cobble sediment scour risk across the widest possible range of flows, nondimensional Shields stress was calculated at each node in the model as described in Pasternack et al. [2006]. The reference grain size used to characterize the mixture of a gravel/cobble bed was 64 mm, which is close to the median size reported for Timbuctoo Bend (Pasternack, 2008a) and is in the range of common values used for assessing spawning habitat rehabilitation materials. Shields-stress values were categorized based on sediment transport regimes defined by Lisle et al. [2000] where values of $\tau^*<0.01$ correspond to no transport, $0.01< \tau^*<0.03$ correspond to intermittent entrainment, $0.03< \tau^*<0.06$ corresponds to "partial transport", and $\tau^*>0.06$ corresponds to full transport.

3.4.4. EDR 2D Model Results

Depth and velocity results are depicted in Figures 3.2-3.5 below. For flows <5000 cfs there are distinct areas of high and low velocity longitudinally down the river. As discharge increases, the longitudinal variation in velocity decreases and lateral variation increases. This is a common pattern previously reported for other constricted reaches (Brown and Pasternack, 2008). It is characteristic of the stage-dependent role of multiple scales of channel nonuniformity in controlling flow-habitat relations and fluvial geomorphology.

The GHSI pattern for Chinook spawning hydraulic habitat (Fig. 3.6) shows that regardless of gravel/cobble presence, the canyon presently has almost no suitable microhabitat (GHSI>0.4) capability to support SRCS spawning. At 855 cfs there is a small area of suitable hydraulics on the bedrock plateau just downstream of the Narrows II pool, a little upstream of the rapid by the gaging station, and a little habitat on the edge of the Sinoro Bar point bar. At 4500 cfs there is significantly less hydraulic habitat present.

The pattern of the sediment transport regime for the EDR (Fig. 3.7-3.8) is highly stage dependent. For flows below 15,400 cfs, the primary area of scour risk is in the narrowest part of the canyon between narrows I and II powerhouses, which is the area studied by Fulton (2007). The only other area of high scour potential is in the rapid below the gaging station. At 30,000 cfs, large area experience full bedload mobility, but there is a small area of lower Shield stress in the pool adjacent to the gaging station. Also, the widest part of the canyon around Sinoro Bar does not experience full mobility at this flow, so it is highly unlikely that a gravel/cobble mixture would move past that area. Note that the model does not include the perpendicular influx from Deer Creek, which would further reduce velocities and block transport. At 50,500 cfs there is full mobility through the upper 2/3 of the reach, but still no full mobility around Sinoro Bar. At 96,100 cfs, there is full mobility through the reach; again, not considering any influx from Deer Creek to block that.

In summary, detailed 2D hydraulic modeling of the EDR found that the river is too deep to provide Chinook spawning habitat right now, necessitating gravel augmentation to fill in the channel and provide opportunities for creating morphological unit complexity. Geomorphically, the river does not exhibit stage-dependent flow convergence, with routing of sediment through pools and deposition on high “riffles” at high discharges. Instead, as discharge increases, depth and velocity simply increase almost everywhere, so the area of scour increases down the river. The widest part of the canyon would be the ideal location for a diverse assemblage of morphological units, but it was degraded by mechanized mining in the 1960s. In terms of a gravel augmentation program, the indication is that the area in the upper half of the EDR where gravel might be augmented into the river is susceptible to full mobility at 10,000 cfs (except for the Narrows II pool, which is deep enough to require much higher discharge to scour the bottom of it). Meanwhile, augmented gravel would be unlikely to move out of the EDR until a flood of >95,000 cfs associated with minimal flow out of Deer Creek, such as during a snowmelt period or the later stages of a rain-on-snow event. The reason Deer Creek flow needs to be minimal (not maximal), is that at high flow the tributary enters the Yuba nearly perpendicular to it. This creates a barrier to sediment transport. Maximum export of sediment out of the EDR is thus expected to occur during the lowest Deer Creek outflow. The timing of flows out of the Yuba and Deer Creek catchments differs, based on their differing watershed hydrology.

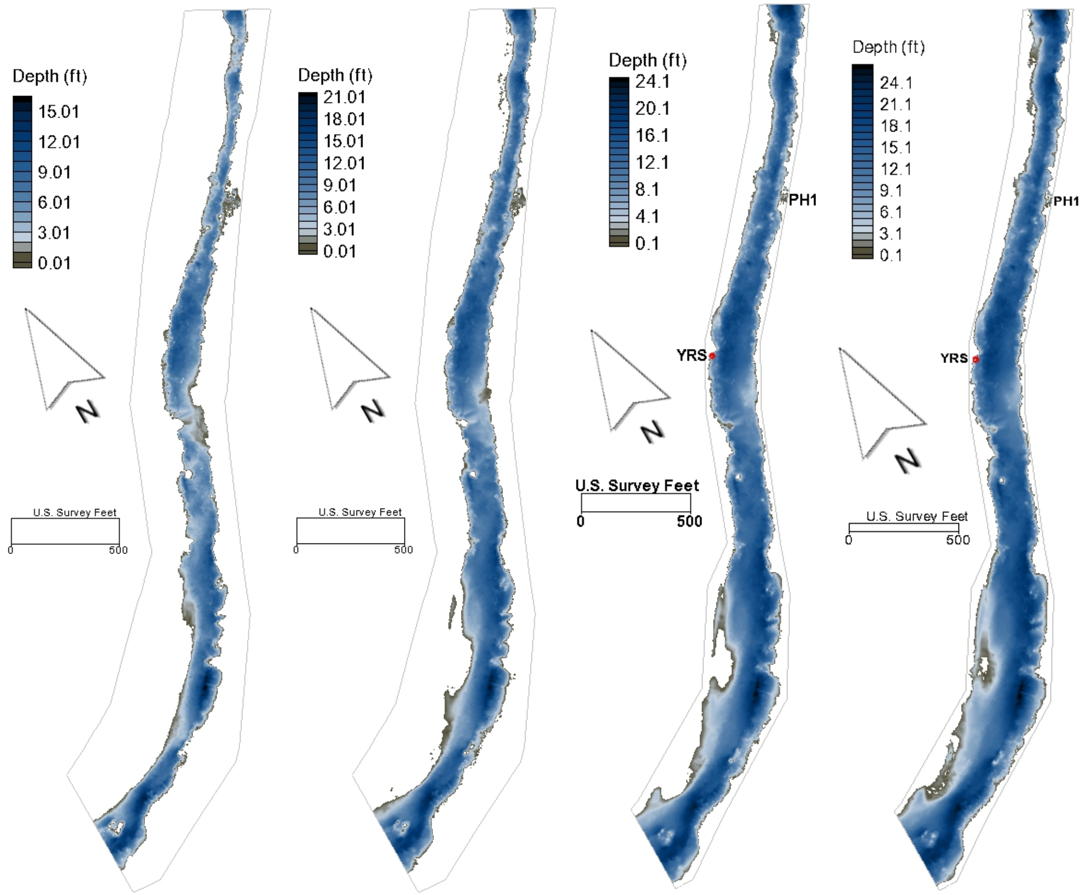

Figure 3.2. EDR water depth for increasing discharge from left to right (855, 4500, 10000, 15400 cfs). Color scale is different for each image.

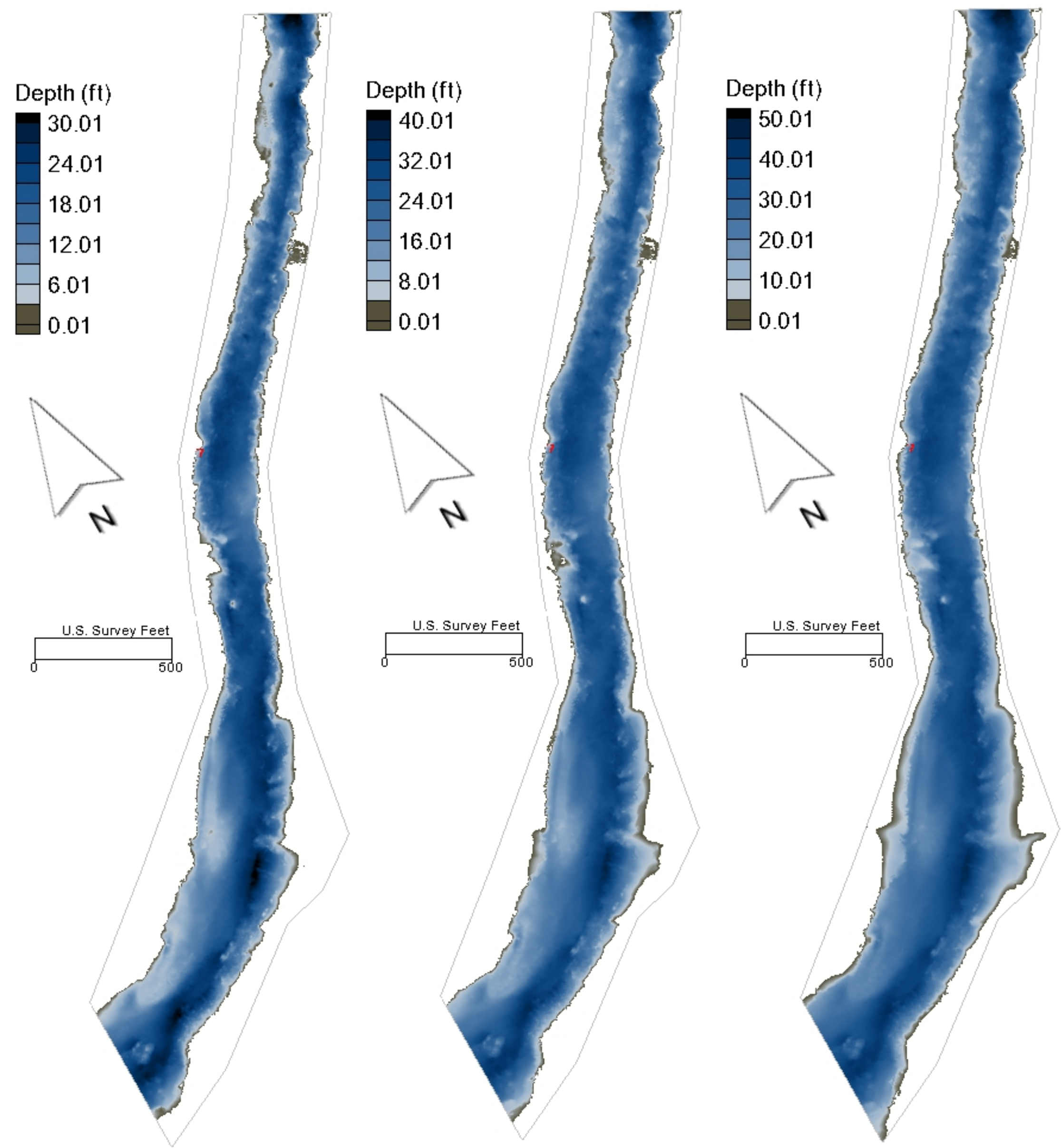

Figure 3.3. EDR water depth for increasing discharge from left to right (30000, 50500, 96100 cfs). Color scale is different for each image.

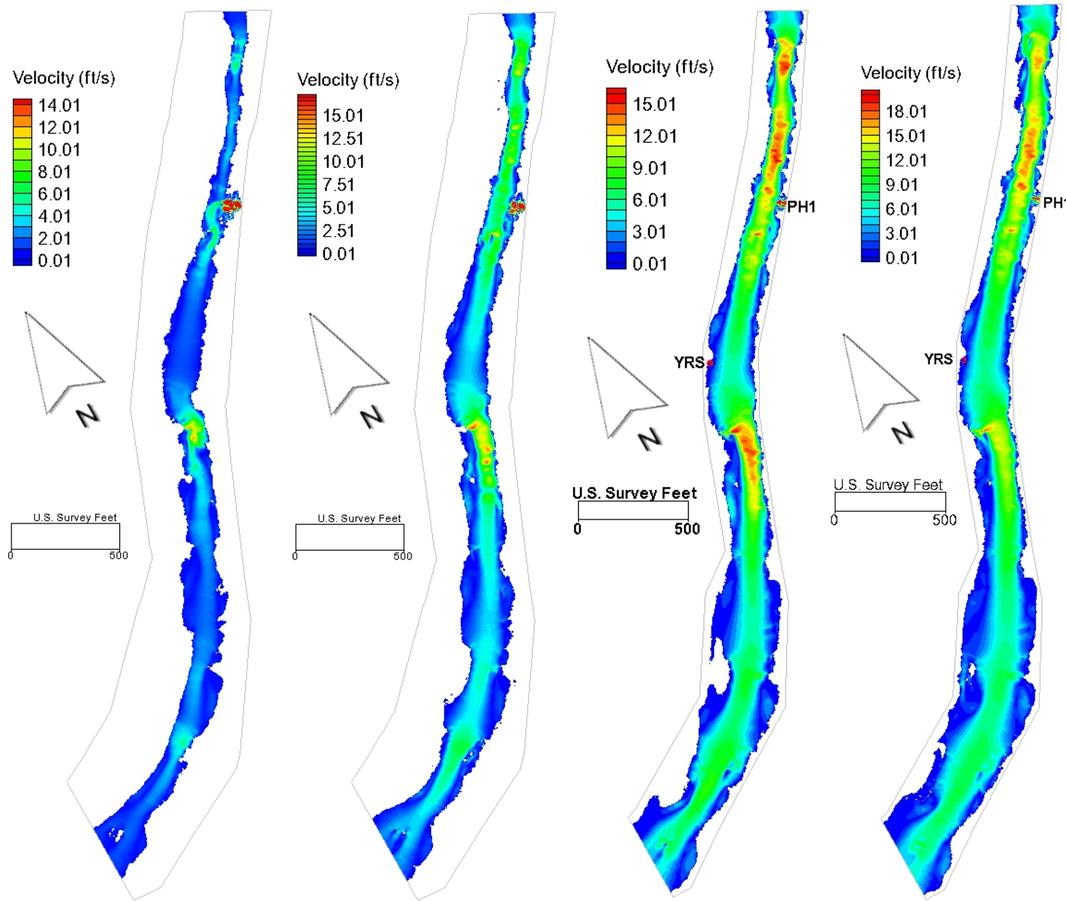

Figure 3.4. EDR water velocity for increasing discharge from left to right (855, 4500, 10000, 15400 cfs). Color scale is different for each image.

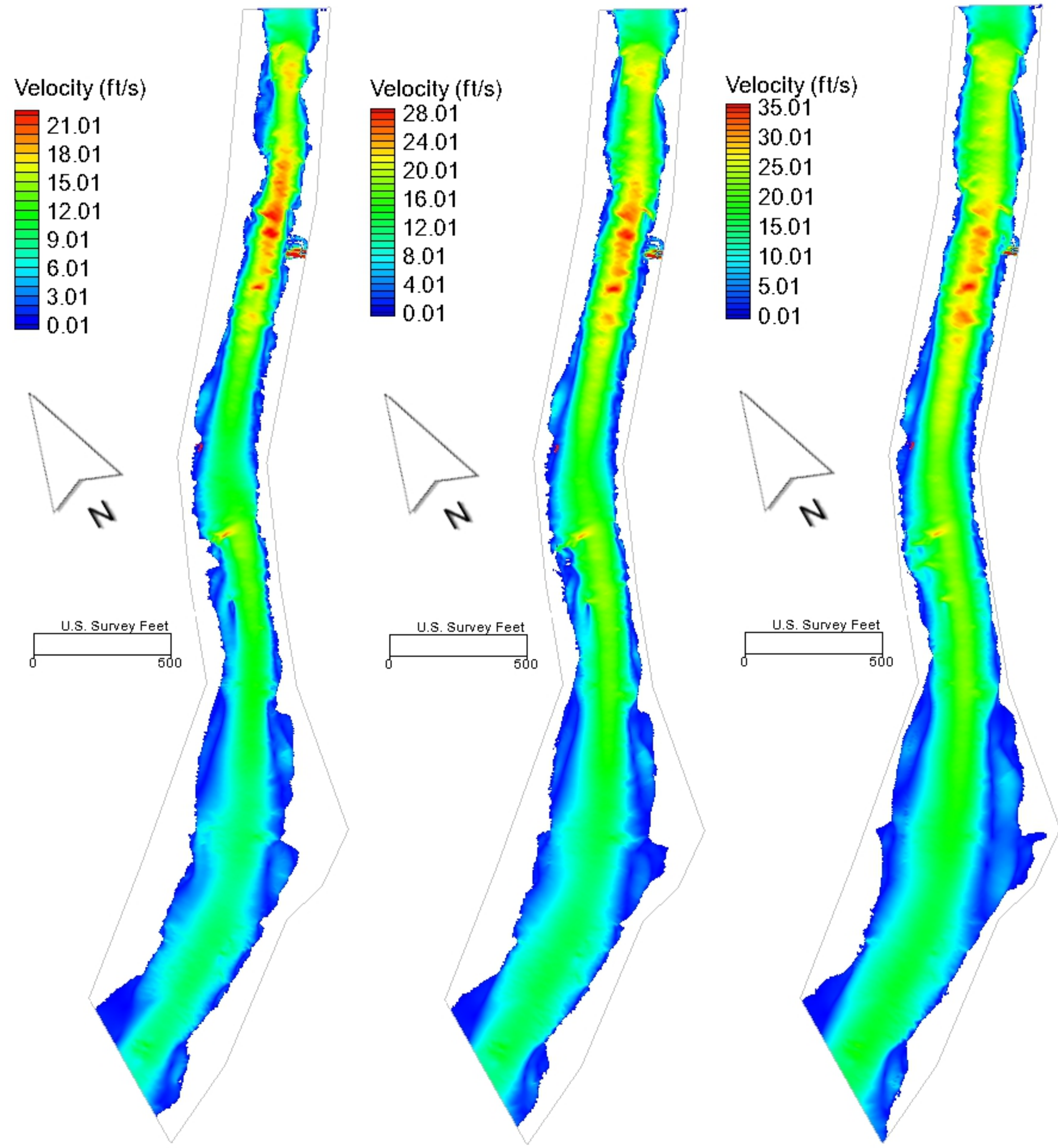

Figure 3.5. EDR water velocity for increasing discharge from left to right (30000, 50500, 96100 cfs). Color scale is different for each image.

