State of California
The Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE

Redd Dewatering and Juvenile Stranding in the Upper Sacramento River Year 2014-2015

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Cover photo: Iron Canyon, Sacramento River by P. Jarrett

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1/ This is the fifth year of this study on Sacramento River redd dewatering. This report and work described herein is funded in part by: the Central Valley Improvement Act Anadromous Fish Restoration Program and by the Federal Aid in Sport Fish Restoration Act (SFRA). Activities described in this report were undertaken through cooperative efforts with the California Department of Fish and Wildlife, the Pacific States Marine Fisheries Commission (PSMFC), and the U.S. Fish and Wildlife Service's Red Bluff Fish and Wildlife Office (USFWS), and were supported by various funding sources including: a U.S. Bureau of Reclamation (USBR) contract with the PSMFC, and a USFWS **Anadromous Fisheries Restoration Program (AFRP) grant (Agreement #81330AJ366)** with the PSMFC.

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SUMMARY

From June of 2014 through March of 2015 staff from the California Department of Fish and Wildlife (CDFW) and Pacific States Marine Fisheries Commission (PSMFC) working together from the CDFW's Red Bluff Fisheries Office (RBFO) conducted a fifth season of data collection to monitor redd dewatering and juvenile stranding-(third year) on the upper Sacramento River. Data on redd dewatering and juvenile stranding was collected from the city of Tehama at river mile (RM) 229 upstream to Keswick Dam (RM-302). This data provided information to fishery managers to guide management of flow releases from Keswick Dam in order to minimize impacts to Chinook salmon redds and juveniles in the Sacramento River.

During monitoring a combined 372 winter, spring, fall, and late-fall-run Chinook redds were marked and monitored. Of these, 47 (1-winter, 1-spring, 43-fall and 2-late-fall) were observed to be dewatered upon first observation or became dewatered as flows were reduced. An estimated 1,744 winter-run, 14,489 fall/spring-run mix, and 1,008 late-fall-run female salmon spawned in the upper Sacramento River in 2014 into 2015. Based on these population estimates, about 0.05% winter, 0.3% fall/spring mixed, and 0.2% late-fall-run Chinook salmon redds were dewatered to various degrees. For the fall/spring mix, large numbers of fish spawning over a period of months likely resulted in many fish spawning on or near the redds of earlier spawners. Individual redds are difficult to identify after multiple fish have spawned in close proximity. As a result, the combined fall and spring-run Chinook dewatered redd totals (44) observed this season represent only the actual marked and dewatered redds.

Juvenile stranding surveys were implemented to observe and report on locations that could potentially contain stranded salmonids that were isolated to varying degrees by flow reductions. Fish rescues were initiated during February 2014 and have become an essential component of these surveys. During monitoring, 174 stranding locations between the Keswick Dam (the uppermost limit of anadromy on the Sacramento River) and the Tehama Bridge (a total of 73 river miles) were observed. Crews logged 334 site visits to selected locations to observe and record data at different flow levels. An estimated 2,574 naturally spawned and 414 hatchery raised juvenile Chinook salmon including 798 endangered winter-run were observed stranded in isolated sites. Of these, crews rescued 2,846 juvenile salmon including 693 winter-run.

The nearly "real-time" reporting of redd depth during the 2014-2015 season provided fishery managers the ability to make management recommendations to prevent the dewatering of redds this season. Regular meetings between fishery agencies and water agencies utilized the data generated by this survey to help manage the limited water resources available from Shasta Reservoir. Relatively few redds were dewatered by flow reductions during this period compared to previous years.

INTRODUCTION

The Sacramento River is the largest river system in California, yielding 35% of the state's water supply. This river system supports the largest contiguous riverine and wetland ecosystem in the Central Valley. The Upper Sacramento River Basin (USRB) of California's Central Valley is unique worldwide because it has four separate spawning runs of Chinook salmon (*Oncorhynchus tshawytscha*) including the federal and state listed endangered winter-run. Winter-run Chinook are endemic only to the USRB and historically thrived in the McCloud River (a tributary to the Sacramento River). Chinook salmon populations of the Sacramento River provide the majority of the state's sport and commercial catch (Killam, 2012). Each run of Chinook has adopted a unique life history (spawning locations, and seasonal timing) that allows it to survive the many different environmental conditions found over the course of a year in the USRB. Figure 1 shows the major spawning reaches of the Sacramento River, home to all four salmon runs.

Most of the Sacramento River flow is controlled by the U.S. Bureau of Reclamation's (USBR) operation of Shasta Dam, which stores up to 4.5 million acre-feet (maf) of water. The median historical unimpaired run-off above Red Bluff is 7.2 maf, with a range of 3.3-16.2 maf, (USFWS, 1995). Population levels of Chinook salmon in the upper Sacramento River reached historically low levels over the last several years (Killam, 2012). In addition California Central Valley steelhead (*Oncorhynchus mykiss*) were listed as threatened under the Federal Endangered Species Act in 1998, and status was reaffirmed in 2006. The 2011 status review (Williams et al. 2011) for Central Valley steelhead indicates that their status has diminished since the 2005 status review (Good et al. 2005), with updated information indicating an increased risk of extinction.

The Anadromous Fish Restoration Program (AFRP) Final Restoration Plan (U.S. Fish and Wildlife Service (USFWS, 2001), recommended six specific actions to address the declines in certain anadromous fish populations that had been observed since 1970. Of specific relevance to this study is the need (as salmon population levels have continued to remain low in the years since the 2001 Plan) for river flows that support and restore salmon and steelhead populations. As outlined in the Final Restoration Plan:

> *Changes in the natural frequency, magnitude, and timing of flows - Reservoirs have changed the natural flow regimes of the Sacramento River by changing frequency, magnitude, and timing of flow. Flows need to be established that support the life history needs of all four races of salmon and steelhead: spawning flows, stable flows for early life stages, outmigration flows, and flushing flows for sediment transport.*

Stable and continuous river flows are important to the early life history (egg incubation to emergence from the gravel) of salmonids. If redds are dewatered or exposed to warm, deoxygenated water, incubating eggs/larval fish may not survive. Additionally, during unstable flows, after emergence from their redd, juvenile salmon may become stranded in shallow isolated pools exposing them to the same poor environmental conditions as well as increased predation. In order for the eggs and juveniles to survive they need a

