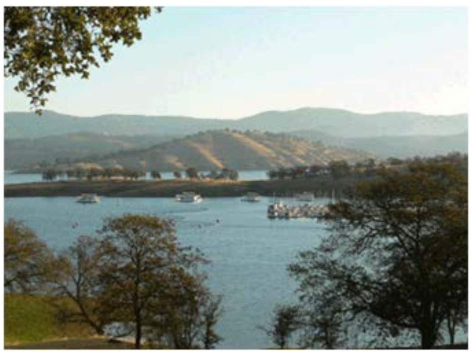
SALMONID REDD MAPPING

STUDY REPORT

DON PEDRO PROJECT

FERC NO. 2299



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Modesto Irrigation District

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

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Salmonid Redd Mapping
Study Report

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List of Acronyms

ac ....acres
ACEC.........................Area of Critical Environmental Concern
AF ....acre-feet
ACOE.........................U.S. Army Corps of Engineers
ADA...........................Americans with Disabilities Act
ALJ.............................Administrative Law Judge
APE............................Area of Potential Effect
ARMR........................Archaeological Resource Management Report
BA..............................Biological Assessment
BDCP.........................Bay-Delta Conservation Plan
BLM...........................U.S. Department of the Interior, Bureau of Land Management
BLM-S ....Bureau of Land Management – Sensitive Species
BMI............................Benthic macroinvertebrates
BMP...........................Best Management Practices
BO..............................Biological Opinion
CalEPPC ....California Exotic Pest Plant Council
CalSPA.......................California Sports Fisherman Association
CAS............................California Academy of Sciences
CCC............................Criterion Continuous Concentrations
CCIC ....Central California Information Center
CCSF..........................City and County of San Francisco
CCVHJV....................California Central Valley Habitat Joint Venture
CD..............................Compact Disc
CDBW........................California Department of Boating and Waterways
CDEC.........................California Data Exchange Center
CDFA.........................California Department of Food and Agriculture
CDFW........................California Department of Fish and Wildlife (formerly known as California Department of Fish and Game)
CDMG........................California Division of Mines and Geology
CDOF.........................California Department of Finance
CDPH.........................California Department of Public Health

CDPR........................California Department of Parks and Recreation
CDSOD......................California Division of Safety of Dams
CDWR........................California Department of Water Resources
CE ....California Endangered Species
CEII............................Critical Energy Infrastructure Information
CEQA.........................California Environmental Quality Act
CESA ....California Endangered Species Act
CFR ....Code of Federal Regulations
cfs...............................cubic feet per second
CGS............................California Geological Survey
CMAP ....California Monitoring and Assessment Program
CMC...........................Criterion Maximum Concentrations
CNDDB......................California Natural Diversity Database
CNPS..........................California Native Plant Society
CORP ....California Outdoor Recreation Plan
CPUE ....Catch Per Unit Effort
CRAM........................California Rapid Assessment Method
CRLF..........................California Red-Legged Frog
CRRF ....California Rivers Restoration Fund
CSAS..........................Central Sierra Audubon Society
CSBP..........................California Stream Bioassessment Procedure
CT ....California Threatened Species
CTR............................California Toxics Rule
CTS ....California Tiger Salamander
CVRWQCB ....Central Valley Regional Water Quality Control Board
CWA ....Clean Water Act
CWHR........................California Wildlife Habitat Relationship
Districts......................Turlock Irrigation District and Modesto Irrigation District
DLA ....Draft License Application
DPRA.........................Don Pedro Recreation Agency
DPS ....Distinct Population Segment
EA ....Environmental Assessment
EC ....Electrical Conductivity

EFH............................Essential Fish Habitat
EIR.............................Environmental Impact Report
EIS..............................Environmental Impact Statement
EPA............................U.S. Environmental Protection Agency
ESA............................Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU............................Evolutionary Significant Unit
EWUA........................Effective Weighted Useable Area
FERC..........................Federal Energy Regulatory Commission
FFS.............................Foothills Fault System
FL...............................Fork length
FMU...........................Fire Management Unit
FOT............................Friends of the Tuolumne
FPC............................Federal Power Commission
ft/mi............................feet per mile
FWCA........................Fish and Wildlife Coordination Act
FYLF..........................Foothill Yellow-Legged Frog
g..................................grams
GIS.............................Geographic Information System
GLO...........................General Land Office
GPS............................Global Positioning System
HCP............................Habitat Conservation Plan
HHWP........................Hetch Hetchy Water and Power
HORB........................Head of Old River Barrier
HPMP.........................Historic Properties Management Plan
ILP.............................Integrated Licensing Process
ISR.............................Initial Study Report
ITA.............................Indian Trust Assets
kV...............................kilovolt
m................................meters
M&I............................Municipal and Industrial
MCL...........................Maximum Contaminant Level
mg/kg.........................milligrams/kilogram

mg/L..........................milligrams per liter
mgd ....million gallons per day
mi ....miles
mi^2.............................square miles
MID...........................Modesto Irrigation District
MOU ....Memorandum of Understanding
MSCS.........................Multi-Species Conservation Strategy
msl.............................mean sea level
MVA ....Megavolt Ampere
MW ....megawatt
MWh ....megawatt hour
mya............................million years ago
NAE ....National Academy of Engineering
NAHC ....Native American Heritage Commission
NAS...........................National Academy of Sciences
NAVD 88..................North American Vertical Datum of 1988
NAWQA ....National Water Quality Assessment
NCCP ....Natural Community Conservation Plan
NEPA ....National Environmental Policy Act
ng/g ....nanograms per gram
NGOs ....Non-Governmental Organizations
NHI ....Natural Heritage Institute
NHPA.........................National Historic Preservation Act
NISC ....National Invasive Species Council
NMFS.........................National Marine Fisheries Service
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent
NPS ............................U.S. Department of the Interior, National Park Service
NRCS ....National Resource Conservation Service
NRHP.........................National Register of Historic Places
NRI............................Nationwide Rivers Inventory
NTU ....Nephelometric Turbidity Unit
NWI...........................National Wetland Inventory

NWIS ....National Water Information System
NWR ....National Wildlife Refuge
NGVD 29 ....National Geodetic Vertical Datum of 1929
O&M ....operation and maintenance
OEHHA ....Office of Environmental Health Hazard Assessment
ORV ....Outstanding Remarkable Value
PAD ....Pre-Application Document
PDO ....Pacific Decadal Oscillation
PEIR ....Program Environmental Impact Report
PGA ....Peak Ground Acceleration
PHG ....Public Health Goal
PM&E ....Protection, Mitigation and Enhancement
PMF ....Probable Maximum Flood
POAOR ....Public Opinions and Attitudes in Outdoor Recreation
ppb ....parts per billion
ppm ....parts per million
PSP ....Proposed Study Plan
QA ....Quality Assurance
QC ....Quality Control
RA ....Recreation Area
RBP ....Rapid Bioassessment Protocol
Reclamation ...............U.S. Department of the Interior, Bureau of Reclamation
RM ....River Mile
RMP ....Resource Management Plan
RP ....Relicensing Participant
RSP ....Revised Study Plan
RST ....Rotary Screw Trap
RWF ....Resource-Specific Work Groups
RWG ....Resource Work Group
RWQCB ....Regional Water Quality Control Board
SC ....State candidate for listing under CESA
SCD ....State candidate for delisting under CESA
SCE ....State candidate for listing as endangered under CESA

SCT ....State candidate for listing as threatened under CESA

SD1 ....Scoping Document 1

SD2 ....Scoping Document 2

SE...............................State Endangered Species under the CESA

SFP.............................State Fully Protected Species under CESA

SFPUC ....San Francisco Public Utilities Commission

SHPO ....State Historic Preservation Office

SJRA ....San Joaquin River Agreement

SJRGA ....San Joaquin River Group Authority

SJTA ....San Joaquin River Tributaries Authority

SPD ....Study Plan Determination

SRA............................State Recreation Area

SRMA ....Special Recreation Management Area or Sierra Resource Management Area (as per use)

SRMP.........................Sierra Resource Management Plan

SRP ....Special Run Pools

SSC ....State species of special concern

ST...............................California Threatened Species under the CESA

STORET ....Storage and Retrieval

SWAMP.....................Surface Water Ambient Monitoring Program

SWE ....Snow-Water Equivalent

SWRCB......................State Water Resources Control Board

TAC............................Technical Advisory Committee

TAF ....thousand acre-feet

TCP ....Traditional Cultural Properties

TDS ....Total Dissolved Solids

TID.............................Turlock Irrigation District

TMDL ....Total Maximum Daily Load

TOC............................Total Organic Carbon

TRT ....Tuolumne River Trust

TRTAC ....Tuolumne River Technical Advisory Committee

UC ....University of California

USDA.........................U.S. Department of Agriculture

USDOC......................U.S. Department of Commerce
USDOI .......................U.S. Department of the Interior
USFS..........................U.S. Department of Agriculture, Forest Service
USFWS ......................U.S. Department of the Interior, Fish and Wildlife Service
USGS .........................U.S. Department of the Interior, Geological Survey
USR............................Updated Study Report
UTM...........................Universal Transverse Mercator
VAMP........................Vernalis Adaptive Management Plan
VELB.........................Valley Elderberry Longhorn Beetle
VRM ....Visual Resource Management
WPT...........................Western Pond Turtle
WSA...........................Wilderness Study Area
WSIP..........................Water System Improvement Program
WWTP ....Wastewater Treatment Plant
WY.............................water year
µS/cm ....microSeimens per centimeter

1.0 INTRODUCTION

1.1 Background

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt (MW) Don Pedro Project (Project) located on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The Don Pedro Dam is located at river mile (RM) 54.8 and the Don Pedro Reservoir has a normal maximum water surface elevation of 830 ft above mean sea level (msl; NGVD 29). At elevation 830 ft, the reservoir stores over 2,000,000 acre-feet (AF) of water and has a surface area slightly less than 13,000 acres (ac). The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2). The Project is designated by the Federal Energy Regulatory Commission (FERC) as project no. 2299.

Both TID and MID are local public agencies authorized under the laws of the State of California to provide water supply for irrigation and municipal and industrial (M&I) uses and to provide retail electric service. The Project serves many purposes including providing water storage for the beneficial use of irrigation of over 200,000 ac of prime Central Valley farmland and for the use of M&I customers in the City of Modesto (population 210,000). Consistent with the requirements of the Raker Act passed by Congress in 1913 and agreements between the Districts and City and County of San Francisco (CCSF), the Project reservoir also includes a "water bank" of up to 570,000 AF of storage. CCSF may use the water bank to more efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. The "water bank" within Don Pedro Reservoir provides significant benefits for CCSF's 2.6 million customers in the San Francisco Bay Area.

The Project also provides storage for flood management purposes in the Tuolumne and San Joaquin rivers in coordination with the U.S. Army Corps of Engineers (ACOE). Other important uses supported by the Project are recreation, protection of aquatic resources in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from RM 53.2, which is one mile below the Don Pedro powerhouse, upstream to RM 80.8 at an elevation corresponding to the 845 ft contour (31 FPC 510 [1964]). The Project Boundary encompasses approximately 18,370 ac with 78 percent of the lands owned jointly by the Districts and the remaining 22 percent (approximately 4,000 ac) owned by the United States and managed as a part of the U.S. Bureau of Land Management (BLM) Sierra Resource Management Area.

The primary Project facilities include the 580-foot-high Don Pedro Dam and Reservoir completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Project and its primary facilities is shown in Figure 1.1-1.

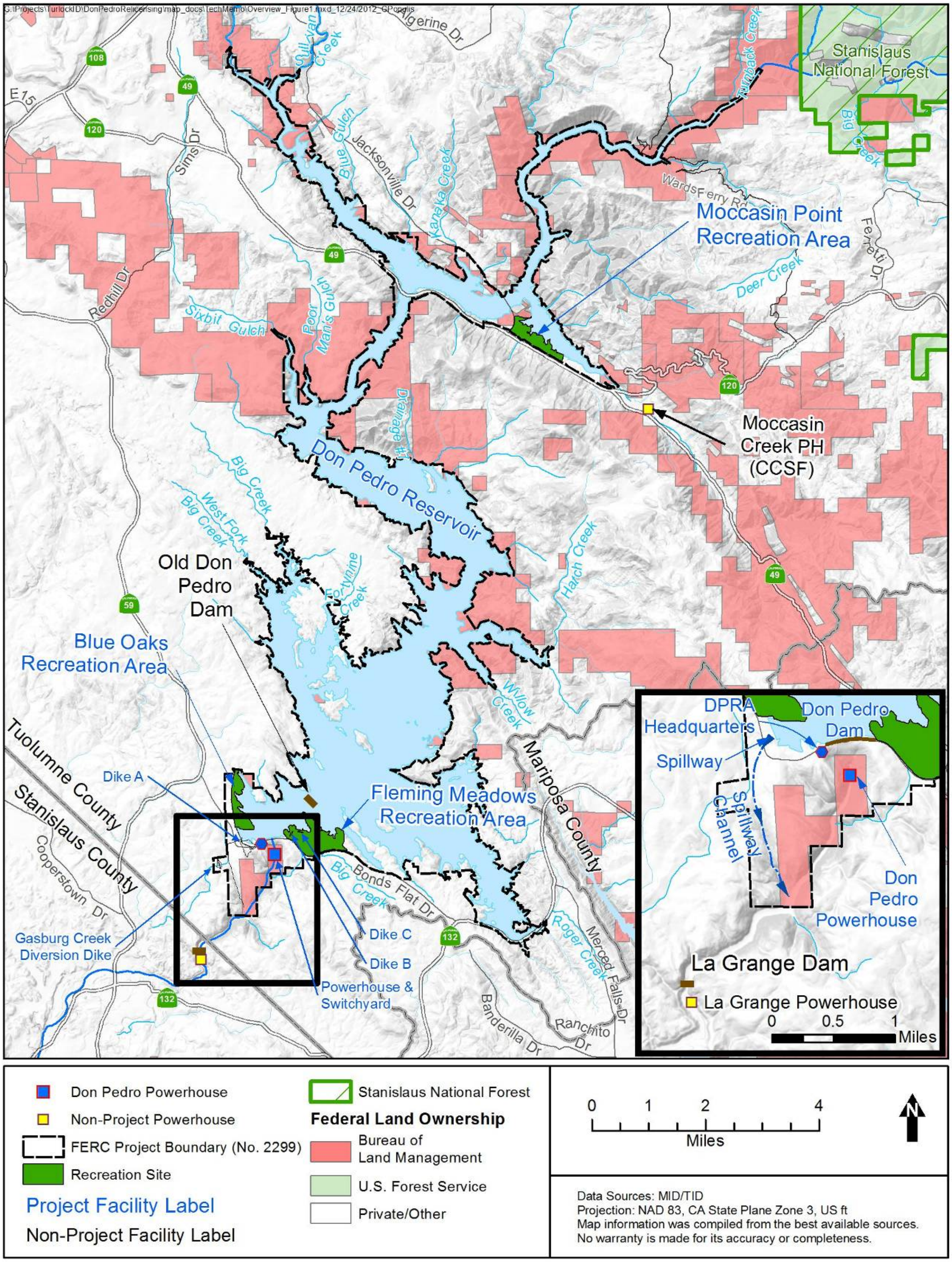

Figure 1.1-1. Don Pedro Project location.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts will apply for a new license no later than April 30, 2014. The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, following the regulations governing the Integrated Licensing Process (ILP). The Districts' PAD included descriptions of the Project facilities, operations, license requirements, and Project lands as well as a summary of the extensive existing information available on Project area resources. The PAD also included ten draft study plans describing a subset of the Districts' proposed relicensing studies. The Districts then convened a series of Resource Work Group meetings, engaging agencies and other relicensing participants in a collaborative study plan development process culminating in the Districts' Proposed Study Plan (PSP) and Revised Study Plan (RSP) filings to FERC on July 25, 2011 and November 22, 2011, respectively.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project, approving, or approving with modifications, 34 studies proposed in the RSP that addressed Cultural and Historical Resources, Recreational Resources, Terrestrial Resources, and Water and Aquatic Resources. In addition, as required by the SPD, the Districts filed three new study plans (W&AR-18, W&AR-19, and W&AR-20) on February 28, 2012 and one modified study plan (W&AR-12) on April 6, 2012. Prior to filing these plans with FERC, the Districts consulted with relicensing participants on drafts of the plans. FERC approved or approved with modifications these four studies on July 25, 2012.