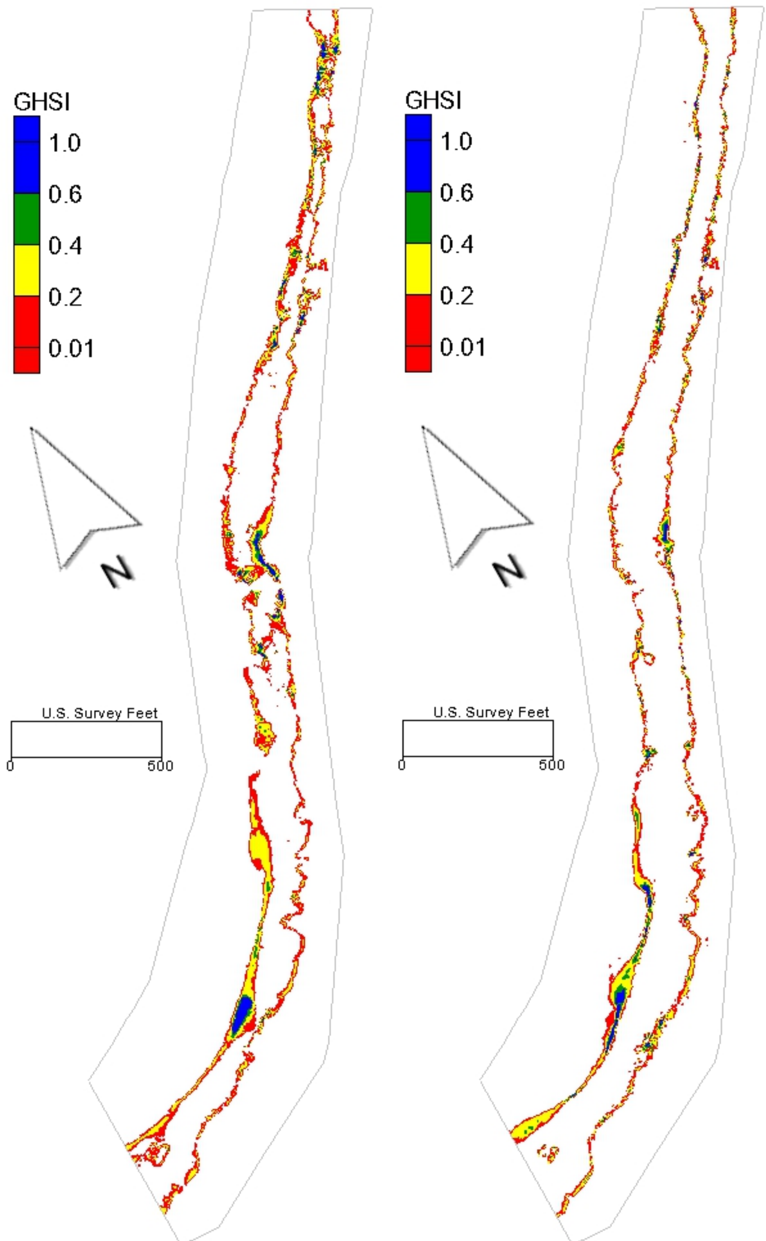

Figure 3.6. EDR Chinook spawning hydraulic habitat quality (GHSI) for 855 (left) and 4500 cfs (right). Color scale is identical for both images

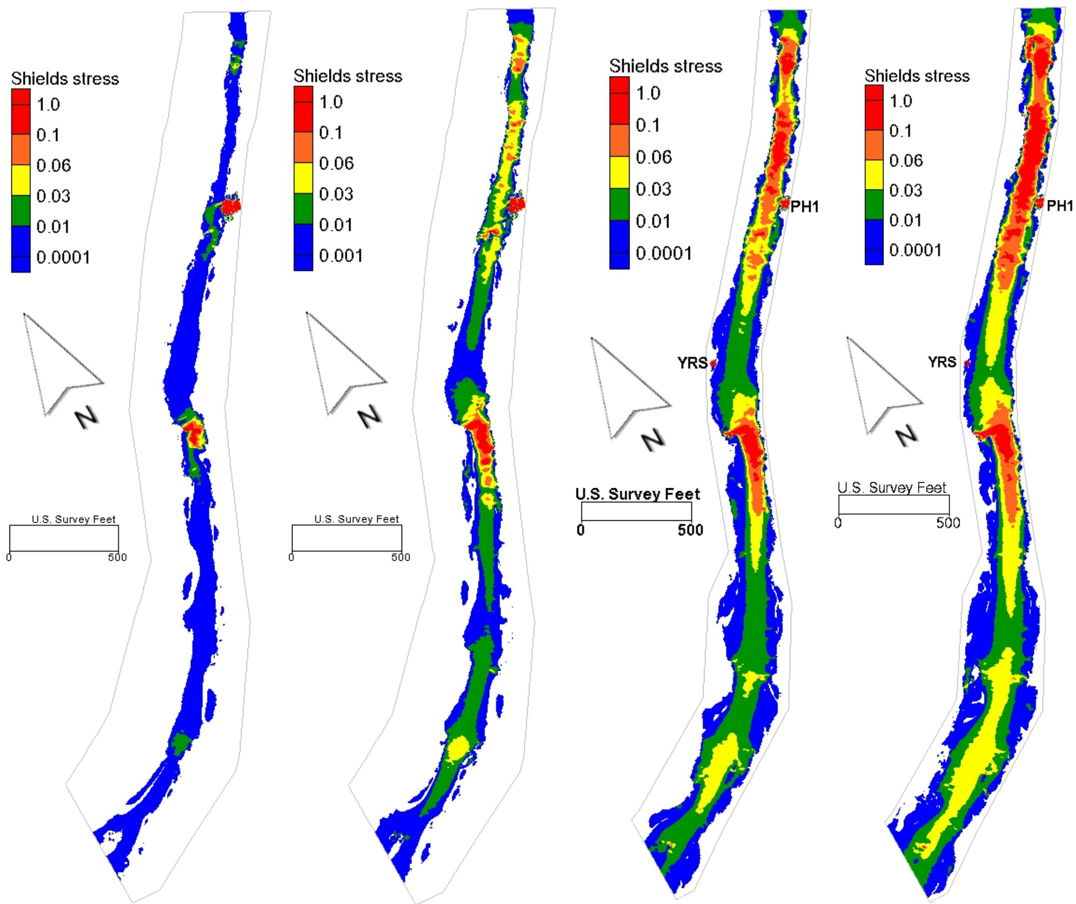

Figure 3.7. EDR Shields stress for increasing discharge from left to right (855, 4500, 10000, 15400 cfs). Color scale is identical for each image.

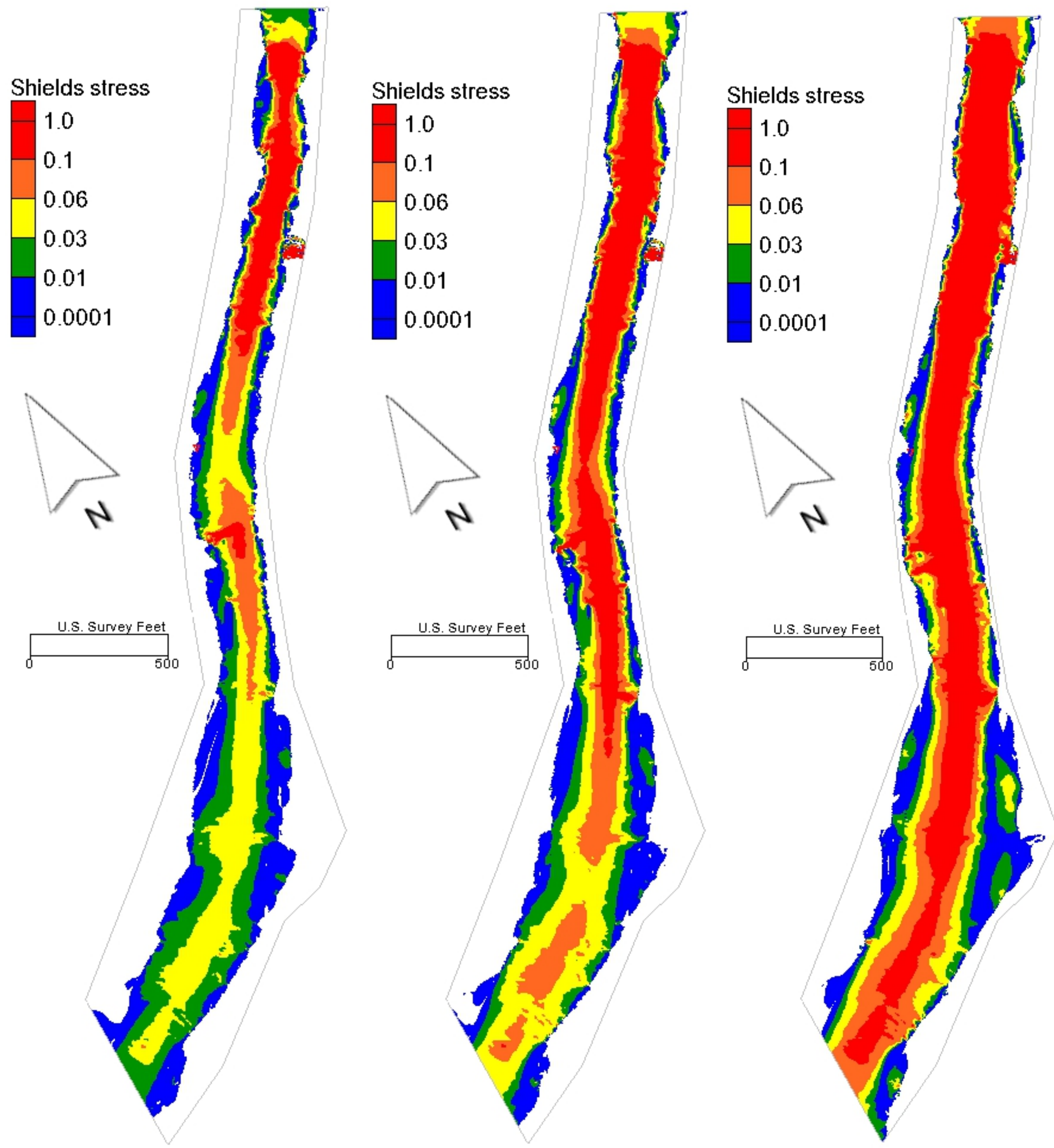

Figure 3.8. EDR Shields stress for increasing discharge from left to right (30000, 50500, 96100 cfs). Color scale is identical for each image.

4. RECOMMENDED METHOD FOR GRAVEL/COBBLE AUGMENTATION

Discussion of how to implement gravel/cobble augmentation below Englebright Dam has been on-going for years. Every idea that has been thought up by diverse stakeholders has been thoroughly discussed and vetted. The Lower Yuba River Technical Working Group and the Yuba Accord River Management Team have provided forums for discussion about this topic over the years. The 2007 pilot gravel injection with a truck-mounted conveyor belt demonstrated that gravel/cobble augmentation is not only technically feasible, but institutionally and politically possible. Observations of Chinook spawning in 2009 prove that salmon will use what is injected.

4.1. Elimination of Inadequate Methods

For the canyon below Englebright Dam, gravel is needed throughout the reach, but most especially in the longer and wider sections downstream of the Narrows I facility, as reflected in the estimates provided in Tables 3.1 and 3.2. This is a key constraint on augmentation methods. The truck-mounted conveyor belt method, roadside-dumping method, and (short of heroic measures) cableway delivery method are simply unable to get gravel into the river downstream of the Narrows I facility. A helicopter theoretically could dump gravel into the river, but the U.S. civil helicopter accident rate per 100,000 flight hours is 8.09 (IHSS, 2005), which is high. Operating in a narrow canyon with uncertain winds is even riskier than normal. Taking such a risk with human life is not necessary. That leaves road construction with front-loader placement and gravel/cobble sluicing.

Part of the reason why there is so much undesirable debris down at Sinoro Bar at the confluence of the Yuba and Deer Creek is that the pre-existing road down to the river at Englebright Dam washed away and deposited down there. Building a road requires a large amount of crushed aggregate, and in this case it has to be placed on a landslide-prone hillside where it will be attacked by large floods (Fig. 4.1). The 1997 flood was not a fluke. Floods of close to the same size or bigger occurred in 1955, 1963, 1964, and 1997 (Pasternack et al., 2010). That is four times in the last 55 years, or roughly once every ~14 years (foregoing detailed flood frequency analysis). If the road went all the way to the baseflow channel, then the lower part of the road would be submerged almost annually and seriously scoured every 3-5 years. The potential environmental harm from this is serious. Together with the long duration for permitting, the difficulty of getting big trucks down the steep road with switchbacks, and water quality impacts, the risk of aggregate entering the river makes road construction an unsatisfactory alternative.

Figure 4.1. Photo of the New Year's 2006 flood drowning the area where a road would have to be built to use trucks and front loaders as the delivery method for gravel/cobble augmentation. Aggressive velocities were evident all along the north bank.

4.2. Best Method for The EDR

By the process of elimination, the only remaining option is gravel/cobble sluicing. To my knowledge, no one has ever attempted to do gravel/cobble augmentation by as long of a sluice pipe as would be necessary for this plan. The long distance that water has to be pumped up and then slurry pumped down make the method much more expensive than for past projects using this method. Also, this method is relatively slow and potentially subjected to regular clogs. At an average rate of 150 tons per day, it would take 33 days to inject 5,000 tons. Front loaders typically place that much into a roadside river in ~4-6 days. On the other hand, the elevation drop for the EDR is so great that clogs may be relatively infrequent; a record speed of injection is possible. Once pipes are purchased in the first year, they can be stockpiled and used again in future years, reducing the overall cost of the system to a normal level. After thorough scrutiny, discussion, and on-site visit with the inventor of the method, no major impediment to the approach is evident at this time.

4.3. Detailed Concept for Sluicing Gravel Mix Down to EDR

Despite the fact that sluicing will have to be done over a long distance, the EDR has excellent attributes that promote the idea of attempting this method. The overall schematic for the application of sluicing to get gravel/cobble into the EDR is shown in Figure 4.2. Prior to the start of sluicing operations, 2000 short tons of gravel would be stockpiled in the three parking/turnaround areas at the overlook on the north side of the dam. This location is behind a locked gate and is inaccessible to the public. Englebright Reservoir is close by and easily accessible. Only ~2.3 cfs is needed for the sluicing operation, in comparison to the typical autumnal release of ~750 cfs- that's just 0.3%. A gravel road on the north side of the reservoir close to the dam (Fig. 4.3, right) goes right to the water's edge (Fig. 4.3, left), so that the water intake pump system (including fish screening custom built by Morrill Industries) can be safely positioned and easily operated. From there, water would be pumped in one or two 6-8" diameter pipes ~1070' up the side of the road (Fig. 4.3, right) to the crest. Where needed, the pipe would cross 1-2 roads in Rain-For-Rent Entrance/Exit Ramps, enabling vehicles to pass over the pipe with no interference to anyone's normal activities. The water pipe(s) would go over the crest of the hill and down the side of the paved road ~300' toward the Narrows II powerhouse until a point at which there is a noticeable slope break especially favorable to beginning gravel/cobble addition to the pipe. At that location a screened hopper on the north side of the road would receive sediment from a front loader bringing the material the short distance from the stockpile. The loader operator would gently bounce the bucket to trickle the sediment into the hopper as the primary control on the flow rate. A hopper operator would be standing there to ensure no blockages, clean out finger rocks as needed, and communicate conditions with other operations participants by radio. Under the hopper the gravel and water would join in a metal pipe that would then connect to the beginning of the 8” diameter, semi-flexible “Yelomine” pipe. This pipe would then go ~1270’ down the ditch on the north side of the road to the switchback. From that point, the best option would be to go 264’ straight down the grassy hillside (Fig. 4.4, left) to a terrace level where an old roadbed and foot trail is located. From there, the pipe would make a straight line 130’ down to the water’s edge near the upstream end of the gravel placement area for 2010 (Fig. 4.4, right). Overall, this approach would use roughly 2000’ of Yelomine pipe to drop a vertical height of roughly 360’, yielding an overall slope of 0.18 (18%).

Figure 4.2. Schematic of the gravel/cobble delivery system using a sluice method.

Figure 4.3. Landing area at the water's edge of Englebright reservoir (left) and gravel road leading up to the hillcrest (right).

Figure 4.4. Hillslope from road down to low terrace (left) and view from low terrace down to the Area A gravel placement location (right).