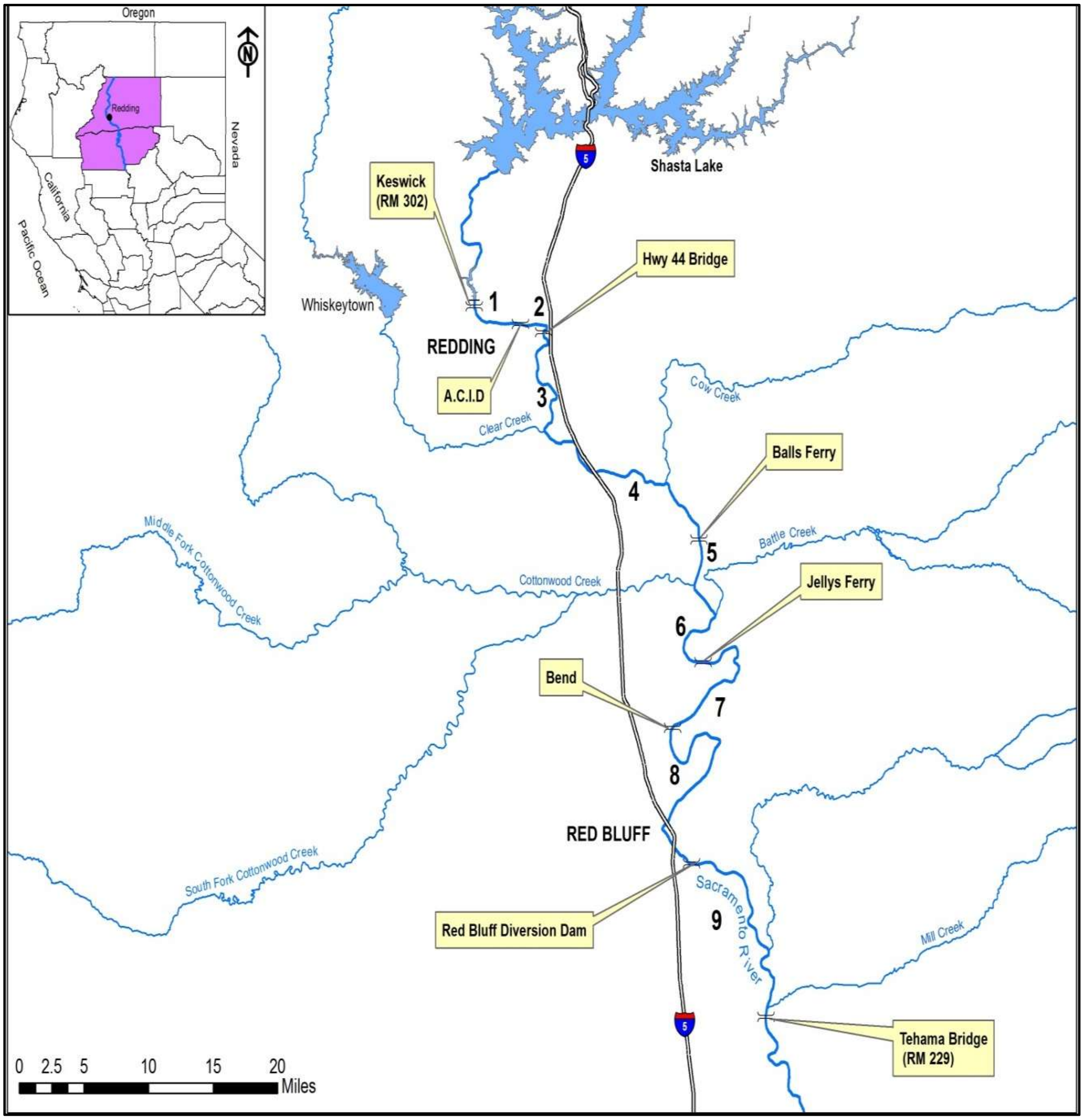

Figure 1. Map of the Upper Sacramento River Basin and study area from the Tehama Bridge to Keswick Dam (73 miles). River sections from study shown as numbers and based on river miles and landmarks.

consistent supply of water, of a suitable temperature, velocity, and water quality, at all times.

Action (A2) from the Final Restoration Plan addresses the concerns regarding flow management:

> *Upper Sacramento River, Action 2: 2. Implement a schedule for flow changes that avoids, to the extent controllable, dewatering redds and isolating or stranding juvenile anadromous salmonids, consistent with SWRCB Order 90-5.*

Relevant actions (Reasonable and Prudent Alternatives, or RPA's) found within the Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and the State Water Project (OCAP BO) (National Marine Fisheries Service, 2009) state the following:

> *Action I.2.2. November through February Keswick Release Schedule (Fall Actions). Objective: Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir. Action: Depending on EOS (End of September) carryover storage and hydrology, (Bureau of) Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.*

The OCAP BO identifies additional "sub" actions for implementation procedures when Shasta Reservoir has storage of various levels (2.4 million acre feet (maf) or higher, 1.9 maf to 2.4 maf, and below 1.9 maf, (Action I.2.2.A, B, and C respectively). These actions include developing release criteria that addresses the need for stable Sacramento River level/stage in order to increase habitat for optimal spring-run and fall-run Chinook redds/egg incubation, and/or to minimize redd dewatering and juvenile stranding. Additional relevant excerpts from the OCAP BO are included in Appendix A.

In 2000, California Department of Fish and Wildlife (CDFW) staff collected data which when compared to the aerial redd survey counts, showed that 18 percent of the total fall-run Chinook salmon (fall-run) redds had been dewatered in December 2000 (CDFW, unpublished data). While this was not a comprehensive study, (aerial survey is not a total count of redds and effort varies annually) it should be considered a valuable "incidental observation", as it provides detail on the amount of redds that were dewatered in one year.

Redd dewatering and juvenile stranding relationships based on flow fluctuations for the thirty-one river miles between Battle Creek and Keswick Dam (Figure 1) are well described in a 2006 report by Dr. Mark Gard of the USFWS for the Instream Flow Investigations of the Central Valley Project Improvement Act (CVPIA), (USFWS, 2006). This report was part of a seven year investigation to describe instream flow needs of anadromous species in CVPIA managed streams. The report provides an in-depth analysis of Sacramento River salmon spawning habitats and stranding sites and their relationship to river flows. The relationships found in the report can be used to predict the consequences of flow fluctuations and their impact to spawning habitat redd dewatering and juvenile stranding. An example table from Gard's 2006 report can be found in Appendix B. These tables can be used by resource managers to model impacts of proposed flow reductions to salmon populations. Data was collected from 1998 to 2001 for the Gard study and while much of this information is dated, its framework is likely still relevant today. The Gard study showed the significant impact that flow regime can have on salmon spawning success. The study did not however focus on the biological consequences or actual impacts of the dewatering or the stranding. In contrast the purpose of this current monitoring effort is to better determine the present day impacts to flow reductions on a relatively real time basis (daily, weekly, or seasonal). Real time monitoring of redd dewatering and stranding due to flow reductions is beneficial to managers to assist decision making based on actual conditions on the river. The timing of flow reductions can often be critical to the survival of large numbers of eggs or juveniles. Up-to-date information can provide fishery managers with the assurances they need to make decisions to mitigate flow changes, if the data shows that the biological consequences will be significant.