Following the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD, or were adopted with modifications, formed the basis of Study Dispute proceedings. In accordance with the ILP, FERC convened a Dispute Resolution Panel on April 17, 2012 and the Panel issued its findings on May 4, 2012. On May 24, 2012, the Director of FERC issued his Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August 17, 2012.

A draft progress report for the Salmonid Redd Mapping Study (W&AR-08) was included in the Initial Study Report filed on January 17, 2013. That draft report provided preliminary results from surveys conducted between October 1, 2012 and December 1, 2012. This report provides the complete results of all field observations and the results of the Salmonid Redd Mapping Study (W&AR-08) as implemented by the Districts in accordance with FERC's SPD and subsequent study modifications and clarifications. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at www.donpedro-relicensing.com.

1.3 Study Plan

FERC approved the Districts' revised study plan, with modifications, in its December 22, 2011 SPD. FERC directed the Districts to modify their study to not only quantify the current spawning capacity and redd/recruitment relationships in the Tuolumne River, but to also evaluate potential changes to redd distribution and superimposition with changes in flow and gravel availability. Empirical redd mapping data collected as part of this Salmonid Redd Mapping Study (W&AR-08) were analyzed within the Spawning Gravel Study (W&AR-04) which in turn provided supporting information for the Chinook Salmon (W&AR-06) and *O. mykiss* (W&AR-10) population models.

FERC's modifications of the Districts' Salmonid Redd Mapping study plan directed the Districts to (1) collect flow data during the redd surveys and (2) expand their assessment of redd distribution and superimposition by integrating the results of this study with results from the Spawning Gravel Study Plan (W&AR-04) and the ongoing IFIM study required by FERC's July 2009 Order on Rehearing in order to produce a "synthesized description of the effects of gravel availability and flows upon redd distribution and superimposition" (SPD, pg 46).

This study was completed consistent with these directions.

2.0 STUDY GOALS AND OBJECTIVES

The purpose of the salmonid redd mapping study is to document the spatial distribution of Chinook salmon and *O. mykiss* redds and redd superimposition in order to assist with quantifying the current spawning capacity and redd/recruit relationships of the Tuolumne River. Objectives of this study are to:

- identify locations of Chinook salmon and *O. mykiss* spawning redds,
- compare redd counts and densities at recent gravel augmentation sites and nearby control sites,
- document redd superimposition at current spawning population levels.

The information obtained by this study supported efforts to model whether redd superimposition is currently limiting salmon production as part of the development of the Chinook salmon population model (W&AR-06).

3.0 STUDY AREA

The study area includes the Tuolumne River from La Grange Dam (RM 52) downstream to Santa Fe Bridge (RM 22), which encompasses the same area surveyed annually by CDFW to document Chinook salmon spawning. The study area was divided into four reaches (Figure 3.0-1) which correspond to the same reach designations used by CDFW:

- Reach 1: La Grange Dam (RM 52.0) to Basso Bridge (RM 47.4)
- Reach 2: Basso Bridge (RM 47.4) to Turlock Lake State Recreation Area (TLSRA) (RM 42.0)
- Reach 3: TLSRA (RM 42.0) to Hickman Bridge (RM 31.6)
- Reach 4: Hickman Bridge (RM 31.6) to Santa Fe Bridge (RM 22.0)

Downstream of RM 22, the river gradient continues to lessen and the river bed is dominated by sand substrates. General habitat characteristics are not favorable to salmonid spawning below RM 22.

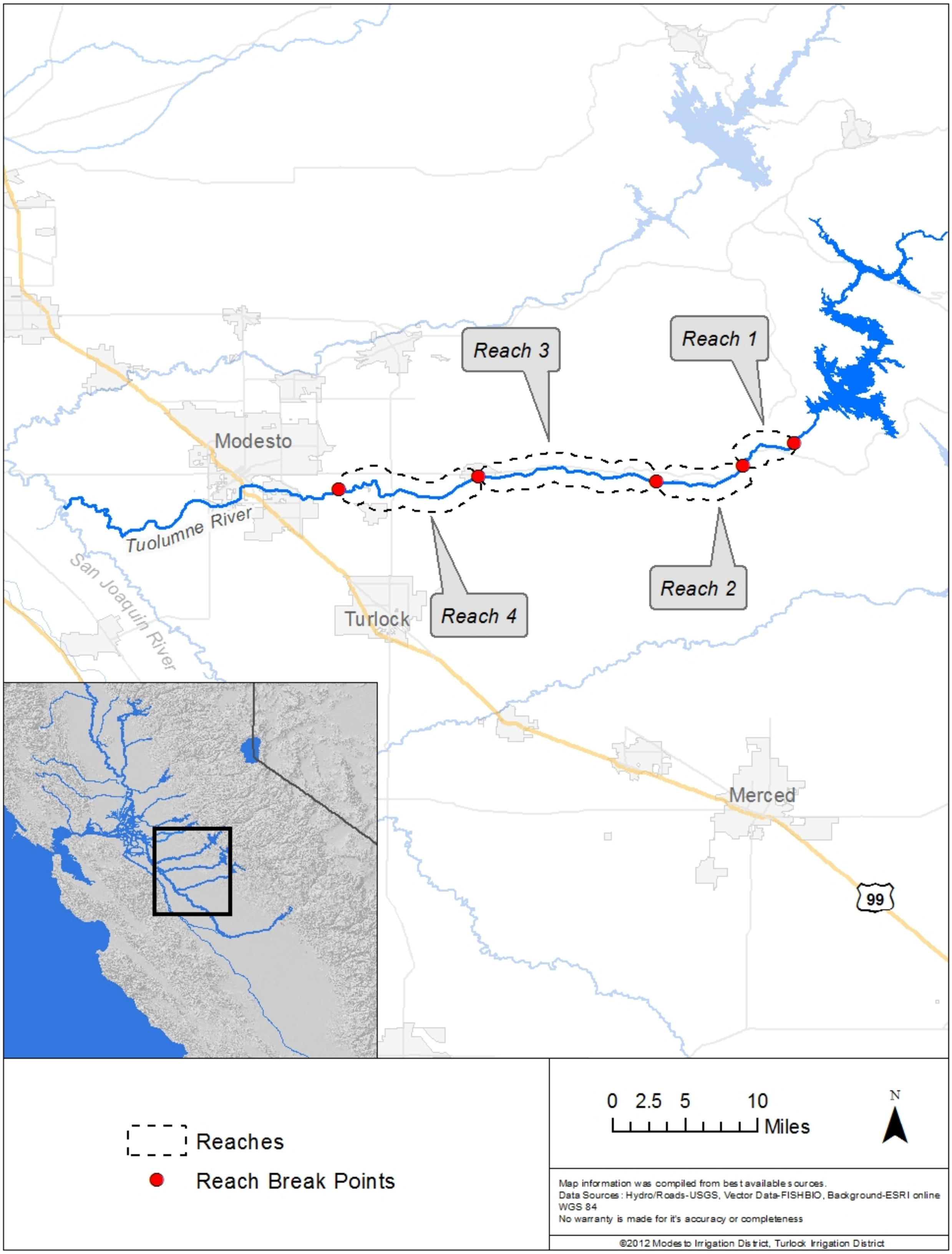

Figure 3.0-1. Map of the study area.

4.0 METHODOLOGY

4.1 Redd Mapping

Bi-weekly redd mapping surveys were conducted between October 1 and November 2, 2012, and survey frequency increased to weekly between November 5 and November 26 to capture the peak Chinook salmon spawning period. Survey frequency resumed to bi-weekly during December 10 through April 19, 2013.

A crew, consisting of one biologist and one technician, floated the entire study area during each survey event. Reaches 1 and 2 were surveyed from a 12-foot inflatable raft equipped with a rowing frame. Reaches 3 and 4 were surveyed from a 14-foot canoe equipped with a battery powered trolling motor to assist in moving through the long slow-water run pool and special-run pool sections of these reaches. One crew member stood at the front of the boat and observed for spawning activity as the boat maneuvered downstream. When the observer could not view the entire river width, the boat was stopped and both crew members surveyed by wading the riffle areas.

All visible redds were georeferenced (marked) using a GPS (Trimble; Geo-XH 6000) equipped with an external antenna (Trimble; Tornado), for sub-meter precision. The external antenna improved satellite reception and accuracy potential of post processed data. GPS coordinates for each redd were recorded at the estimated egg pocket location. For areas appearing to contain multiple redds with no clear boundaries, total dimensional area was delineated with the GPS. Care was taken to avoid impacting redds during the survey. Surveyors also documented redd age, status, presence of fish, and evidence of superimposition (Table 4.1-1).

To ensure consistency in field data collection, data dictionaries were constructed using GPS Pathfinder Office software (Trimble; Sunnyvale, CA) with fields outlining each required redd parameter. Data dictionaries were transferred to the GPS unit and opened within TerraSync Software (Trimble; Sunnyvale, CA). A minimum of 10 GPS points were required to record each redd position. GPS data were downloaded from the GPS unit to a desktop computer and post-processed using GPS Pathfinder Office software. To account for positional error due to various sources (e.g., atmospheric conditions, satellite distributions, GPS clock errors) GPS data was differentially corrected using the nearest reliable base data provider (CORS, Modesto COOP (CMOD), California). The GPS files were then exported to shapefile format and opened within ArcGIS software (ESRI; Redlands, CA) where data from previous events was appended to a single master file and stored within a file geodatabase. Mapped redd locations were overlaid onto mapped riffle habitats from the Spawning Gravel Study (W&AR-04).

Table 4.1-1. Data collected to describe each identified redd.

Parameter	Attribute	Description
Redd Status	New	Signs of fresh digging activity, well developed pot and tail spill.
	Old	Redd fading, algae and or redd flattening out but still visible.
	Incomplete	Not well developed, no defined pot or tail spill.

Parameter	Attribute	Description
Superimposition	Yes	Evidence of superimposition with adjacent redd(s)
	No	No evidence of superimposition
Fish Presence	Species	Chinook or *O. mykiss*
	Count	Number of fish observed actively guarding or constructing the identified redd.
Redd Characteristics	Depth	Water depth immediately upstream of the pot
	Velocity	Water velocity at 60% of depth immediately upstream of the pot.
	Substrate	Estimated median grain-size immediately upstream of the pot.
	Pot Length (P_L)	Total length of the pot parallel to streamflow, measured from the top to bottom edge.
	Pot Width (P_W)	Maximum width of the pot perpendicular to the stream flow or pot length. When the pot is irregularly shaped, estimate the total width as accurately as possible.
	Tail Spill Length (TS_L)	Total length of the tail spill parallel to the stream flow. Measured from the top edge of the middle of the pot to the bottom edge of the tail spill.
	Tail Spill Width 1 (TS_{W1})	Maximum width of the tail spill perpendicular to the stream flow or pot length; measured about one-third of the distance down from the top edge of the tail spill.
	Tail Spill Width 2 (TS_{W2})	Maximum width of the tail spill perpendicular to the stream flow or pot length;measured about two-thirds of the distance down from the top edge of the tail spill.

For each new redd marked, physical dimensions were recorded as described in Gallagher et al. (2009) (Figure 4.1-1). Redd measurements included pot length, pot width, tail spill length, and tail spill width. Measurements were recorded to the nearest 0.1 foot using a stadia rod. Measurements were not recorded for redds that were classified “old” since most had already been measured when recorded as “new”, and new redd dimensions are most accurate since gravels move through time.

Total redd area was calculated as the horizontal plane of an ellipsoid encompassing the pot and tail spill areas.

$$Total\ Redd\ Area = \pi \frac{2\left(\sqrt{P_L \times TS_L}\right)\left(P_L + TS_L\right)}{\left(\sqrt{P_L} + \sqrt{TS_L}\right)} \left(\frac{P_W}{2}\right)$$

Disturbed redd area was calculated as the ellipsoidal area of the pot width and pot length.

$$Disturbed\ Redd\ Area = \frac{\pi\ (P_L \times P_W)}{4}$$

Depth and velocity measurements were recorded immediately upstream of the pot. Velocity measurements were taken using a FH950 portable velocity meter (Hach Company; Loveland, CO) at 60 percent of the depth and recorded in feet per second (ft/sec). Median grain size was visually estimated on the substrate immediately upstream of the pot.

The following criteria were used to determine whether redds were constructed by Chinook salmon or *O. mykiss*:

- Redd construction timing: Chinook salmon typically construct redds between November–January, while O. mykiss typically spawn in January–March (McEwan 2001).
- Redd location: Chinook salmon usually construct redds in the middle of a riffle, while O. mykiss redds are usually nearer cover such as cut banks and overhanging trees (Giovannetti et.al 2013).
- Redd protection: Chinook salmon generally defend their redds for 1-2 weeks after being built, while O. mykiss do not defend their redds.
- Gravel size: Chinook salmon construct redds in larger gravel sizes than O. mykiss Giovannetti et.al 2013).
- Redd size: Chinook salmon redds are larger than *O. mykiss* redds (Reynolds et al. 1990).

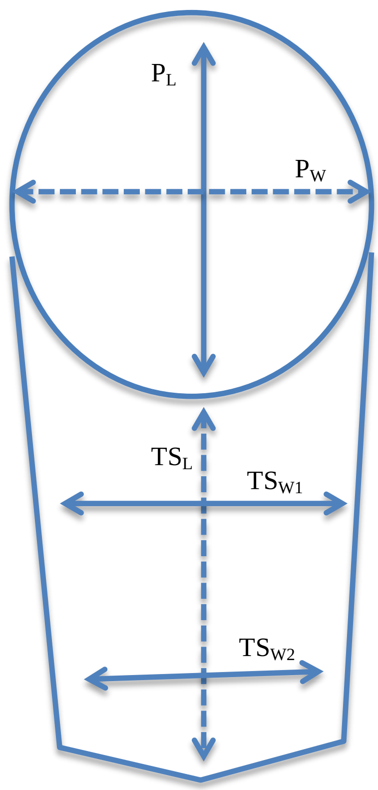

Figure 4.1-1. Schematic of the redd measurement locations.

4.2 River Conditions

Provisional daily average flow data for the Tuolumne River at La Grange was obtained from USGS at http://waterdata.usgs.gov/ca/nwis/uv/?site_no=11289650&agency_cd=USGS. Water temperature data were obtained from hourly recording Hobo Pro v2 water temperature data loggers (Onset Computer Corporation) at eight sites from La Grange powerhouse (RM 52) to Santa Fe Bridge (RM 22), which are maintained by the Districts under their real time monitoring

(RTM) program. Daily mean water temperatures for these eight sites from October 2012 through April 2013 are included in Attachment A.