4.4. Gravel/Cobble Placement Location

The selection of the specific location within the EDR for focusing gravel/cobble placement was guided by constraints in powerhouse operations, potential benefits to the river, and feasible delivery methods. Powerhouse operations presently make gravel/cobble augmentation between Englebright Dam and the Narrows I powerhouse uncertain for the reasons described in section 2.3.3. To get the most benefit and longevity from adding gravel to the river, the further upstream it is introduced, the better. Thus, gravel/cobble augmentation could begin in the scour pool adjacent to the Narrows I facility. This pool is up to 8' deep at 855 cfs. To avoid having to fill in that scour hole and yield riffle habitat for immediate spawning use with the least amount of initial gravel injection during a pilot gravel sluicing operation, it would be advantageous to begin placement ~115' downstream of the end of the Narrows 1 powerhouse where the maximum depth is under 5' at 855 cfs. If the sluicing operation is successful, the Narrows 1 pool could be partially filled in a future year. Accessing this placement location with the gravel/cobble sluicing method is highly feasible according to the pipe pathway described in section 4.3. From this point, additional sluice pipe could be added to reach across the river or shift placement downstream in future years.

4.5. Gravel Cobble Mixture Design

Table 4.1 below provides the design of the gravel mixture to be used at the site. This mixture is consistent with the scientific literature on what is preferred for salmon spawning, embryo incubation, and fry emergence. Because the mix only specifies 2.5% of the material to be 4-5" in its B-axis dimension, that helps reduce the likelihood of having large finger rocks that can clog the sluice pipe.

Table 4.1. EDR gravel and cobble specifications (from USACE, 2007).

Gravel Size (inches)	Percent Retained	Target % of Total Mix
4 to 5	0 - 5	2.5
2 to 4	15 - 30	20
1 to 2	50 - 60	35
¾ to 1	60 - 75	15
½ to ¾	85 - 90	15
¼ to ½	95 - 100	10
< ¼	100	2.5

5. 2010 EDR SPAWNING RIFFLE DESIGN DEVELOPMENT

The Watershed Hydrology and Geomorphology Lab at UC Davis has been designing spawning habitat rehabilitation projects since 1999 using the Spawning Habitat Integrated Rehabilitation Approach (SHIRA) (Fig. 5.1). Over the years, testing of numerous gravel-contouring schemes in 2D models and in actual construction has yielded a conceptual understanding of expected hydraulic attributes, geomorphic processes, and ecologic benefits. Numerous specific design examples are illustrated on the SHIRA website at http://shira.lawr.ucdavis.edu/casestudies.htm.

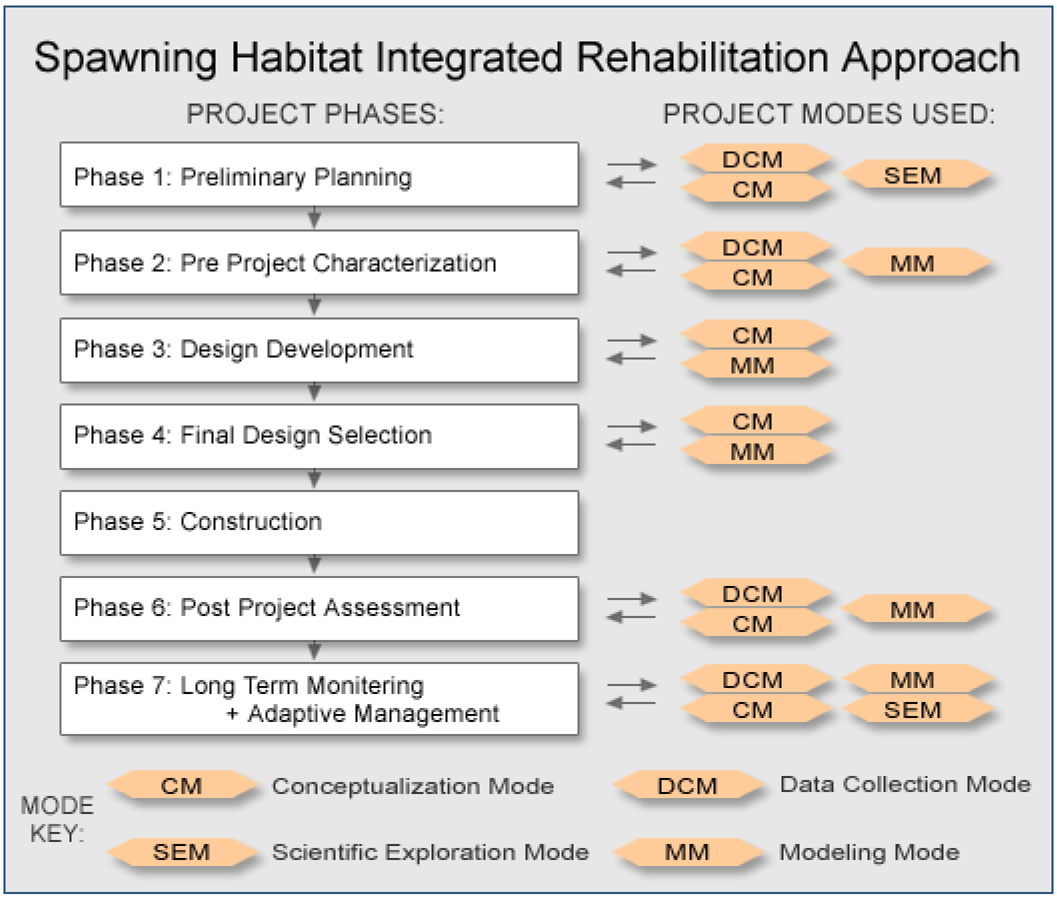

Figure 5.1. General schematic illustrating what is involved in the SHIRA framework.

5.1. Project Constraints

Based on past experience and site-specific constraints, it is possible to reduce the number of possible alternatives down considerably. An enumeration of key constraints helps put the options into focus. First, the amount of gravel to be added in the 2010 pilot trial of the gravel/cobble sluicing method has to be relatively small compared to the total deficit in the EDR given the uncertainty over how the method will work out. A lot of lessons may be learned from this trial in support of improvement to facilitate larger placements in future years. The consequence of placing a small amount of gravel is that there may not be enough material to form a resilient landform at the injection location in the face of a range of flow releases. Second, even at the typical low discharge of ~500-950 cfs in the EDR in September and October, baseline 2D modeling shows that the flow in the placement area is deep and fast (Figs. 3.1-3.4). This location is in a narrow part of the canyon that focuses flow over a range of discharges (Figs. 3.3-3.4). Several placement configurations (e.g. diagonal bar and chevron) would be at risk to scour away quickly under such focused scour. Third, the rate of gravel sluicing may be to low relative to the ambient velocity to control placement pattern at all. As sediment settles out of the water column, it will be pushed downstream in a way that is not easy to control.

One element excluded from consideration for this plan was the addition of large wood to the wetted channel in support of habitat heterogeneity, refugia, and cover. Presently there is large wood stored in the EDR (Fig. 5.2), which is ultimately derived from the small tributaries of the Middle and South Yuba Rivers. These two high-order tributaries have long stretches of unblocked channel network leading into Englebright Dam. The dam itself passes streamwood over its top during floods (wood floats, gravel/cobble does not), as evidenced by the available large wood stored in the EDR and the debris clogging Daguerre Point Dam and its fish ladders during and after floods. Historical photos 1909-2006 do not show wood jams or smaller wood accumulations in the wetted channel of the EDR. Given the width of the channel in the EDR and the power of the flow during floods, there is no reason to expect that large wood was ever stored in the channel there, in contrast to gravel/cobble, which was stored there and is now absent. Finally, because wood floats, any placement of large wood as part of the gravel/cobble augmentation plan would be highly likely to wash downstream. Use of engineered cables and fasteners to force wood to stay in place is problematic, because the underlying sediment is not expected to stay in place. Hard-wiring objects in place is also inconsistent with the approach of rehabilitating naturalized dynamic processes.

Figure 5.2. Example of large wood stored in the EDR.

5.2. Project Goals

Regardless of these constraints, the primary project goal of injecting river-rounded gravel/cobble is not at risk in the choice of placement design. If the sluice method gets the sediment into the wetted channel, then it is a success with regard to the primary goal of the project. *Creating a placement design is a bonus opportunity enabled by the ability of the sluicing method to have moderate control over where gravel is laid down on the river bed.* The extent to which the bonus can be achieved hinges on the amount of gravel added and ambient flow conditions. It is impossible to predict in advance how that will turn out. Nevertheless, it is sensible to be prepared for a successful outcome in which it is possible to control gravel placement on the bed. In that case the extra effort of controlling placement can yield physical habitat immediately available for Chinook salmon spawners to use (Elkins et al., 2007).

5.3. Design Objectives And Hypotheses

A design objective is a specific goal that is aimed for when a project plan is implemented. To achieve the objective, it has to be translated into a design hypothesis. According to Wheaton et al. (2004b), a design hypothesis is a mechanistic inference, formulated on the basis of scientific literature review and available site-specific data, and thus is assumed true as a general scientific principle. Once a design hypothesis is stated, then specific morphological features are designed to work with the flow regime to yield the mechanism in the design hypothesis. Finally, a test is formulated to determine after implementation whether the design hypothesis was appropriate for the project and the degree to which the design objective was achieved. Through this sequence, a process-oriented rehabilitation is achieved. From the mathematics of differential equations, it is evident that processes derive from the physics of motion, input conditions, and boundary conditions. Changes to either of input or boundary conditions impact processes, so it is possible and appropriate to design the shape of the river bed to yield specific fluvial mechanism associated with desired ecological functions.

The design objectives and associated information for the EDR gravel/cobble augmentation plan are enumerated in Table 5.1. This table provides a transparent accounting of the objectives, hypotheses, approaches, and tests for the gravel/cobble augmentation effort.

The last column in the table lists specific measures for monitoring the success of gravel/cobble augmentation.

Table 5.1. Design objectives and hypothesis for EDR gravel/cobble augmentation.

Design objective	Design hypothesis	Approach	Test
1. Restore gravel/cobble storage	1A. Total sediment storage should be at least half of the volume of the wetted channel at a typical base flow under a heavily degraded state (Pasternack, 2008b).	Inject gravel into the river to fill up recommended volume of sediment storage space.	Use DEM differencing of bed topography over time to track changes in storage
2. Provide higher quantity of preferred-quality Chinook spawning habitat	2A. SRCS require deep, loose, river-rounded gravel/cobble for spawning (Kondolf, 2000).	Add river-rounded gravel/cobble.	Perform Wolman pebble counts of the delivered sediment stockpile and in the river after each gravel injection to insure that the mixture's distribution is in the required range.
	2B. Spawning habitat should be provided that is as close to GHSI-defined high-quality habitat as possible (Wheaton et al., 2004b)	Place and contour gravel to yield depths and velocities consistent with salmon spawning microhabitat suitability curves.	Measure and/or simulate the spatial pattern of GHSI after project construction to determine quantity of preferred-quality (GHSI>0.4) habitat present.
3. Provide adult and juvenile refugia in close proximity to spawning habitat.	3A. Structural refugia in close proximity to spawning habitat should provide resting zones for adult spawners and protection from predation and holding areas for juveniles.	Create spawning habitat in close (<10 m) proximity to pools, overhanging cover, bedrock outcrops, boulder complexes, and/or streamwood.	Measure distance from medium and high GHSI quality habitats to structural refugia and check to see that most spawning habitat is within reasonable proximity.
4. Provide morphological diversity to support ecological diversity, including behavoral choice by individuals.	4A. Designs should promote habitat heterogeneity to provide a mix of habitat patches that serve multiple species and lifestages.	Avoid GHSI optimization of excessively large contiguous areas of habitat; design for functional mosaic of geomorphic forms and habitat.	Large (>2 channel widths) patches of homogenized flow conditions in hydrodynamic model and homogenized habitat quality in GHSI model results should not be present at spawning flows.
5. Allow gravel/cobble to wash downstream	5A.Suitable mechanisms of riffle-pool maintenance are not present or realistically achievable in the upper section of the EDR	no specific action required	Conduct annual recon of EDR to track where injected gravel/cobble goes.
	5B. Flows that overtop Englebright Dam erode sediment off the placement area	no specific action required	Measure and/or simulate the spatial pattern of Shields stress and identify areas with values >0.06

5.4. Design Concept

Given the array of site and project constraints described earlier, there is a limited range of concepts possible for implementing spawning habitat rehabilitation. To facilitate a larger, longer term vision, a staged design concept was developed that can be aimed for over time. The design concept for the plan is illustrated in Figure 5.3. Area A is the focus of the effort for 2010. The design for Area A involves filling in the channel to a depth of ~2' for the primary spawning area at 855 cfs and then having a 3' deep thalweg going up to the crest. The thalweg is in the 2D model-predicted location of the pre-existing thalweg for 855 cfs. A deeper thalweg is required to cope with the total volume of flow focusing through the gravel-placement site. The thalweg ends at the riffle crest allowing water to diverge laterally across the crest. By design the thalweg does not go all the way through riffle, because that would increase the rate and likelihood of the flow cutting the gravel deposit into two lateral benches, which is not desirable (Pasternack et al., 2004). However, given the strength of the flow, it may be unavoidable, even without the thalweg going through the whole riffle by design. If fully built, Area A would use up an estimated 4673 short tons of gravel. The conversion of gravel amount from a design volume to a tonnage is based on the density measurements of Merz et al. (2006) reported earlier in section 2.2, noting that with the sluicing method there is no heavy machinery to compact the bed, in contrast to the effect of front loaders reported by Sawyer et al. (2009). A key reason to aim for 2' water depth at 855 cfs is that flows can drop to 700 cfs in a schedule A year and 500 cfs in a schedule B year. This depth provides a hydrologic buffer so that the riffle does not dewater. This is consistent with design objective #4. Another factor is that the design has to be constructible using the gravel sluicing method, and this simple design meets construction criteria based on past experience.

Figure 5.3 also illustrates design concepts for adding coarse sediment in future years to continue to meet the design objectives (Areas B and C). Because the channel deepens downstream, Area B uses more gravel than Area A, but is about half as long. Area B divides the flow and refocuses it into two 3'-deep thalwegs. Between them is a medial bar. This channel pattern is known to promote habitat diversity as well as resiliency against interannual flow differences during the spawning season. Area B requires an estimated 4870 short tons. Area C terminates the medial bar and joins the two thalwegs along the right bank, before beginning to shift it back toward the center. Area C requires an estimated 3192 short tons. Thus, the overall design concept would use 12735 short tons of gravel if it were possible to build it out over a period of a few years. This accounts for 56% of the estimated gravel/cobble storage deficit for the area from Narrows II to the rapid below the gaging station (Table 3.1). For the sake of comparison, a "blanket fill" design that would involve filling half of the pre-existing mean water depth at 855 cfs with coarse sediment between Narrows I and the rapid downstream of the gaging station would require an estimated 15850 short tons. Such a blanket installation is not feasible by gravel sluicing as it is currently practiced. Nevertheless, this value is helpful to appreciate that the creation of a heterogeneous spawning riffle in a relatively small area can achieve the same gravel/cobble storage goal, while also yielding the benefit of providing preferred SRCS spawning habitat.

If the gravel introduced in the first year washes downstream consistent with design objective #5, then that is fine, as the eroded material would still be serving the primary plan goal (design objective 1). Future injections would use the next amount of material purchased to rebuild as much of Area A, then Area B, and then Area C as possible. It is possible that frequent floods could preclude the complete design concept from ever being achieved, and that is an acceptable outcome consistent with the overall goals of the plan and the specific design objectives.