One source for flow reduction mitigation is to supplement Keswick Dam flows with water dedicated for environmental purposes. This water "account" is commonly referred to as "the B2 water" and is part of the CVPIA, section 3406(b)(2). This directs the Secretary of the Interior to dedicate and manage annually 800,000 acre-feet of CVP water yield for the purpose of implementing the fish, wildlife, and habitat restoration purposes and measures as authorized by the CVPIA. Water from the B2 account can be used to supplement existing flows to prevent dewatering and stranding. This, in combination with up-to-date information on salmon in the river and close coordination between the different water and fishery agencies, can help reduce the impacts of flow management to salmon survival on the Sacramento River.

Winter-run Chinook salmon (winter-run) begin spawning in the upper reaches of the Sacramento River below Keswick from early May through August. Redd surveys are necessary beginning in June to locate and monitor possible dewatering sites during flow reductions in late summer. Fall-run Chinook salmon (and limited spring-run Chinook) begin spawning in the Sacramento River from the first week of September through mid-to-late November (Killam and Johnson 2013). Late-fall-run Chinook salmon (late-fall-run) spawning begins in early-December and peaks in mid-December to mid-January. Field surveys during the months of September through March provide opportunities to observe and collect data on current year fall and late-fall-run redds that are constructed in shallow water along the stream margins and in riffles. These surveys allow subsequent surveys to document dewatering with assurance that an active redd is being impacted. Dewatering can occur anytime a flow reduction is made. A typical reduction in flow, or "stepping down" of flow, occurs from September to November as less water is needed for agricultural purposes. When flow decreases coincide with large numbers of salmon spawning the impacts to spawning success can be significant. Figure 2 shows the stepping down of flow in both from late summer through early winter of 2014.

Redd dewatering on the Sacramento River can be observed anytime, but the biological significance of the dewatering depends on the timing of the flow decreases. When flows are increasing or maintained at a constant level there is minimal concern that new redds will be dewatered or juveniles stranded. Juvenile salmon will reside in the redd after hatching until their yolk sac is absorbed then "swim up" or emerge between the gravel and escape the redd structure into the water column. The development from egg to "swim up fry" depends on water temperature during development, (Beacham 1990), but can typically take up to 100 days or more for water temperatures normal to the Sacramento River. Fall-run salmon spawning takes place in the fall when under natural conditions rainfall can be expected to maintain or increase natural flows. In the Sacramento River, under USBR managed Keswick Dam flow releases, this flow regime is often reversed (Figure 2) leading to decreased survival. Years in which flows are relatively high during the spawning season, and are then "stepped-down" as the season progresses can create conditions that result in high levels of redd dewatering for main stem spawning salmon.

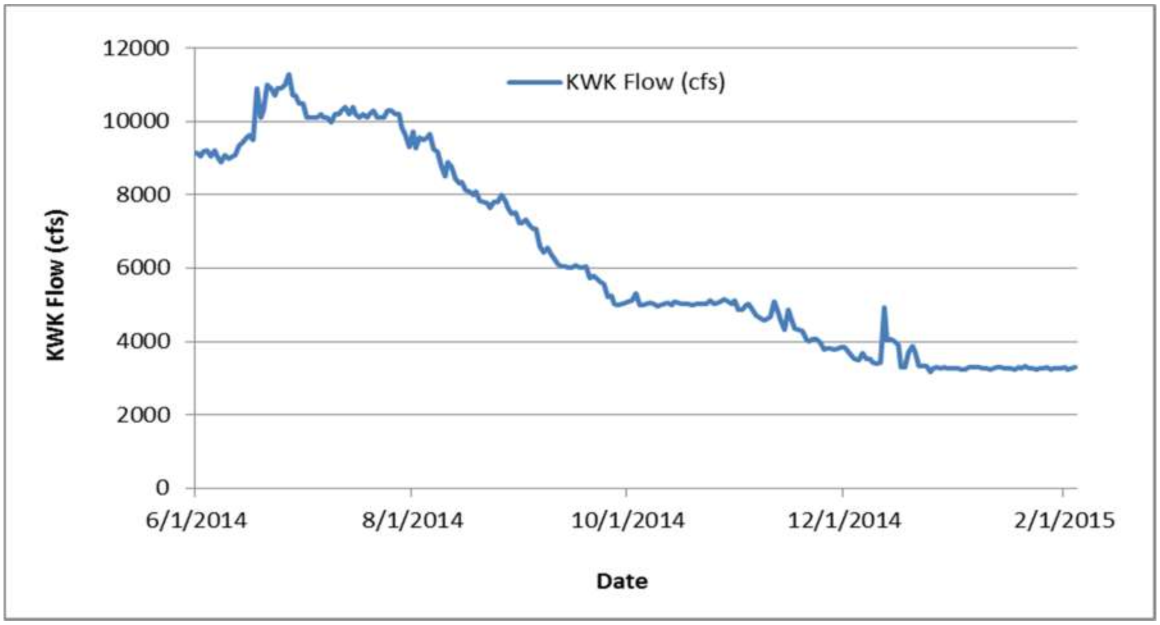

Figure 2. Flow releases from Keswick Dam on Sacramento River during selected periods in 2014 and 2015, from internet KWK-USGS gauge (CDEC, 2015).

Stranding of juvenile salmonids can also occur as a result of flow reductions throughout the Sacramento River. These stranding events have the potential to affect all four runs of the Sacramento Chinook (fall, late-fall, winter and spring-run). The historical migration timing of all four adult Chinook salmon runs passing the Red Bluff Diversion Dam is provided in Appendix B Table B2. Spawning and juvenile rearing occurs year round in the USRB with spawning peaks occurring in October through January (fall and late-fall-runs) and again in June and July (winter-run) (Killam 2012).

Redd dewatering assessment can be challenging. For example, if dewatered redds are first observed out of water, these redds may be ones that were made by salmon that spawned in earlier runs or previous years, and from which the juvenile fish have already vacated. This creates difficulty in verifying if a dewatered redd contains eggs or juveniles, or if it is an older, inactive redd from a previous salmon run. Another challenge is that storm events can cause flow fluctuations downstream of Keswick Dam. Storm inflow from the many tributary streams below Keswick Dam (Figure 1) has the potential to re-water redds for various periods of time. The larger tributaries (e.g. Cow and Cottonwood Creek(s)), can contribute flows that increase main stem flows for a much longer time period. Therefore, the best time to observe potential dewatered redds is immediately after Sacramento River flows have dropped but prior to large storms.