4.3 Comparison of Redd Counts and Densities Between Gravel Augmentation and Control Sites

As directed under the 1995 Tuolumne River Settlement Agreement and 1996 FERC Order, the Tuolumne River Technical Advisory Committee (TRTAC) developed 10 priority habitat restoration projects separated into three classes based on the individual project goals and type of restoration activity: (1) channel and riparian restoration, (2) predator isolation, and (3) sediment management (TID/MID 2005). Gravel augmentation projects aimed at improving spawning gravel availability and quality in the lower Tuolumne River began in 1999. Approximately 73,250 yds^3 of spawning gravel were added through projects implemented by CDFW, United States Fish and Wildlife Services, and Friends of the Tuolumne from 2002 to 2011 (CDWR 2004, TID/MID 2005, 2006, 2007, McBain and Trush 2013) (Table 4.3-1).

Table 4.3-1. Gravel augmentation projects in the lower Tuolumne River, 2002–2011.

Location (RM)	Year	Volume, yd^3
50.0 to 50.7	2002	9,600
50.0 to 50.7	2003	5,330
43	2005	11,000
51	2005	10,820
43	2011	17,500
51	2011	19,000

During the present study, there were 88 riffles identified from river mile 51.9 to 23.6 and Chinook redd densities were calculated for each riffle throughout the entire study period (sum of all unique redds). Redd densities were calculated using the total number of redds observed on each riffle divided by the area (in square feet) of the riffle. Redd densities in the six restored riffles were compared with densities of redds from unrestored riffles. Unrestored riffles were selected for comparison if they were located within one river mile of any restored riffle, which resulted in ten unique riffles used for this particular comparison.

4.4 Redd Superimposition

Redd superimposition occurs when later arriving female salmonids dig redds on top of existing redds, which can result in mortality to incubating eggs. This study documented redd superimposition throughout the study reach, but no attempt was made to quantify associated egg mortality. Redd superimposition was determined both through visual observations in the field, and evaluation of overlap between weekly mapping layers in ArcGIS. The amount of overlap between measured redd areas of two superimposed redds was used to indicate the degree of redd superimposition. Field observations of superimposition were considered empirical evidence and retained when subsequent GIS analysis was inconclusive. Further investigation of superimposition was conducted as each survey week was processed in ArcMap and added to the previous data set. Using the measuring tool in ArcMap the pot widths upstream of the marked redd points were individually inspected to determine if an older redd's egg pocket fell into the area. Furthermore, the extent of superimposition of each redd was measured in ArcMap by using the buffer tool to create a polygon around each redd point based on pot width. For redds where no pot width value was recorded the average pot width was substituted. The union tool was then used to partition overlapping portions of adjacent redds and areas were calculated to determine percent superimposition. The degree of redd superimposition was classified as follows (TID/MID 1992):

- Total superimposition is defined as the case where the area excavated by the superimposing fish includes all the egg pockets of the prior redd.
- Partial superimposition occurs when either the front or back of the redd is superimposed, leaving part of the redd undisturbed.
- Incidental superimposition is defined as overlap of redds but no disturbance of the earlier egg pockets.

5.0 RESULTS

5.1 Redd Counts

A total of 653 completed Chinook salmon redds were observed and catalogued between October 1, 2012 and April 19, 2013, of which 622 (95%) were observed between October 29 and November 29 (Table 5.1-1). An additional 233 Chinook salmon redds were classified as incomplete. Peak spawning in all survey reaches occurred during the week of November 12, when 186 new Chinook salmon redds were identified (Figure 5.1-1). Approximately 40 percent of Chinook salmon spawning occurred between October 1 and November 9, 2012, and >90 percent by November 18, 2012 (Figure 5.1-2). Nine new Chinook redds were identified during the January to April time period. These redds were classified as Chinook redds based on either the presence of fish or similar size to redds identified earlier in the spawning season.

Table 5.1-1. New Chinook salmon redds identified by reach and date during the survey period.

Week[1]	Survey Dates	Reach (RM)				Grand Total	Percent
		1 (52.0-47.4)	2 (47.4-42.0)	3 (42.0-31.6)	4 (31.6-22.0)		
1	10/1- 10/4/12	7	1	1	0	9	1.4%
3	10/15- 10/18/12	1	0	0	0	1	0.2%
5	10/29- 11/2/12	28	13	30	5	76	11.6%
6	11/5- 11/9/12	86	48	36	11	181	27.7%
7	11/12- 11/15/12	87	48	37	14	186	28.5%
8	11/18- 11/21/12	84	15	37	8	144	22.1%
9	11/26- 11/29/12	14	9	4	8	35	5.4%
11	12/10- 12/13/12	3	4	5	0	12	1.8%
14	1/2- 1/5/13	0	1	2	0	3	0.5%
15	1/7- 1/10/13	2	0	0	0	2	0.3%
17	1/21- 1/24/13	0	0	1	0	1	0.2%
19	2/5- 2/8/13	2	0	0	0	2	0.3%
21	2/18- 2/21/13	0	0	0	0	0	0.0%
23	3/4- 3/7/13	0	0	0	0	0	0.0%
25	3/18- 3/21/13	1	0	0	0	1	0.2%
27	4/1- 4/4/13	0	0	0	0	0	0.0%
29	4/17- 4/19/13	0	0	0	0	0	0.0%
	Grand Total	315	139	153	46	653	--
	Percent	48.2%	21.3%	23.4%	7.0%	--	--

[1] Week refers to the number of weeks after the week of 10/1/12.

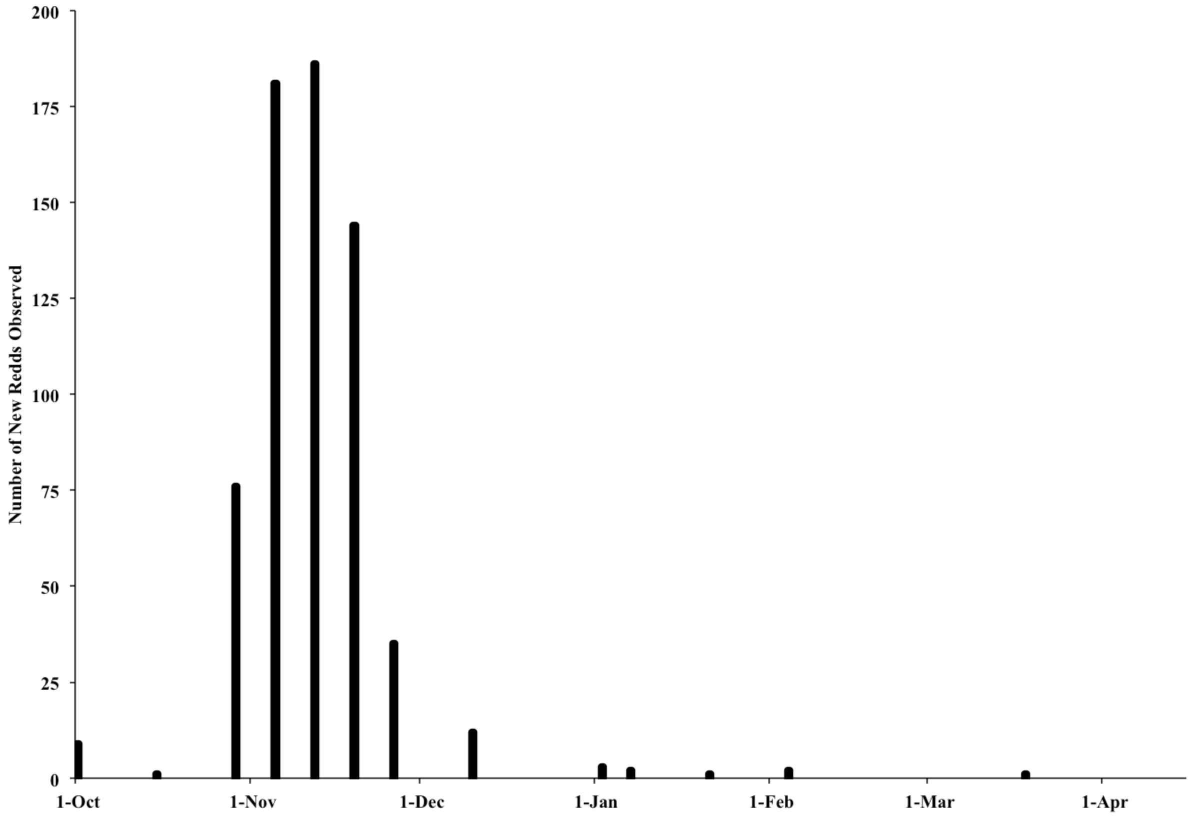

Figure 5.1-1. Weekly number of observed new Chinook salmon redds in the surveyed reaches of the lower Tuolumne River during 2012/2013.

A total of 38 *O. mykiss* redds were observed through April 19, 2013. The first *O. mykiss* redds were observed January 7, and peak observations occurred during the week of April 1, when 10 new redds were identified (Figure 5.1-3). The highest abundance of observed *O. mykiss* redds occurred in Reach 1 (RM 52.0 to RM 47.4), accounting for 63.2 percent of the *O. mykiss* redds identified (Table 5.1-2). Ninety-seven percent (97%) of *O. mykiss* redds were observed above RM 42. *O. mykiss* were observed to be actively guarding or constructing only two of the identified redds. No *O. mykiss* redds were identified below RM 39 during the 2012/2013 study period.

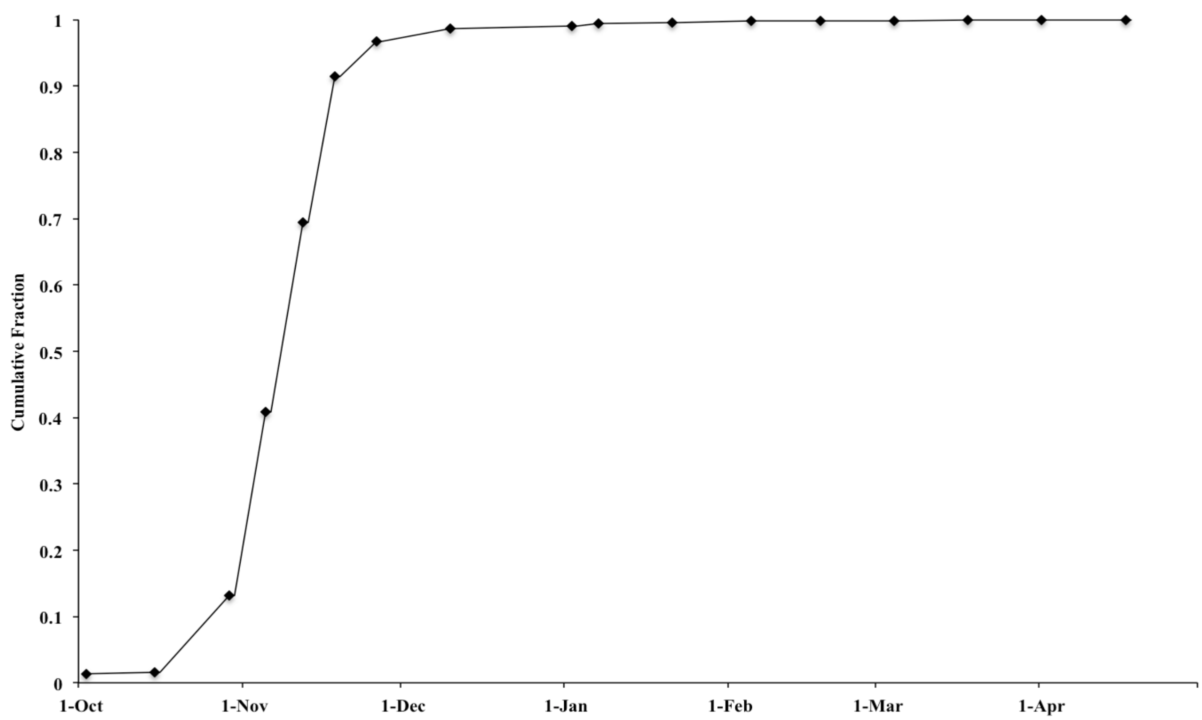

Figure 5.1-2. Cumulative temporal distribution of new Chinook salmon redds in the surveyed reaches of the lower Tuolumne River during 2012/2013.

Table 5.1-2. New *O. mykiss* redds identified by reach and date during the survey period.

Week[1]	Survey Dates	Reach				Grand Total	Percent
		1 (52.0-47.4)	2 (47.4-42.0)	3 (42.0-31.6)	4 (31.6-22.0)		
1	10/1- 10/4/12	0	0	0	0	0	0.0%
3	10/15- 10/18/12	0	0	0	0	0	0.0%
5	10/29- 11/2/12	0	0	0	0	0	0.0%
6	11/5- 11/9/12	0	0	0	0	0	0.0%
7	11/12- 11/15/12	0	0	0	0	0	0.0%
8	11/18- 11/21/12	0	0	0	0	0	0.0%
9	11/26- 11/29/12	0	0	0	0	0	0.0%
11	12/10- 12/13/12	0	0	0	0	0	0.0%
14	1/2- 1/5/13	0	0	0	0	0	0.0%
15	1/7- 1/10/13	5	0	0	0	5	13.2%
17	1/21- 1/24/13	3	2	0	0	5	13.2%
19	2/5- 2/8/13	5	2	1	0	8	21.1%
21	2/18- 2/21/13	0	1	0	0	1	2.6%
23	3/4- 3/7/13	5	2	0	0	7	18.4%
25	3/18- 3/21/13	0	2	0	0	2	5.3%
27	4/1- 4/4/13	6	4	0	0	10	26.3%
29	4/17- 4/19/13	0	0	0	0	0	0.0%
	Grand Total	24	13	1	0	38	--
	Percent	63.2%	34.2%	2.6%	0.0%	--	--

[1] Week refers to the number of weeks after the week of 10/1/12.