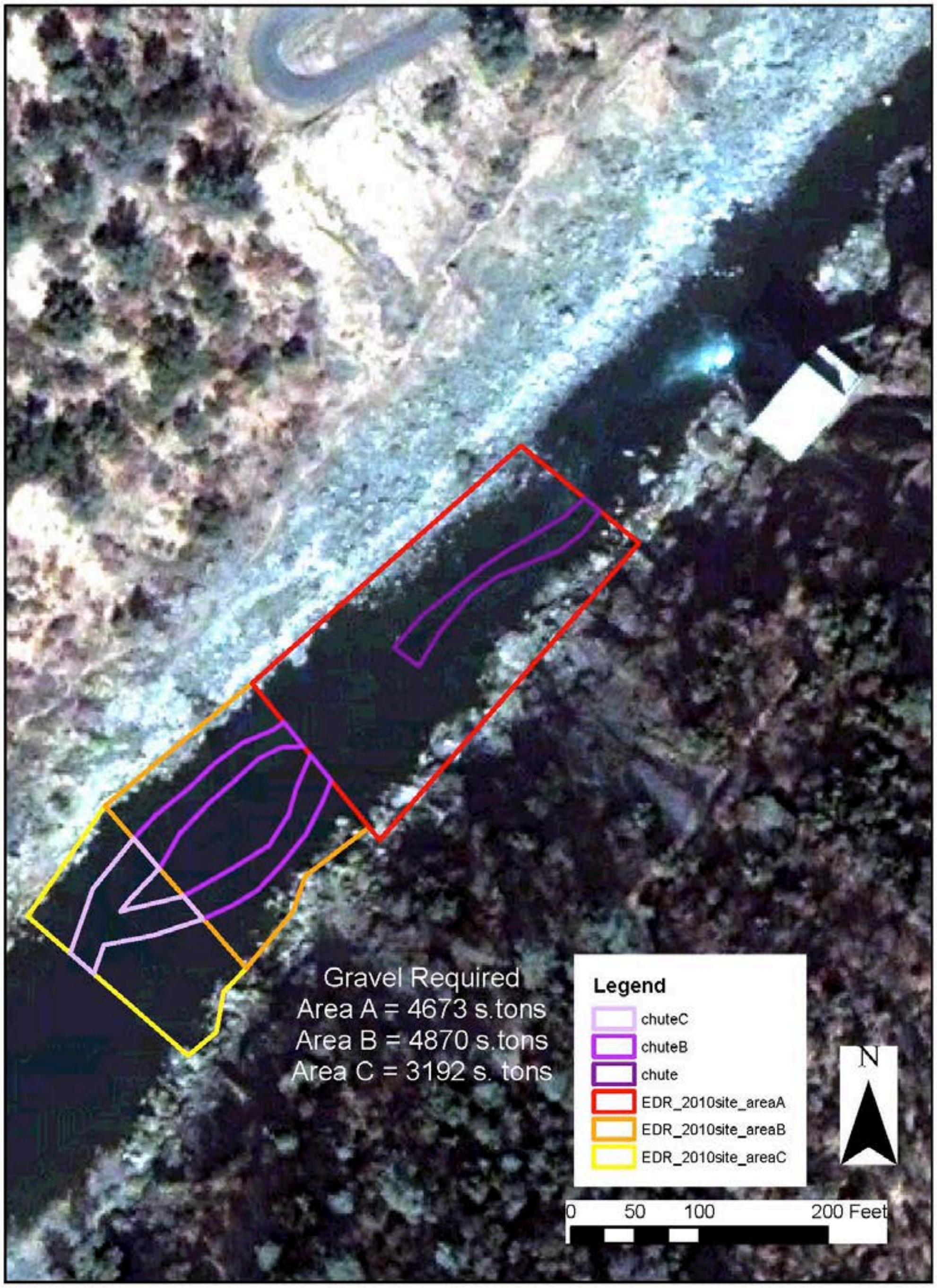

Figure 5.3. Design concept for using gravel augmentation in the EDR to possibly obtain a salmon-spawning riffle with diverse microhabitat features.

5.5. 2D Model Testing of Design Hypotheses

The likely ability of the design concept to achieve design objectives 2 and 5 is testable by performing spatially distributed, mechanistic numerical modeling of the design. Objective 2 and hypothesis 2B require that the design yield areas with GHSI>0.4 at a typical autumnal discharge of ~500-950 cfs. Objective 5 and hypothesis 5B require that the design yield areas with Shield stress values > 0.06 at flows overtopping Englebright Dam, which is Q>4500 cfs. The abilities of the design for Area A, Areas A+B, and Areas A+B+C to achieve these requirements were tested by incorporating their respective topographic features into SRH-2D models of the EDR and putting these models through the same paces as the models reported in section 3. The computational meshes used were the same as for the baseline simulations, with only the bed topography changed.

The SRH-2D model simulation for 855 cfs revealed that the design concept for Area A successfully achieves substantial area of spawning habitat with GHSI>0.4 (Fig. 5.4). Because excessive depth appears to be the limiting variable, lower discharges would have lower depths, higher GHSI values, and thus a larger total area of preferred Chinook spawning habitat.

The SRH-2D model simulation for 855 cfs revealed that the design concept for Area A yields a stable bed with a Shields stress of 0.01-0.03 during this spawning discharge (Fig. 5.5). Depending on how loosely the gravel/cobble settles onto the bed and whether any grain size fractionation occurs during settling, it is unclear whether this range of Shields stress values would be associated with partial transport. However, if that happened, the bed can be expected to adjust very quickly to yield a stable configuration prior to the autumn 2011 spawning season.

The SRH-2D model simulation for 10,000 and 15,400 cfs revealed that the design concept for Area A successfully provides a condition of full bedload mobility over the majority of the project area at these discharges (Fig. 5.6). That means that at these high discharges and any higher ones, the project site will scour significantly. Beginning with the 1991 water year, flows of >10,000 cfs have occurred in 12 out of 20 years, or once every 1.67 years. Therefore, there is a high likelihood that the placed grave/cobble will transport downstream in accordance with design objective #5. Results shown in Figures 3.6-3.7 indicate that the placed material is unlikely to leave the EDR. Considering that those analyses do not account for the impeding effects of flow out of Deer Creek, then the likelihood is even stronger that the material will stay in the EDR.

One other consideration related to any riffle design is the fact that a riffle is a partial barrier to flow. Water backs up behind a riffle and accelerated over it. When a riffle is added artificially or degraded riffle-pool relief is rehabilitated, then an increased backwater effect will result (Wheaton et al., 2004a). The Area A 2D model simulations show that effect for that design. In the EDR, there is no negative environmental impact of this upstream backwater effect, because it serves to decrease velocity and increase depth in an area that is already mostly devoid of spawning habitat anyway. In terms of powerhouse operations, both powerhouses operate normally with a wide range of tailwater depths, so an increase in water surface elevation in the Narrow I pool and Narrows II pool should not impact their operations.

Overall, there do not appear to be any impediments for the use of the Area A design. The design uses a reasonable amount of gravel to pilot the gravel sluicing method in 2010. If the material survives in its placement location through winter and spring 2011, the design is predicted to yield preferred Chinook spawning habitat and is predicted to yield a stable riffle during spawning and embryo incubation in 2011 prior to winter storms in 2012. The designed riffle is predicted to be erodible during floods overtopping Englebright Dam roughly every other year, but when moved the material is expected to stay within the EDR. This means that the tonnage still counts toward achieving the geomorphic goal of eliminating the gravel/cobble deficit for the reach over the long term. Further gravel additions to re-build Area A in future years would yield short-term habitat benefits and add up toward the longer term geomorphic goal. The last column of Table 5.1 lists specific measures than can be used to test the efficacy of gravel augmentation toward meeting each specific design objective.

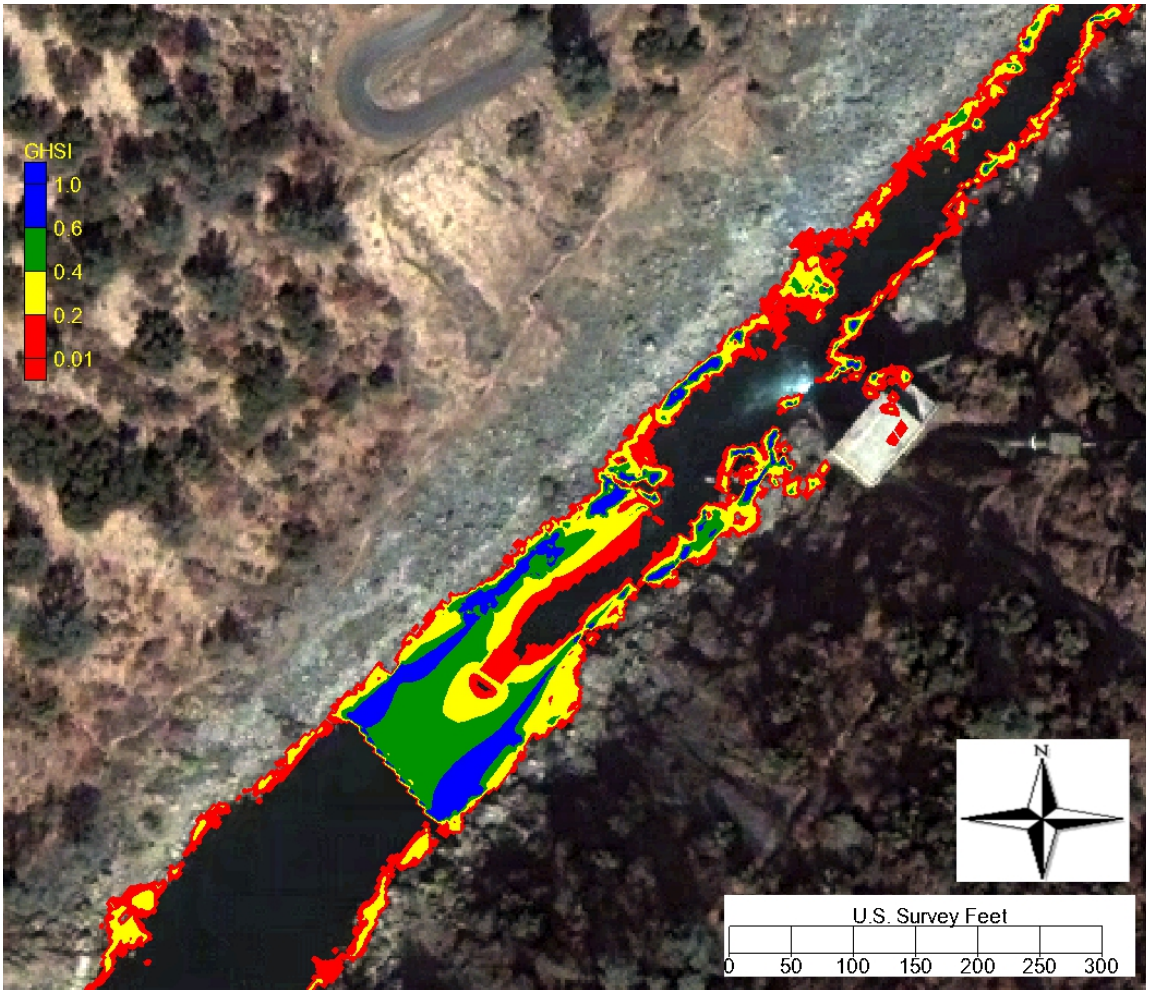

Figure 5.4. GHSI prediction for Area A at 855 cfs. Areas of green and blue are predicted to be preferred Chinook spawning habitat.

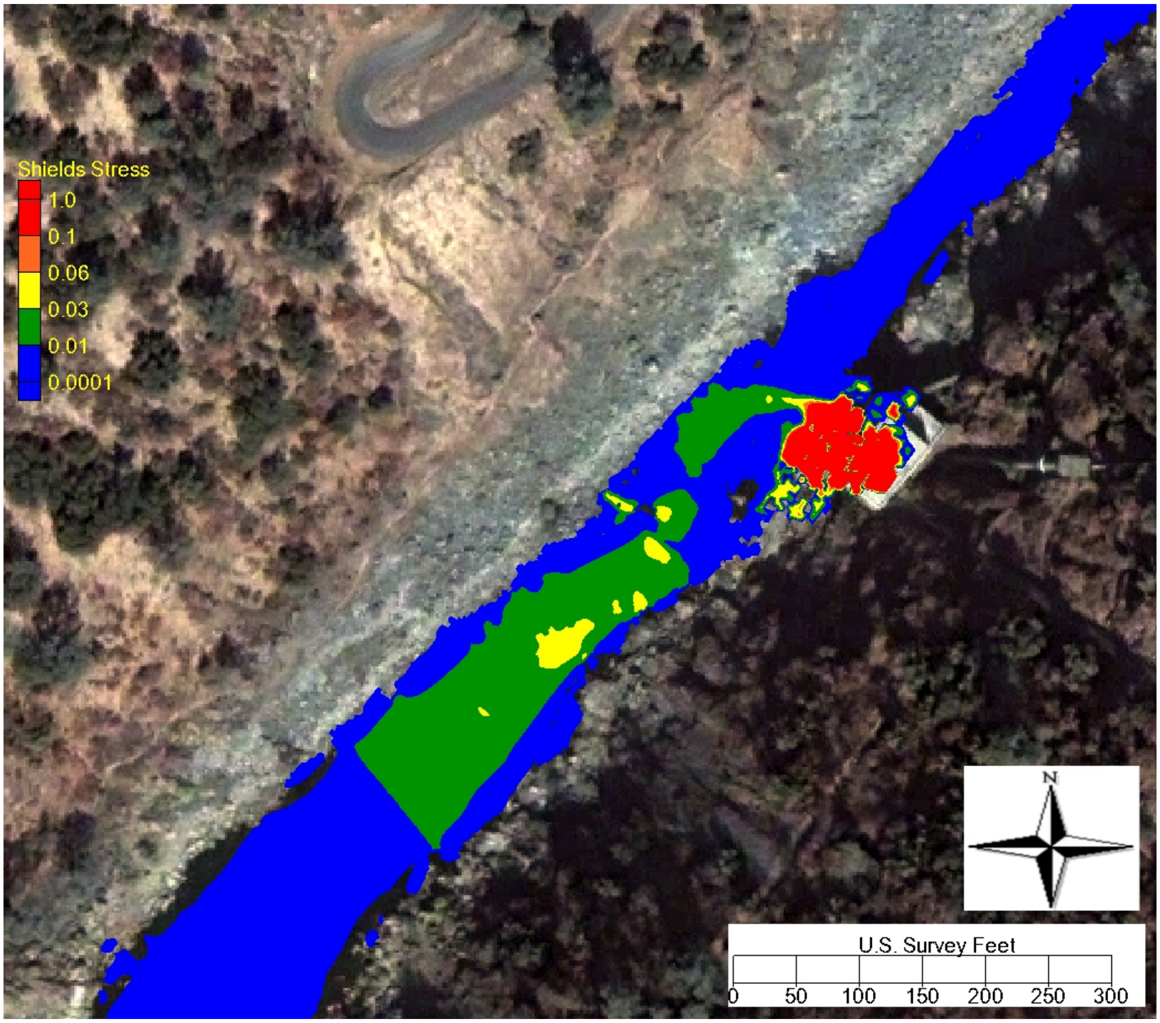

Figure 5.5. Shields stress prediction for Area A at 855 cfs.

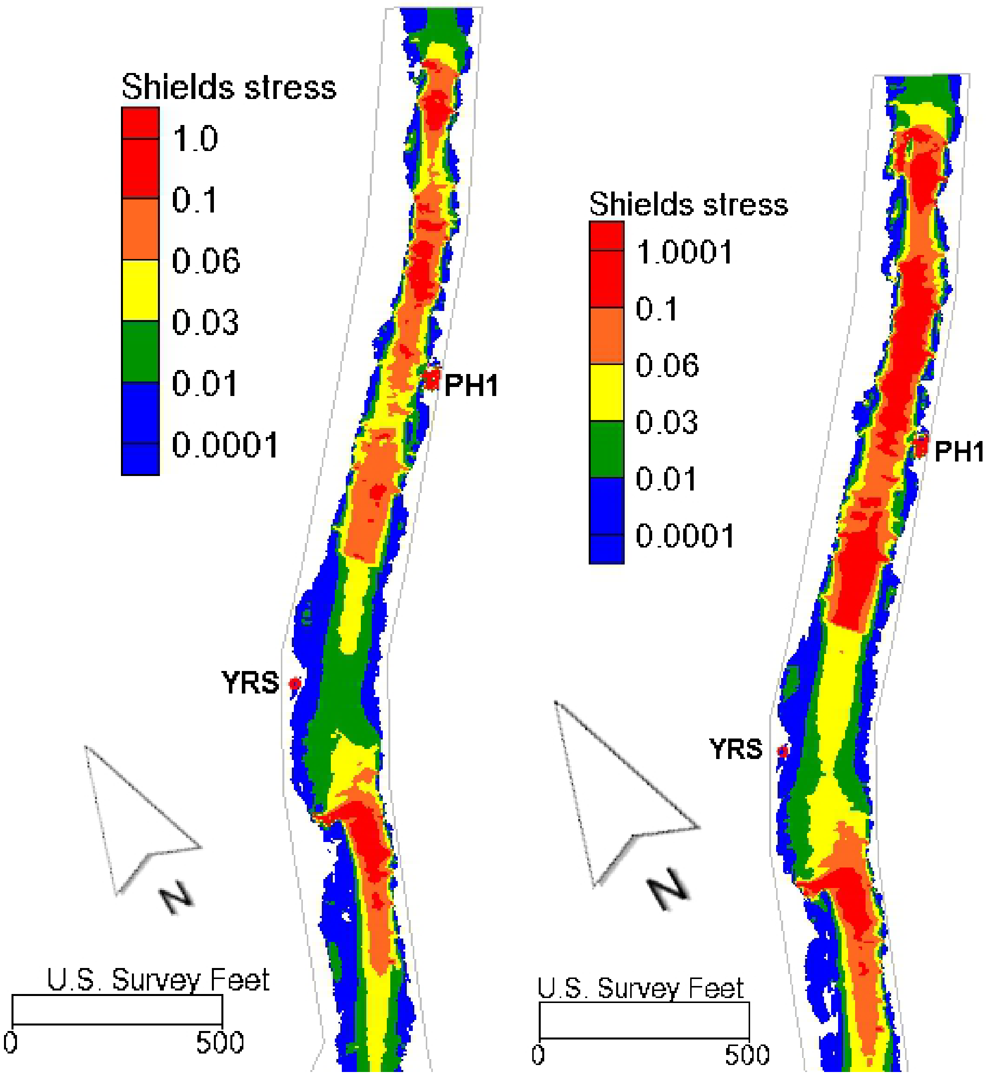

Figure 5.6. 2D model predictions of Shields stress for flows of 10,000 cfs (left) and 15,400 cfs (right), focusing on the location of gravel placement below the Narrows I powerhouse (PH1). In both scenarios, Shields stress > 0.06 over the majority of Area A.

