REDD MONITORING AND MAPPING
IN THE
ENGLEBRIGHT DAM REACH OF THE LOWER YUBA RIVER, CA

SUMMARY REPORT

Prepared for: The U. S. Army Corps of Engineers

By

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1. INTRODUCTION

The lower Yuba River in Yuba County, California extends about 38.6 km (24 mi) from Englebright Dam, the first impassible fish barrier on the river, downstream to the confluence with the Feather River near Marysville, California. The lower Yuba River is host to a number of native fishes, including Federally- and State-protected species like spring-run Chinook salmon and Central Valley steelhead. In 2007, the National Marine Fisheries Service issued a Biological Opinion that required the United States Army Corps of Engineers (USACE) to develop a long-term gravel augmentation program downstream of Englebright Dam to restore quality spawning habitat to the area. A pilot gravel injection of 500 tons was subsequently placed below the Narrows 2 powerhouse in November 2007, and larger gravel injection efforts were undertaken during November 2010 through January 2011, and July through August of 2012 and 2013 as part of the long-term stream rehabilitation approach. Gravel substrates have been injected downstream of Englebright Dam for the purpose of rehabilitation and restoration of spawning habitat. The implementation of a long-term augmentation program is intended to improve the overall ecological functionality of the river channel by providing gravel and cobble suitable for anadromous salmonid adult spawning, embryo incubation, and survival.

The purpose of this summary report is to detail the temporal and spatial use of spawning substrates downstream of Englebright Dam by Chinook salmon and steelhead, and to provide supplemental data for a more robust rehabilitation and monitoring effort currently being completed by Dr. Greg Pasternack at the University of California, Davis.

1.1. Objectives

- Evaluate the spatial and temporal distribution of Chinook salmon redds in the Englebright Dam study area.
- Estimate the number of Chinook salmon redds located in the Englebright Dam study area.
- Estimate the level of redd superimposition for Chinook salmon in the Englebright Dam study area.
- Examine attributes for each individual redd encountered during the surveys; including the physical redd measurements, substrate and habitat characterizations.

2. FIELD METHODS

2.1. General Survey Methods

Approximately 1.6 kilometers (1 mile) of the lower Yuba River was surveyed to assess the temporal and spatial distribution of Chinook salmon and steelhead spawning. Surveys were conducted by two divers wearing drysuits, mask/snorkel and fins. Divers searched and identified Chinook salmon spawning (redds) on the lower Yuba River from the Narrows 2 Powerhouse to approximately 0.4 kilometers (0.25 miles) downstream of the confluence with Deer Creek. Divers entered the river from the upstream end of the survey area near the powerhouse and systematically searched for evidence of Chinook salmon spawning. Each surveyor scanned the river bed from the shore to the middle of the river, working downstream. When redds were located, positional data and abiotic measurements were recorded for each observation. Surveyors were able to mark redds in water depths < 1.2 meters (4 feet).

2.2. Survey Location

The survey area was located at the uppermost reach of the lower Yuba River from the Narrows 2 Powerhouse to approximately 0.4 kilometers (0.25 miles) downstream of the confluence of Deer Creek **(Figure 1).**

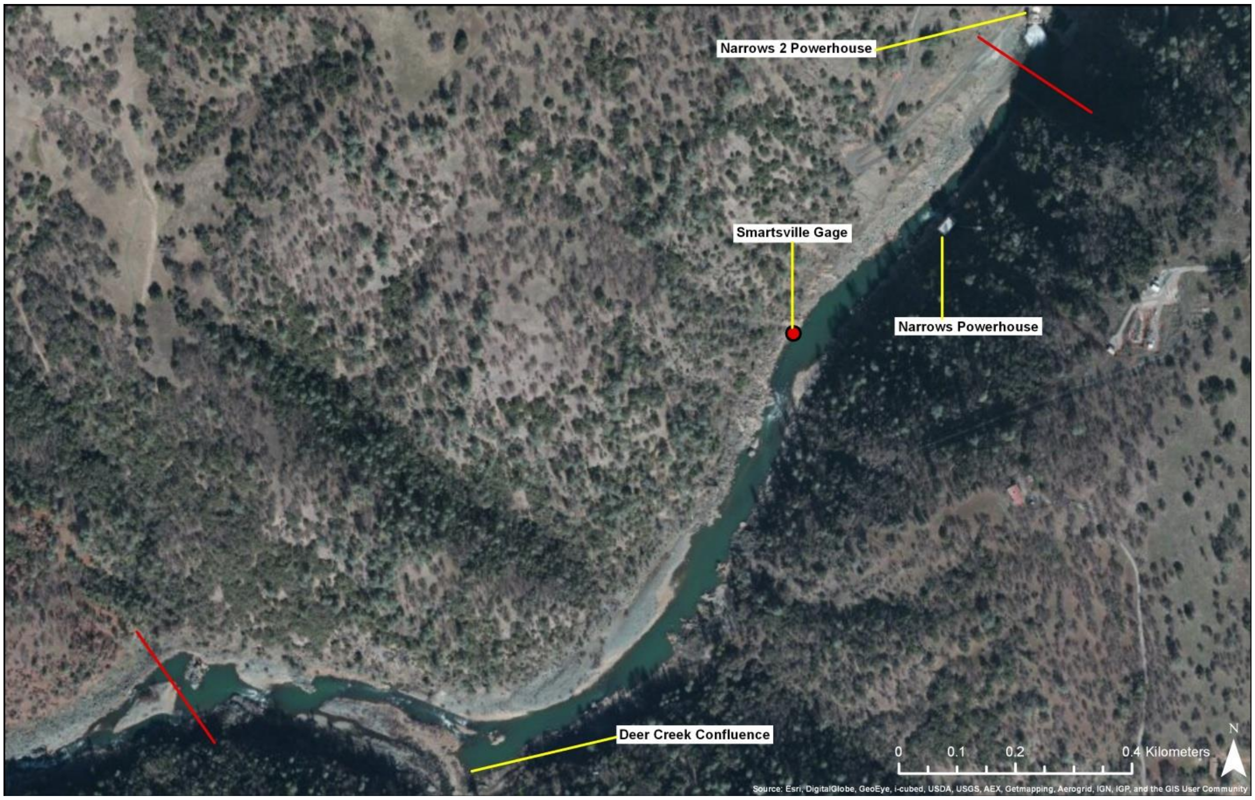

Figure 1. Aerial image of the Englebright Dam study area (marked by red boundary lines) in the lower Yuba River, CA.

2.3. Survey Period

The survey period began on September 18, 2013 and ended April 1, 2014.

2.4. Sampling Frequency

Surveys were conducted weekly as conditions allowed.

2.5. Sample Size

For estimates of total abundance and temporal distribution of salmonid redds, the sample size for was the number of weekly surveys conducted for the entire survey period.

2.6. Redd Location

The following abiotic data were recorded during each survey: 1) survey date; 2) surveyors' initials; 3) survey section; 4) number of crews; 5) specific crew identification (Crew A or B); 6) weather; 7) stream flow; and 8) Secchi disk depth. Flow data were obtained from the Yuba River Smartsville gage through the California Department of Water Resources' (CDWR) online California Data Exchange Center (CDEC).

Each redd was consecutively numbered through the sampling season. For each redd observed, the following data were recorded: 1) a positional data point taken at the center of the redd's pot with a unique identifying number (i.e., Date + plus redd number; e.g. 20130918-001); 2) the time of observation; 3) redd species identification; 4) number of fish observed on the redd; 5) comments regarding observable redd superimposition (i.e., redd overlap); and 6) any additional comments.

A handheld global positioning system (GPS) manufactured by Trimble Navigation Limited® (GeoExplorerXT®/GeoExplorerXH®) and a data dictionary were used to record positional and abiotic data for each redd observation. In addition, surveyors marked each redd with a fluorescent-colored bed marker to ensure that redds observed during previous surveys were not double-counted.

2.7. Redd Area Measurements

The physical dimensions of each observed redd were measured using a fiberglass extendable rod demarcated at every 0.1 meters (0.49 feet) according to the procedures identified in **Table 1 and Figures 2 – 3.**

Table 1. Description of redd dimension measurements.