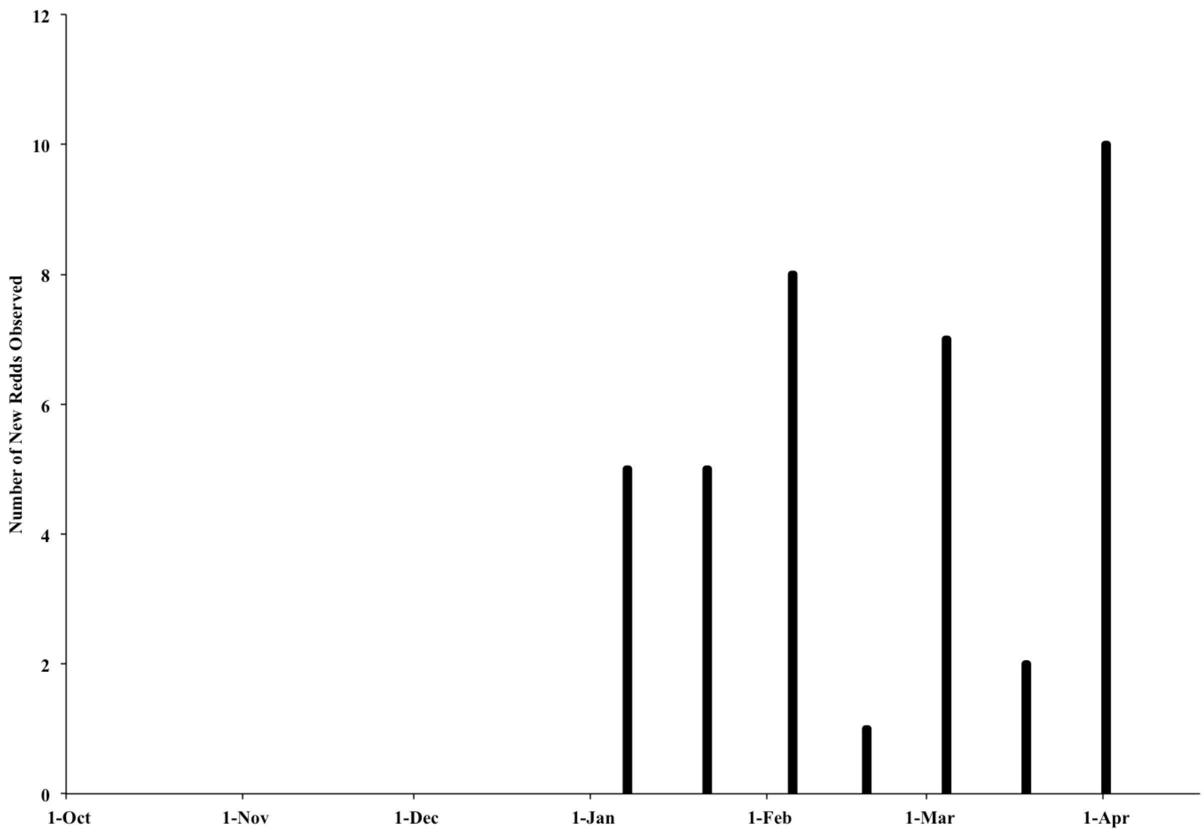

Figure 5.1-3. Weekly number of observed new *O. mykiss* redds in the surveyed reaches of the lower Tuolumne River during 2012/2013.

5.2 River Conditions

During the study period (10/1/12- 4/20/13) average daily flow recorded at the USGS gage at La Grange ranged from 163 to 590 cfs (Figure 5.2-1). Except for the late-October and mid-April pulse flow periods, flows at the La Grange gage were relatively constant at approximately 165 cfs throughout the entire study period. During the study period, average daily water temperatures near the bottom of Reach 1 (RM 49) ranged from 46.3° to 55.2° F (Figure 5.2-2). During the time period when the majority of salmon redds were detected (October 29, 2012 through November 29, 2012), mean daily water temperatures in Reach 1 ranged from 49.7° to 53.1° F, and averaged 51.3° F. Mean daily water temperatures near the bottom of Reach 4 (RM 23.6) from October 29, 2012 through November 29, 2012 (time period when majority of salmon redds were detected) ranged from 52.8° to 61.6° F, and averaged 57.1° F.

Mean daily water temperatures in Reach 1 during the time period *O. mykiss* redds were identified (January 7, 2013 to April 1, 2013) ranged from 46.3° to 52.5° F, and averaged 50.9° F. Mean daily water temperatures at the bottom of Reach 2 (RM 42.9) during the time period when *O. mykiss* were detected (January 7, 2013 to April 1, 2013) ranged from 44.6° to 59.9° F and averaged 52.2° F.

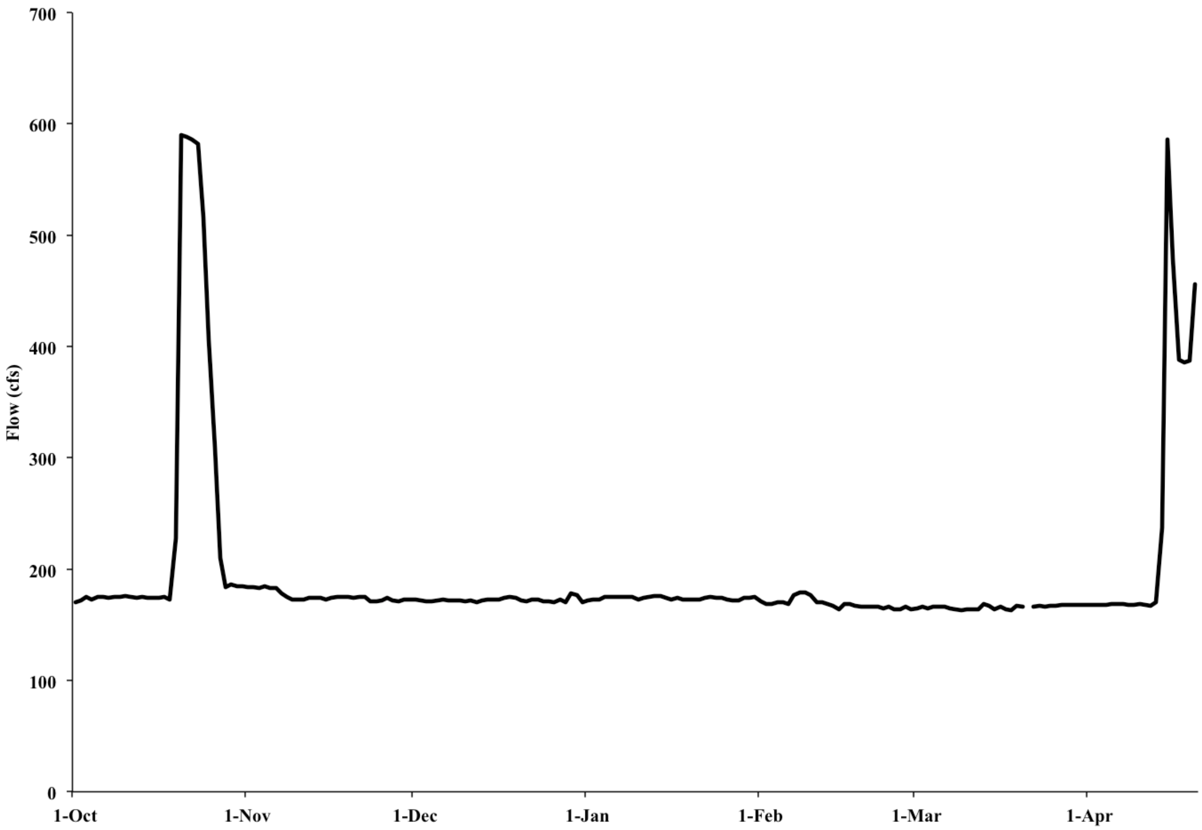

Figure 5.2-1. Mean daily flow (cfs) at La Grange (LGN) during the redd survey period.

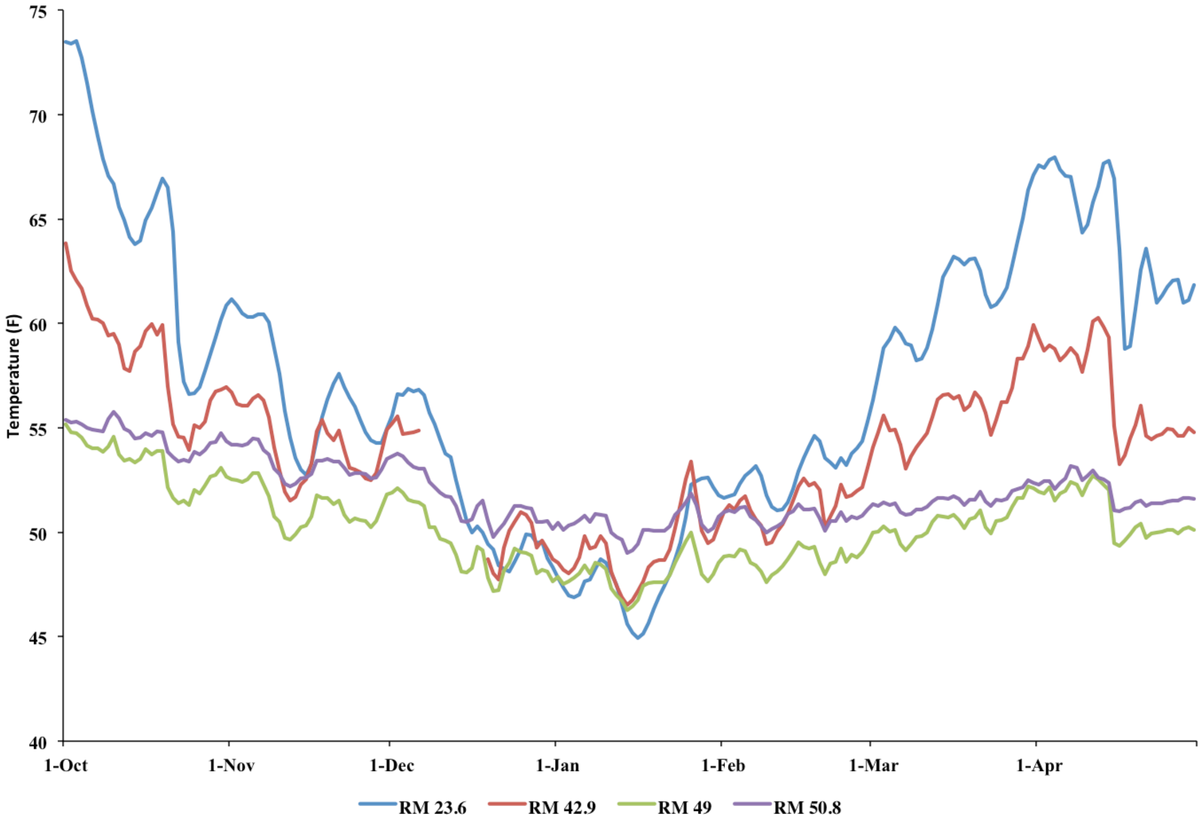

Figure 5.2-2. Daily mean water temperatures in the lower Tuolumne River during October 2012 through April 2013.

5.3 Redd Characteristics

Mean water depth at Chinook salmon redd locations was 1.45 ft (range, 0.50 - 2.95 ft). Mean associated water velocity was 1.98 ft/sec (range, 0.12 - 4.06 ft/sec.) Median grain size (+1 S.D.) of salmon redds were estimated to be 1.8 in ± 0.6 in. These observed depths and velocities fell within the expected ranges for Chinook salmon (Reynolds et al. 1990).

Chinook salmon redd measurements indicated the mean pot length (+1 S.D.) was 6.82 ft ± 2.50 ft and the mean pot width was 7.25 ft ± 3.35 ft. The mean tail spill length was 8.89 ft ± 4.04 ft, the mean tail spill width #1 was 6.26 ft ± 2.11 ft and the mean tail spill width #2 was 4.48 ft ± 1.67 ft (Table 5.3-1).

Table 5.3-1. Physical size measurements of sampled Chinook salmon redds.

	Gravel Median Size (in)	Depth (ft)	Flow (ft/s)	Pot Depth (ft)	Pot Length (ft)	Pot Width (ft)	Tail Length (ft)	Tail Width #1 (ft)	Tail Width #2 (ft)
Sample Size	36	313	313	295	290	290	286	283	269
Max	4.0	2.95	4.06	3.45	15.00	22.00	25.00	14.00	10.00
Min	0.5	0.50	0.12	0.90	1.00	1.00	2.00	1.00	0.80
Avg	1.7	1.45	1.96	1.91	6.82	7.25	8.89	6.26	4.48
Median	1.8	1.40	1.98	1.82	6.50	6.70	9.00	6.00	4.20

	Gravel Median Size (in)	Depth (ft)	Flow (ft/s)	Pot Depth (ft)	Pot Length (ft)	Pot Width (ft)	Tail Length (ft)	Tail Width #1 (ft)	Tail Width #2 (ft)
Variance	0.3	0.22	0.53	0.20	6.20	11.17	16.28	4.42	2.79
Std Dev	0.6	0.47	0.73	0.44	2.50	3.35	4.04	2.11	1.67

Mean depth at *O. mykiss* redd locations was 1.04 ft, (range, 0.40 - 1.70 ft). Mean velocity was 1.81 ft/sec, (range 0.31 - 3.52 ft/sec). Median grain size (+1 S.D.) of identified *O. mykiss* redds was estimated to be 1.50 in ± 0.40 in.

O. mykiss redd measurements indicated the mean pot length was 2.03 ft ± 0.91 ft and the mean pot width was 1.75 ft ± 0.70 ft. The mean tail spill length was 2.71 ft ± 1.33 ft, the mean tail spill width #1 was 1.96 ft ± 0.73 ft and the mean tail spill width #2 was 1.39 ft ± 0.44 ft (Table 5.3-2).

Table 5.3-2. Physical size measurements of sampled *O. mykiss* redds.

	Gravel Median Size (in)	Depth (ft)	Flow (ft/s)	Pot Depth (ft)	Pot Length (ft)	Pot Width (ft)	Tail Length (ft)	Tail Width #1 (ft)	Tail Width #2 (ft)
Sample Size	36	36	32	36	36	36	33	32	31
Max	2.00	1.70	3.52	1.90	4.00	3.50	6.50	4.20	2.20
Min	0.75	0.40	0.31	0.60	0.70	0.50	1.00	0.80	0.60
Avg	1.39	1.04	1.81	1.23	2.03	1.75	2.71	1.96	1.39
Median	1.50	1.00	1.70	1.20	1.90	1.55	2.30	1.95	1.40
Variance	0.16	0.10	0.65	0.11	0.81	0.47	1.73	0.52	0.18
Std Dev	0.40	0.32	0.82	0.33	0.91	0.70	1.33	0.73	0.44

The total redd areas for *O. mykiss* were significantly smaller than Chinook salmon redds, ranging from 0.8 ft^2 to 26.6 ft^2 for *O. mykiss* and from 2.3 ft^2 to 405.6 ft^2 for Chinook. Based on this range in *O. mykiss* redd size it is likely that all spawning was by resident rather than anadromous *O. mykiss*, as average redd sizes for anadromous *O. mykiss* range from 57 ft^2 to 74.3 ft^2 (Shapovalov and Taft 1954; Wilson and Collins 1992). This is supported by weir monitoring on the Tuolumne River, which only detected four *O. mykiss* passing upstream during the 2012/2013 monitoring season (FISHBIO, unpublished).

All redd characteristics were tested using one-sided Welch's t-test which accounts for unequal variation in each group (Welch 1947; Ruxton 2006). Total redd area was calculated using calculations for the horizontal plane of an ellipsoid which encompassed the pot and tail spill areas. Disturbed redd area was calculated using the ellipsoidal area of the pot width and pot length, and was used as an estimate of the egg pocket area that may be potentially disturbed by subsequent spawning activity (i.e., superimposition).

Median gravel sizes found in Chinook salmon redds (1.7 inches, n = 295) were significantly larger than median gravel sizes found in *O. mykiss* redds (1.4 inches, n = 36) using Welch's t-test ($t = 4.5$, $df = 54.6$, $P < 0.0001$) (Figure 5.3-1).