Most redds in this study were marked before dewatering even occurred and while adult female salmon were observed actively guarding the redd from other females. This marking of active redds (still underwater) assured that crews could positively identify these marked redds as redds with eggs in them from the current run of salmon and not redds from a previous run (e.g., Figure 3). Active marking has also allowed biologists to date each redd to provide an estimated fry emergence date for that particular redd.

This 2014-2015 year was the fifth season of redd dewatering monitoring and the third year of juvenile stranding monitoring. Prior year reports from 2011, 2011-2012, 2012-2013, and 2013-2014 studies are available online through the RBFO's CALFISH internet link at this address, or by request from the authors.: http://www.calfish.org/Programs/CDFGUpperSacRiverBasinSalmonidMonitoring/tabid/222/Default.aspx)

The data collected from this year's survey provided resource managers a more accurate understanding of the impacts of flow reduction on redd dewatering and frequency of juvenile stranding occurring during this period.

Figure 3. Aerial photograph of spring/fall-run Chinook new redds and previously marked redds (blue flagging) on October 10, 2014. This location is known for high density spawning and redd superimposition, located at RM-297 in Redding.

METHODS

Redd Dewatering Field Survey Methods

Redd dewatering survey efforts were conducted primarily by boat and foot. Survey crews typically consisted of two staff members from the Red Bluff Fisheries Office (PSMFC or CDFW). Crews collected data on both active underwater redds (adult fish recently present) or dewatered redds from the present salmon run. This data was recorded onto a paper datasheet which printed on both sides that represented data collected in a single section of river (Figure 1). Data categories included: date, river section, boat, water temperature, water clarity, weather, crew, and GPS model. The datasheet had four other redd specific sections which included sections on new and previously observed redds and redd measurements. Appendix C provides an example of field datasheets used by crews in the 2014-2015 surveys. A Microsoft Access database was used to maintain and update data allowing analysis of findings.

Chinook salmon redds are constructed by female fish using their tails to excavate a shallow depression in the streambed. As females lay on their side digging with their caudal fin, a vacuum force is created which lifts sediment into the current and shapes the beginning egg pit of the redd. Once the pit is made, the male (or multiple competing males) and female salmon deposit milt and eggs side by side into the lowest point and the fertilized eggs sink to the bottom. The female then immediately covers the eggs with new gravel from just upstream of the pit. The female continues this process in an upstream movement until all her eggs are deposited, (may take days). As the eggs are covered in gravel a redd mound is created sheltering the eggs. When the female dies, the finished redd typically has an upstream borrow pit (a.k.a. redd pot) that she has used to cover the last of her eggs located just below the surface of the mound. This mound (called a tailspill) is the distinctive characteristic of salmon redds that the survey crews observed for dewatering and is shown in Figure 4 with other redd details.

Fish presence on or around redds along with cleaned gravel are both defining characteristics of a "fresh redd" or redd that was recently constructed. Fresh redds are used to assist with aging and assigning a fry emergence date to that particular redd. Knowledge of fry emergence dates is utilized when making certain water management decisions. Knowing how many redds contain eggs or fry allows water managers to determine the quantity of redds affected by future flow release reductions.

During the study, each observed redd was classified in the database from a list of five dewatering descriptors ranging from "not dewatered" to "totally dry". For the purposes of this study a dewatered redd was minimally identified as any active redd that had its highest section (the tailspill mound) exposed to the air. This would indicate that the river flow had decreased from the time when the redd was constructed and that impacts to egg or juvenile survival could be present. A small number of dewatered redds were excavated to observe if eggs or juveniles survived.

Active redds (underwater with recent activity or fish near them) were identified by boat crews while surveying from the Tehama Bridge (RM-229) upstream to Keswick Dam

(RM-302) near Redding. Figure 1 shows an area view of the survey area including the landmarks and river miles dividing the river sections used in the survey. Table 1 lists the survey sections with corresponding river miles. Redd surveys were conducted after periods of Keswick flow decreases to allow crews to make observations of new redds and repeat observations of previously marked redds.

Active new redds were marked with round aluminum disc tags (1.25-inch diameter) attached by hog rings to a link of heavy steel chain placed underwater on the redd between the tailspill and pot (Figure 4). A short length of surveyors flagging tape was added to the tag to increase visibility. Flagging was color coded based on salmon "race" or run. Pink flagging was used during winter-run, blue for spring-run, and yellow for fall-run and late-fall-run. Figures 3 and 4 show markers placed near active redds and the physical components of a finished redd. Occasionally crews encountered and marked redds that were not marked before they were dewatered but showed similar characteristics to actively marked active redds (lack of algal growth on rocks in the redd).