Pot Length (PL)	Total length of the pot parallel to the stream flow, and should be measured in meters (to the nearest cm) from the top to bottom edge. When the pot is irregularly shaped, estimate the total length as accurately as possible.
Pot Width (PW)	Maximum width of the pot perpendicular to the stream flow or pot length in meters (to the nearest cm). When the pot is irregularly shaped, estimate the total length as accurately as possible.
Tail Spill Length (TSL)	Total length of the tail spill parallel to the stream flow (in meters to the nearest cm). Measurements will be taken from the top edge (i.e., downstream edge of the pot) to bottom edge of the tail spill.
Tail Spill Width 1 (TSW1)	Maximum width of the tail spill perpendicular to the stream flow or pot length (in meters to the nearest cm). Measurements will be taken from one edge to the other, about one-third of the distance downstream from the top edge of the tail spill
Tail Spill Width 2 (TSW2)	Maximum width of the tail spill perpendicular to the stream flow or pot length (in meters to the nearest cm). Measurements will be taken from one edge to the other, about two-thirds of the distance downstream from the top edge of the tail spill.

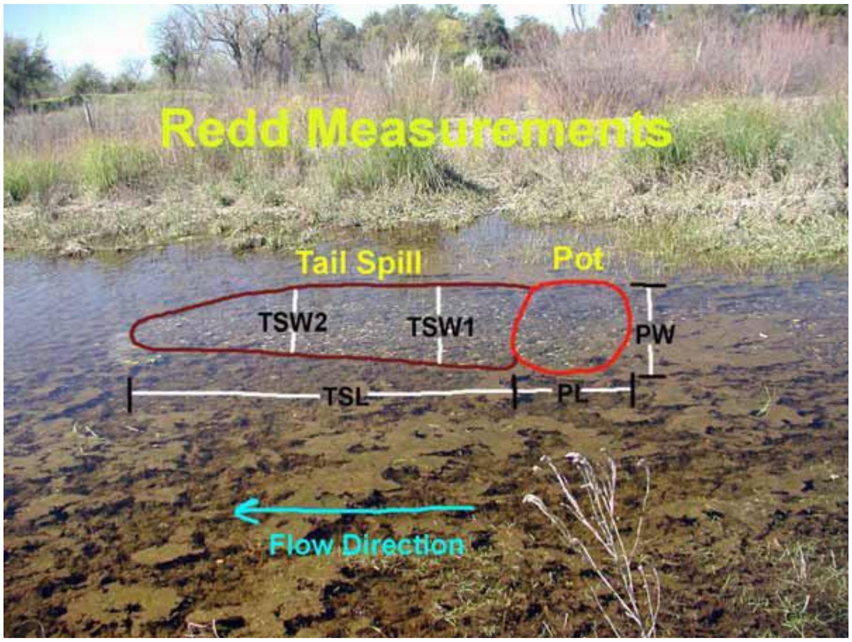

Figure 2. Illustration of redd measurements (PL = pot length; PW = pot width; TSL=tailspill length; TSW2 and TSW1 = tail-spill widths), as presented in Hannon and Deason (2005).

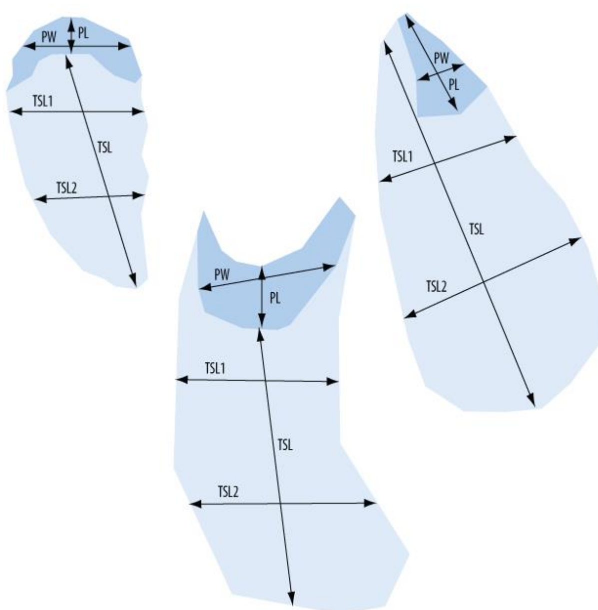

Figure 3. Measurements for unusually shaped redds (PL=pot length, PW=pot width, TSL=tail-spill length, TSL1 and TSL2=tail-spill widths). Illustration reproduced from Gallagher *et al.* (2007).

2.8. Habitat Utilization Characterization

At each fresh redd located, measurements of mean water column velocity, nose velocity[1], total water depth and visual estimates of substrate composition were made to approximate habitat conditions prior to gravel disturbance caused during redd construction. All measurements were taken 0.15 meters (0.49 feet) upstream of the leading edge of the pot along the mid-line of the redd, unless field personnel determined that measurements adjacent to the mid-point of the pot were more representative of undisturbed conditions for that specific location. The specific locations of the measurements were recorded on the data dictionary.

Total water depths were measured to the nearest 0.01 meter (0.03 feet) with a top-setting wading rod. Water velocities were measured with a Hach FH950 Handheld Flow Meter® water velocity meter to the nearest 0.01 meters/second (0.03 feet/second) parallel to the current according to methods described by Trihey and Wegner (1981). Mean water column velocity was measured at 60% of the distance from the surface in depths less than 0.77 meters (2.5 feet). In water between 0.77 meters (2.5 feet) and 1.22 meters (4 feet) deep, water velocities were measured at 20% and 80% of the total water depth, then were averaged to obtain mean column velocity (Buchanan and Somers 1969). Velocities at 20%, 60%, and 80% were measured and averaged in depths greater than 1.22 meters (4 feet), or where the velocity distribution in the water column was inconsistent. In addition to mean water column velocities, “nose velocities” were measured 0.15 meter (0.49 feet) above the undisturbed streambed.

Redd substrate composition was visually estimated as percentage composition (to the nearest 10 percent) of each of eight size categories **(Table 2).** Visual estimation of substrate sizes were taken along the *B* axis of the substrate elements.

Table 2. Substrate classification that links statistical properties of lower Yuba River bed material grain size distributions and physical habitat suitability (unpublished data - Yuba Accord RMT 2010).

Class	Particle Size Range (mm)	Habitat suitability
Bedrock	No alluvium	Periphyton only
Boulder Field*	D>256	Chinook salmon and steelhead trout fry, parr, and smolt cover and foraging
Large Cobble	128<D<256	Chinook salmon and steelhead trout fry and parr cover and foraging
Cobble	90<D< 128	Chinook salmon spawning, embryo incubation, and fry cover
Medium Gravel/Small Cobble	32<D<90	Chinook salmon and steelhead trout spawning, embryo incubation, and fry cover
Fine Gravel	2<D<32	Steelhead trout spawning and embryo incubation
Sand	0.0625<D<2	
Silt/Clay	D<0.0625	Submerged Aquatic Vegetation

[1] The nose velocity was taken at a predetermined distance of 0.15 meters above the undisturbed streambed to represent the velocity present at a fish’s position during redd construction.

3. DATA ANALYSIS METHODS

3.1. Redd Survey Efficacy

The duration and number of days required to implement this redd survey were evaluated, including temporal sampling periods and causal descriptions for missed surveys.

3.2. Abundance

An evaluation and comparison of the temporal redd distribution for Chinook salmon, including the temporal distribution of redd egg pocket overlap for all observed redds was performed. Correlative analyses using simple linear regression of GIS-based spatial outputs for mapped Chinook salmon redds was completed to assess the number of fresh redds observed during the survey period.

An analysis of potential redd superimposition impact was conducted using redd GPS locations, field measurements of redd dimensions, and modeled flow data to create ellipse polygons in ArcMap 10.1®. The modeled polygons represented three areas of the redd structure: the pot, the egg pocket, and the tail spill. The orientation of the pot and tail spill ellipses were determined by the direction of the river's flow at each individual redd location, according to flow vectors calculated at base flow using a SRH-2D flow model developed by Dr. Greg Pasternack and Dr. Josh Wyrick from the University of California Davis. The dimensions of these ellipses were based on measurements recorded for each observed redd during the survey year. The length of the recorded pot was increased by a factor of two and used with the original pot width measurement to construct an ellipse that was representative of the total excavated pot dimensions for each redd observed. The tail spill ellipses were drawn downstream of the recorded redd locations at a length equaling the original pot measurements. The location of the redd egg pocket was then defined as the area of overlap between the pot and tail spill ellipses **(Figure 4)**.