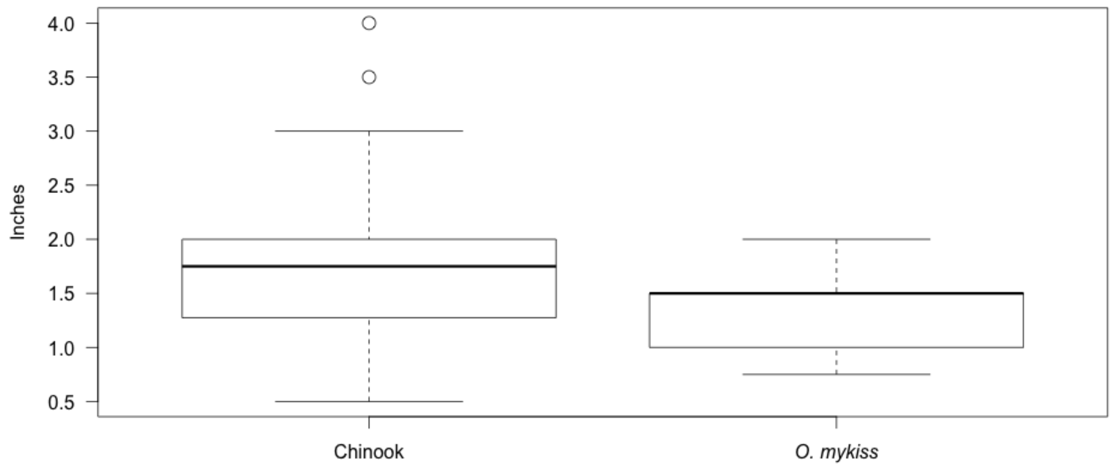

Figure 5.3-1. Boxplots of median gravel sizes measured in Chinook salmon and *O. mykiss* redds surveyed on the lower Tuolumne River during 2012/2013.

Water depths measured at Chinook salmon redds (1.45 ft, n = 313) were significantly greater than depths measured at *O. mykiss* redds (1.04 ft, n = 36) using Welch's t-test (t = 6.9, df = 53.9, P<0.0001) (Figure 5.3-2).

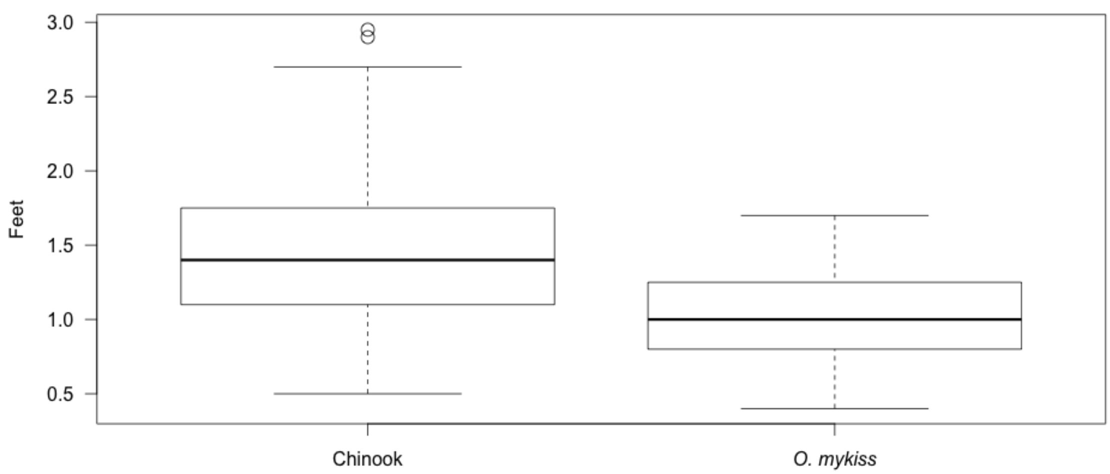

Figure 5.3-2. Boxplots of water depths measured in Chinook salmon and *O. mykiss* redds surveyed on the lower Tuolumne River during 2012/2013.

Water velocities measured at Chinook salmon redds (1.96 ft/s, n = 313) were not significantly greater than velocities measured at *O. mykiss* redds (1.81 ft/s, n = 32) using Welch's t-test (t = 1.0, df = 36.2, P = 0.1601) (Figure 5.3-3).

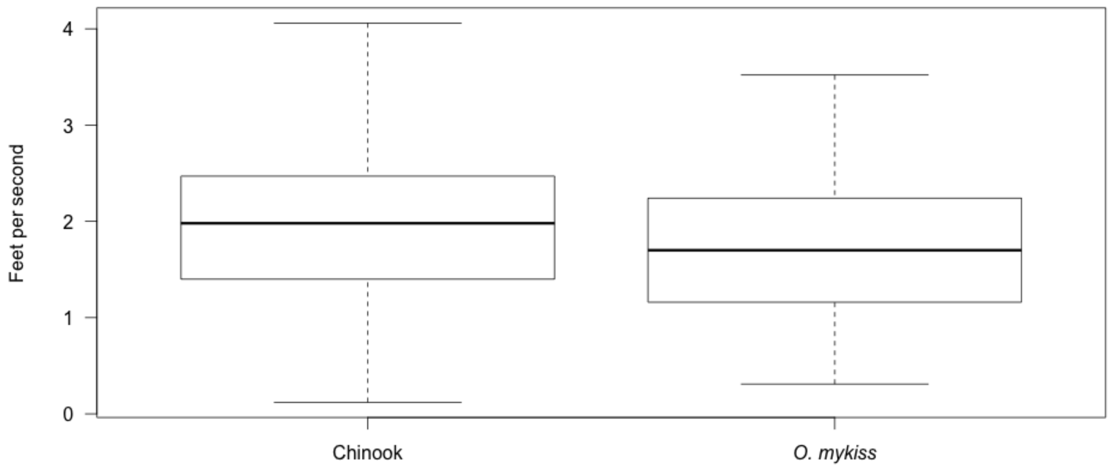

Figure 5.3-3. Boxplots of water velocity measured in Chinook salmon and *O. mykiss* redds surveyed on the lower Tuolumne River during 2012/2013.

Pot depths measured at Chinook salmon redds (1.91 ft, n = 295) were significantly greater than pot depths measured at *O. mykiss* redds (1.23 ft, n = 36) using Welch's t-test (t = 11.2, df = 51.8, P = 9.838e-16) (Figure 5.3-4).

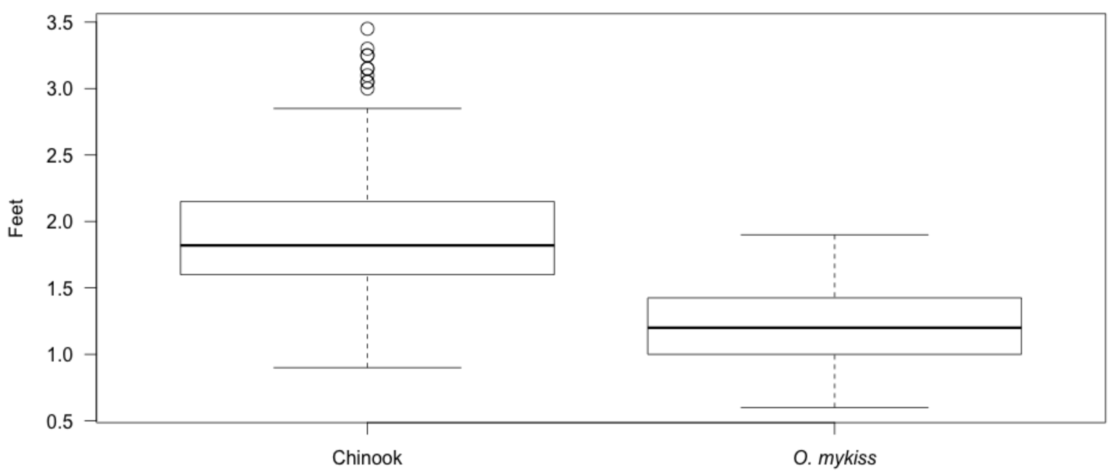

Figure 5.3-4. Boxplots of pot depths measured in Chinook salmon and *O. mykiss* redds surveyed on the lower Tuolumne River during 2012/2013.

Total redd areas were calculated using calculations for the horizontal plane of an ellipsoid. Total redd areas measured at Chinook salmon redds (97.1 ft^2, n = 286) were significantly greater than areas measured at *O. mykiss* redds (7.2 ft^2, n = 33) using Welch's t-test (t = 21.8, df = 308.5, P < 2.2e-16). Estimated disturbed redd areas from Chinook salmon (43.1 ft^2, n = 290) were also greater in size than for *O. mykiss* redds (3.1 ft^2, n = 36) using Welch's t-test (t = 20.9, df = 308.5, P < 2.2e-16) (Figure 5.3-5). Lastly, Table 5.3-3 shows a comparison of Chinook salmon redd areas from the 2012/2013 study to redd measurements (n=354) from previous studies conducted in 1988–1989 on the Tuolumne River (TID/MID 1992, Appendix 6).

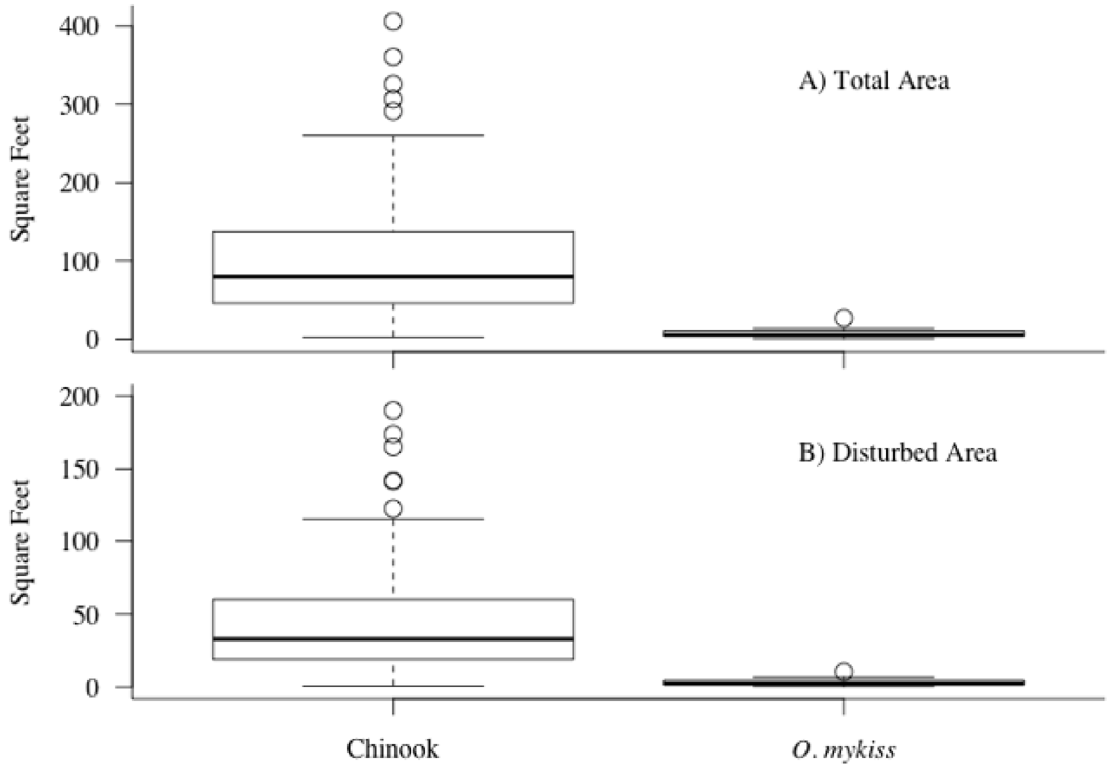

Figure 5.3-5. Boxplots of total redd areas (Panel A) and disturbed areas (Panel B) measured in Chinook salmon and *O. mykiss* redds surveyed on the lower Tuolumne River during 2012/2013.

Table 5.3-3. Comparison of Chinook salmon redd areas from 1988-1989 (TID/MID 1992) and 2012/2013.

	1988-1989 (n=354)	2012/2013 (n=290)
Total Redd Area (ft²)	80.4	97.1
Disturbed Redd Area (ft²)	52.5	43.1

5.4 Spawning Distribution and Use of Gravel Augmentation Sites

In general, Chinook salmon spawning activity (by absolute number of redds and densities) increased as river mile increased (Figure 5.4-1). The highest abundance of observed redds occurred in Reach 1 (RM 52.0 to RM 47.4), accounting for 48.2 percent of redds identified. Reaches 2 and 3 accounted for 21.3 percent and 23.4 percent of redds, respectively, with Reach 4 accounting for 7.0 percent of the Chinook spawning activity.

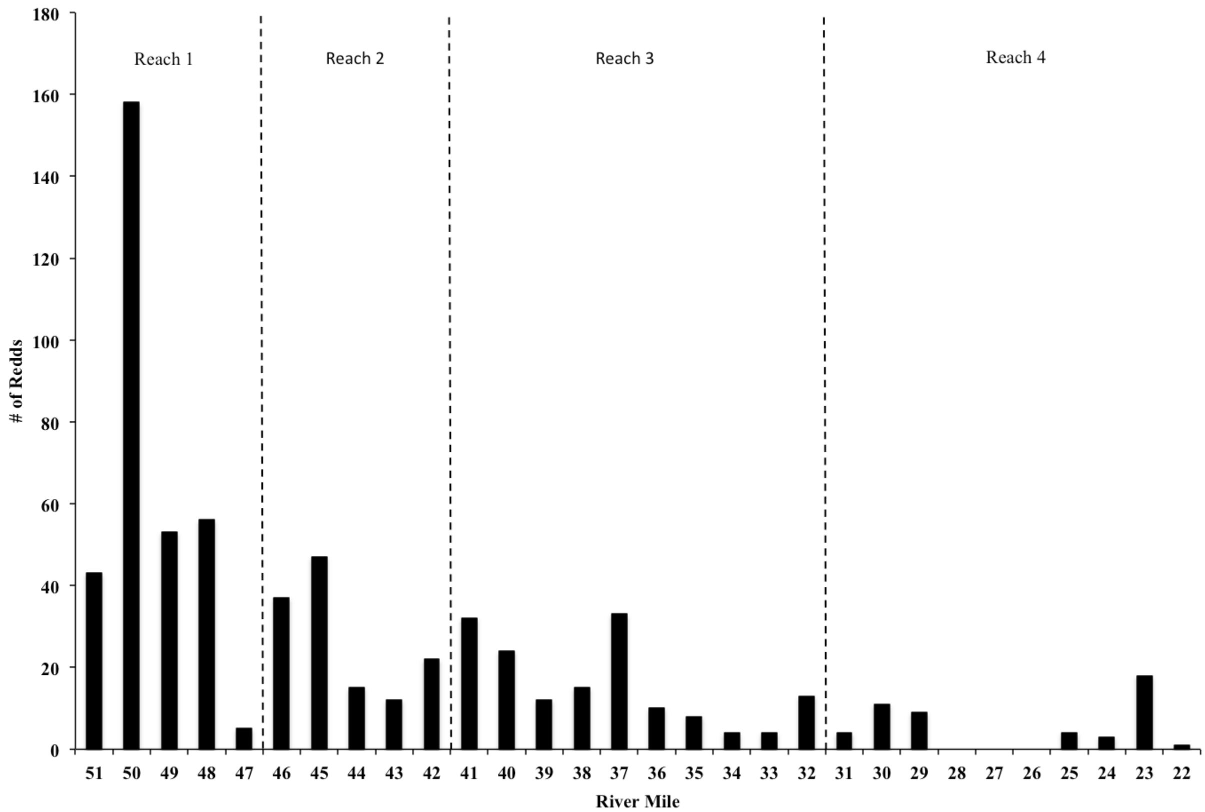

Figure 5.4-1. Chinook salmon redd distribution by river mile on the lower Tuolumne River during 2012/2013.