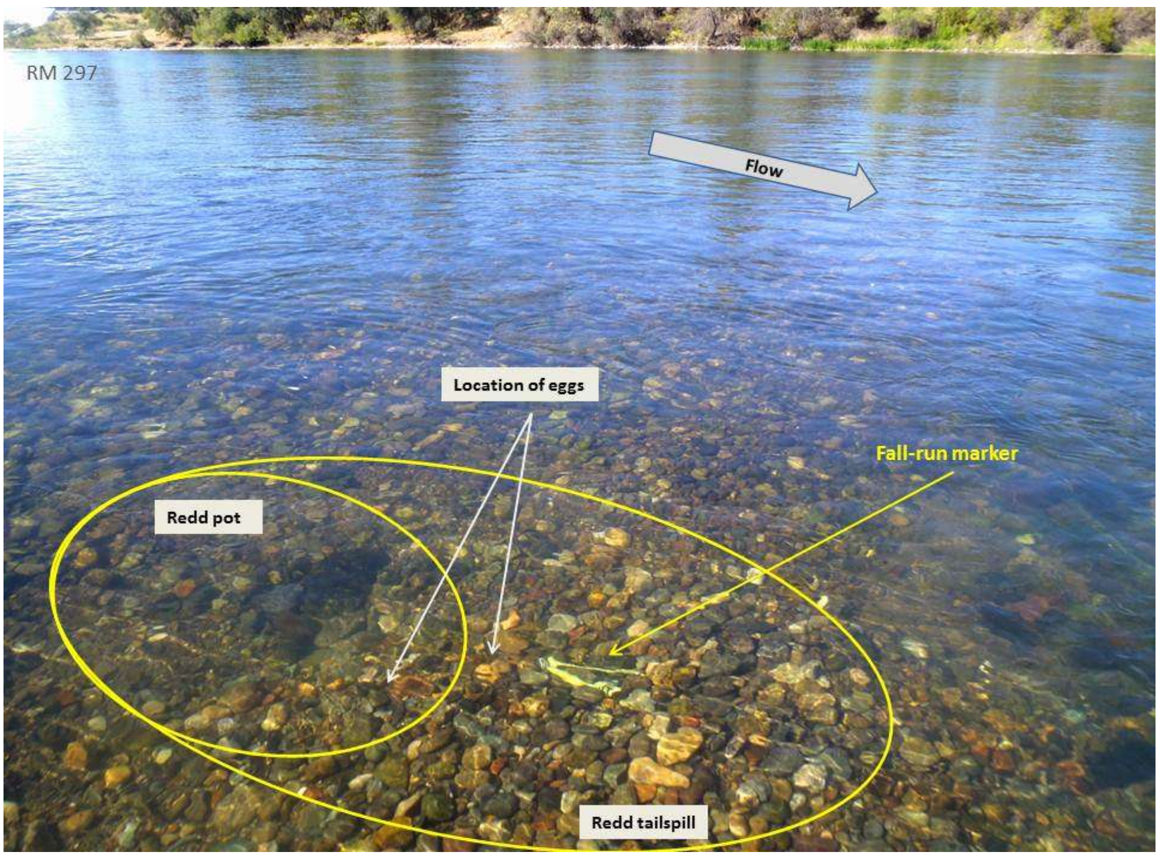

Figure 4. Fall-run Chinook redd marked during the 2014-2015 redd survey. Key identifying features of Chinook redds are illustrated in the diagram.

Table 1. Dewatered Redd Survey river section numbers by river miles and landmarks for the 2014-2015 survey season.

Survey Section	River Miles	Landmarks
1	302-298	Keswick Dam **to** ACID Dam in Redding, CA
2	298-296	ACID Dam **to** Turtle Bay Brg (Hwy 44) in Redding, CA
3	296-288	Turtle Bay Brg (Hwy 44) **to** just below Clear Creek mouth
4	288-276	Clear Creek **to** Balls Ferry Brg near Anderson, CA
5	276-271	Balls Ferry Brg **to** mouth of Battle Creek near Cottonwood, CA
6	271-266	Battle Creek **to** Jellys Ferry Brg near Red Bluff, CA
7	266-257	Jellys Ferry Brg **to** Bend Ferry Brg near Red Bluff, CA
8	257-242	Bend Ferry Brg **to** Red Bluff Diversion Dam in Red Bluff, CA
9	242-229	RBDD downstream **to** Tehama Brg in Los Molinos, CA

Active newly encountered redd locations were documented on the datasheet with a handheld Garmin GPS Map 76CSX. The status and current condition of each new redd was recorded. Redd data categories were as follows:

a.) **Redd Number:** This is the unique number assigned to a redd and is obtained from the disc tag placed on the redd.
b.) **Time:** This is the recorded military time a redd is marked and recorded.
c.) **Picture Number:** Photos are usually taken of each redd. These assist crews in determining the timeline of each redd's dewatering sequences.
d.) **Salmon Present:** This is a range of options to help crews identify active redds. The four choices include: none, fish on redd, fish observed nearby, or redd dewatered.
e.) **Dewatered:** This is a range of options describing the extent of dewatering for each new redd encountered. The five choices include: no, top only, mostly, pot still wet, and pot dry.
f.) **Action:** This is a range of options to describe any actions taken at the redd location. The five choices include: depth and photo, measured, egg check, combination, or mark expired.
g.) **Depth:** This is a measurement in inches of water above the redd tail spill. Once a redd becomes "dewatered," a negative number is recorded.
h.) **Comments:** This allows crews to document any unusual qualities of each redd.

Once a new redd was marked, repeat trips to that redd were made after flow changes to document any changes to the water conditions at the redd. These observations were treated similar to new redds with the exception of marker placement and gps waypoint collection. The depth of each redd was measured in inches from the top of the tailspill to the existing water surface. Dewatered redds received a negative number which corresponded to the height of the tailspill out of water (shown in Figure 9). A hand level and stadia rods were utilized to obtain depth measurements.

The datasheet also provided a Redd Measurement section to allow crews to document physical measurements of dewatered redds for future analysis. Dewatered redds were sub-sampled and the dimensions were measured with a measuring tape and followed a standardized protocol. Categories for redd measurements were as follows:

a.) **Redd Number:** This is the unique number assigned to a redd and is obtained from the disc tag placed on the redd.
b.) **Total Length:** This is the length of the disturbed area upstream near the pit to the downstream edge of the redd.
c.) **Pot Length:** This is the length of the final digging pit (or pot) as it is commonly termed.
d.) **Pot Width:** This is width of the pot.
e.) **Tail Width:** crews measure the mound (or redd tailspill) in two locations and average these measurements.
f.) **Flow Average:** This is the average water velocity measured in four locations around a redd.
g.) **Substrate:** This is a range of choices to describe the predominant streambed substrate in the redd. Choices include: cobble 3 to 5 inches, small gravel 1 to 3 inches, larger cobble 5 to 12 inches, or sandy gravels.
h.) **Pot Water Temperature:** This is the water temperature of the pot and is relevant for dewatered redds to indicate possible survival limitations from higher water temperatures.

Juvenile Stranding Field Survey Methods

Juvenile salmon can become stranded when decreasing river flows cause fish to become physically trapped in isolated pools or channels that at higher flows are previously connected (allowing free passage) to the Sacramento River. Stranding can lead to direct mortality when these areas drain or dry up. Indirect mortality can result through increased susceptibility to predators (otters, raccoons, birds, etc.) or water quality deterioration in shallow or stagnant stranding locations.

A juvenile salmonid stranding field datasheet was developed to document the presence and characteristics of stranding site locations on the Sacramento River for both rescue and restoration purposes. The datasheet categories were developed by RBFO staff to describe the unique characteristics of each potential site and provide information on the site's potential for impacting juvenile salmon survival. New stranding site locations were recorded on the field data sheet and a handheld Garmin GPS 78 SC. Crews routinely carried both the Dewatered Redd datasheets and Stranding datasheets on surveys, completing the appropriate sheet if any observations were made. The Stranding datasheets included a similar river section to the one described for the Dewatered Redd sheet. Individual stranding sites were documented using the following categories:

a.) **Time:** This is the recorded military time during site visit.