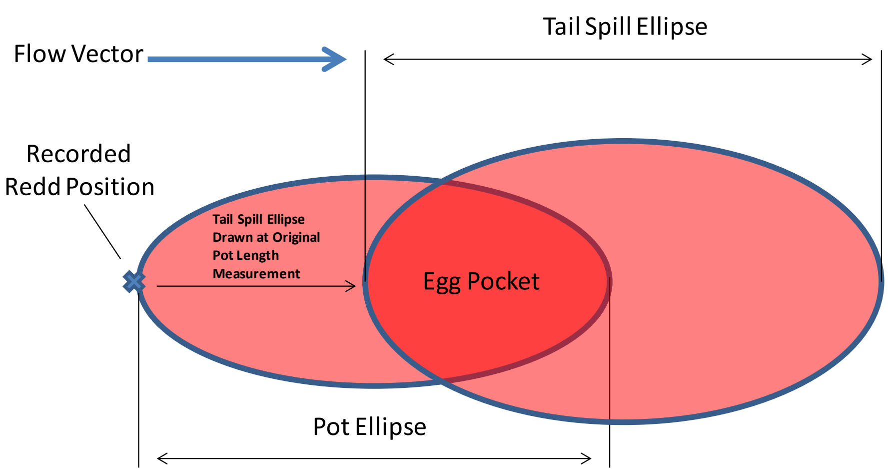

Figure 4. Conceptual view of the pot and tail spill ellipses used to indicate the relative location of the egg pocket.

Weekly and cumulative estimates of potential redd superimposition impact were estimated using GIS-based spatial output. Potential superimposition impact was defined as the overlap of a neighboring redd's pot ellipse over a modeled egg pocket polygon for the cumulative analysis **(Figure 5)** and the overlap of the pot and egg pocket polygons within each survey stratum for the weekly analysis **(Figure 6)**. For the weekly estimates of redd superimposition impact, statistics were calculated based on the amount of overlap and the number of overlapping pot polygons. For the cumulative estimates of redd superimposition impact, metrics were calculated based on the cumulative amount of egg pocket overlap. As an indicator of superimposition impact, an index was developed to better understand the actual potential for egg pocket disturbance relative to the number of Chinook salmon redds observed for each survey year and during each weekly stratum. An index of redd superimposition impact was calculated for each stratum and cumulatively. The index was expressed as the frequency of redds that exhibited overlap multiplied by the average egg pocket overlap. The index of potential superimposition impact was calculated as:

$$I = \frac{R_o}{R_{tot}} \times R_{o_f} \text{ , where}$$

R_o is the total number of redds demonstrating a measurable degree of superimposition,

R_{tot} is the total number of redds observed during the survey season,

And R_{o_f} is the average measure of overlap for redds exhibiting superimposition.

Using this method, we can infer that index values ranging from 0-1 can represent varying degrees of increasing potential for redd superimposition impact, with values approximating zero representing a low potential for redd superimposition impact. A trend analysis using simple linear regression of the weekly and cumulative indices of superimposition impact for Chinook salmon redds during the spawning period was performed.

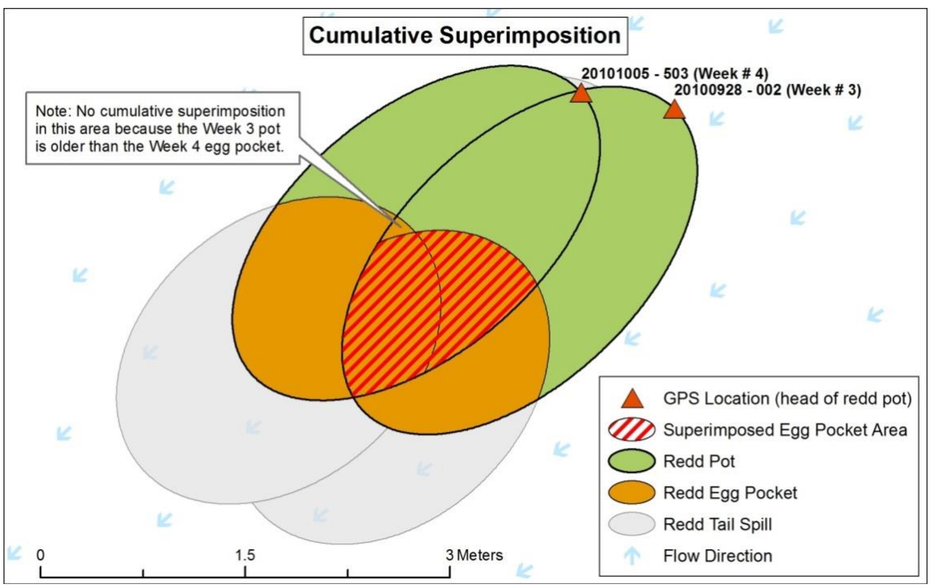

Figure 5. Sample map showing potential superimposition impact from subsequent redd pot construction on existing egg pocket.

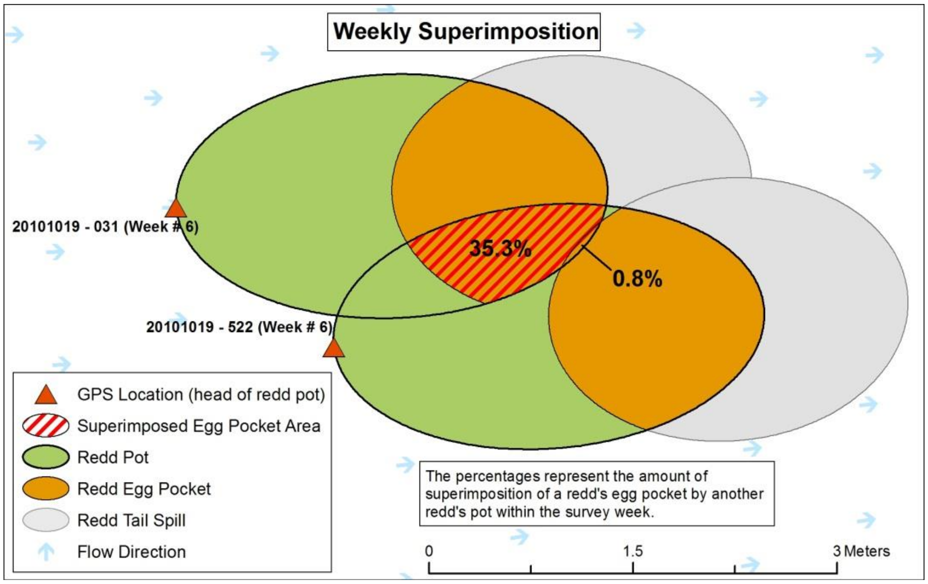

Figure 6. Sample map showing potential superimposition impact from within-stratum pot and egg pocket overlap.

Redd data were used to enumerate Chinook salmon redds in the study area. The temporal distribution of spawning Chinook salmon were identified using the number of redds observed and the number of redds documented for each survey stratum through the survey period.

Dates associated with percentile expressions (1%, 10%, 25%, 50%, 75%, 90% and 99%) of the cumulative temporal distribution of Chinook salmon spawning were identified by fitting an asymmetric logistic function to the cumulative temporal distribution of fresh redds from the redd survey data (Richards 1959):

$$\sum_{i=1}^{D_i=n} Y_i(\%) = 100 \times \left(\frac{1}{1+\exp\left(\alpha+\beta\times D_i\right)} \right)^{\frac{1}{\delta}};$$

where $\sum_{i=1}^{D_i=n} Y_i(\%)$ is the percentage of the cumulative temporal distribution of each run of Chinook salmon from day 1 through time D_i, and α, β and δ are parameters (*i.e.* constants) that describe the shape of the resulting relative cumulative curve. The values of these parameters were obtained through non-linear least squares estimation. Once the asymmetric logistic function curve was fitted to the data, the dates at which a particular percentage (X) of Chinook salmon spawning ($\hat{D}_{X\%}$) was identified using the inverse estimation:

$$\hat{D}_{X\%} = \frac{\log_e\left(\dfrac{100}{X^{\delta}} - 1\right) - \alpha}{\beta};$$

where α, β and δ were the parameter values obtained from the asymmetric logistic function, and *X* was the percentage of interest (e.g., 1%, 10%, 25%, 50%, 75%, 90% and 99%). For example, the resulting estimates of $\hat{D}_{10\%}$, $\hat{D}_{25\%}$, $\hat{D}_{50\%}$, $\hat{D}_{75\%}$ and $\hat{D}_{90\%}$ summarized the characteristics of the corresponding temporal distribution of spawning Chinook salmon.

3.3. Diversity

Redd attribute data were used to examine redd physical size attributes. Redd size was described using standard metrics (*e.g.* maximum, minimum, mean, median and variance of redd measurements).

Redd attribute data were used to examine microhabitat features encountered at redd locations. Redd microhabitat features were described using standard metrics (*e.g.* maximum, minimum, mean, median and variance of measurements).