Spawning activity at recent gravel augmentation sites accounted for 21.6 percent (141 of 653 total) of the new Chinook salmon redds observed on the Tuolumne River during 2012/2013. The majority of these redds were observed at the CDFW augmentation sites near La Grange (RM 50.6 to 51). Spawning densities at these sites ranged from 0.075 to 0.436 redds/100 ft^2. Redd densities throughout the spawning reach ranged from 0 to 0.436 redds/100 ft^2 (mean = 0.025 redds/100 ft^2) during the 2012/2013 spawning season (Figure 5.4-2, Attachment B).

O. mykiss spawning activity at recent gravel augmentation sites accounted for 31.6 percent (12 of 38 total) of the redds observed during the 2012/2013 spawning season. Eleven of these redds were observed at the CDFW 2011 augmentation site near La Grange (RM 51), and a single *O. mykiss* redd was identified within the Bobcat Flat augmentation site (RM 43). Due to the low number of *O. mykiss* redds, no comparison was made between use of restored and unrestored riffles.

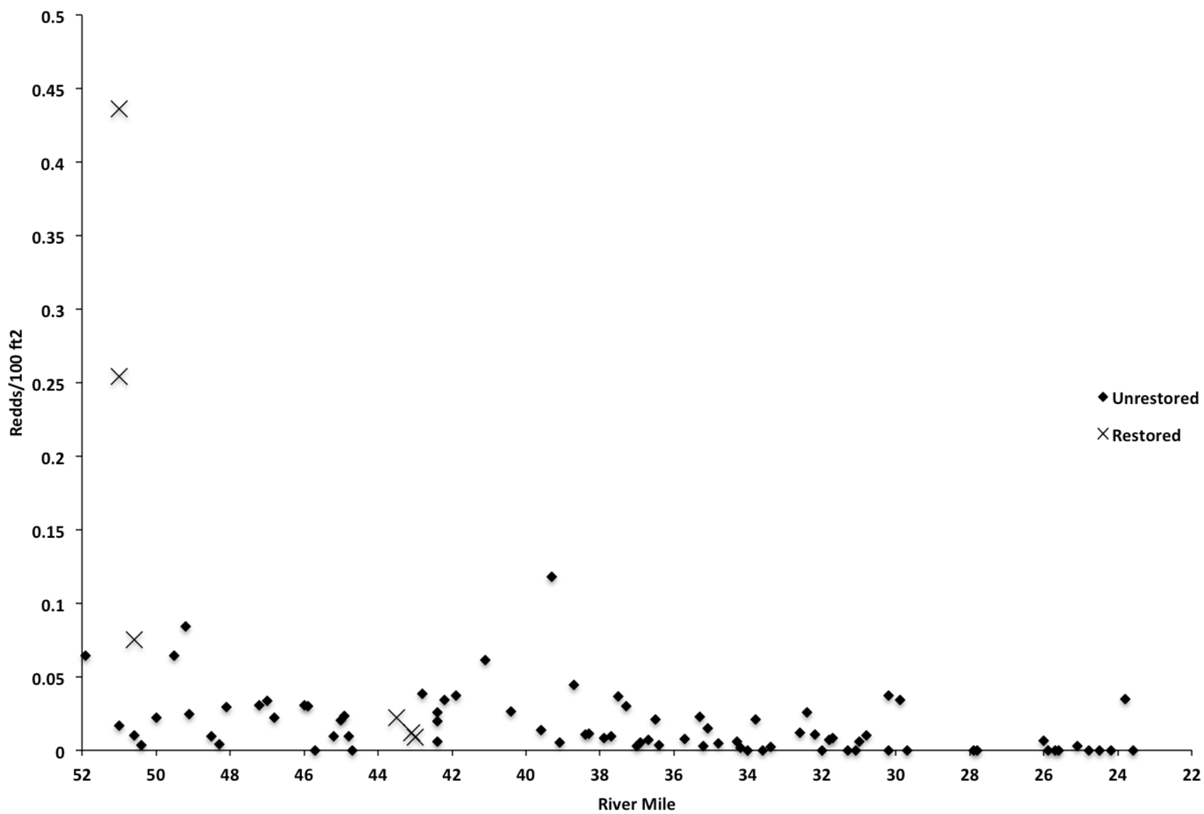

Figure 5.4-2. Areal densities of Chinook salmon redds in the 88 riffles on the lower Tuolumne River during 2012/2013.

The distribution of all Chinook salmon redd densities was non-normally distributed with a majority of the both restored and unrestored riffles having low redd densities (Figure 5.4-3). Due to the non-normality of the data, a Mann-Whitney test (Hollander and Wolfe 1999) was used to detect differences between redd densities in restored versus unrestored riffles. In addition, Fisher's F-test (Sokal and Rohlf 1981) was used to compare the variances between restored and unrestored riffles. Results from the Mann-Whitney test showed that there was no difference between Chinook redd densities in restored and unrestored riffles (W=19, P = 0.2635). The Fisher's F-test showed that the variance of redd densities in restored riffles was significantly higher than the variance in unrestored riffles (within one mile of restored riffles; F-test, F = 0.01, P < 0.000001). We should note that the F-test is highly sensitive to outliers and that redd densities from two of the restored riffles were two of the highest densities observed for all 88 riffles surveyed (Crawley 2007).

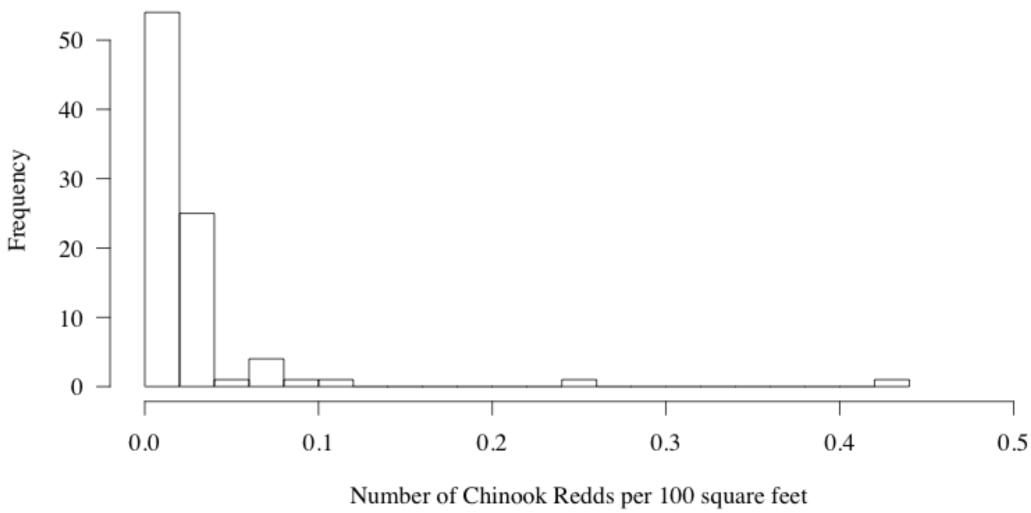

Figure 5.4-3. Histogram of redd densities from riffles (n = 88; restored and unrestored) on the lower Tuolumne River during 2012/2013.

5.5 Redd Superimposition

During the 2012/2013 sampling season, a measureable degree of redd superimposition was identified in 15.2 percent (99 of 653 total) of Chinook salmon redds. The majority (87 of 99; 88%) of superimposition was identified between November 5 and November 21, 2012 (Figure 5.5-1). There was no evidence of *O. mykiss* redd superimposition during the 2012/2013 study period.

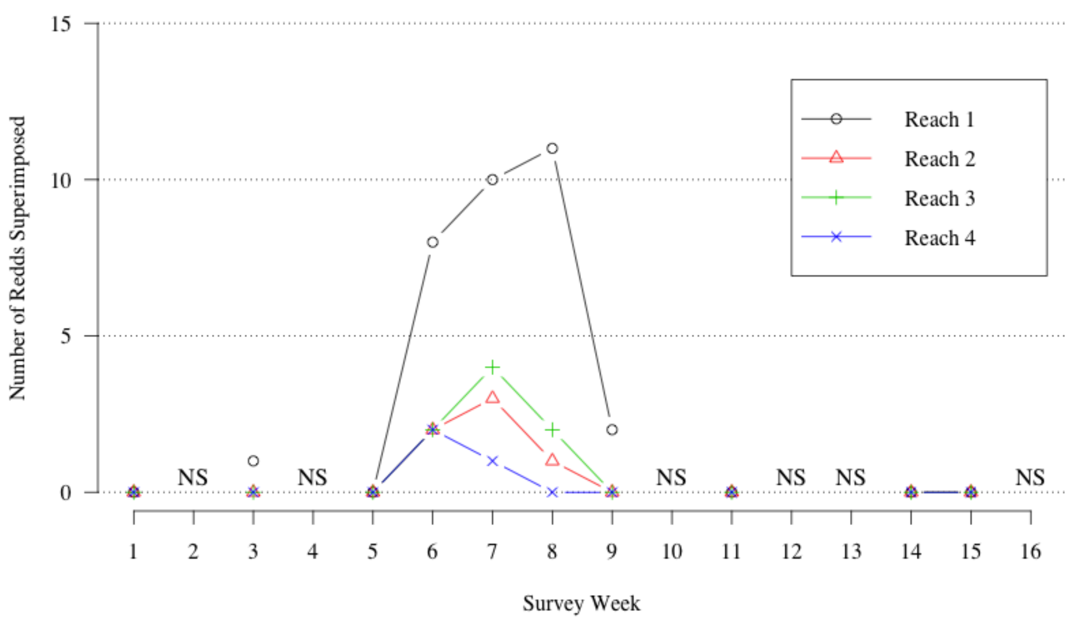

Figure 5.5-1. Total number of Chinook salmon redds superimposed by survey week (surveys began on October 1, 2012) and by reach on the lower Tuolumne River during fall and winter 2012/2013. "NS" denotes that no surveys were conducted during that week.

Redd superimposition was highest in Reach 1 where a measureable degree of superimposition was identified at 50 redd locations. The number of superimposition events varied by river mile, with most superimposition events occurring above RM 44 (Figure 5.5-2). The highest number of observed superimposition events occurred at RM 51 (11 FW Riffle), where spawning gravel augmentation was conducted in 2011. Other locations that experienced more than 5 superimposition events were riffles 14 (RM 50.6), 25 (RM 49.5), 54 (RM 46) and 57 (RM 45.9). Reaches 2 and 3 had 22 and 24 superimposition events, respectively, and only three superimposition events were observed in Reach 4.

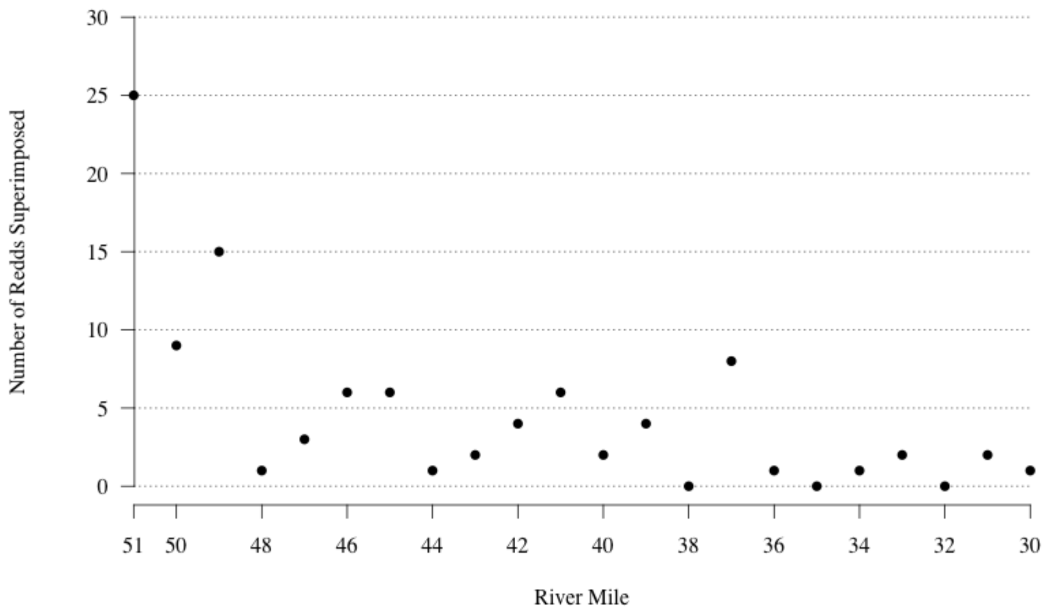

Figure 5.5-2. Total number of Chinook salmon redds superimposed by river mile on the lower Tuolumne River during fall and winter 2012/2013. Surveys began on October 1, 2012 and lasted until mid-January for Chinook salmon.

The amount of overlap between measured redd areas of two superimposed redds was used to indicate the degree of superimposition. Based on GIS analysis, the degree of superimposition for 49 redds during the 2012/2013 sampling period was determined. The degree of superimposition ranged from incidental (0.2%) to total (96.4%), with an average overlap of 32.5 percent (Figure 5.5-3).

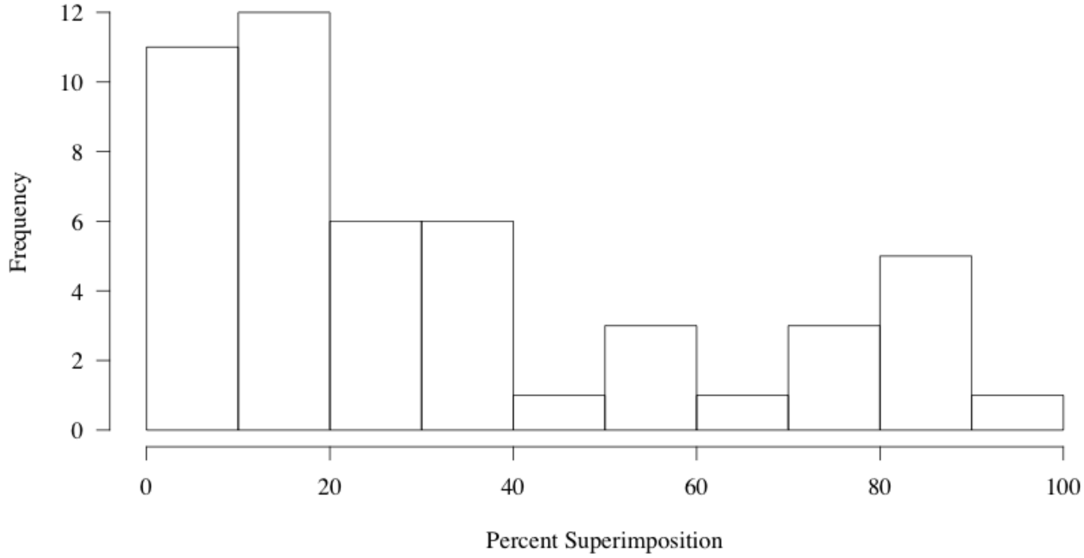

Figure 5.5-3. Histogram of the degree of redd superimposition (grouped in bins of 10% increments) among observed superimposed Chinook salmon redds on the lower Tuolumne River during fall and winter 2012/2013.