6. LONG-TERM GRAVEL AUGMENTATION PLAN

The estimated gravel/cobble deficit for the EDR is 63,077 to 100,923 in the current condition. Considering just the area from the Narrows I powerhouse to the rapid downstream of the gaging station, the amount is 15,949 to 25,518 short tons. The lower value for each domain is consistent with the idea of having a diversity of complex morphological units in the reach, while the higher value for each domain is consistent with the idea of having a fully alluvial reach with a lot of riffle area and low morphological diversity. The former conception involving a balanced role of alluvial and bedrock influences is interpreted to be the best match for what was likely present prior to hydraulic mining. The latter conception of a fully alluvial river within the canyon would more resemble the state of the river during severe alluviation with hydraulic mining debris, and therefore is deemed less appropriate.

Strategically, different approaches are feasible for the sequencing of placing gravel and cobble. It is not feasible to erase the entire gravel/cobble deficit in one year. It is very important to use an incremental approach in this type of project, because it yields a more resilient and better-tested outcome (Elkins et al., 2007). The area of the river that is presently appropriate for gravel augmentation is the domain from the Narrows I pool to the top of the rapid downstream of the gaging station. The recommendation for the 2010 pilot project is to use the sluicing method to place 2000 to 5000 short tons of gravel/cobble to build up an Area A riffle. This project is a “pilot”, because the gravel/cobble sluicing method has never been attempted for salmon habitat rehabilitation over such a long distance and with such a high height drop.

During and after the 2010 pilot gravel/cobble placement, a monitoring program should be instituted to evaluate what happened. Baseline data exists for the pre-project characterization (see section 3). Observation, description, and photo-documentation of the gravel/cobble sluicing operation would help assess its logistical effectiveness to get gravel/cobble into the river. After construction, an as-built topographic survey should be performed to enable 2D hydrodynamic modeling for mapping of physical habitat and sediment transport potential for the site. The as-built survey is also required for DEM differencing to track volumetric change over time. Thereafter, the seven tests listed in

Table 5.1 should be carried out. These tests will ascertain the veracity of the design hypotheses and the suitability of the design objectives. Based on the outcome of a thorough evaluation, future projects may be designed differently to yield improved outcomes.

Assuming the gravel-sluicing method of doing gravel/cobble augmentation is judged successful after evaluation of the 2010 pilot project, then a long-term plan that continues to use this approach would be recommended. The concept would be to add gravel and cobble to Areas A, B, and C until the EDR deficit is erased. Building out the design concept for Areas A, B, and C would come close to achieving the total deficit for this section, and it would be easy to add an Area D to finish it off when and if that is needed. Thereafter, as floods relocate the sediment into the lowermost section of the EDR, further additions would be made to the placement area to keep up with the flux into the lowermost section plus any outflux leaving the EDR. Eventually, the gravel deficit for the whole reach would be erased. Once the overall deficit is erased, then further additions would only be appropriate after material is observed leaving the EDR, and then the amount would match the estimated loss.

For the section between the Narrows II and I powerhouses, it may or may not be feasible to ever erase the gravel/cobble deficit. Further evaluation of options in light of existing and possible future powerhouse operations is required.

Overall, the evidence shows that the EDR has the potential to accommodate thousands of Chinook spawners. Erasing the gravel/cobble deficit for the reach would be beneficial toward achieving that potential. Gravel sluicing is the recommended method for augmenting gravel into the EDR. Going further to build diverse morphological units in the reach would yield a sufficient amount of preferred holding, spawning, and embryo-incubation habitat for the population. Such actions would account for the most significant and evident geomorphic impacts of Englebright Dam on the lower Yuba River.

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Lower Yuba River Large Woody Material Management Plan

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Table of Contents

1.0 Introduction

Instream large woody material (LWM) provides escape cover and relief from high current velocities for juvenile salmonids and other fishes (**Figure 1**). Snorkeling observations in the lower Yuba River have indicated that juvenile Chinook salmon had a strong preference for near-shore habitats with instream woody material (JSA 1992). As part of the Central Valley Project Improvement Act Anadromous Fish Restoration Program, the United States Fish and Wildlife Service (USFWS) (1995) identified the need for increasing the amount of instream woody material to improve juvenile salmonid rearing habitat in the lower Yuba River. Beak (1996, as cited in CALFED and YCWA 2005) recommended the addition of instream woody material as a habitat enhancement action to increase annual salmonid smolt production in the lower Yuba River.

Figure 1. Juvenile salmonids associated with LWM.

It has been reported by the lower Yuba River Fisheries Technical Working Group (CALFED and YCWA 2005) that little instream woody material occurs in the lower Yuba River, because upstream dams block some downstream transport of woody material, and because of the lack of riparian vegetation throughout much of the lower Yuba River. However, the CALFED and YCWA (2005) report did not indicate that any surveys or studies were conducted to support these statements. Some woody material may not reach the lower Yuba River due to collecting on the shoreline and sinking in Englebright Reservoir. However, Englebright Dam does not substantively block woody material from reaching the lower Yuba River because there is no woody material removal program implemented for Englebright Reservoir, and accumulated woody material therefore spills over the dam during uncontrolled flood events (R. Olsen, Corps, pers. comm. 2011). Nonetheless, few pieces of large wood reportedly are found within the reach of the lower Yuba River extending from Parks Bar to Hammon Bar, presumably due to upstream dams disrupting downstream transport from the upper watershed and the overall lack of supply and available inventory along the riparian corridor of the river downstream of Englebright Dam (USFWS 2010).

On November 21, 2007, National Marine Fisheries Service (NMFS) issued a long-term biological opinion (BiOp) regarding the U.S. Army Corps of Engineers' (Corps) operation and maintenance of Daguerre Point and Englebright dams. The BiOp included an incidental take statement (ITS) with several terms and conditions. Term and condition D.2. requires the Corps to "*develop and implement a long term program to replenish large woody materials in the lower Yuba River*." In accordance with this term and condition, the Corps must "*determine an effective method of* *replenishing the supply of large woody material ... back into the lower Yuba River, in a manner that provides instream cover, invertebrate flood sources, and micro-habitat complexity…*"

In October of 2011, the Corps submitted a Biological Assessment (BA) to NMFS assessing the effects of ongoing operations and maintenance of Englebright and Daguerre Point dams in the lower Yuba River. The BA included a conservation measure addressing LWM. The conservation measure in the BA stated that the Corps will: (1) develop a plan or policy for management of LWM, consistent with recreation safety needs; (2) conduct a pilot program to identify suitable locations and evaluate the efficacy of placing large instream woody material to modify local flow dynamics to increase cover and diversity of instream habitat for the primary purpose of benefitting juvenile salmonid rearing; and (3) based upon the outcomes of the pilot program, develop and implement a long-term Large Woody Material Management Plan (LWMMP) for the lower Yuba River, anticipated to occur within one year following completion of the pilot program.

This LWMMP has been prepared consistent with term and condition D.2. in the BiOp and the conservation measure presented in the BA, with technical assistance provided by HDR Engineering, Inc. It includes the following key elements.

- Metrics for assessing LWM value and selection criteria
- Design considerations including LWM sources, collection location(s), collection methods, transportation methods, and stockpiling location(s).
- Description of a LWMMP Pilot Program

1.1 Goals of the LWMMP

The overall goal of this plan is to provide and manage LWM in the lower Yuba River downstream of Englebright Dam to improve habitat for juvenile salmonids and other non-listed fish species, by improving cover and diversity of instream habitat for rearing juvenile anadromous salmonids, and provide increased cover, invertebrate food sources, and micro-habitat complexity. The Corps recognizes that the accomplishment of this goal has to occur while maintaining recreation and public safety values.

2.0 LWMMP Design Considerations

The application of LWM to improve habitat for juvenile salmonids and other non-listed fish species in the lower Yuba River considers several design characteristics including the source of LWM, collection methods, size and type criteria for selection, access and transportation of LWM, and placement techniques for optimal benefit of LWM.

LWM is a naturally occurring feature in stream channels. LWM may alter existing hydrodynamics, habitat availability and use, and a redistribution of species (Saldi-Caromile et al. 2004). The deliberate placement of wood in streams and floodplains to form discrete structures at specific locations may create habitat immediately, or may take years to develop (Saldi-Caromile et al. 2004). Wood can be a naturally occurring feature anywhere in a stream system where trees are present in the adjacent riparian zone or upstream watershed. However, there is risk associated with adding mobile wood to certain stream types. For example, as the velocity and depth of flow increases, so do the buoyant and drag forces acting to transport LWM. And as the width and depth of the stream increases, the likelihood of wood getting wedged between banks, or held up on bank and channel obstructions decreases. Consequently, the risk of wood transport (though not necessarily project failure) increases with channel gradient, channel depth, and channel width (Saldi-Caromile et al. 2004). Ideal locations for wood replenishment include less developed watersheds where infrastructure is not located within or immediately adjacent to the stream (Saldi-Caromile et al. 2004).

2.1 LWM Availability and Collection

Within the Yuba River Basin, several dams have altered the downstream movement of large wood into the lower Yuba River. New Bullards Bar Dam and Reservoir is located relatively low in the watershed and functions as the dominant flood control and water supply reservoir in the Yuba River Basin (CALFED and YCWA 2005). The drainage area of the North Yuba Basin is approximately 489 square miles (mi^2), which is the largest drainage area of the three Yuba River sub-basins (i.e., North Yuba River Basin, South Yuba River Basin, and Middle Yuba River Basin). Since completion of New Bullards Bar Dam in 1969, the movement of LWM from the North Yuba River Basin into the Yuba River has been reduced. A cable-and-buoy line (floating boom) spans New Bullards Bar Reservoir just upstream of the dam, which captures woody material that has entered and traveled downstream on the reservoir's surface.

The woody debris that accumulates on New Bullards Bar Reservoir consists of various materials, including leaves, twigs, branches, logs, root-wads, and trees. However, the quantity, size, and type of LWM entering New Bullards Bar Reservoir on an annual basis are not well known. In general, the most commonly available floating wood is generally small diameter material, with large diameter trees occurring less frequently and usually associated with flood events.

A flood event that occurred December 31, 2005 reportedly resulted in approximately 6,300 cubic yards (yd^3) of floating woody material on the surface of New Bullards Bar Reservoir (**Figure 2**). The Yuba County Water Agency (YCWA) obtained a Federal Emergency Management Agency (FEMA) grant to gather up and remove the woody material, and about 4,800,000 pounds of wood was chipped and hauled to Oroville to be used as fuel for a biomass generation unit.

Because the availability of LWM is related to magnitude, duration and frequency of large floods (City of Tacoma 2004), it is likely that the quantity and quality of LWM entering New Bullards Bar Reservoir from the North Yuba River vary inter-annually. Research quantifying the large wood loading in the Yuba River Basin is presently underway by Anne Senter, a UC Davis student advised by Dr. Pasternack (USFWS 2010). Preliminary estimates have quantified the volume of wood stored in New Bullards Bar Reservoir at two times - 1998 and 2006.

Figure 2. Large Woody Material in New Bullards Bar Reservoir (YCWA 2006).

Aerial photography examinations resulted in an estimated 34,400 yd^3 of wood accumulated on New Bullards Bar Reservoir during 1998, and an estimated 110,000 yd^3 accumulated on New Bullards Bar Reservoir during 2006 (A. Senter unpublished data, as cited in USFWS 2010).

YCWA presently manages the LWM that is washed into New Bullards Bar Reservoir from the North Yuba River Basin upstream. Although no formal LWM Management Plan has been established, YCWA methods currently involve pushing the floating LWM into shallow coves of New Bullards Bar Reservoir using tug boats, and subsequently gathering and removing the dry LWM from the reservoir using a boom (G. Rabone, YCWA, pers. comm.). USFWS (2010) reports that accumulated wood from New Bullards Bar Reservoir is burned every 1 to 3 years.

Consistent with past LWM removal efforts on New Bullards Bar Reservoir, YCWA will continue to manage LWM on New Bullards Bar Reservoir by pushing the floating LWM using tug boats into shallow coves that have landside access along New Bullards Bar Reservoir, and subsequently stockpiling the LWM on the shoreline using a boom. The Corps will coordinate with YCWA to gather some of the stockpiled LWM along New Bullards Bar Reservoir and place it onto transport trucks for relocation downstream in the lower Yuba River. It is anticipated that LWM that is not selected for enhancement downstream will be burned on the shoreline of New Bullards Bar Reservoir.

For the Pilot Program (see Section 4.0, below), the Corps will use LWM available from the stockpiles located along New Bullards Bar Reservoir, which is anticipated to be dominated by coniferous species. However, if the amount, type and size of available LWM from the stockpiled sources along New Bullards Bar Reservoir are insufficient to meet the needs of the Pilot Program, then the LWMMP will consider augmentation of LWM from New Bullards Bar Reservoir with LWM from orchard trees, if a suitable source and quantity can be identified.

2.1.1 LWM Selection Criteria

LWM is highly variable in size, texture, plant species, and degree of decomposition (SAFCA 1999). Not all the woody material entering New Bullards Bar Reservoir is expected to be suitable for meeting the goal of this LWMMP. In general, some LWM that enters reservoirs may not be removed from a reservoir such as wood that is habitat for snag and log dependent species and provide greater ecological benefit by remaining in place rather than being removed and stockpiled (Puget Sound Energy 2011). For example, large trees along a reservoir shoreline riparian zone that fall into the reservoir are not necessarily removed if their rootwad rests more than a couple of feet above the full pool surface elevation and prevents the wood from floating away. For the LWMMP, LWM selected for removal from the stockpiles located along the shoreline of New Bullards Bar Reservoir will be based on the size and type criteria identified below.

Size

A review of available literature indicates that LWM size criteria is highly variable, although two general size criteria methods were identified: (1) specific length and diameter dimensions of LWM irrespective of channel width; and (2) length and diameter criteria that are scaled to the width of the channel under consideration (PG&E 2008). Several studies that specify a minimum length and diameter define LWM as being wood with a diameter of at least 10 centimeters (cm) along 2 meters (m) of their length, or rootwads less than 2 m long with a minimum bole diameter of 20 cm, and may include whole trees with rootwad and limbs attached, pieces of trees with or without rootwads and limbs, and cut logs (Saldi-Caromile et al. 2004). USFWS (2010) identified large wood (conifers or hardwoods) as greater than or equal to 16 inches (in) in diameter and greater than or equal to 15 feet (ft) in length. Fox (2004, as cited in CRH 2007) specifies a mid-point diameter of 10 cm or greater, a length of 2 m or greater, and protruding into the bankfull channel is required for designation as LWM (CRH 2007). Additionally, a log with a rootwad is considered a “key piece” because it is likely to be stable during bankfull flows and influences many of the physical and ecological characteristics (CRH 2007). Similarly, the 1998 CDFG Stream Habitat Restoration Manual (Flosi et al. 1998) identifies a single piece of large wood greater than 12 inches in diameter and 6 ft long as LWM, and small woody material as any amount of small wood that is less than 12 in diameter. Other studies are less specific and focus on LWM that ranges between 10-20 cm in diameter, 1-3 m in length, or both (e.g., Robison and Beschta 1990; Bilby and Ward 1991; Fausch and Northcote 1992; Crispin et al. 1993; Beechie and Sibley 1997, as cited in SAFCA 1999).

Other management plans suggest that the length of LWM selected for placement must be shorter than the bankfull width of the river, due to transport considerations and the potential for log jams to occur downstream following mobilizing flood events (Flanagan 2004 and Wohl 2000, as cited in Energy Northwest 2005). However, this LWM size criterion may not be relevant to the lower Yuba River in consideration that the river generally is much wider (e.g., 300-600 ft) than the rivers addressed in these other plans. LWM is defined in the USFS Region 5 Stream Condition Inventory (SCI) protocol as all pieces of wood lying within the bankfull width of the channel that measures one half bankfull width or longer (SMUD undated). Cramer et al. (2002) suggests size of trees and rootwads have a minimum trunk diameter 0.5 × bankfull discharge depth, and minimum tree length 0.25 × bankfull discharge width. Again, however, these types of criteria and considerations are generally most relevant to smaller streams.

Size criteria in this LWMMP are more inclusive to provide a greater range of options for future monitoring, and to facilitate comparison with other existing data sets on LWM load in streams. Therefore, based on a review of the literature, this LWMMP defines LWM as pieces of wood that are minimally 12 inches in diameter, and 6 ft long. The maximum length of LWM pieces will correspond to that length with is capable of being transported by truck.

Type

In addition to size of the LWM, the type influences stability of the LWM and is defined as the species, geometry, and presence versus absence of rootwad (Saldi-Caromile et al. 2004). Decay rates are climate dependent, due to the requirements of the fungi responsible for aerobic decomposition of wood. Differences in the durability between coniferous and hardwood species can be quite dramatic when not fully submerged. Several studies conducted in the northern hemisphere recommend coniferous species be used for all key pieces of wood that are critical to structure stability and function and may not be continuously submerged. Lacking tannins that slow decay, deciduous wood decays much more rapidly and may lose structural integrity within a decade, depending on its size and the degree of wetting and drying that occurs (Saldi-Caromile et al. 2004).

Widely spreading or multiple-stemmed hardwoods are more prone to forming snags than the more cylindrical conifers which are more readily transported and accumulate as racked members, and may beneficially enhance recruitment of other woody material (CRH 2007). Complex woody material structures that feature numerous branches and high stem density locally decrease flow velocity, inducing sediment deposition. Accordingly, materials should be selected that have numerous branches, being careful not to break or remove branches during wood placement (Corps 2007).