Redd attribute data were used to examine substrate characterizations. Substrate characterizations were described using standard metrics (*e.g.* maximum, minimum, mean, median and variance of substrate characterizations).

4. RESULTS

4.1. Redd Survey Efficacy

Redd surveys began on September 18, 2013 following preliminary field reconnaissance surveys that observed Chinook salmon adults staging proximal to known spawning areas. Redd surveys continued uninterrupted through the week of February 10, 2014. No surveys were conducted from the week of February 17, 2014 to March 24, 2014 due to high turbidity levels. Surveys resumed briefly during the week of March 31, 2014 and were concluded after surveying on April 1, 2014 due to high turbidity for the remainder of the survey period. Results were tabulated for each weekly stratum including the number of days required to complete the survey, Secchi depth measurements, the minimum, maximum and mean of mean daily flows and water temperatures at the USGS Smartsville gage and the number of Chinook salmon redds observed **(Table 3).**

Table 3. Weekly survey results in the Englebright Dam study area of the lower Yuba River, CA from the week of September 16, 2013 to the week of March 31, 2014.

Week	Survey Days	Secchi Depth (m)	Smartsville Flow (cfs) Min.	Max.	Mean	Smartsville Temp. (°C) Min.	Max.	Mean	Number of Redds Observed Chinook	Steelhead	Unidentified
9/16/2013	1	4.0	751	753	752	12.3	12.6	12.4	9	0	0
9/23/2013	1	4.0	750	797	781	12.1	12.7	12.4	27	0	0
9/30/2013	1	3.5	792	887	821	12.0	12.5	12.2	15	0	0
10/7/2013	1	4.0	926	1,103	1,011	11.8	12.0	11.9	12	0	0
10/14/2013	1	3.5	1,037	1,101	1,068	11.2	11.7	11.4	4	0	0
10/21/2013	1	3.7	1,036	1,054	1,044	11.0	11.2	11.1	12	0	0
10/28/2013	1	3.7	1,037	1,050	1,041	10.6	11.1	10.8	11	0	0
11/4/2013	1	3.5	1,014	1,040	1,031	10.3	10.7	10.4	45	0	0
11/11/2013	1	3.5	1,003	1,041	1,017	10.0	10.2	10.1	19	0	0
11/18/2013	1	3.5	925	1,054	1,005	9.9	10.5	10.1	8	0	0
11/25/2013	1	3.5	863	919	883	9.7	9.9	9.8	16	0	0
12/2/2013	1	3.5	855	875	865	8.9	9.6	9.3	4	0	0
12/9/2013	1	3.5	868	888	879	8.4	8.8	8.6	3	0	0
12/16/2013	1	3.5	745	866	806	8.3	8.4	8.4	0	0	0
12/23/2013	1	3.5	724	738	730	8.3	8.4	8.3	3	0	0
12/30/2013	1	3.5	722	725	724	8.2	8.3	8.2	0	0	0
1/6/2014	1	3.5	724	728	726	8.1	8.4	8.2	1	0	0
1/13/2014	1	3.5	718	722	720	8.2	8.3	8.3	0	0	0
1/20/2014	1	3.0	719	732	723	8.3	8.4	8.3	0	0	0
1/27/2014	1	3.5	714	734	726	8.4	8.7	8.6	0	0	0
2/3/2014	1	3.0	717	3,134	1,065	8.5	8.7	8.6	0	0	1
2/10/2014	1	0.6	699	4,835	1,410	8.7	9.1	9.0	0	0	0
2/17/2014	No Surveys		525	697	620	9.1	9.3	9.2	No Surveys		
2/24/2014			525	532	528	9.0	9.7	9.3			
3/3/2014			589	2,553	1,434	9.3	10.4	10.0			
3/10/2014			521	710	556	10.1	10.4	10.2			
3/17/2014			520	523	522	10.5	10.7	10.6			
3/24/2014			521	617	535	10.7	11.0	10.9			
3/31/2014	1	1.0	525	747	646	10.5	10.8	10.7	0	0	0

4.2. Abundance

A total of 189 Chinook salmon redds were mapped during the survey period. Peak observations of Chinook salmon redds occurred during the week of November 4, 2013 when 45 Chinook salmon redds were observed in the study area. Additionally, during the weeks of September 30 and October 7, 2013 as many as five Chinook salmon redds were observed in the study area that were too deep and unsafe to collect accurate spatial data (boundary of unmarked redds denoted by polygon in **Figures 7 and 8**). One unidentified[2] salmonid redd was observed during the week of February 3, 2014. An aerial image of the study area including spatial raster data for all cumulative redd observations was prepared **(Figure 7). Figure 8** has been prepared to illustrate individual redds mapped in the uppermost spawning locations of the Englebright Dam study area.

[2] Redds observed during this temporal period without attending Chinook salmon or steelhead were marked as unidentified salmonid redds. Chinook salmon and steelhead spawning periodicities overlap from January through April and previous studies on the lower Yuba River indicate that physical redd measurements alone cannot positively differentiate between Chinook salmon and steelhead redds.

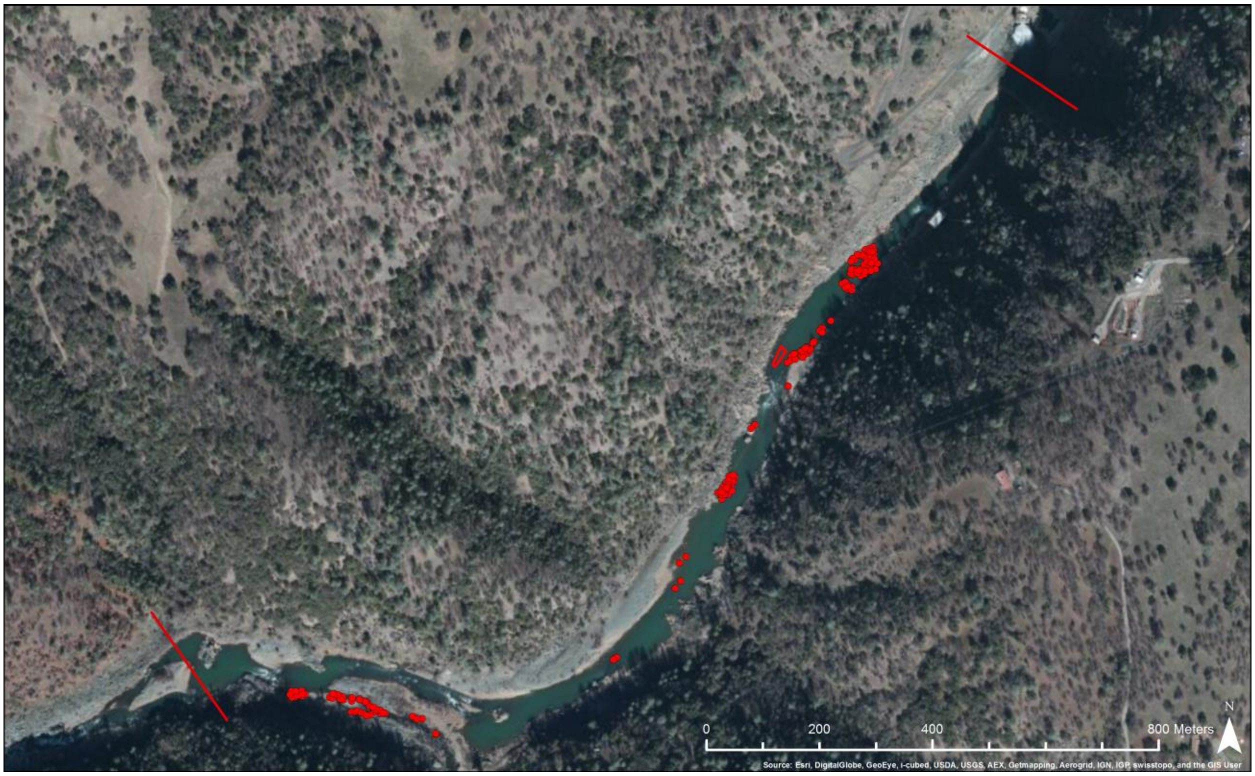

Figure 7. Aerial image of the survey area (red boundary lines) with cumulative redd observations (red markers) from September 18, 2013 to April 1, 2014 in the Englebright Dam study area of the lower Yuba River, CA.