6.0 DISCUSSION AND FINDINGS

Similar to previous Tuolumne River studies (TID/MID 1992), there was a strong positive relationship between upriver location (i.e., increased river mile) and Chinook spawning usage. Although Reach 1 (RM 52 to RM 47.4) contains less than 25 percent of the available suitable spawning habitat in the Tuolumne River (McBain and Trush 2004), more than half of the Chinook salmon spawning activity is consistently observed in this reach. While redd densities in two restored riffles (RM 50.6 and RM 51) were the two highest densities observed for all 88 riffles surveyed, there was no statistical difference between mean redd densities in restored riffles versus unrestored riffles during 2012/2013. The rate of redd superimposition was also highest within Reach 1, accounting for 50.5 percent of observed superimposition events during 2012/2013.

The redd measurement data collected by this 2012/2013 study is being used in conjunction with the interrelated relicensing studies (e.g., W&AR-04 Spawning Gravel Study, W&AR-06 Tuolumne River Chinook Salmon Population Model, and W&AR-10 *O. Mykiss* Population Study) to quantify potential redd superimposition effects on juvenile production as well as to provide an upper bound on maximum spawning run sizes supported under current conditions.

7.0 STUDY VARIANCES AND MODIFICATIONS

The study was conducted consistent with the approved study plan. No variances occurred.

The study is complete. No modifications are proposed.

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STUDY REPORT W&AR-08
SALMONID REDD MAPPING

ATTACHMENT A

DAILY MEAN WATER TEMPERATURES IN THE TUOLUMNE RIVER DURING OCTOBER 2012 THROUGH APRIL 2013

Table A-1. Daily mean water temperatures in the Tuolumne River during October 2012 through April 2013.

Date	Hughson Sewer (RM 23.6) Temperature (F)	Waterford (RM 29.8) Temperature (F)	Hickman Bridge (RM 31.6) Temperature (F)	Roberts Ferry (RM 39.6) Temperature (F)	Riffle 21 (RM 42.9) Temperature (F)	Riffle 13B (RM 45.5) Temperature (F)	Riffle 3B (RM 49.0) Temperature (F)	Riffle A7 (RM 50.8) Temperature (F)
10/01/12	73.5	72.3	71.3	66.4	63.8	61.0	55.2	55.4
10/02/12	73.4	71.6	70.6	65.2	62.5	60.0	54.8	55.2
10/03/12	73.5	70.1	69.8	64.4	62.1	59.8	54.7	55.3
10/04/12	72.7	69.3	68.5	63.8	61.7	59.5	54.5	55.2
10/05/12	71.5	67.7	67.1	62.8	60.9	58.9	54.1	55.0
10/06/12	70.2	66.4	66.0	62.0	60.2	58.4	54.0	54.9
10/07/12	69.0	65.9	65.6	61.9	60.2	58.5	54.0	54.9
10/08/12	67.9	65.5	65.3	61.6	60.0	58.3	53.8	54.8
10/09/12	67.1	64.9	64.6	61.0	59.4	57.9	54.1	55.4
10/10/12	66.7	64.5	64.4	60.8	59.5	58.3	54.6	55.8
10/11/12	65.6	63.2	63.3	60.3	59.0	57.6	53.7	55.5
10/12/12	64.9	61.7	61.9	59.3	57.9	56.9	53.4	54.9
10/13/12	64.1	61.5	61.6	59.0	57.7	56.8	53.5	54.8
10/14/12	63.8	62.5	62.6	59.7	58.7	57.5	53.4	54.5
10/15/12	64.0	63.5	63.6	60.3	58.9	57.6	53.5	54.5
10/16/12	64.9	64.8	64.8	61.1	59.6	58.2	54.0	54.7
10/17/12	65.5	65.0	64.9	61.5	60.0	58.3	53.7	54.6
10/18/12	66.3	64.9	64.9	61.2	59.4	58.0	53.9	54.8
10/19/12	66.9	65.5	65.4	61.6	59.9	58.4	53.9	54.8
10/20/12	66.5	63.8	63.2	58.9	57.0	55.5	52.2	53.8
10/21/12	64.4	58.2	57.7	56.1	55.2	54.3	51.6	53.6
10/22/12	59.1	56.5	56.2	55.4	54.6	53.9	51.4	53.4
10/23/12	57.2	56.0	55.9	55.1	54.5	54.0	51.5	53.5
10/24/12	56.6	55.3	55.1	54.3	53.9	53.6	51.3	53.4
10/25/12	56.6	56.3	56.3	55.5	55.1	54.7	52.0	53.8
10/26/12	57.0	56.6	56.6	55.5	55.0	54.5	51.8	53.7
10/27/12	57.7	57.0	57.1	55.7	55.3	54.8	52.2	53.9
10/28/12	58.5	58.4	58.5	56.7	56.3	55.7	52.7	54.3
10/29/12	59.3	59.3	59.4	57.4	56.7	56.0	52.8	54.3
10/30/12	60.2	59.9	59.9	57.6	56.8	56.1	53.1	54.8
10/31/12	60.8	60.0	60.0	57.7	57.0	56.1	52.7	54.3

Date	Hughson Sewer (RM 23.6) Temperature (F)	Waterford (RM 29.8) Temperature (F)	Hickman Bridge (RM 31.6) Temperature (F)	Roberts Ferry (RM 39.6) Temperature (F)	Riffle 21 (RM 42.9) Temperature (F)	Riffle 13B (RM 45.5) Temperature (F)	Riffle 3B (RM 49.0) Temperature (F)	Riffle A7 (RM 50.8) Temperature (F)
11/01/12	61.2	59.6	59.7	57.9	56.7	55.7	52.5	54.2
11/02/12	60.9	58.9	58.9	57.1	56.1	55.4	52.5	54.2
11/03/12	60.5	58.7	58.9	56.6	56.0	55.4	52.4	54.2
11/04/12	60.3	58.8	58.9	56.6	56.1	55.5	52.5	54.2
11/05/12	60.3	59.0	59.1	56.9	56.4	55.8	52.8	54.5
11/06/12	60.4	59.3	59.3	57.1	56.6	56.0	52.8	54.4
11/07/12	60.4	58.6	58.7	56.9	56.3	55.5	52.3	53.9
11/08/12	60.1	58.5	58.3	56.2	55.5	54.7	51.7	53.7
11/09/12	58.8	56.3	56.1	54.6	54.1	53.4	50.8	53.0
11/10/12	57.6	54.7	54.6	53.2	53.0	52.6	50.5	52.8
11/11/12	55.8	52.8	52.7	51.9	51.9	51.7	49.7	52.3
11/12/12	54.5	52.1	52.2	51.3	51.5	51.5	49.7	52.2
11/13/12	53.6	51.9	52.1	51.4	51.7	51.7	49.9	52.3
11/14/12	53.0	52.3	52.6	52.0	52.3	52.3	50.3	52.6
11/15/12	52.8	52.6	52.9	52.4	52.5	52.5	50.3	52.6
11/16/12	53.3	53.5	53.8	53.4	53.3	53.2	50.7	52.8
11/17/12	54.5	55.4	55.7	55.2	54.8	54.5	51.8	53.4
11/18/12	55.5	56.8	56.7	55.9	55.4	54.7	51.7	53.4
11/19/12	56.4	56.3	56.3	55.2	54.7	54.2	51.6	53.5
11/20/12	57.1	56.2	56.2	54.7	54.4	54.0	51.4	53.4
11/21/12	57.6	56.5	56.5	55.3	54.9	54.4	51.5	53.4
11/22/12	57.0	55.8	55.8	54.5	53.9	53.4	50.8	53.1
11/23/12	56.5	54.8	54.8	53.3	53.1	52.8	50.5	52.7
11/24/12	56.0	54.2	54.5	53.2	53.0	52.9	50.6	52.8
11/25/12	55.4	53.8	54.0	52.9	52.9	52.8	50.6	52.8
11/26/12	54.8	53.4	53.5	52.4	52.6	52.6	50.5	52.8
11/27/12	54.4	53.2	53.4	52.5	52.5	52.3	50.2	52.6
11/28/12	54.3	53.2	53.5	53.0	52.8	52.7	50.5	52.6
11/29/12	54.3	54.0	54.3	54.1	53.9	53.6	51.2	53.0
11/30/12	54.9	55.5	55.8	55.3	54.9	54.5	51.8	53.5
12/01/12	55.6	56.4	56.6	55.9	55.2	54.6	51.9	53.6
12/02/12	56.6	57.1	57.1	56.2	55.6	55.0	52.1	53.8

Date	Hughson Sewer (RM 23.6) Temperature (F)	Waterford (RM 29.8) Temperature (F)	Hickman Bridge (RM 31.6) Temperature (F)	Roberts Ferry (RM 39.6) Temperature (F)	Riffle 21 (RM 42.9) Temperature (F)	Riffle 13B (RM 45.5) Temperature (F)	Riffle 3B (RM 49.0) Temperature (F)	Riffle A7 (RM 50.8) Temperature (F)
12/03/12	56.6	55.7	55.6	54.9	54.7	54.3	51.9	53.6
12/04/12	56.9	55.7	55.8	55.1	54.8	54.2	51.6	53.4
12/05/12	56.7	56.1	56.2	55.4	54.8	54.2	51.5	53.1
12/06/12	56.8	56.5	56.5	55.5	54.9	54.4	51.4	53.1
12/07/12	56.6	55.8	55.9	55.2	--[1]	54.1	51.2	53.0
12/08/12	55.7	54.3	54.5	53.3	--[1]	52.5	50.2	52.4
12/09/12	55.2	53.7	53.9	53.1	--[1]	52.9	50.3	52.2
12/10/12	54.4	53.2	53.3	52.1	--[1]	51.6	49.7	51.9
12/11/12	53.8	52.6	52.7	51.4	--[1]	51.7	49.6	51.7
12/12/12	53.6	52.4	52.6	51.9	--[1]	51.8	49.5	51.7
12/13/12	52.5	51.1	50.9	50.5	--[1]	50.6	48.9	51.2
12/14/12	51.5	49.7	49.7	49.2	--[1]	49.7	48.1	50.5
12/15/12	50.5	48.9	48.9	48.9	--[1]	49.6	48.1	50.5
12/16/12	50.0	49.0	49.1	49.2	--[1]	49.8	48.3	50.6
12/17/12	50.3	50.6	50.8	50.8	--[1]	51.3	49.3	51.3
12/18/12	50.0	51.0	51.1	51.0	--[1]	51.4	49.1	51.5
12/19/12	49.4	49.1	49.0	48.4	48.7	49.1	47.8	50.5
12/20/12	49.2	47.5	47.5	47.1	48.0	48.5	47.2	49.8
12/21/12	48.4	46.7	46.8	46.9	47.7	48.2	47.2	50.1
12/22/12	48.2	47.7	47.8	48.5	49.3	49.8	48.2	50.4
12/23/12	48.1	48.9	49.1	49.7	50.1	50.2	48.5	50.8
12/24/12	48.6	49.9	50.1	50.2	50.5	50.8	49.2	51.3
12/25/12	49.2	50.1	50.2	50.4	51.0	51.0	49.0	51.3
12/26/12	49.9	50.2	50.4	50.7	50.8	50.9	49.0	51.2
12/27/12	49.9	50.2	50.3	50.4	50.4	50.7	48.9	51.1
12/28/12	49.5	48.9	48.9	48.9	49.3	49.4	48.0	50.5
12/29/12	49.6	48.8	48.9	49.2	49.6	49.9	48.2	50.5
12/30/12	48.8	48.2	48.3	48.7	49.2	49.6	48.1	50.5
12/31/12	48.3	47.7	47.8	47.9	48.7	49.1	47.7	50.2
01/01/13	47.8	47.2	47.4	47.7	48.5	49.1	47.8	50.5
01/02/13	47.4	47.0	47.1	47.2	48.2	48.8	47.5	50.1
01/03/13	47.0	46.7	46.8	47.0	48.0	48.7	47.6	50.3

Date	Hughson Sewer (RM 23.6) Temperature (F)	Waterford (RM 29.8) Temperature (F)	Hickman Bridge (RM 31.6) Temperature (F)	Roberts Ferry (RM 39.6) Temperature (F)	Riffle 21 (RM 42.9) Temperature (F)	Riffle 13B (RM 45.5) Temperature (F)	Riffle 3B (RM 49.0) Temperature (F)	Riffle A7 (RM 50.8) Temperature (F)
01/04/13	46.9	46.9	47.0	47.2	48.3	49.0	47.8	50.4
01/05/13	47.0	47.2	47.4	47.7	48.8	49.4	48.1	50.6
01/06/13	47.7	48.5	48.8	49.4	49.8	50.2	48.4	50.8
01/07/13	47.7	48.7	48.9	49.0	49.2	49.6	48.1	50.5
01/08/13	48.3	48.6	48.6	48.6	49.3	49.9	48.5	50.9
01/09/13	48.7	48.8	48.9	49.0	49.8	50.2	48.5	50.8
01/10/13	48.5	48.4	48.7	49.0	49.5	49.9	48.2	50.8
01/11/13	48.0	47.5	47.5	47.5	48.1	48.6	47.3	50.0
01/12/13	47.5	46.4	46.4	46.6	47.4	48.0	47.0	49.8
01/13/13	46.5	45.4	45.5	45.9	46.9	47.7	46.7	49.6
01/14/13	45.6	44.5	44.6	45.3	46.5	47.3	46.3	49.0
01/15/13	45.2	44.8	45.0	45.6	46.7	47.5	46.5	49.1
01/16/13	44.9	45.2	45.4	46.0	47.2	47.9	46.8	49.4
01/17/13	45.1	45.9	46.1	46.4	47.6	48.4	47.4	50.1
01/18/13	45.7	46.6	46.8	47.0	48.3	49.0	47.6	50.1
01/19/13	46.3	47.2	47.3	47.5	48.6	49.1	47.6	50.1
01/20/13	46.9	47.6	47.8	47.8	48.7	49.2	47.6	50.1
01/21/13	47.5	47.8	47.9	47.8	48.7	49.1	47.6	50.1
01/22/13	48.0	48.2	48.2	48.2	49.2	49.6	47.9	50.3
01/23/13	48.7	49.1	49.3	49.5	50.2	50.5	48.5	50.8
01/24/13	49.5	49.7	50.0	50.9	51.3	51.4	49.1	51.1
01/25/13	50.7	52.2	52.3	52.3	52.5	52.2	49.6	51.4
01/26/13	52.3	54.1	54.1	53.7	53.4	52.9	50.0	51.8
01/27/13	52.4	53.2	53.1	52.2	51.7	51.3	49.0	51.3
01/28/13	52.6	51.5	51.2	50.1	50.1	50.0	48.0	50.4
01/29/13	52.6	50.4	50.2	49.4	49.5	49.6	47.7	50.0
01/30/13	52.2	50.1	50.0	49.3	49.6	49.8	48.0	50.2
01/31/13	51.8	50.5	50.4	49.8	50.3	50.5	48.5	50.7
02/01/13	51.6	51.1	51.1	50.4	51.0	51.1	48.8	51.0
02/02/13	51.7	51.5	51.5	51.0	51.3	51.2	48.9	51.0
02/03/13	51.8	51.4	51.3	51.0	51.1	51.0	48.9	51.0
02/04/13	52.3	52.2	52.1	51.1	51.5	51.4	49.2	51.2