b.) **Waypoint Number:** This is a number assigned to each potential stranding site using the GPS unit. The first digit corresponds to the site survey section number.
c.) **Picture Numbers:** These are photographs of the site for comparative purposes between visits.
d.) **River Mile:** Obtained from the online Sacramento River map atlas and represents distance from Sacramento River mouth, near Antioch, CA. Used to assist locating stranding sites during repeat observations and for flow calculations. (http://www.sacramentoriver.org/forum/index.php?id=atlases)
e.) **Connection:** This is a range of choices determined by crews at each site and describes the connection of the stranding site to the nearest flowing water of the river. Choices include: site open both up and downstream (crews determine site likely to become isolated), downstream open only, upstream open only, and isolated completely.
f.) **Winter-run Number:** This is the estimated number of winter-run sized salmon observed in the stranding site. Size cut-offs are determined by each specific date using a screw trap developed length cut off chart for the Upper Sacramento River (example: Appendix B Table B3).
g.) **Fall-run Number:** This is same as winter-run above except for fall-run.
h.) **Late-fall-run Number:** This is same as winter-run above except for late-fall-run.
i.) **Habitat:** This is a range of choices describing the predominant habitat of the site and includes: pool, riffle, or combination.
j.) **Survival:** This a range of choices based on the crew's best judgment of the site and the knowledge of weather forecasts and future hydrological expectations based on the date and current environmental conditions. It describes the expectations for survival of salmon at the site and includes choices for: survival likely, death likely, and survival uncertain
k.) **Substrate:** This is a range of choices and describes the predominant substrate of the stranding site. Choices include: bedrock, cobble, small rock-sand, sand-silt-mud, or a combination of these.
l.) **Pool Temperature:** This is water temperature from a hand held thermometer or water quality meter.
m.) **Dissolved Oxygen:** This is dissolved oxygen level from a water quality meter.
n.) **Length:** Measured or estimated length of the stranding site.
o.) **Width:** Measured or estimated width of the stranding site.
p.) **Depth:** Measured or estimated depth of the stranding site.
q.) **Shelter:** This category describes the predominant type of shelter for stranded fish available in each site. It is a range of choices including: tree branches, submerged wood, aquatic vegetation, none, or combinations.
r.) **Reconnect:** This category describes a range of choices for the methods that could be used to reconnect the site to the river should that option be pursued. It is a simplified description of the type of work necessary to prevent stranding in future times at the site. Choices include: by hand, by power tools, by machinery, or not possible.

s.) **Rescue:** This category describes the level of effort (estimated by crews experienced in similar rescue efforts) that would be necessary to rescue the fish in the stranded site. Choices include: easy, moderate, difficult, or not possible.

t.) **Comments:** Allows crews to include other descriptions of each site.

Juvenile stranding events and stranding sites were observed while surveying the Sacramento River and side channels by boat and on foot. Efforts to locate and monitor stranding sites were conducted from the Tehama Bridge (RM-229) to Keswick Dam (RM-302). Isolated and partially or potentially isolated pools were observed and marked on a handheld GPS. Stranding sites are assigned a unique number that corresponds to the survey section the site is located within and typically increases in a downstream fashion. For example, Site number 106 is located near the top (upstream) of Section One and Site number 140 is located near the bottom (downstream) of Section One. All stranding sites observed were photographed and examples are presented in Appendix E. Fish present were enumerated and identified by visual observation, including underwater observation and underwater photography. Juvenile salmonids were identified by species, and juvenile Chinook were classified by run based on approximate fork length relative to date. This is accomplished using the Central Valley Chinook length-at-date fork length table, an example of which is located in Appendix B Figure B3. Hard copies of this table were utilized in the field for size referencing observed salmon located in stranding pools. Figure 5 provides an example photo of the different size (winter-run and fall-run) fish observed in stranding locations. The site location and environmental conditions were also recorded. Some stranding pools were subsequently measured and environmental conditions such as temperature, substrate, type of shelter present, etc., were recorded. Likelihood of juvenile survival was assessed at observed stranding pools and was based on current and expected environmental conditions (e.g., if site was isolated and drying up with warm dry weather forecasted, then survival probability would be unlikely for that site).

The feasibility of juvenile fish rescue and removal from the observed stranding site was also evaluated. This was based on the size and substrate of the stranding site, as well as surrounding habitat. For example fish stranded in a wide, shallow pool with little aquatic vegetation, could be removed and relocated to adjacent flowing water easily using beach seines or other capture methods. Conversely, a deep bedrock pool with submerged debris such as downed logs or tree branches would be very difficult to effectively capture and remove juveniles for relocation. Other sites may require alternative methods such as electrofishing or using dip nets for small shallow water pools.

In the spring of 2013 the CDFW developed a new fish rescue policy that directs all fish rescues made under CDFW authority go through a rigorous management level review process. Juvenile rescues were authorized in January of 2014 and became a drought related priority for the Sacramento River. Juvenile salmonids within stranding sites suitable for rescues were immediately rescued upon observation. Crews used seine nets of various lengths, backpack electro-fishing shockers, dip nets and assorted tubs and buckets. Multiple passes were made with seine nets at each site and captured fish were transferred to buckets of water. Fish were then identified, tallied, and relocated to the nearest flowing river channel with minimal handling.