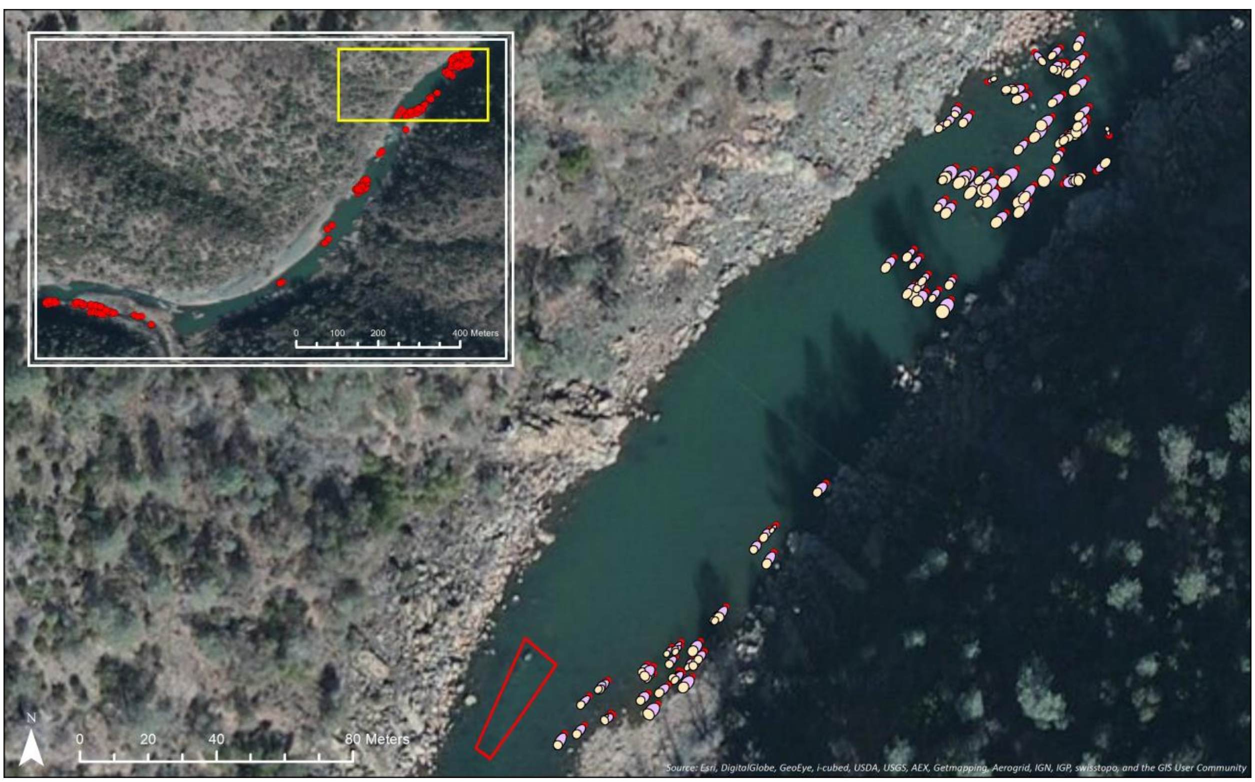

Figure 8. Mapped salmonid redds in the Englebright Dam study area of the lower Yuba River, CA from September 18, 2013 to April 1, 2014.

Correlative analysis *via* simple linear regression was used to analyze potential relatedness between the observed temporal distribution of Chinook salmon redd abundance. Simple linear regression analysis indicated a weak, declining, statistically significant relationship in the temporal distribution of observed Chinook salmon redds. The resulting regression described 39.6% of the observations **(Figure 9).**

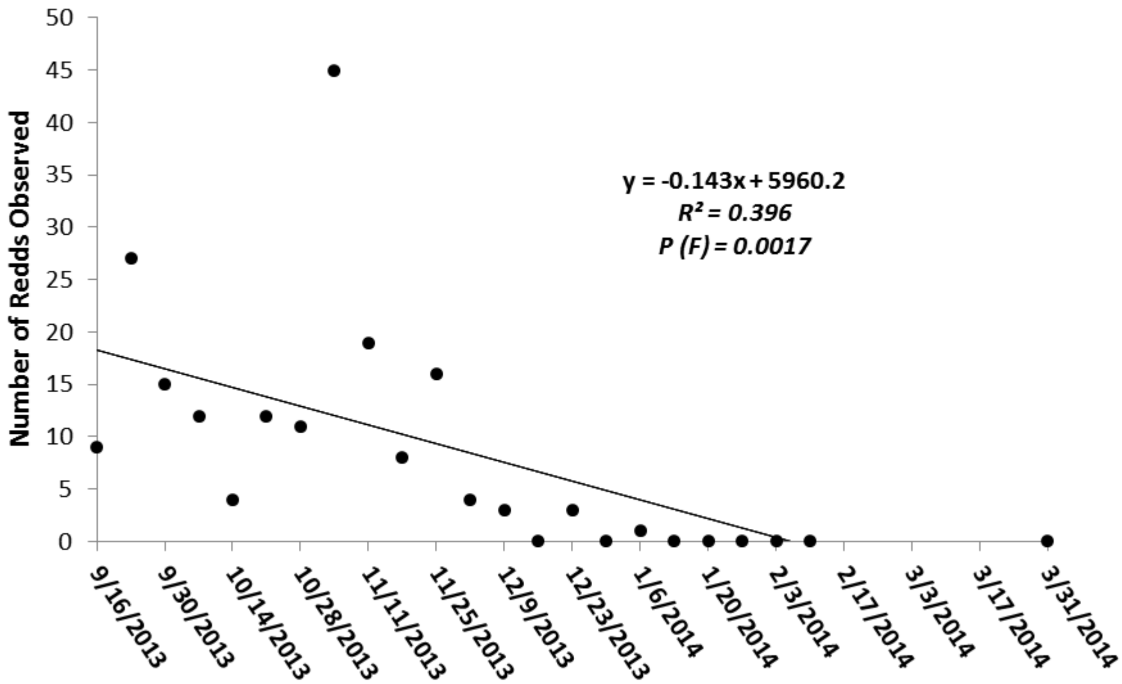

Figure 9. Simple linear regression of the number of observed Chinook salmon redds by survey week in the Englebright Dam study area of the lower Yuba River, CA from September 16, 2013 to March 31, 2014.

Within stratum calculated egg pocket overlap did not occur during the survey period. **(Appendix A, Tables A1 – A8).** The calculated cumulative egg pocket impact indices ranged from 0.05 to 0.13 during the survey period **(Appendix A, Table A9)**. The cumulative mean egg pocket overlap ranged from 47.1% to 54.3% **(Appendix A, Table A10)**. A simple linear regression of the cumulative superimposition impact indices produced a statistically strong relationship between response and explanatory variables moving through the survey period. The resulting regression described 75% of the observations. A third order polynomial function was found to be an even better fit of the data and described nearly 96% of the observations **(Figure 10).**

Cumulative redd egg pocket impact analysis using ArcGIS demonstrated that 46 of 189 redds (24%) exhibited a measureable degree of egg pocket overlap, 24 of those redds were found to have a level of egg pocket overlap greater than 50% **(Appendix A, Tables A1 – A8).**

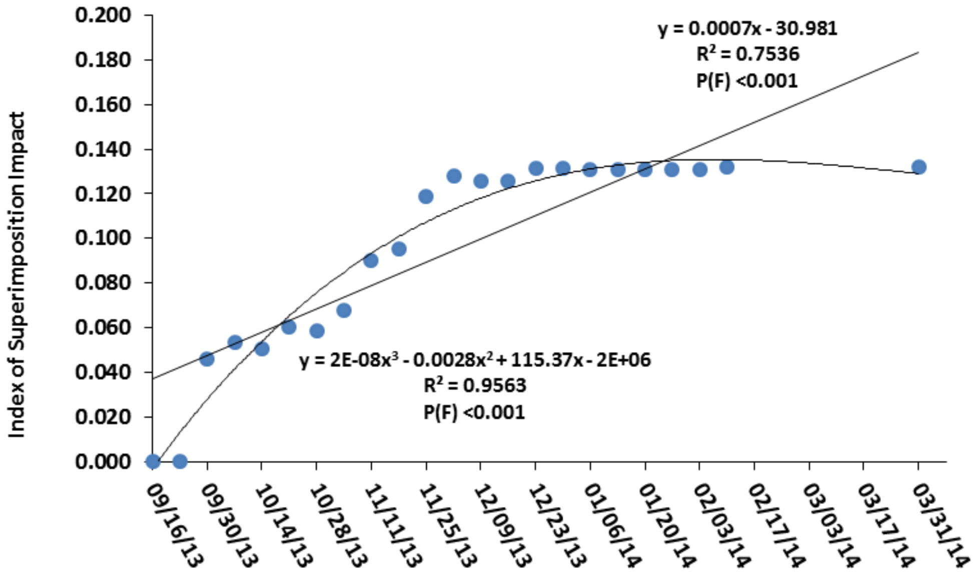

Figure 10. Simple linear regression of the cumulative index of superimposition impact for all redds observed in the Englebright Dam study area of the lower Yuba River, CA from the weeks of September 16, 2013 to March 31, 2014.