Date	Hughson Sewer (RM 23.6) Temperature (F)	Waterford (RM 29.8) Temperature (F)	Hickman Bridge (RM 31.6) Temperature (F)	Roberts Ferry (RM 39.6) Temperature (F)	Riffle 21 (RM 42.9) Temperature (F)	Riffle 13B (RM 45.5) Temperature (F)	Riffle 3B (RM 49.0) Temperature (F)	Riffle A7 (RM 50.8) Temperature (F)
02/05/13	52.7	52.5	52.5	51.6	51.7	51.6	49.1	51.2
02/06/13	52.9	52.2	52.0	51.2	51.1	50.9	48.5	50.8
02/07/13	53.2	51.6	51.4	50.8	50.6	50.6	48.4	50.6
02/08/13	52.7	50.9	50.8	50.4	50.3	50.2	48.1	50.3
02/09/13	51.8	50.0	49.8	49.5	49.4	49.4	47.6	50.0
02/10/13	51.2	49.7	49.7	49.2	49.5	49.7	47.9	50.2
02/11/13	51.0	50.1	50.0	49.5	50.0	50.1	48.1	50.3
02/12/13	51.1	50.6	50.6	49.9	50.4	50.5	48.4	50.4
02/13/13	51.4	51.3	51.3	50.5	50.9	50.9	48.7	50.9
02/14/13	52.1	52.1	52.1	51.0	51.5	51.5	49.1	51.0
02/15/13	52.9	53.1	53.0	51.8	52.2	52.1	49.5	51.4
02/16/13	53.6	53.7	53.7	52.4	52.6	52.3	49.3	51.1
02/17/13	54.1	53.9	53.7	52.4	52.2	51.9	49.2	51.1
02/18/13	54.6	54.1	53.9	52.3	52.4	52.0	49.3	51.1
02/19/13	54.4	53.2	53.0	52.2	52.0	51.7	48.5	50.7
02/20/13	53.6	51.6	51.4	50.7	50.2	50.0	48.0	50.1
02/21/13	53.3	52.0	51.9	50.6	50.8	50.7	48.5	50.5
02/22/13	53.1	52.1	52.0	51.0	51.3	51.1	48.6	50.5
02/23/13	53.6	53.4	53.3	52.3	52.3	52.3	49.2	51.0
02/24/13	53.2	52.6	52.4	51.6	51.7	51.2	48.6	50.5
02/25/13	53.8	53.1	53.0	51.7	51.8	51.5	48.9	50.7
02/26/13	54.0	53.5	53.3	52.0	52.0	51.7	48.8	50.7
02/27/13	54.3	53.7	53.5	52.1	52.2	51.8	49.1	50.8
02/28/13	55.3	53.6	54.0	53.1	53.1	52.6	49.5	51.1
03/01/13	56.3	56.4	56.3	54.1	54.1	53.4	50.0	51.3
03/02/13	57.5	57.6	57.4	55.0	54.8	53.8	50.0	51.3
03/03/13	58.8	58.7	58.4	56.3	55.6	54.5	50.3	51.4
03/04/13	59.2	58.6	58.3	55.9	54.9	53.6	50.0	51.3
03/05/13	59.8	58.8	58.4	55.6	54.9	53.9	50.1	51.4
03/06/13	59.5	57.8	57.4	55.3	54.2	53.3	49.4	50.9
03/07/13	59.0	56.5	56.1	54.2	53.0	52.1	49.1	50.8
03/08/13	58.9	56.6	56.3	54.2	53.7	52.8	49.4	50.9

Date	Hughson Sewer (RM 23.6) Temperature (F)	Waterford (RM 29.8) Temperature (F)	Hickman Bridge (RM 31.6) Temperature (F)	Roberts Ferry (RM 39.6) Temperature (F)	Riffle 21 (RM 42.9) Temperature (F)	Riffle 13B (RM 45.5) Temperature (F)	Riffle 3B (RM 49.0) Temperature (F)	Riffle A7 (RM 50.8) Temperature (F)
03/09/13	58.2	56.7	56.5	54.7	54.1	53.3	49.8	51.1
03/10/13	58.3	57.3	57.1	54.9	54.4	53.4	49.8	51.1
03/11/13	58.8	58.0	57.9	55.3	54.7	53.7	50.0	51.2
03/12/13	59.7	59.2	59.0	56.1	55.5	54.4	50.5	51.5
03/13/13	60.9	60.6	60.4	57.1	56.4	55.1	50.8	51.6
03/14/13	62.2	61.5	61.2	57.6	56.6	55.1	50.7	51.6
03/15/13	62.7	61.4	61.0	57.8	56.6	55.2	50.7	51.6
03/16/13	63.2	61.2	60.9	57.8	56.4	55.0	50.8	51.7
03/17/13	63.0	61.3	61.0	57.8	56.5	55.1	50.6	51.6
03/18/13	62.8	60.5	60.2	57.1	55.9	54.4	50.2	51.3
03/19/13	63.1	60.7	60.4	57.2	56.1	54.7	50.6	51.6
03/20/13	63.1	61.2	60.9	57.9	56.7	55.2	50.7	51.6
03/21/13	62.5	60.9	60.6	57.7	56.4	55.2	51.1	52.0
03/22/13	61.4	59.4	59.2	56.7	55.7	54.5	50.2	51.5
03/23/13	60.8	58.2	58.0	55.7	54.7	53.5	50.0	51.3
03/24/13	60.9	59.0	58.9	56.2	55.4	54.3	50.6	51.6
03/25/13	61.3	60.2	60.1	57.3	56.2	54.9	50.6	51.5
03/26/13	61.7	60.8	60.4	57.5	56.2	55.0	50.7	51.6
03/27/13	62.8	61.4	61.2	58.2	56.9	55.4	51.2	52.0
03/28/13	63.9	63.2	63.1	59.8	58.3	56.6	51.7	52.1
03/29/13	65.0	64.4	64.2	60.1	58.3	56.4	51.6	52.2
03/30/13	66.4	65.5	65.2	60.6	58.9	57.2	52.2	52.5
03/31/13	67.1	65.6	65.1	61.6	59.9	57.8	52.1	52.4
04/01/13	67.6	65.6	65.2	61.5	59.3	57.2	51.9	52.3
04/02/13	67.4	65.4	65.0	60.7	58.7	56.7	51.9	52.5
04/03/13	67.8	65.4	63.1	60.6	58.9	57.1	52.2	52.5
04/04/13	67.9	65.5	61.2	60.7	58.8	56.8	51.5	52.1
04/05/13	67.3	64.6	60.7	60.3	58.2	56.4	51.8	52.4
04/06/13	67.1	64.4	62.8	60.1	58.5	56.8	52.0	52.6
04/07/13	67.0	64.5	62.9	60.5	58.8	57.0	52.4	53.2
04/08/13	65.6	63.4	61.9	60.0	58.5	57.0	52.3	53.1
04/09/13	64.3	62.0	61.3	58.9	57.7	56.2	51.8	52.5

Date	Hughson Sewer (RM 23.6) Temperature (F)	Waterford (RM 29.8) Temperature (F)	Hickman Bridge (RM 31.6) Temperature (F)	Roberts Ferry (RM 39.6) Temperature (F)	Riffle 21 (RM 42.9) Temperature (F)	Riffle 13B (RM 45.5) Temperature (F)	Riffle 3B (RM 49.0) Temperature (F)	Riffle A7 (RM 50.8) Temperature (F)
04/10/13	64.7	63.0	62.3	59.8	58.7	57.0	52.3	52.7
04/11/13	65.8	64.0	63.0	61.7	60.1	58.1	52.7	52.9
04/12/13	66.5	66.4	66.1	61.9	60.3	58.1	52.5	52.6
04/13/13	67.6	66.7	66.2	61.9	59.8	57.7	52.3	52.6
04/14/13	67.8	65.7	65.2	61.2	59.3	57.4	52.0	52.3
04/15/13	66.9	62.9	62.1	58.0	55.1	53.3	49.5	51.0
04/16/13	63.5	56.9	56.4	54.3	53.3	52.5	49.4	51.0
04/17/13	58.8	56.7	56.5	54.8	53.7	52.8	49.6	51.2
04/18/13	58.9	58.1	57.8	55.6	54.5	53.4	49.9	51.2
04/19/13	60.7	59.8	59.3	56.5	55.1	53.9	50.2	51.4
04/20/13	62.6	61.1	60.5	57.6	56.1	54.5	50.4	51.5
04/21/13	63.6	60.4	59.5	56.3	54.6	53.2	49.7	51.3
04/22/13	62.4	58.6	58.1	55.7	54.5	53.3	50.0	51.4
04/23/13	61.0	58.9	58.5	56.1	54.6	53.4	50.0	51.4
04/24/13	61.3	59.1	58.6	56.1	54.7	53.5	50.0	51.4
04/25/13	61.8	59.5	58.9	56.4	55.0	53.7	50.1	51.5
04/26/13	62.0	59.6	58.9	56.4	54.9	53.6	50.1	51.5
04/27/13	62.1	59.0	58.4	56.0	54.6	53.4	49.9	51.5
04/28/13	61.0	58.4	57.9	55.7	54.6	53.6	50.2	51.7
04/29/13	61.1	59.4	58.8	56.3	55.0	53.8	50.2	51.7
04/30/13	61.8	59.4	58.8	56.3	54.8	53.5	50.1	51.6

[1] Data unavailable do to a thermograph malfunction.

STUDY REPORT W&AR-08
SALMONID REDD MAPPING

ATTACHMENT B

CHINOOK SALMON AND *O. MYKISS* SPAWNING DISTRIBUTION ON THE TUOLUMNE RIVER DURING 2012/2013

Table B-1. Chinook salmon and *O. mykiss* spawning distribution on the Tuolumne River during 2012/2013.

Riffle ID	RM	Riffle Area (ft^2)	# Chinook Redds	Chinook Redd Density (redd/100ft^2)	# *O. mykiss* Redds
4 FW Riffle	51.9	38,804	25	0.064	0
11 FW Riffle	51	53,581	9	0.017	0
11 FW Riffle-R[1]	51	6,287	16	0.254	0
11 FW Riffle-R2011[1]	51	14,222	62	0.436	11
14 BC Riffle	50.6	44,651	12	0.010	5
14 BC Riffle-DFW[1]	50.6	73,207	55	0.075	0
18 BC Riffle	50.4	30,596	1	0.003	0
21 FW Riffle	50	63,348	14	0.022	0
25 BC Riffle	49.5	60,699	39	0.064	3
27 FW Riffle	49.2	15,468	13	0.084	4
30 FW Riffle	49.1	114,769	28	0.024	0
33 FW Riffle	48.5	155,935	15	0.010	0
36 BC Riffle	48.3	24,008	1	0.004	1
38 BC Riffle	48.1	13,651	4	0.029	0
41 BC Riffle	47.2	68,536	21	0.031	1
43 FW Riffle	47	29,713	10	0.034	0
46 FW Riffle	46.8	26,942	6	0.022	0
54 BC Riffle	46	55,788	17	0.030	5
57 BC Riffle	45.9	96,122	29	0.030	4
61 BC Riffle	45.7	38,773	0	0.000	0
70 BC Riffle	45.2	20,526	2	0.010	0
72 BC Riffle	45	39,428	8	0.020	1
75 BC Riffle	44.9	8,525	2	0.023	0
79 BC Riffle	44.8	10,295	1	0.010	0
81 BC Riffle	44.7	23,334	0	0.000	0
89 BC Riffle-Bobcat U[1]	43.5	22,310	5	0.022	1
91 BC Riffle- Bobcat M[1]	43.1	16,373	2	0.012	0
94 BC Riffle- Bobcat L[1]	43	11,183	1	0.009	0
96 BC Riffle	42.8	7,851	3	0.038	0
99 BC Riffle	42.4	25,364	5	0.020	0
102 BC Riffle	42.4	16,428	1	0.006	0
104 FW Riffle	42.4	15,413	4	0.026	0
107 BC Riffle	42.2	37,954	13	0.034	1
109 BC Riffle	41.9	29,689	11	0.037	0
116 BC Riffle	41.1	19,520	12	0.061	0
120 BC Riffle	40.4	19,120	5	0.026	0
124 BC Riffle	39.6	28,817	4	0.014	1
285 BC Riffle	39.3	6,786	8	0.118	0
126 BC Riffle	39.1	36,186	2	0.006	0
128 FW Riffle	38.7	13,475	6	0.045	0
132 FW Riffle	38.4	9,176	1	0.011	0
135 BC Riffle	38.3	45,119	5	0.011	0
140 BC Riffle	37.9	36,089	3	0.008	0

Riffle ID	RM	Riffle Area (ft^2)	# Chinook Redds	Chinook Redd Density (redd/100ft^2)	# *O. mykiss* Redds
144 BC Riffle	37.7	42,122	4	0.009	0
146 BC Riffle	37.5	24,624	9	0.037	0
148 BC Riffle	37.3	26,748	8	0.030	0
152 BC Riffle	37	35,940	1	0.003	0
156 BC Riffle	36.9	36,182	2	0.006	0
158 BC Riffle	36.7	13,904	1	0.007	0
160 BC Riffle	36.5	14,309	3	0.021	0
162 BC Riffle	36.4	27,731	1	0.004	0
165 FW Riffle	35.7	37,627	3	0.008	0
167 BC Riffle	35.3	8,700	2	0.023	0
170 BC Riffle	35.2	35,329	1	0.003	0
172 BC Riffle	35.1	13,278	2	0.015	0
175 BC Riffle	34.8	21,135	1	0.005	0
182 BC Riffle	34.3	32,429	2	0.006	0
185 BC Riffle	34.2	54,462	1	0.002	0
187 BC Riffle	34	67,286	0	0.000	0
190 BC Riffle	33.8	14,143	3	0.021	0
192 BC Riffle	33.6	17,312	0	0.000	0
194 BC Riffle	33.4	45,803	1	0.002	0
197 FW Riffle	32.6	25,154	3	0.012	0
200 BC Riffle	32.4	23,300	6	0.026	0
203 BC Riffle	32.2	27,765	3	0.011	0
206 BC Riffle	32	28,305	0	0.000	0
209 BC Riffle	31.8	42,196	3	0.007	0
211 BC Riffle	31.7	11,667	1	0.009	0
214 FW Riffle	31.3	22,235	0	0.000	0
216 BC Riffle	31.1	46,057	0	0.000	0
219 BC Riffle	31	98,003	6	0.006	0
221 BC Riffle	30.8	29,697	3	0.010	0
227 FW Riffle	30.2	8,050	0	0.000	0
229 FW Riffle	30.2	5,379	2	0.037	0
235 BC Riffle	29.9	26,243	9	0.034	0
237 BC Riffle	29.7	19,403	0	0.000	0
240 FW Riffle	27.9	6,845	0	0.000	0
242 FW Riffle	27.8	12,750	0	0.000	0
244 FW Riffle	26	44,415	3	0.007	0
246 FW Riffle	25.9	11,081	0	0.000	0
248 FW Riffle	25.7	16,353	0	0.000	0
250 FW Riffle	25.6	104,566	0	0.000	0
253 FW Riffle	25.1	33,484	1	0.003	0
255 FW Riffle	24.8	37,399	0	0.000	0
257 FW Riffle	24.5	26,956	0	0.000	0
259 BC Riffle	24.2	28,935	0	0.000	0
261 FW Riffle	23.8	17,155	6	0.035	0
263 FW Riffle	23.6	12,972	0	0.000	0

[1] Gravel augmentation sites