Hilderbrand et al. (1997) suggest using trees with branches or rootwads left intact because they are less likely to move when flow is high (SAFCA 1997). Root tissue is more resistant to decomposition and provides increased stability than trunks and stems (SAFCA 1999). The

Sacramento River Bank Protection Project (SAFCA et al. 2011) states that selected trees for LWM placement should have a structurally complex canopy and/or root mass containing many branches and roots of various sizes. Trees that provide optimal LWM have many fine- and medium-sized branches or roots. A dense network of smaller roots and branches provides optimal cover for target fish species. Emphasis should be placed on selecting those trees with the greatest volume, density, and complexity of branches or roots. For example, SAFCA et al. (2011) state that trees to be imported to the Sacramento River Bank Protection Project sites should have a minimum trunk diameter of 10 in diameter at breast height (DBH) and a minimum total length of 25 ft (including trunk, canopy, and/or root wad) (DBH is a standard measurement of trunk diameter as measured 4 ft above the ground). Therefore, for the LWMMP, pieces with rootwads will be preferentially selected from the materials stockpiled along the shoreline of New Bullards Bar Reservoir.

Quantity

Several different methods of identifying the appropriate loading levels of LWM have been used in various localities, including proportion of adjacent riparian, volume per stream channel area, emulation of natural loading, and pieces per length. Classifying and inventorying LWM within a stream is a key step in a LWM management plan. A LWM assessment provides a baseline on the amount and type of LWM and the locations along a stream. The assessment also helps to quantify the impact of LWM on the designated uses of the stream. Following a LWM assessment, management options should be evaluated. Any management action needs to fit within what is expected of the stream through its designated uses and what is feasible based on a stream's characteristics. Other key factors that determine management options include cost and the experience of the responsible parties designing and/or implementing management activities (CRH 2007).

As a part of the Corps' compliance with term and condition D.2. of the BiOp and as part of a conservation measure identified in the BA, the Corps will: (1) develop a plan or policy for management of LWM, consistent with recreation safety needs; (2) conduct a pilot program to identify suitable locations and evaluate the efficacy of placing large in-stream woody material to modify local flow dynamics to increase cover and diversity of instream habitat for the primary purpose of benefitting juvenile salmonid rearing, anticipated to occur no later than one year of NMFS issuance of a new biological opinion for this project; and (3) based upon the outcomes of the pilot program, develop and implement a long-term large woody material management plan for the lower Yuba River, anticipated to occur within one year following completion of the pilot program.

Under Agreement No. W912HZ-11-2-0004, the Corps is a federal agency partner in the University of California's Office of Research Cooperative Ecosystem Studies Unit (CESU). Through the CESU, the Corps coordinated with Dr. Greg Pasternack at UC Davis in the spring of 2011 regarding the potential development of a multi-disciplinary research study that would investigate ecologic, hydrologic, and geomorphologic considerations associated with large woody material adaptive management actions. In September 2011, a one-year study was approved. A contract will be awarded and the study implemented in spring 2012. It is anticipated that the results of this study will provide the following information: (1) a streamwood budget for the Yuba River watershed above Englebright Dam; (2) a detailed accounting of large woody material distribution and abundance; and (3) potential design concepts for instream hydraulic structure placement in the Englebright Dam Reach of the lower Yuba River. The technical information provided by this research would be used to facilitate the development and implementation of a large woody material adaptive management plan for the lower Yuba River, including identifying the appropriate quantities of LWM to be placed in the lower Yuba River.

2.2 New Bullards Bar Reservoir Access Site

The Corps will coordinate with YCWA regarding access to, and availability of LWM at accessible shoreline sites around New Bullards Bar Reservoir prior to LWM collection activities. In their determination of suitable access locations related to the collection of LWM, the Corps and YCWA will consider equipment size, available space, as well as minimizing impacts to recreational facilities. Recreational facilities located along New Bullards Bar Reservoir include Emerald Cove Marina, Hornswoggle Group Camp, Schoolhouse Family Camp, Dark Day Campground, Dark Day Boat Ramp, Garden Point Campground, Madrone Cove Campground, and Cottage Creek Boat Ramp.

2.3 LWM Transportation Methods

LWM collected from the surface of New Bullards Bar Reservoir and placed in stockpiles along the shoreline that meets the suitable criteria stated above (see Section 2.1.1) will be transported downstream to placement sites identified below in Section 2.4. The equipment needed to move the LWM can include self-loading log trucks, excavators, end dumps, skidders and dump trucks (Saldi-Caromile et al. 2004). The LWM will be transported to downstream areas along the lower Yuba River via truck.

The Corps will identify a Licensed Timber Operator, who is licensed under the Forest Practice Act law and is authorized to conduct forest tree cutting and removal operations, for the loading, transporting and unloading of LWM collected from New Bullards Bar Reservoir.

2.4 LWM Placement

Placement of LWM in the lower Yuba River is anticipated to temporarily improve habitat for juvenile salmonids and other non-listed fish species in the lower Yuba River directly at the placement site, in addition to areas downstream as transport of LWM occurs during high flow conditions. The following factors will be considered in identifying potentially suitable LWM placement sites: (1) within the boundaries of the lower Yuba River frequently occurring inundation zone (approximately 880 to 5,000 cfs); (2) located at the downstream end of a meander bend, the head of a side channel, the apex of a bar, in backwatered reaches, pools, or relatively low energy sites, consistent with LWM stability guidelines presented in Saldi-Caromile et al. (2004); (3) consistent with potential habitat rehabilitation sites identified in the *Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* by USFWS (2010) and *Potential Juvenile Rearing Habitat Expansion Actions in the Lower Yuba River, Appendix L to the Final Habitat Expansion Plan* by PG&E (2010); (4) provide access for heavy equipment; and (5) sites under federal land management or where the Corps can obtain necessary real estate rights. The Corps will conduct a real estate assessment for each of the potential sites as part of the Pilot Program (see Section 4.0).

Additionally, it is preferable to place appropriate LWM at bank locations where juvenile salmonids are most likely to occur so that they will benefit most from the LWM. The LWM placement sites identified in this LWMMP are approximate locations for improving juvenile salmonid rearing habitat on the lower Yuba River. Implementation ultimately relies on the experience and judgment of the equipment operators or supervisor to select the specific location and orientation of each individual log and the methods for placing LWM.

Factors influencing the structural stability of LWM clusters include magnitude, duration, and frequency of flooding, as well as natural geomorphic processes in the channel. Hydrologic assessment methods are useful in identifying the most appropriate bank position for placement of LWM (SAFCA 1999). According to Pasternack (2009), the lower Yuba River experiences floods capable of inducing geomorphic changes to the mainstem, which potentially would influence downstream transport of placed LWM complexes. Additionally, a review of 2D-hydrologic modeling developed by the Yuba Accord River Management Team (RMT) indicates that the frequently occurring inundation zone is defined by the inundated channel between the low flow (e.g., 880 cfs) and nearly annual high flow (e.g., 5,000 cfs) boundaries.

LWM stability guidelines presented in Saldi-Caromile et al. (2004) suggest that optimal placement locations for LWM include the downstream end of a meander bend, the head of a side channel, at the apex of a bar, in backwatered reaches, pools, or relatively low energy sites. The upper portions of the bars or inlets where LWM placement sites are identified would remain undisturbed in order to preserve natural hydrologic and geomorphic structure. LWM will be placed and allowed to potentially move under high flow conditions. In some locations, large wood would promote the geomorphic processes of scour and deposition, further enhancing a heterogeneous mosaic of aquatic habitat types. This LWMMP identifies suitable LWM placement sites, consistent with optimal placement locations identified by Saldi-Caromile et al. (2004) and within the boundaries of the lower Yuba River frequently occurring inundation zone (e.g., the floodplain between 880-5,000 cfs).

Two studies were primarily referenced in the identification of approximate LWM placement sites in this LWMMP, including *Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* by USFWS (2010) and *Potential Juvenile Rearing Habitat Expansion Actions in the Lower Yuba River, Appendix L to the Final Habitat Expansion Plan* by PG&E (2010). USFWS (2010) reports that the approximate 4-mile reach of the lower Yuba River downstream of the

Highway 20 Bridge, often referred to as the Parks Bar to Hammon Bar reach, is relatively dynamic because of the availability of sediment and the potential for the alignment of this sediment to be altered during large magnitude floods in the reach. Further, USFWS (2010) states that the entire reach between Parks Bar and Hammon Bar could be suitable for placing large wood along the margins of the active main channel, side channels and backwaters. The Parks Bar to Hammon Bar reach (**Figure 3**) is considered a focal reach for restoration because of its proximity to the primary spring-run Chinook salmon and steelhead spawning reaches, favorable rearing temperatures, and the limited current extent of off-channel habitat (PG&E 2010). Pending the results of the five factors considered in identifying potentially suitable LWM placement sites, additional sites upstream of the Highway 20 Bridge also may be considered.

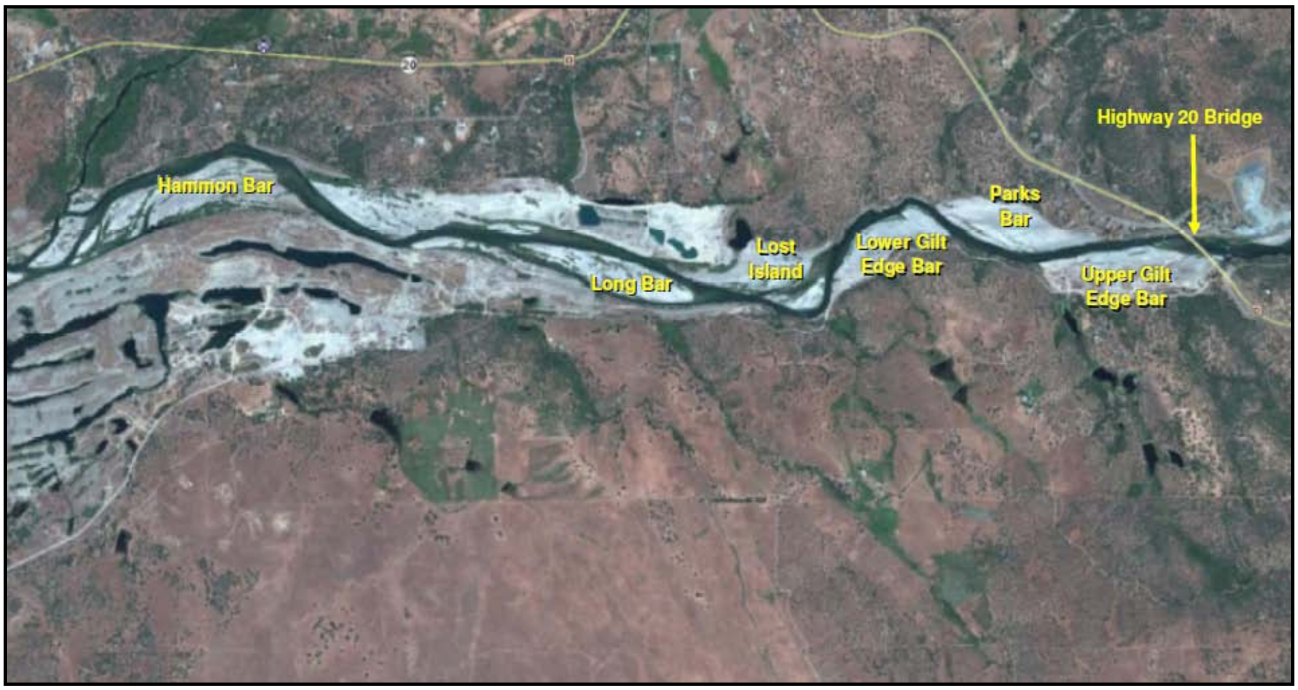

Figure 3. Proposed LWM placement areas within the Parks Bar to Hammon Bar reach of the lower Yuba River (Modified from PG&E 2010).

At the upstream portion of the Parks Bar to Hammon Bar reach, the river is laterally confined by bedrock canyon walls; however, in the downstream portion of the reach, the river is laterally confined to approximately the same width by the remnant sediment (i.e., training walls) of historic gold dredging activities (USFWS 2010). The functional valley width in the reach ranges between approximately 310 ft to 1,420 ft, with a mean width of approximately 980 ft and a mean gradient of 0.19% (G. Pasternack unpublished data). LWM placement guidelines presented in Saldi-Caromile et al. (2004) indicates that constructed log jams work well in alluvial channels having less than a 2% slope and may not be appropriate in alluvial channels with high sediment loads that can cause frequent channel avulsions and lateral migrations that can abandon log jams shortly after construction. In consideration of these criteria, the Parks Bar to Hammon Bar reach is identified in this LWMMP as suitable for placing LWM to improve the availability of juvenile salmonid rearing habitat.

Potential habitat enhancement actions proposed in PG&E (2010) include large wood placement. The general design concept for the rearing habitat enhancement actions proposed by PG&E (2010) were informed by aerial photography and extensive field surveys of off-channel habitats reportedly conducted beginning in 2007. PG&E (2010) reports that many of the surveyed floodplain habitats support fry for variable periods of time following winter flows, but do not provide suitable rearing habitat after flows recede because they become too shallow, too warm, or lack sufficient cover to protect fry from piscivorous birds and other predators. Locations identified by PG&E (2010) as suitable for juvenile salmonid rearing habitat expansion projects include Upper Gilt Edge Bar, Lower Gilt Edge Bar, Lost Island, and Hammon Bar (Figure 3). These habitat expansion projects generally consisted of provision of currently unavailable side-channel and/or backwater habitat areas, and not LWM placement *per se*. However, these locations may be appropriate as LWM placement sites in consideration of the selection criteria, particularly heavy equipment access and proximity to salmonid spawning and rearing areas.

Although USFWS (2010) stated that the entire stream margin along this 4-mile reach of the lower Yuba River is potentially suitable for LWM placement, specific locations have been identified for LWM placement, corresponding to sites identified in *Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River (*USFWS 2010) and *Potential Juvenile Rearing Habitat Expansion Actions in the Lower Yuba River, Appendix L to the Final Habitat Expansion Plan* (PG&E 2010). Within the 4-mile reach of the lower Yuba River that has been identified for LWM placement, vehicular access to the river is limited, and the transport of LWM would require the Corps to use roads that traverse privately owned lands. Therefore, site selection, LWM stockpiling and placement within the frequently inundated floodplain will be dependent on whether or not the Corps is able to obtain permission from private landowners for an easement or right-of-way access.

<u>Lower Gilt Edge Bar</u>

Potential LWM placement sites are located along the southern edge of Lower Gilt Edge Bar, which is a stable point bar that starts near the low water elevation at the top of the bar and extends well above the low water elevation at the downstream end of the bar (USFWS 2010). Based on assessment of aerial photography, this location has been stable in recent years, and may be a suitable candidate for LWM placement, as long as there are no real estate constraints with this location.

<u>Hidden Island (also referred to as Lost Island)</u>

Hidden Island, which is also referred to as Lost Island, is located on the northern side of the lower Yuba River downstream of Lower Gilt Edge Bar, where a high flow side channel is present

(USFWS 2010). Inspection of historic aerial photography indicates that the side channel used to remain inundated and longitudinally connected at lower river discharges and has presumably become disconnected at lower discharges (USFWS 2010). Field observation indicates that at present the high flow side channel becomes longitudinally connected at mainstem flows >3,300 cfs (USFWS 2010). LWM would be placed along the banks and within the side channel, predominantly in the most upstream and downstream region where the side channel joins the lower Yuba River and backwater habitat may occur at lower flows. USFWS (2010) hypothesize that the historic side channel has converted into a high flow channel due to incision of the mainstem and/or deposition on the bar. It is uncertain how long this side channel will be maintained at this location, if the main channel is indeed incising in this area or a future flood deposits on the bar. In addition, access and cooperation the north bank land owner is unknown and will need to be pursued.

Hammon Bar

LWM placement could occur within and along the existing backwater on the southern edge of Hammon Bar. Along the upper portion and some edges of the existing backwater, woody riparian vegetation is well established. LWM would be placed throughout the length of Hammon Bar, along existing backwater and riparian vegetation, as well as along vegetation planted during recent riparian restoration activities. Additionally, the western end of Hammon Bar is characterized by a series of remnant channels that intersect the bar and lead to a large side channel sustained by groundwater flows from the river and the Yuba Goldfields. This side channel supports high densities of juvenile Chinook salmon, steelhead, and other native fishes during spring and summer. LWM placement could occur in the large side channel to provide additional cover. It should be noted that potential placement of LWM on Hammon Bar would need to avoid disruption of the recently implemented riparian vegetation enhancement pilot project being undertaken by USFWS.

2.4.1 Placement Configuration

Large wood in interaction with channel margins has been shown to create a variety of microhabitats and affect geomorphic processes in a way that supports natural riparian recruitment and diversity (Gerhard and Reich 2000 in USFWS 2010). Juvenile salmonids are known to show preference for habitats with cover and velocity refugia associated with large wood (Roni and Quinn 2001). Large wood has been found to locally improve spawning conditions (Merz 2001; Senter and Pasternack 2010).

LWM is found in many natural configurations. In general, placement of in-channel structures has had mixed results in providing sustained habitat improvement and one factor influencing the persistence or risk of such projects is the dynamics or flood potential of the stream. Placement of LWM should allow for potential transport under high flow conditions. LWM placement also can be configured to provide specific habitat benefit, such as provision of low velocity refuges during high flow conditions (**Figure 4**).