A fitted asymmetric logistic function predicted that 50% of the Chinook salmon spawning was observed by the week of October 21, 2013, with 90% of the observations occurring by the week of December 2, 2013 **(Figure 11).**

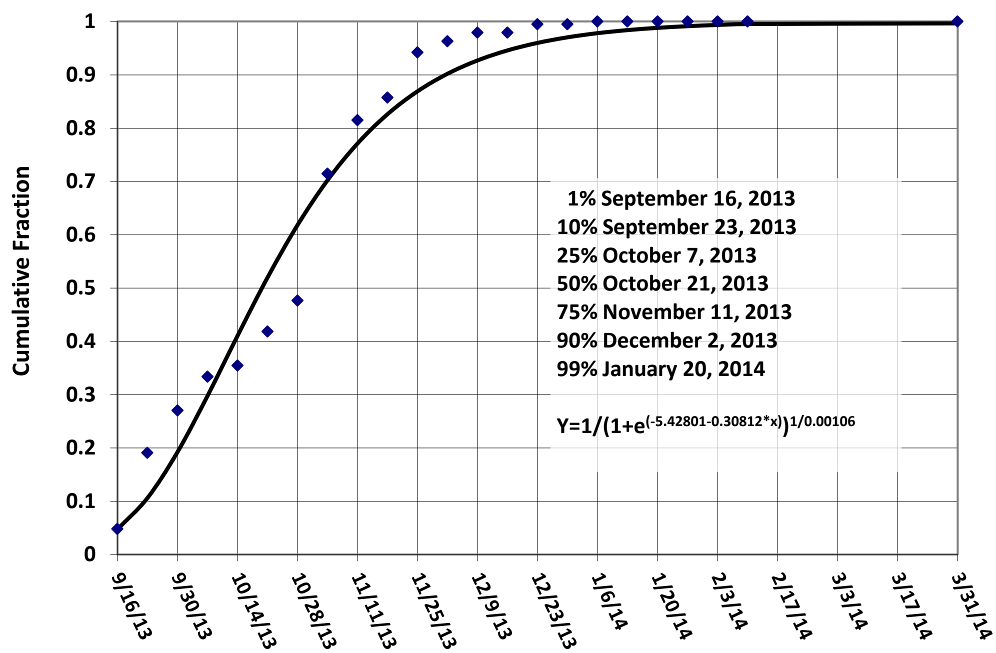

Figure 11. Cumulative weekly temporal distribution of observed Chinook salmon redd abundance in the Englebright Dam study area of the lower Yuba River, CA from September 16, 2013 to March 31, 2014.

The predicted date associated with the percentile expressions for Chinook salmon was plotted against mean flow and water temperature for each corresponding stratum **(Figure 12).** The resulting figure illustrated varied flow and decreasing temperature at the USGS Smartsville gages through the percentile expressions.

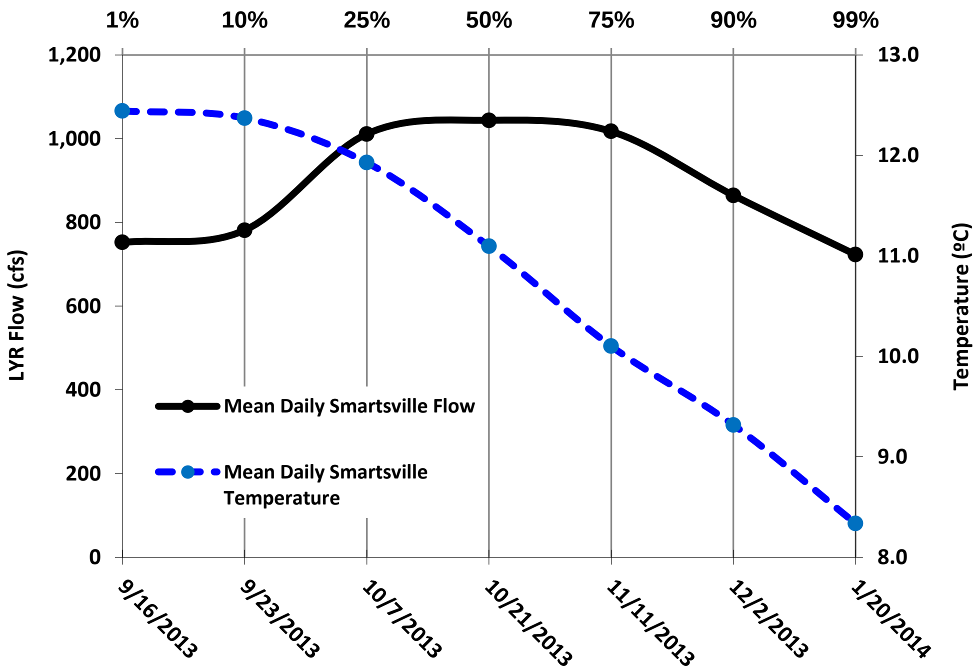

Figure 12. Mean weekly flow and mean weekly temperature (calculated from mean daily values) at the USGS Smartsville gage through the percentile expressions (1%, 10%, 25%, 50%, 75%, 90% and 99%) for Chinook salmon redd abundance in the Englebright Dam study area of the lower Yuba River, CA from September 16, 2013 to March 31, 2014.

4.3. Diversity

Physical size measurements collected at each observed Chinook salmon redd identified that the mean pot length was 1.4 ± 0.06[3] meters (4.6 ± 0.20 feet) and the mean pot width was 1.9 ± 0.07 meters (6.4 ± 0.24 feet). The mean tail spill length was 2.2 ± 0.07 meters (7.2 ± 0.22 feet), the mean tail spill width #1 was 1.9 ± 0.07 meters (6.3 ± 0.21 feet) and the mean tail spill width #2 was 1.6 ± 0.06 meters (5.1 ± 0.19 feet). The mean depth was 0.6 ± 0.05 meters (1.9 ± 0.15 feet), the mean nose velocity was 0.35 ± 0.04 meters/second (1.16 ± 0.14 feet/second) and the mean water column velocity was 0.53 ± 0.06 meters/second (1.75 ± 0.20 feet/second) **(Table 4).**

[3] All confidence intervals calculated at 95%

Table 4. Descriptive statistics for the physical size measurements (m) and microhabitat features of sampled Chinook salmon redds in the Englebright Dam study area of the lower Yuba River, CA from September 18, 2013 to April 1, 2014.

	Pot Length	Pot Width	Tail Spill Length	Tail Spill Width #1	Tail Spill Width #2	Depth (m)	Nose Velocity (m/sec)	Mean Velocity (m/sec)
Sample Size	189	189	189	189	189	189	189	189
MIN	0.6	0.5	1.0	0.7	0.4	0.0	0.00	0.00
MAX	3.0	3.2	3.5	3.1	2.6	1.7	1.41	1.77
MEAN	1.4	1.9	2.2	1.9	1.6	0.6	0.35	0.53
MEDIAN	1.4	1.9	2.2	1.9	1.6	0.6	0.24	0.41
VARIANCE	0.2	0.3	0.2	0.2	0.2	0.1	0.10	0.18
STD DEV	0.4	0.5	0.5	0.5	0.4	0.3	0.31	0.42
95% CONFIDENCE	0.06	0.07	0.07	0.07	0.06	0.05	0.04	0.06

The unidentified salmonid redd physical measurements indicated that the pot length was 1.1 meters (3.6 feet) and the pot width was 1.3 meters (4.3 feet). The tail spill length was 1.6 meters (5.2 feet), the tail spill width #1 was 1.4 meters (4.6 feet) and the tail spill width #2 was 1.0 meters (3.3 feet). The depth was 0.68 meters (2.20 feet), the nose velocity was 0.00 meters/second (0.00 feet/second) and the mean water column velocity was 0.23 meters/second (0.8 feet/second).

Substrate characterizations collected for each Chinook salmon redd identified that cobble and fine cobble comprised the majority of observations. Substrate observations for cobble were represented by 27.02 ± 1.54%, whereas fine cobble represented 27.13 ± 1.35% of the characterizations for Chinook salmon redds **(Table 5).**

Table 5. Descriptive statistics for the substrate characterization percentages of sampled Chinook salmon redds in the Englebright Dam study area of the lower Yuba River, CA from September 18, 2013 to April 1, 2014.