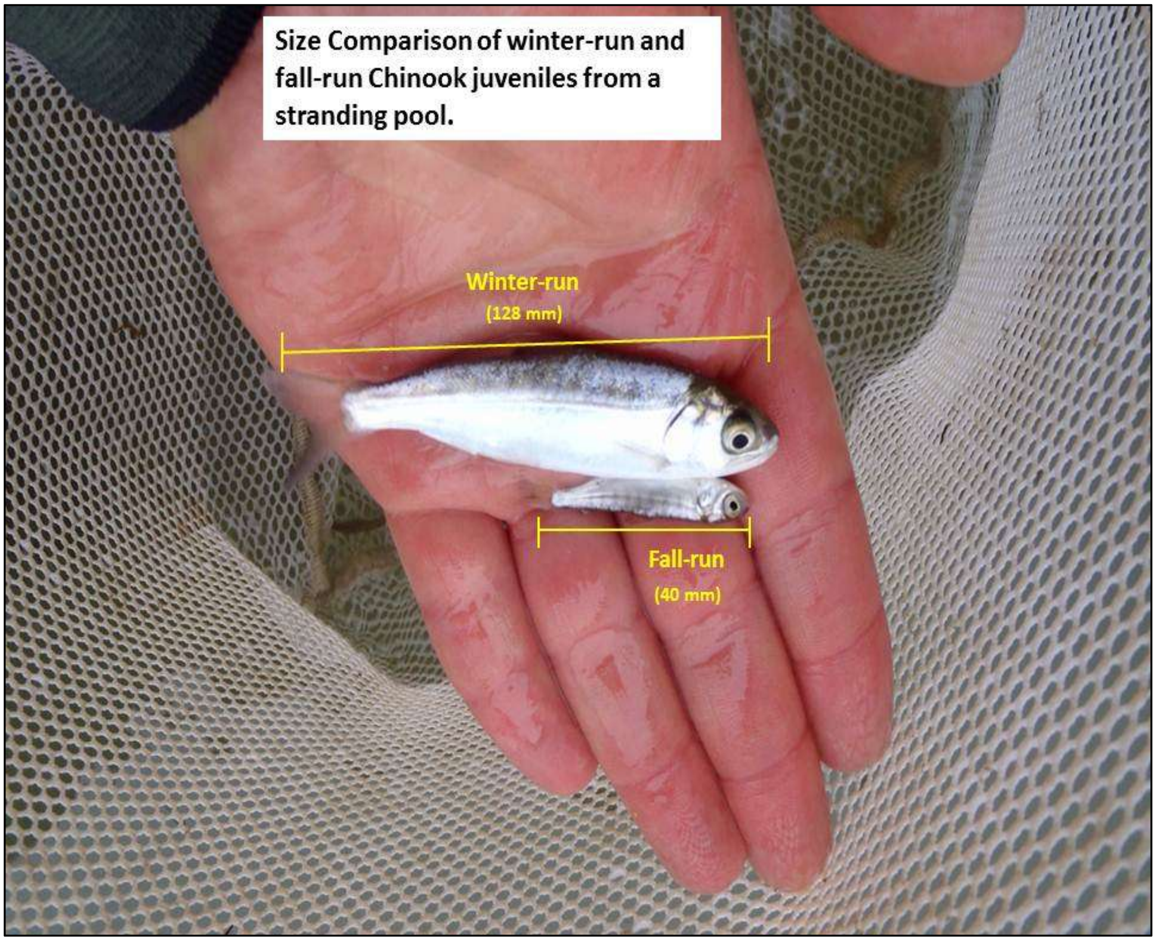

Figure 5. Photo taken on February 18, 2015 demonstrating the size difference between a hatchery juvenile winter-run and wild fall-run Chinook stranded in an isolated pool near Red Bluff Diversion Dam.

Another characteristic assessed at each observed stranding site was the potential for reconnection. This was based on the substrate of the stranding site and the proximity to the nearest watered portion of Sacramento River. The feasibility of reconnection included the potential for use of hand tools (e.g., shovels), power tools (e.g., jack hammers) and more aggressive reconnection using machinery such as backhoes, etc. Both permanent and temporary reconnection techniques were considered during assessment. Documented stranding sites were regularly revisited as resources allowed throughout the survey season. The status of each stranding site was evaluated to determine if and when the location reconnected or disconnected to the main river system. Fish present were counted and identified to assess mortality of stranded juveniles that were unable to be rescued over time.

RESULTS

Dewatered Redd Data Summary

Despite the long term drought, in 2014 Northern California experienced a short significant wet period during the month of December following the third driest water year in California's history (California Department of Water Resources, (CDWR), 2015). The 2014-2015 dewatered redd monitoring season began with the winter-run spawning season that occurs from May through August each year. An estimate of 2,627 winter-run spawned in the Sacramento River in the summer of 2014, (Killam and Johnson, 2015). The first winter-run redds were located and identified during aerial redd surveys in late May and early June. These redds were then marked and monitored by boat. The ongoing drought raised concern that water quality would impact winter and fall-run salmon egg and juvenile survival. This resulted in an effort by the CDFW RBFO staff to document water temperatures and dissolved oxygen (DO) levels throughout the salmon spawning areas. This effort is reported in Killam and Thompson, 2015. Twelve dissolved oxygen/temperature loggers along with numerous temperature only loggers were deployed in the vicinity of winter-run redds. Figure 6 presents an example of this data collected near a winter-run redd.

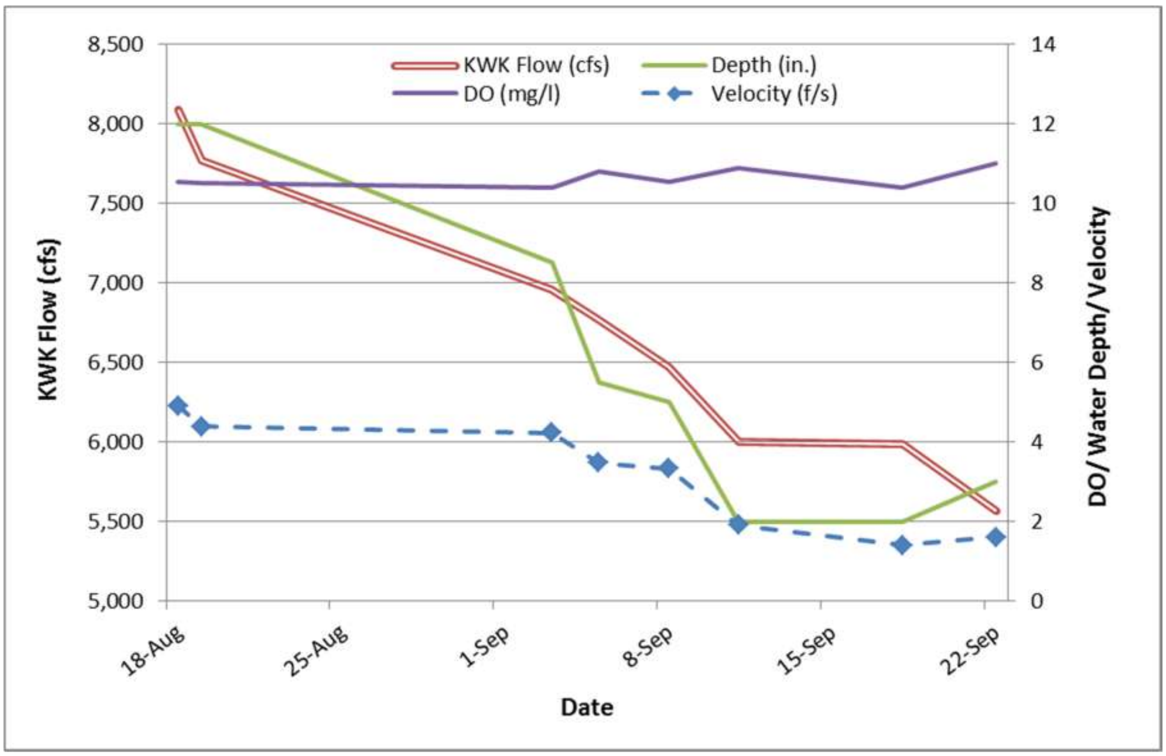

Figure 6. An example of water quality measurements collected during 2014 on a winter-run redd and compared to flow. Note: this redd was modified on September 18. Data collected on September 22 displays an increase in depth.