Figure 4. Example of large wood placed on the floodplain will provide low velocity refuge during high flows (Finney Creek in Skagit County, Washington, as shown in Saldi-Caromile et al. 2004).

Corps (2007) suggests that combinations of woody materials with stone and living plant materials are common. Rootwads may be placed at spaced intervals or in an interlocking fashion so they may be considered either intermittent or continuous types. Intermittent structures provide greater aquatic habitat diversity than continuous protection. The configuration of LWM structures should consider the dominant erosion processes operating on the site (Shields and Aziz 1992 in Corps 2007), as well as key habitat deficiencies such a lack of pools, cover, and woody substrate. Intermittent structures could be built by stacking whole trees and logs in crisscross arrangements that emulate natural formations, creates diverse physical conditions, and traps additional debris. Alternatively, LWM may be placed as single logs and angled upstream. Large accumulations are frequently the result of a key log that is transported or falls into the stream at a low energy point, becomes anchored in that location, and collects additional debris that is transported from upstream (Saldi-Caromile et al. 2004; CRH 2007).

The specific influence of woody debris on velocity and habitat formation is determined by LWD type and orientation within the channel. For example, a log with a root-wad in a stream will create a scour pool on the upstream end of the root-wad and a sediment bar on the downstream end (Saldi-Caromile et al. 2004). In larger streams, LWM creates scour pools, controls floodplain construction and side channel development (Saldi-Caromile et al. 2004; CRH 2007).

The stability of LWM once it enters a stream is determined by the interaction of the forces resisting its transport downstream and the forces driving its transport downstream. Examples of resisting forces would be the LWM's weight and friction on the streambed and channel banks. Driving forces would be the drag from the flowing water on the LWM and the buoyancy of the wood (Saldi-Caromile et al. 2004). Large wood debris is stable when the resistive forces are greater than the driving forces (CRH 2007). Often, the most stable LWM structure in a stream is a log with an attached rootwad (Fox 2001, as cited in CRH 2007). Channel constrictions and bends, or locations where the channel depth is less than the buoyant depth, tend to be the locations where mobilized LWM becomes trapped (Braudrick and Grant 2001, as cited in Energy Northwest 2005).

Moving a log that is perpendicular to the stream channel to a forty-degree angle to the bank, away from the flow will increase the capacity of the channel and maintain the local habitat (Rutherford et al. 2002 in CRH 2007). It is important to determine after changing the orientation of a LWM structure whether or not the structure will require anchoring, which should be done by estimating the net buoyancy force and drag force on the LWM (Shields et.al. 2004 in CRH 2007).

LWM can be anchored to the stream channel or bed by one of four basic techniques (Saldi-Caromile et al. 2004; Washington State Aquatic Habitat Guidelines Program 2003): (1) No anchors - existing and newly recruited wood is mobile and finds stable locations based on stream characteristics; (2) Passive - the weight and shape of the LWM structure provides resistance to downstream transport; (3) Flexible - LWM is tethered in by at least one point into the bank or bed, but allowed to float and rotate during high flows; (4) Rigid - LWM is tethered by two or more connection points to anchors such as standing trees, duckbill or deadman anchors or keyed into a bank and not allowed to move (CRH 2007). Not anchoring any existing or newly recruited LWM, but rather allowing LWM to find stable locations based on the stream characteristics, provides the greatest benefits to stream function (CRH 2007).

For this LWMMP, the LWM will be placed in the functional inundated floodplain, or deposited directly within the low flow channel, as access allows. The low flow channel is defined by the edge of the wetted channel top width which is generally occurs at about a 880 cfs baseflow. The upper extent of the frequently inundated floodplain is defined by 5,000 cfs. Because high flows have been reported to import LWM into the channel and recruit it downstream (Keller and Swanson 1979 in CRH 2007), it is anticipated that for this LWMMP, placement of LWM within the functional inundated floodplain will result in the transport and distribution of LWM to downstream reaches in the lower Yuba River and the creation of new habitat for aquatic species downstream.

2.4.2 Placement Equipment

Sites for stockpiling of LWM along the lower Yuba River need to provide sufficient space for operation of equipment used to transport LWM to and from the site. Equipment used to place individual LWM elements and/or complexes includes an excavator with a hydraulic thumb and/or a track log loader (Saldi-Caromile et al. 2004). A “spyder” excavator (**Figure 5**) is preferred because it is relatively low-impact, requires minimal disruption of the surrounding environment to maneuver, can operate on steep slopes, and can work in water up to 1.7 m depth. However, “spyder” excavators are relatively slow which can be a time/cost issue if they are used to transport materials very far. Dual fuel tanks allow the excavator to work for 4 days between refueling, which is important when working on remote, steep or environmentally sensitive sites. The telescopic extending boom provides long reach which reduces the number of times

Figure 5. “Spyder” excavator (Source: ArcRidge LTD Environmentally Responsible Forest Services 2011).

the machine must move thereby reducing ground disturbance. Panolin biodegradable hydraulic fluid is used to protect the environment in the event of a hose failure (ArcRidge LTD Environmentally Responsible Forest Services 2011). A loader, however, does not have the ability to dig or move rocks if required. Regardless of the specific equipment used, heavy machinery that is operated in the floodplain of the lower Yuba River will use biodegradable hydraulic fluid and will be steam cleaned of residual hydraulic fluid and oil prior to operating.

2.5 Timing and Frequency

Natural LWM recruitment is generally considered to be episodic due to variable frequency and magnitude of storm events which may result in few LWM pieces entering New Bullards Bar Reservoir in some years and large amounts of LWM entering in other years. Therefore, LWM collection and downstream placement activities are anticipated to be variable in the frequency of activity in response to the episodic nature of LWM recruitment. The long-term frequency of LWM collection in New Bullards Bar Reservoir, stockpiling and placement along the lower Yuba River will be informed by the results of the previously described CESU woody material investigations, particularly the large woody material adaptive management plan.

Collection will generally occur during early summer months (e.g., June and July) following the spring snow melt and rain events when LWM is most likely to be mobilized from the North Yuba River Basin, and transported to New Bullards Bar Reservoir. It is further anticipated that stockpiling along the reservoir will continue through the summer, and LWM will be transported to the lower Yuba River during fall. Stockpiling at the enhancement sites in the lower Yuba River will occur when river stage is low to ensure placement of LWM is within the boundaries of the active floodplain. The Corps will conduct the initial collection, transporting, and placement of LWM within one year upon acceptance of this LWMMP, pending funding and fulfillment of all regulatory compliance requirements.

Prior to implementation of the LWMMP Pilot Program (see Section 4.0, below), it is anticipated that the Corps would need to comply with applicable environmental and regulatory requirements such as National Environmental Policy Act (NEPA) and the Clean Water Act (CWA). As part of compliance with the CWA, it is anticipated that the Corps will coordinate with the Regional Water Quality Control Board. As part of the NEPA process, it is also anticipated that the Corps would coordinate with NMFS, as well as USFWS and CDFG regarding potential effects to botanical and terrestrial species that may be present in areas selected for LWM stockpiling and placement along the lower Yuba River.

3.0 Recreation and Public Safety Considerations

Safety issues for recreational use and public safety on New Bullards Bar Reservoir and on the lower Yuba River are important considerations in this LWMMP. Floating debris or LWM located near the water surface of New Bullards Bar Reservoir represents a hazard to other forms of water-based recreation such as water skiing and tubing. While associated with boating, these activities require participants to be outside of the boat. Participants travel at relatively high speeds without anything to protect them should an impact with any object occur. Generally, these activities are conducted away from areas with potential hazards; however, due to the transient nature of floating debris, hazards could be present in areas where they had previously been absent. It is important to note that potential boating hazards, including debris, exist in all waterways. It is impossible to identify or remove all potential boating hazards. However, removal of LWM from New Bullards Bar Reservoir is anticipated to reduce public risk posed by floating material.

Structures that protrude into a river channel, block the channel, or are designed to trap floating materials can be hazardous to recreational users and boaters (Saldi-Caromile et al. 2004). For this LWMMP, LWM will be placed along the shoreline of the frequently inundated channel and not transversing a significant portion of the cross-sectional length of the channel at any location, to minimize impediments to flow or navigation. Some concerns regarding LWM structures stem from the fact that materials used in anchoring often persist long beyond the functional life of the structure. Cables can pose significant public safety concerns as they can form traps for recreational users, and often have sharp ends (Saldi-Caromile et al. 2004). Thus, this threat will be avoided by placing LWM without the use of cables or anchoring structures. Potential safety hazards may be reduced by placing warning signs at public access points and upstream from the LWM placement reach to alert the public.

4.0 LWMMP Pilot Program

Upon acceptance of this LWMMP, the Corps in consultation with NMFS and CDFG will conduct field reconnaissance investigations of road access, site stockpiling and LWM placement locations for the LWMMP Pilot Program. For the Pilot Program, the Corps will use LWM available from the stockpiles located along New Bullards Bar Reservoir, which is anticipated to be dominated by coniferous species. However, the long-term LWMMP will consider augmentation of LWM from New Bullards Bar Reservoir with LWM from orchard trees, if a suitable source and quantity can be identified. According to SAFCA et al. (2011), trees appropriate for use as imported LWM include orchard trees being removed for urban development or agricultural conversion, native and non-native trees designated to be removed at project sites, and other native and non-native trees designated for removal from unrelated projects. Preferred species of trees to use as LWM include almond (*Prunus dulcis*), because of the hardness, flexibility of limbs, durability of branches, and their resistance to decay. If almond trees are not available, other dense hardwood trees such as walnut (*Juglans regia*), pistachio (*Pistacia vera*), orange (*Citrus sp.*), lemon (*Citrus sp.*), olive trees (*Olea europaea*), and durable ornamental species such as redwood, cedar, other resinous trees can be used. Trees such as eucalyptus, pine species and trees of the pome fruit family (e.g., cherry, apricot, pear and apple) should be avoided (SAFCA et al. 2011).

For the LWMPP Pilot Program, wood will be placed in either LWM complexes, defined as being comprised of 10 or more pieces of LWM, or as individual pieces. The specific quantity and arrangement of LWM placement during the LWMPP Pilot Program will be determined through site-specific accessibility, and through Corps consultation with NMFS and CDFG. Preliminary considerations regarding the quantity of LWM included in the LWMMP Pilot Program include log truck capacity, end dump truck capacity, distance from New Bullards Bar Reservoir to sites identified along the lower Yuba River, individual LWM pieces or pieces with rootwads and multiple branches. These considerations indicate that, depending on the nature and availability of the LWM, quantities of LWM for the LWMMP Pilot Program could range from approximately 500 – 1,000 logs (1-2 ft in diameter) and from 1,000 – 3,000 yd^3 of rootwad material.

The Corps will take advantage of studies currently being undertaken by YCWA as part of the FERC Relicensing study plan process and by the Yuba Accord RMT to establish a baseline of LWM presence, location and abundance in the lower Yuba River. Field mapping efforts of LWM in select locations within the lower Yuba River was performed by the RMT, but the extensive amount of material present made the ground surveys unrealistically time consuming. RMT field methods were revised to largely substitute aerial photograph analyses.

Aerial photography and other remote sensing techniques can be used to obtain inventory data and can be valuable tools for making management decisions (USDOI 2001). Aerial photos have proven especially useful in the management of riparian-wetland areas. Aerial photography can also assist in assessing functionality, determining classification, and improving management planning processes. Aerial photos also link data geographically, allowing detailed vegetation maps to be transferred to a Geographic Information System (GIS) for spatial modeling purposes (USDOI 2001). Aerial photo baseline data, when carefully selected prior to a project, allows analysis of a large area of interest, at a minimum cost, in less time per hectare than conventional on-the-ground methods (Keating 1993 in USDOI 2001). Certainly tree canopy, herbaceous cover, and to some extent, age distribution of woody dominant species can also be identified using aerial photos at an adequate scale.

As part of the YCWA FERC Relicensing process and the RMT process, an analysis of historic aerial photographs and maps of the lower Yuba River dating from 1906 through 1998 will be undertaken as a joint project between YCWA and the RMT. This effort is anticipated to be completed prior to summer 2012. In addition, YCWA will conduct field measurement of LWM along study sites in the lower Yuba River during spring/summer of 2012. According to YCWA, LWM occurring within study sites will be counted as follows: all LWM greater than 3 ft in length within the active channel within four diameter classes (4-12 in, 12-24 in, 24-36 in, and greater than 36 in) and four length classes (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 riparian habitat study sites. Key pieces of LWM are defined as pieces either longer than 1/2 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 LWM piece is associated with a jam or not (number of LWM pieces in the jam) recruitment source and mechanism function in the channel

These same key piece characteristics will be recorded for all LWM placed in the lower Yuba River as part of the LWMMP Pilot Program, in addition to photographs taken of all placed LWM. In addition to key pieces, measurements will be taken and data recorded for all LWM greater than 3 ft in length within the active channel within four diameter classes (4-12 in, 12-24 in, 24-36 in, and greater than 36 in) and four length classes (3-25 ft, 25-50 ft, 50-75 ft, and greater than 75 ft).

Because fish habitat creation is usually identified as one of the primary goals of an in-stream project utilizing LWM, project monitoring generally focuses on the physical expressions of this goal (Larson et al. 2001). However, structural habitat may be only one of numerous conditions that are a limiting factor for fish survival, as well as survival of other aquatic species (such as benthic invertebrates) that are critical links in the aquatic food web (Larson et al. 2001). Studies have shown that macroinvertebrate community structure changes and diversity increases when structures are added (Hilderbrand et al. 1997; Gortz 1998).

Effectiveness monitoring of LWM placed in the lower Yuba River is anticipated to be conducted by using: (1) aerial photography to visually detect wood movement into downstream reaches; and (2) field-based reconnaissance/verification using GPS tracking to detect and record wood movement.

The resultant effects of the Corps' LWMMP Pilot Program will be evaluated to assess the effectiveness of LWM placement in the lower Yuba River, including whether LWM placement at the locations selected has resulted in improved habitat conditions for anadromous salmonids. It is anticipated that a performance evaluation will be conducted, which will use the performance criteria described below. Performance evaluation considerations will include the size and quantities of LWM collected from New Bullards Bar Reservoir, and the spatial and temporal distribution of

LWM in the lower Yuba River. Components of the performance evaluation to be conducted include the following.

- Estimate the quantity of LWM collected that met the size, type, and density suitability criteria
- Evaluate the spatial and temporal distribution of LWM in the placement reaches and the downstream reaches of the lower Yuba River
- Estimate the proportion of LWM contributed to the lower Yuba River by introduction, relative to LWM contributed to the lower Yuba River by natural recruitment
- Evaluate the physical, geomorphic characteristics where LWM was deposited (e.g., landform, water velocity, geomorphologic unit)
- Characterize the extent and substrate size of spawning gravel recruitment in areas directly downstream of LWM
- Assess the potential for public safety to be affected given the distribution of LWM in the placement reaches and in the downstream reaches of the lower Yuba River

The effectiveness monitoring is anticipated to be conducted during the first low flow period (i.e., fall) occurring after initial placement of the LWM as part of the LWMMP Pilot Program. Thus: (1) baseline monitoring will be complete by end of September 2012; (2) initial LWM placement under the Pilot Program will occur during September 2012; and (3) Pilot Program monitoring will be conducted during September 2013. During winter 2012/2013, the Corps will prepare an interim report describing the results of the monitoring and analyses conducted as part of the LWMMP Pilot Program performance evaluation. The interim report will include:

- Summary description of the existing LWMMP, and proposed plan modifications (if any)
- Summary of efforts completed in the previous year relating to the plan requirements, including a tally of the LWM collected from the stockpiles along the shoreline of New Bullards Bar Reservoir and transported to the lower Yuba River
- Inventory of the number and size of LWM along the lower Yuba River
- Information regarding: (1) the sizes, types and locations of LWM mobilized during higher flow conditions; and (2) LWM movement patterns in the lower Yuba River, as observed via aerial photography and field reconnaissance efforts
- Description of any problems encountered and associated remedies

The interim report also may identify provisions addressing future LWM needs and the frequency of subsequent LWM reintroductions into the lower Yuba River, as well as recommended considerations for the integration of the LWMMP with other future or ongoing plans (e.g., Riparian Restoration Plan).

The Corps will submit a copy of the interim report to NMFS and CDFG for review, comment and identification of other potential LWMMP recommendations. During the performance evaluation, lower Yuba River site conditions or study findings also may warrant modifications to the approach that will be used in the long-term LWMMP, which will be described in the report.

If necessary, following completion of the performance evaluation and report review by NMFS and CDFG, recommended modifications to the LWMMP would be considered and incorporated into the Long-term Adaptive Monitoring and Evaluation Plan. LWM placement under the long-term LWMMP is anticipated to occur during September 2014.

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APPENDIX C
Protective Conservation Measures Incorporated into the Proposed Action

This Appendix Includes:

- Daguerre Point Dam Fish Passage Sediment/Gravel Management Plan
- Flashboard Management Plan
- Debris Monitoring and Maintenance Plan for Daguerre Point Dam, Lower Yuba River, California

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DAGUERRE POINT DAM FISH PASSAGE SEDIMENT/GRAVEL MANAGEMENT PLAN

Purpose: The purpose of this plan is to describe the methods used to manage the sediment/gravel that accumulates upstream of Daguerre Point Dam. The sediment/gravel could impede upstream fish passage. This plan was developed by the US Army Corps of Engineers (Corps) with cooperation and advice from the National Marine Fisheries Service (NMFS), the California Department of Fish and Game (CDFG) and the US Fish and Wildlife Service (FWS).