	Bedrock	Boulder >256mm	Lg. Cobble 128-256 mm	Cobble 90-128 mm	Fine Cobble 32-90 mm	Gravel 2-32 mm	Sand 0.0625-2 mm	Silt/Clay <0.0625 mm
Sample Size	189	189	189	189	189	189	189	189
MIN %	No Bedrock Substrate Use Observed	0.0	0.0	0.0	0.0	0.0	0.00	No Silt/Clay Substrate Use Observed
MAX %		60.0	70.0	60.0	50.0	60.0	20.00	
MEAN %		2.87	21.38	27.02	27.13	21.22	0.27	
MEDIAN %		0.0	20.0	30.0	30.0	20.0	0.00	
VARIANCE		117.9	248.3	116.2	89.0	150.9	4.74	
STD DEV		10.9	15.8	10.8	9.4	12.3	2.18	
95% CONFIDENCE		1.55	2.25	1.54	1.35	1.75	0.31	

Substrate characterizations collected for the single unidentified salmonid redd identified that the redd location was comprised of 30% cobble, 40% fine cobble and 30% gravel.

5. DISCUSSION

Cumulative temporal distributions followed a distinct pattern and an asymmetric logistic function fit temporal distributions well. Most importantly, distributional spatial data identified redds located in some areas where previously suitable spawning gravels did not exist prior to USACE gravel injections. Additionally, Chinook salmon redds were observed in freshly augmented gravels less than one month following gravel placement activities by the USACE, indicating that these gravel injections provide immediately available spawning habitat for lower Yuba River salmonids.

The survey period encompassed by this report adequately captures known spawning periods for Chinook salmon and steelhead in the lower Yuba River. However, some temporal overlap of Chinook salmon and steelhead trout spawning periods are known to occur, particularly from January through April. Much difficulty exists when attempting to assign redd observations to species due to the temporal overlap in spawning timing, and due to the overlap in measured physical attributes between Chinook salmon and steelhead redds. Spawning studies by the USFWS (2008) on the lower Yuba River were able to accurately identify only 53% of steelhead redds using physical attribute measurements alone. As a result of this limited application to physical redd dimensional attributes, redds observed from January through April required the presence of identifiable adult spawners to positively assign redds to species (i.e. Chinook salmon or steelhead). Redds occurring during this time period were identified as 'unknown' if adult spawners were not observed actively constructing or guarding a redd during the time of observation.

Indices for superimposition impact potentials were tightly correlated with cumulative survey strata (i.e. modeled egg pocket overlap frequency increased as the spawning period progressed), suggesting a selective preference for aggregate spawning. Yet, relatively low levels of egg pocket overlap were calculated from these most recent survey data. The analytical approach for potential redd superimposition impacts, defined on *pages 10-12* of this report, identified that the cumulative superimposition impact indices ranged from 0.05 to a maximum of 0.13, indicating that the potential for disruption and dislodgement of incubating eggs within individually constructed redds was relatively small. These results suggest that aggregate spawning appears to have a low potential for impact to incubating eggs via encroachment into the egg pocket by adjacent redds. This result was not surprising, given that a small fraction (26%) of the total redds observed during the survey period demonstrated a measureable level of egg pocket overlap for modeled polygons, and that the calculated degree of egg pocket overlap for these modeled redds ranged between 47% and 54%.

A probability exists that these results overrepresented the actual potential for disruption and dislodgement to incubating eggs. Chinook salmon eggs incubating within redds constructed in September and early October 2012 were likely not affected by superimposition observed past December 2012, as the juvenile alevins had likely already emerged from the nest prior to subsequent superimposition. This conservative approach to superimposition analysis utilized all survey strata available, regardless of initial redd construction dates. Additionally, these methods simply employed a two-dimensional (2D) approach in identifying potential impacts to incubating eggs; excluding the depth at which the egg pockets occur relative to adjacent redd construction. Further investigations into the Z-plane (i.e. the depth of excavation by adjacent redd construction relative to egg pocket depth) may demonstrate that the actual potential for disruption or dislodgement of incubating eggs may be less than identified relative to this 2D approach. As provided, the methods and results defined in this 2D approach represent the most inclusive to date relative to redd superimposition, and demonstrate a very low level of impact potential from aggregate spawning for Chinook salmon on the lower Yuba River.

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8. APPENDIX A

Table A1. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA between the weeks of September 16, 2013 and October 7, 2013.

Percentage of Redd Overlap	9/16/2013		9/23/2013		9/30/2013		10/7/2013	
	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative
0-5%	0	0	0	0	0	0	0	0
5-10%	0	0	0	0	0	0	0	0
10-15%	0	0	0	0	0	0	0	0
15-20%	0	0	0	0	0	1	0	2
20-25%	0	0	0	0	0	1	0	1
25-30%	0	0	0	0	0	0	0	0
30-35%	0	0	0	0	0	0	0	0
35-40%	0	0	0	0	0	1	0	1
40-45%	0	0	0	0	0	0	0	0
45-50%	0	0	0	0	0	0	0	0
50-55%	0	0	0	0	0	0	0	0
55-60%	0	0	0	0	0	1	0	0
60-65%	0	0	0	0	0	0	0	1
65-70%	0	0	0	0	0	0	0	0
70-75%	0	0	0	0	0	0	0	0
75-80%	0	0	0	0	0	0	0	0
80-85%	0	0	0	0	0	0	0	1
85-90%	0	0	0	0	0	0	0	0
90-95%	0	0	0	0	0	0	0	0
95-100%	0	0	0	1	0	1	0	1
TOTALS	0	0	0	1	0	5	0	7

Table A2. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA between the weeks of October 14, 2013 and November 4, 2013.

Percentage of Redd Overlap	10/14/2013		10/21/2013		10/28/2013		11/4/2013	
	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative
0-5%	0	0	0	0	0	0	0	0
5-10%	0	0	0	0	0	0	1	1
10-15%	0	0	0	0	0	0	0	1
15-20%	0	2	0	1	0	1	0	1
20-25%	0	1	0	2	0	3	0	3
25-30%	0	0	0	0	0	1	0	1
30-35%	0	0	0	1	0	1	0	4
35-40%	0	1	0	1	0	1	0	0
40-45%	0	0	0	1	0	1	0	2
45-50%	0	1	0	0	0	0	0	0
50-55%	0	0	0	0	0	0	0	0
55-60%	0	0	0	0	0	0	0	0
60-65%	0	1	0	2	0	2	0	2
65-70%	0	0	0	0	0	0	0	0
70-75%	0	0	0	0	0	0	0	0
75-80%	0	0	0	0	0	0	0	0
80-85%	0	0	0	1	0	1	0	1
85-90%	0	0	0	0	0	0	0	1
90-95%	0	0	0	0	0	0	0	2
95-100%	0	1	0	1	0	1	0	1
TOTALS	0	7	0	10	0	12	1	20

Table A3. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA between the weeks of November 11, 2013 and December 2, 2013.

Percentage of Redd Overlap	11/11/2013		11/18/2013		11/25/2013		12/2/2013	
	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative
0-5%	0	0	0	0	0	1	0	1
5-10%	0	1	0	1	0	1	0	1
10-15%	0	0	0	0	0	1	0	1
15-20%	0	2	0	2	0	2	0	2
20-25%	0	4	0	4	0	3	0	3
25-30%	0	1	0	1	0	1	0	1
30-35%	0	5	0	5	0	5	0	5
35-40%	0	0	0	0	0	1	0	1
40-45%	0	2	0	2	0	3	0	3
45-50%	0	0	0	0	0	2	0	2
50-55%	0	0	0	0	0	1	0	2
55-60%	0	2	0	3	0	5	0	5
60-65%	0	2	0	2	0	2	0	2
65-70%	0	0	0	0	0	1	0	2
70-75%	0	0	0	0	0	1	0	1
75-80%	0	0	0	0	0	0	0	0
80-85%	0	1	0	1	0	1	0	1
85-90%	0	1	0	1	0	1	0	2
90-95%	0	2	0	2	0	2	0	2
95-100%	0	4	0	5	0	6	0	6
TOTALS	0	27	0	29	0	40	0	43

Table A4. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA between the weeks of December 9, 2013 and December 30, 2013.

Percentage of Redd Overlap	12/9/2013		12/16/2013		12/23/2013		12/30/2013	
	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative
0-5%	0	1	0	1	0	1	0	1
5-10%	0	1	0	1	0	2	0	2
10-15%	0	1	0	1	0	1	0	1
15-20%	0	2	0	2	0	1	0	1
20-25%	0	3	0	3	0	3	0	3
25-30%	0	1	0	1	0	2	0	2
30-35%	0	5	0	5	0	4	0	4
35-40%	0	1	0	1	0	2	0	2
40-45%	0	3	0	3	0	3	0	3
45-50%	0	2	0	2	0	3	0	3
50-55%	0	2	0	2	0	2	0	2
55-60%	0	5	0	5	0	5	0	5
60-65%	0	2	0	2	0	2	0	2
65-70%	0	2	0	2	0	2	0	2
70-75%	0	1	0	1	0	2	0	2
75-80%	0	0	0	0	0	0	0	0
80-85%	0	1	0	1	0	1	0	1
85-90%	0	2	0	2	0	2	0	2
90-95%	0	2	0	2	0	2	0	2
95-100%	0	6	0	6	0	6	0	6
TOTALS	0	43	0	43	0	46	0	46

Table A5. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA between the weeks of January 6, 2014 and January 27, 2014.

Percentage of Redd Overlap	1/6/2014		1/13/2014		1/20/2014		1/27/2014	
	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative
0-5%	0	1	0	1	0	1	0	1
5-10%	0	2	0	2	0	2	0	2
10-15%	0	1	0	1	0	1	0	1
15-20%	0	1	0	1	0	1	0	1
20-25%	0	3	0	3	0	3	0	3
25-30%	0	2	0	2	0	2	0	2
30-35%	0	4	0	4	0	4	0	4
35-40%	0	2	0	2	0	2	0	2
40-45%	0	3	0	3	0	3	0	3
45-50%	0	3	0	3	0	3	0	3
50-55%	0	2	0	2	0	2	0	2
55-60%	0	5	0	5	0	5	0	5
60-65%	0	2	0	2	0	2	0	2
65-70%	0	2	0	2	0	2	0	2
70-75%	0	2	0	2	0	2	0	2
75-80%	0	0	0	0	0	0	0	0
80-85%	0	1	0	1	0	1	0	1
85-90%	0	2	0	2	0	2	0	2
90-95%	0	2	0	2	0	2	0	2
95-100%	0	6	0	6	0	6	0	6
TOTALS	0	46	0	46	0	46	0	46

Table A6. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA between the weeks of February 3, 2014 and February 24, 2014.

Percentage of Redd Overlap	2/3/2014		2/10/2014		2/17/2014		2/24/2014	
	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative
0-5%	0	1	0	1	No Survey		No Survey	
5-10%	0	2	0	2				
10-15%	0	1	0	0				
15-20%	0	1	0	1				
20-25%	0	3	0	3				
25-30%	0	2	0	2				
30-35%	0	4	0	4				
35-40%	0	2	0	2				
40-45%	0	3	0	4				
45-50%	0	3	0	3				
50-55%	0	2	0	2				
55-60%	0	5	0	5				
60-65%	0	2	0	2				
65-70%	0	2	0	2				
70-75%	0	2	0	2				
75-80%	0	0	0	0				
80-85%	0	1	0	1				
85-90%	0	2	0	2				
90-95%	0	2	0	2				
95-100%	0	6	0	6				
TOTALS	0	46	0	46	0	46	0	46

Table A7. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA between the weeks of March 3, 2014 and March 24, 2014.

Percentage of Redd Overlap	3/3/2014		3/10/2014		3/17/2014		3/24/2014	
	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative	Within Stratum	Cumulative
0-5%	No Survey		No Survey		No Survey		No Survey	
5-10%								
10-15%								
15-20%								
20-25%								
25-30%								
30-35%								
35-40%								
40-45%								
45-50%								
50-55%								
55-60%								
60-65%								
65-70%								
70-75%								
75-80%								
80-85%								
85-90%								
90-95%								
95-100%								
TOTALS	0	46	0	46	0	46	0	46

Table A8. Redd egg pocket overlap magnitude within each stratum including cumulative totals in the Englebright Dam study area of the lower Yuba River, CA for the week of March 31, 2014.

Percentage of Redd Overlap	3/31/2014	
	Within Stratum	Cumulative
0-5%	0	1
5-10%	0	2
10-15%	0	0
15-20%	0	1
20-25%	0	3
25-30%	0	2
30-35%	0	4
35-40%	0	2
40-45%	0	4
45-50%	0	3
50-55%	0	2
55-60%	0	5
60-65%	0	2
65-70%	0	2
70-75%	0	2
75-80%	0	0
80-85%	0	1
85-90%	0	2
90-95%	0	2
95-100%	0	6
TOTALS	0	46

Table A9. Cumulative redd counts, number estimated to be overlapped, average egg pocket ellipse overlap and cumulative index of redd superimposition impact in the Englebright Dam study area of the lower Yuba River, CA from the week of September 16, 2013 to the week of March 31, 2014.

Week	Number of Redds in Analysis	Cumulative Number Superimposed	Average Egg Pocket Ellipse Overlap	Cumulative Index of Superimposition Impact
9/16/2013	9			
9/23/2013	36	1	N/A	N/A
9/30/2013	51	5	0.47	0.046
10/7/2013	63	7	0.48	0.054
10/14/2013	67	7	0.48	0.051
10/21/2013	79	10	0.47	0.060
10/28/2013	90	12	0.44	0.058
11/4/2013	135	20	0.46	0.068
11/11/2013	154	27	0.51	0.090
11/18/2013	162	29	0.53	0.095
11/25/2013	178	40	0.53	0.119
12/2/2013	182	43	0.54	0.128
12/9/2013	185	43	0.54	0.126
12/16/2013	185	43	0.54	0.126
12/23/2013	188	46	0.54	0.131
12/30/2013	188	46	0.54	0.131
1/6/2014	189	46	0.54	0.131
1/13/2014	189	46	0.54	0.131
1/20/2014	189	46	0.54	0.131
1/27/2014	189	46	0.54	0.131
2/3/2014	189	46	0.54	0.131
2/10/2014	189	46	0.54	0.132
2/17/2014	No Survey Conducted			
2/24/2014				
3/3/2014				
3/10/2014				
3/17/2014				
3/24/2014				
3/31/2014	189	46	0.54	0.132

Table A10. Descriptive statistics of the calculated cumulative percent egg pocket overlap for salmonid redds in the Englebright Dam study area of the lower Yuba River, CA from the week of September 16, 2013 to the week of March 31, 2014.

Week	Sample Size	Mean (%)	Median (%)	Minimum (%)	Maximum (%)	Standard Deviation (%)	Confidence (95%)
9/16/2013							
9/23/2013	1	N/A	N/A	N/A	N/A	N/A	N/A
9/30/2013	5	47.08	38.26	18.01	96.97	32.12	16.31
10/7/2013	7	48.37	38.26	18.01	96.97	32.15	16.76
10/14/2013	7	48.37	38.26	18.01	96.97	32.15	16.76
10/21/2013	10	47.50	40.32	18.57	96.97	26.86	18.26
10/28/2013	12	43.80	34.37	18.57	96.97	25.80	17.17
11/4/2013	20	45.81	33.45	6.03	96.97	29.69	16.67
11/11/2013	27	51.38	41.30	6.03	100.00	30.84	18.39
11/18/2013	29	53.26	42.38	6.03	100.00	31.13	18.75
11/25/2013	40	52.96	49.90	0.25	100.00	29.37	19.28
12/2/2013	43	54.08	53.63	0.25	100.00	28.86	20.03
12/9/2013	43	54.11	53.63	0.25	100.00	28.84	20.04
12/16/2013	43	54.11	53.63	0.25	100.00	28.84	20.04
12/23/2013	46	53.70	52.21	0.25	100.00	28.53	19.89
12/30/2013	46	53.70	52.21	0.25	100.00	28.53	19.89
1/6/2014	46	53.70	52.21	0.25	100.00	28.53	19.89
1/13/2014	46	53.70	52.21	0.25	100.00	28.53	19.89
1/20/2014	46	53.70	52.21	0.25	100.00	28.53	19.89
1/27/2014	46	53.70	52.21	0.25	100.00	28.53	19.89
2/3/2014	46	53.70	52.21	0.25	100.00	28.53	19.89
2/10/2014	46	54.27	52.21	0.25	100.00	27.98	20.47
2/17/2014	No Survey Conducted						
2/24/2014							
3/3/2014							
3/10/2014							
3/17/2014							
3/24/2014							
3/31/2014	46	54.27	52.21	0.25	100.00	27.98	20.47