Goal: The goal is to maintain an adequate water depth across the face of the dam to allow unimpeded fish passage from the ladders to the main channel upstream from Daguerre Point Dam. An adequate water depth is defined as a "channel" at least 30 feet wide when measured from the face of the dam upstream and 3 feet deep when measured from the crest of the dam to the riverbed. The process to determine the adequacy of the water depth is described in the Criteria section of this plan.

Criteria: In June of each year, water depth measurements will be taken across the face of the dam to determine the depth of the channel. The goal is to keep an area 30 feet wide by 3 feet deep upstream from the face of the dam cleared of sediment/gravel in order to facilitate fish passage. If the flows are too high in June to take the measurements, they will be taken as soon as conditions are safe.

If the water depth measurements show that the channel is still at least 30 feet wide by 3 feet deep, no sediment removal is required for that year.

If the water depth measurements show that sediment/gravel has encroached and the channel has filled in to less than 30 feet wide by 3 feet deep, sediment/gravel removal will be conducted during the first 2 weeks in August (01-15). The channel will be widened to 45 feet and deepened to 5 feet.

High Flow Events: In addition to the annual inspections described above, the Corps shall also inspect the channel as soon as practicable following a "high flow event". A "high flow event" is defined as a storm "that generates Yuba River flow exceeding 20,000 cubic feet per second as measured at the Marysville flow gauge or flow that is sufficient to move sediment loads into the bed of the river." If the "high flow event" inspection reveals significant sediment buildup that risks impairing fish passage, the Corps shall dredge the channel in a manner that minimizes adverse impact risks to the fish. The Corps will reconsider the need for "high flow event" inspections upon issuance by NMFS of a Biological Opinion for the continued operation and maintenance of Daguerre Point Dam and Englebright Dam.

Equipment: A tracked excavator will be used to remove the sediment/gravel. The excavator will be cleaned of all oils and greases, and will be inspected and re-cleaned daily as necessary to insure no contaminants are released into the water. All hydraulic hoses and fittings will be inspected to insure there are no leaks in the hydraulic system.

Management: Sediment/gravel removed shall be managed in one of two ways. The preferred method is to deposit this material downstream from the dam on either bank above the ordinary high water mark to augment downstream spawning gravels. With this method, natural river flows during the spring run-off will naturally recruit the gravel. If conditions do not allow the downstream placement, then the material will be removed and disposed of above the ordinary high water mark.

Monitoring/Coordination: Management of the sediment/gravel at Daguerre Point Dam will be monitored and coordination will be made with NMFS, CDFG and FWS to ensure the methods used are beneficial to the fishery. Any recommended changes to the procedures will be discussed and coordinated with these agencies.

FLASHBOARD MANAGEMENT PLAN

The long-term flashboard operations plan developed by the Corps includes the following.

- Conditions of Placement. Flashboards will be used in periods of low flow to direct water toward the fish ladders to provide optimal flow conditions. Because there is no recorded flow information at this time to set a flow-based trigger, the flashboards will be set in place when the flows recede to a point that only part of the dam has water flowing over it. Flows will be recorded at the time of placement to determine the flow rate trigger for future placement.
- Period of Placement. Flashboards and brackets will be installed as described above, but only after April 15 and will be removed before November 1 of each year. Further, flashboards will be removed within 24 hours, if directed by the Corps, NMFS or CDFW.
- Flashboard Adjustments. Flashboards will be closely monitored in accordance with monitoring and inspection activities (see below) to ensure they have been placed in a manner that leads to actual improvement in fish passage and will be adjusted accordingly based on such monitoring. All adjustments will be coordinated with NMFS and CDFW. Any recommended adjustments will be made within 24 hours of notification unless flow conditions prohibit them. In that case, the adjustments will be made as soon as conditions allow.
- Method of Placement. Flashboards will be installed using metal brackets that are attached to the dam with anchor bolts. The brackets will be fabricated of material that is light enough that it will break away if the flows increase too rapidly before the brackets can be removed.
- Location of Placement. When flashboard placement is required, they will be placed in the center portion of the dam in such a way that the flows are directed toward both fish ladders. This will ensure adequate flows through the fish ladders to promote optimal flow conditions and attraction flows to the fish ladders. The number of boards placed and the exact location will be determined based upon flow conditions and channel position. Adjustments will be made as necessary to provide optimal fish attraction and passage. All adjustments will be coordinated with NMFS and CDFW.
- Flashboard Material. Flashboard material will be 2” x 10” Douglas Fir or equal material. Material will be free of preservatives and other contaminants – no pressure treated material will be used.

- Monitoring and Inspection. Once the flashboards have been placed, fish passage will be closely monitored for the first week after placement to confirm that the flashboard installation improves fish passage. This monitoring will be conducted via the VAKI in coordination with the RMT. Additionally, during the period that flashboards are installed in accordance with this plan, the flashboards will be monitored at least once per week to make sure that the flashboards have not collected debris that might contribute to juvenile fish mortality. The flashboards will be cleared within 24 hours of finding a blockage, or as soon as it is safe to clear them.
- Updates. The Corps will update and adjust this plan as required based upon new information generated through monitoring efforts.

As part of future Cordua Irrigation District license renewal and approval processes after 2016, the Corps will refine the description of specific operations addressing the placement, timing and configuration of the flashboards at Daguerre Point Dam and incorporate changes to the Flashboard Management Plan into the terms and conditions for the Corps license to be re-issued to Cordua Irrigation District (Grothe 2011a), and Cordua Irrigation District will remain responsible for implementing the flashboard operations.

If the Corps does not renew the license to Cordua Irrigation District or another entity when it expires in 2016, then the Corps will assume responsibility for implementing the operations and maintenance activities addressing the placement, timing and configuration of the flashboards at Daguerre Point Dam that are described in the Flashboard Management Plan on a long-term basis.

DEBRIS MONITORING AND MAINTENANCE PLAN FOR DAGUERRE POINT DAM

LOWER YUBA RIVER, CALIFORNIA

US Army Corps of Engineers ®
Sacramento District

Purpose: The purpose of this plan is to describe the methods used for clearing accumulated debris and blockages in the fish ladders at Daguerre Point Dam. This plan was developed by the US Army Corps of Engineers (Corps) with cooperation and advice from the National Marine Fisheries Service (NMFS) and the California Department of Fish and Wildlife (CDFW).

Goal: The goal is to clear any accumulated debris and blockages in the fish ladders at Daguerre Point Dam.

History: In 2003, the Corps installed a log boom at the north ladder exit to divert debris away from the ladder. In September 2011, as a result of an order issued by Judge Karlton in *South River Citizens League, et al. v. National Marine Fisheries Servce et al (SYRCL 1),* Case No. S-06-2845 LKK-JFM (ECF Doc. 402), the Corps installed locking grates over most of the fish ladder bays. To date, these grates have helped to keep debris from collecting in the fish ladders.

Monitoring/Coordination: Through coordination with CDFW and NMFS, the Corps will implement the Debris Monitoring and Maintenance Plan. This plan specifies that CDFW is responsible for inspecting and clearing the portion of the ladders containing the VAKI device, and that the Corps is responsible for all other parts of the ladders.

Inspection Criteria: Inspections will include sub-surface inspections of the ladders. The Corps will conduct weekly inspections of the Daguerre Point Dam fish ladders for surface and subsurface debris. The Corps also will routinely inspect the fish ladder gates to ensure that no third parties close them. Routine inspections shall occur at least weekly, and may be conducted under agreement with CDFW.

This plan also specifies that routine inspection and clearing of debris from the two fish ladders at Daguerre Point Dam may be conducted by CDFW pursuant to agreement with the Corps, or by other parties (e.g., PSMFC) under CDFW direction. Routine inspections and debris clearing will occur weekly, although more frequent inspections and debris clearing activities may be conducted by CDFW, or other parties (e.g., PSMFC) under CDFW direction.

High Flow Events: When river flows are 4,200 cfs or greater, the Corps or other designated parties as described above, will conduct daily manual inspections of the Daguerre Point Dam fish ladders. Upon discovering debris in the ladders, the debris will be removed within twelve hours, even if the Corps or CDFW determines that flow levels are adequate for fish passage.

If conditions do not allow for safe immediate removal of the debris, the debris will be removed within twelve hours after flows have returned to safe levels.

APPENDIX B

July 3, 2012 Letter
from the U.S. Army Corps of Engineers,
Sacramento District,
to the National Marine Fisheries Service
Regarding the February 29, 2012 Biological Opinion

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DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, SACRAMENTO
CORPS OF ENGINEERS
1325 J STREET
SACRAMENTO CA 95814-2922

REPLY TO
ATTENTION OF

Operations and Readiness Branch

JUL 03 2012

Mr. Rod McInnis
Regional Administrator
National Marine Fisheries Service
501 West Ocean Boulevard, Suite 4200
Long Beach, CA 90802-4213

Dear Mr. McInnis:

The U.S. Army Corps of Engineers, Sacramento District (Corps) has received the National Marine Fisheries Service's Biological Opinion (Opinion) related to the effects of the Corps' long-term operation and maintenance of Englebright and Daguerre Point Dams and Englebright Reservoir on the Yuba River on threatened Central Valley spring-run Chinook salmon (*Oncorhynchus tshawytscha*), threatened California Central Valley steelhead (*O. mykiss*), threatened Southern distinct population segment of north American green sturgeon (*Acipenser medirositris*), and their designated critical habitat. I appreciate the time you and your staff have devoted to preparing the Opinion and your willingness to maintain a continuing dialogue regarding the content and conclusions in the Opinion, including meeting with my staff and me on March 14, May 29 and June 22, 2012.

As you are aware, based on the discussions we have had since NMFS issued the Opinion, the Corps has very serious concerns about various aspects of the Opinion such as the description of the action and action area, the scientific basis for the analysis and conclusions, and the scope and breadth of the Reasonable and Prudent Alternative (RPA), the reasonable and prudent measures (RPMs) associated with the Incidental Take Statement, and NMFS' approach to baseline effects among other things. Our concerns are described in more detail in three documents enclosed with this letter – Attachment 1, *U.S. Army Corps of Engineers, Sacramento District Itemized Comments on the NMFS' February 2012 Final Jeopardy Biological Opinion on the Lower Yuba River*, Attachment 2, *Comments on NMFS February 29, 2012 Biological Opinion* prepared by HDR Engineering, Inc and Attachment 3, *Comments on NMFS Biological Opinion of Continued Operation and Maintenance of Englebright Dam and Reservoir, Daguerre Point Dam, and Recreational Facilities On and Around Englebright Reservoir* prepared by Dr. Gregory B. Pasternack, Ph.D., M.ASCE. Notwithstanding these serious concerns, the Sacramento District conditionally accepts the RPA. Nonetheless, we will we continue to review the RPA actions to determine which actions are within the scope of the Corps' existing authority and appropriations and which actions require additional authority or appropriations. We will also assess whether there may be opportunities for the Corps to participate in other federal or non-federal entities' processes to achieve the goals of the RPA.

The Corps is proceeding immediately to implement RPA measure NTFP 5 which involves maintaining the current fish passage facilities at Daguerre in accordance with the terms of Judge Karlton's July 25, 2011 order. We are also in the process of preparing two Environmental Assessments – one for the proposed injection of 5,000 tons of gravel into the Englebright Dam Reach in summer 2012 (RPA Measure GAP 1) and one for the placement of instream woody material during fall 2012.

The Corps shall work collaboratively with NMFS and other stakeholders in the Yuba River watershed to improve conditions for anadromous fish in the Yuba River. We look forward to having an open and continuing dialogue with NMFS as we further refine our approach to the RPA and RPMs. As we continue our discussions with NMFS and various stakeholders, we reserve the right to provide a supplement to these comments if necessary. If you have any questions regarding the Corps' approach to the RPA or RPMs, please contact Mr. Randy Olsen at (916)557-5275 or Mr. Doug Grothe at (530) 432-6427.

A copy of this letter is being furnished to Ms. Maria Rea, National Marine Fisheries Service, Mr. Curt Aikens, Yuba County Water Agency, and Mr. David Moller, Director, Power Generation, Pacific Gas and Electric Company.

Sincerely,

for William J. Leady, P.E.
Colonel, U.S. Army
District Commander

Enclosures

ATTACHMENT 1

U.S. Army Corps of Engineers, Sacramento District Itemized Comments on the NMFS' February 2012 Final Jeopardy Biological Opinion on the Lower Yuba River

I. INTRODUCTION

The formal section 7 consultation process between the U.S. Army Corps of Engineers, Sacramento District (Corps) and the National Marine Fisheries Service (NMFS) on the Englebright and Daguerre Point Dams has a long history dating back to March 2000, when the Corps first initiated formal consultation on its operation and maintenance activities at the Dams. Since then, NMFS has issued four Biological Opinions (BO) related to these projects, with the most recent opinion in February 2012 reaching a conclusion of "jeopardy". The long consultation history on these projects will not be repeated here as it is summarized in the NMFS BO. The Corps appreciates the time and effort that NMFS' staff has devoted to the various consultations on these projects. However, because the information and analysis in the BO on the Corps' action will likely be used in future opinions on other federal actions, the Corps thinks it is important that the technical and factual deficiencies with the February 2012 jeopardy BO be corrected.

The purpose of this document is to provide a discussion and analysis of the major concerns the Corps has with the February 29, 2012 jeopardy BO and Reasonable and Prudent Alternative (RPA) on the operation and maintenance of Englebright and Daguerre Point Dams on the Yuba River. (NMFS No. 2012/00238). This document, in addition to Attachments 2 and 3, discusses why the Corps believes the analysis in the BO is flawed and the RPA is inappropriate and inconsistent with the requirements of 50 CFR § 402.02. It also discusses concerns with the Incidental Take Statement and Conservation recommendations.

II. BACKGROUND

On October 14, 2011, the Corps submitted a comprehensive draft Biological Assessment (BA) to NMFS requesting formal consultation on the operation and maintenance of both Englebright and Daguerre Point Dams. The final BA was submitted in January 2012. The BA evaluated the effects of the operation and maintenance activities on 3 species listed as "threatened" under the Endangered Species Act (*16 U.S.C. 1531, et seq.*) (ESA) and their designated critical habitat. The BA determined that the proposed operation and maintenance activities "*may affect, and are likely to adversely affect*" Central Valley spring-run Chinook salmon and Central Valley steelhead, but concluded that these adverse effects would not appreciably reduce the likelihood of both the survival and recovery either species. The BA also concluded that operation and maintenance would not result in the destruction or adverse modification of spring-run Chinook salmon or Central Valley steelhead critical habitat. As for the Southern Distinct Population Segment (DPS) of North American green sturgeon, the BA determined that the Corps' actions "*may affect, but are not likely to adversely affect*" that species and its critical habitat. The conclusions in the Corps' BA are based on the best currently available science regarding the species and their habitat and the Yuba River. Chapter 3 of the Corps' BA provides a detailed description of the ongoing operation and maintenance activities at Englebright and Daguerre Point Dams. For purposes of this document, only a brief summary of the project authorizations and ongoing activities is provided.

Englebright Dam and Reservoir are located downstream of New Bullards Bar Dam on the Yuba River. Authorized by the Rivers and Harbors Act of August 30, 1935 (P. L. 409, 74th Congress, 1st Session, 49 Stat. p. 1028-1049), for the purpose of debris storage and power development, Englebright Dam was constructed by the California Debris Commission in 1941. Englebright Dam is 260 feet high, and the storage capacity of Englebright Reservoir was 69,700 acre-feet (AF) at the time of construction. When the California Debris Commission was decommissioned in 1986, administration of Englebright Dam passed to the Corps pursuant to Section 1106 of the 1986 Water Resources Development Act (P. L. 99-662, 99th Congress, 2nd Session, November 7, 1986).

Because Englebright Dam was constructed as a sediment retention facility, it does not contain a low-level outlet. Unregulated flood flows spill over Englebright Dam. Following construction of Englebright Dam in 1941 and extending until approximately 1970, controlled flow releases from Englebright Dam were made through the Pacific Gas & Electric (PG&E) Narrows I Project facilities. Since about 1970 to the present, controlled flow releases from Englebright Reservoir into the lower Yuba River have been made from the PG&E Narrows I and the Yuba County Water Agency (YCWA) Narrows II power plants.

The purpose for the Corps' ongoing maintenance of Englebright Dam pertains to dam infrastructure safety and security. The Corps does not have authority or discretion to control Narrows I, Narrows II or Englebright Reservoir operations; the Corps activities are restricted to coordination and cooperation with PG&E and YCWA. The water stored in Englebright Reservoir provides opportunities for recreation and hydroelectric power. YCWA and PG&E administer water releases for hydroelectric power, irrigation, and other beneficial uses (e.g., instream flow requirements) and is regulated and permitted for these activities by the Federal Energy Regulatory Commission (FERC).

Additionally, the Corps operates and maintains recreation-related facilities on and around Englebright Reservoir, as identified and described in the 2007 Harry L. Englebright Lake Operational Management Plan. Along the 24 miles of Englebright Reservoir's shoreline, the developed facilities include: (1) 96 campsites; (2) 9 picnic sites; (3) 1 group picnic shelter with 4 tables; (4) 2 boat launching ramps (Narrows and Joe Miller Ravine) maintained by the Corps; (5) a private marina operated by a concessionaire; and (6) 5 parking lots containing a total of 163 parking spaces.