Thirty-two winter-run redds were closely monitored from August 13, 2014 through November 7, 2014. Thirty of these redds were located in a five-mile reach from Anderson Cottonwood Irrigation District Dam (ACID) downstream to Bonnyview Bridge. The remaining two redds were located upstream of the ACID dam near RM-301. Keswick flow reductions initiated during early August prompted substantial monitoring efforts. Small incremental flow reductions of 250 cfs occurred on a weekly and occasionally daily schedule during this period. This schedule allowed survey crews to monitor and report current or potential future impacts to these redds to fisheries managers for use in making water management decisions. Redd water depth, velocity, and other water quality measurements were also collected on this particular group of winter-run redds.

A total of 95 dewatered redd surveys were conducted between June 6, 2014 and February 2, 2015. The Keswick (KWK-CDEC) flow gauge was used to report flows in the 2014-2015 season. Flows remained relatively stable around 5,000 cfs from September 26 through November 11. Flows from Keswick Dam decreased to around 4,500 cfs from November 12 to November 18, 2014 and continued to decrease to 4,000 cfs from November 19 to November 24. State wide extreme drought conditions initiated further Keswick flow reductions to 3,250 cfs on December 10, 2014. A large rain event on December 11 resulted in a sudden release of 7,900 cfs from Keswick. Flows were reduced back to 3,250 cfs on December 16, 2014. Figure 7 provides a summary of Keswick Dam Flow releases for the entire survey season and displays its relationship to the number of dewatered redds observed. The last dewatered redd survey was conducted on February 2, 2015.

A total of 372 active redds were marked during this 2014-2015 period, (58 winter, 18 spring and 293 fall-run, see Appendix D). Of the 372 redds marked, 47 (12%) were considered dewatered to different degrees. Dewatering was categorized into four different levels and all are considered to impact egg or fry survival. The four levels include: top only dewatered, most of redd dewatered, pot still wet, and pot completely dry. Of the 47 dewatered redds, 32 (68%) were top dewatered, eight (17%) were mostly dewatered, three (6.3%) were pot wet (but tailspill mound dry), and four (8.5%) were pot dry (completely dry on all exposed areas). A total of **one** (2%) winter-run redd, **one** (2%) spring-run, **43** (89.3%) fall-run, and **two** (4.2%) late-fall-run redds were dewatered to various degrees. Redds were assigned to a salmon run based on time of year observed (i.e Spring-run surveys start the first week of September through October 1st).

Figure 8 displays the number of dewatered redds marked per survey section. Most redd dewatering occurred in the upper three survey sections coincident with the lack of significant sources of tributary influences (sections 1,2,3- see Figure 1). These three sections contributed to 95.7 % (45 of the 47 redds) dewatered. Superimposition of redds by later arriving females spawning in same areas as previous spawners was observed at several different locations. This made enumerating the total number of redds at these sites difficult and likely resulted in an overall under estimation of redd dewatering for the study.

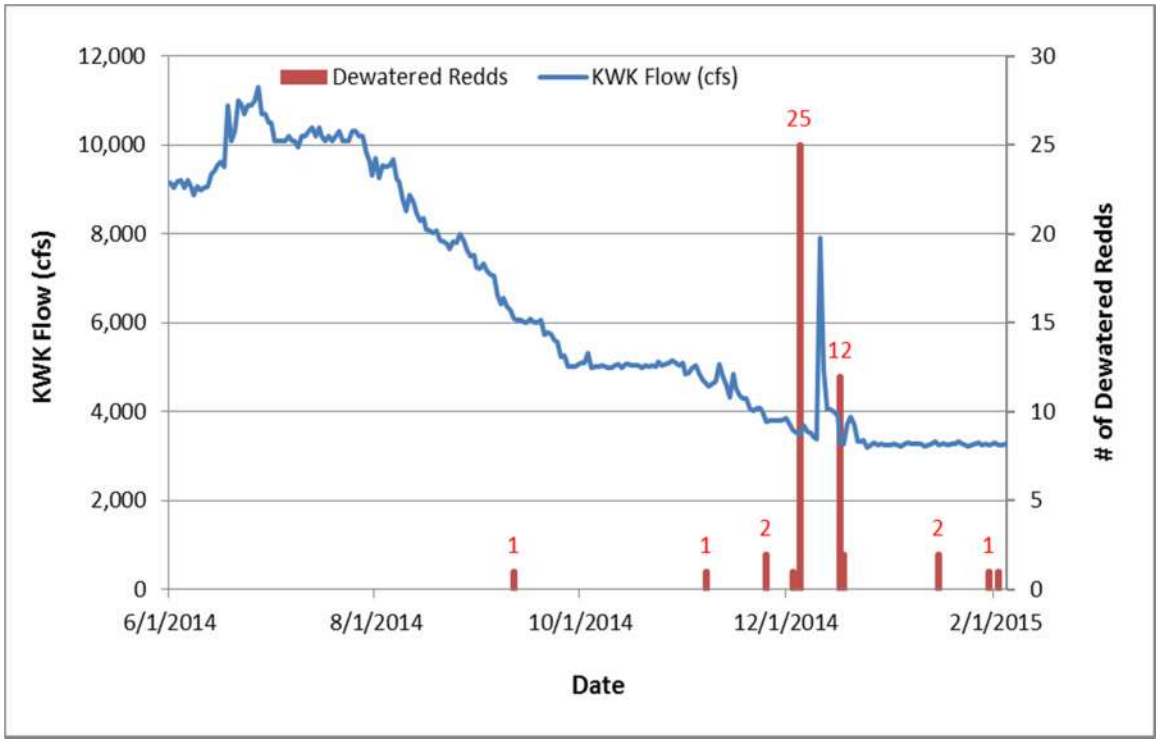

Figure 7. Graph comparing the number of dewatered redds to Sacramento River flow (obtained from the KWK gauge) by date for the 2014-2015 survey period.

The time of day was recorded when each redd was observed. This allowed analysis of the flow at each marked redd based on the redd's distance from Keswick Dam and the time it takes for flows to travel downstream. A multi-year time series of flow changes was analyzed using multiple linear regressions of flow changes coming from Keswick Dam and other points. Flows from Keswick Dam during periods of steady tributary inputs were compared with flows at other fixed monitoring stations along the river (CDEC: Bend station (BND), Red Bluff Diversion Dam (RDB), and Tehama Bridge (TEH)) to develop a relationship between time-distance and flows enabling crews to determine river flows at redds or stranding sites by recording time and the location during survey observations. Appendix F Table F1 provides the results of this time-distance-flow relationship.

Data from Appendix F Table F1 was used to calculate the flow at each marked redd or stranding site. This enables comparison between water depths at redds and stranding site inlets and outlets. This data can be useful in predicting at what flow a certain area can become dewatered or isolated. For this study the Sacramento River was divided into half-mile segments based on the river mile designations available in the online CDWR atlas at the following link: [http://www.sacramentoriver.org/forum/index.php?id=atlases.](http://www.sacramentoriver.org/forum/index.php?id=atlases)

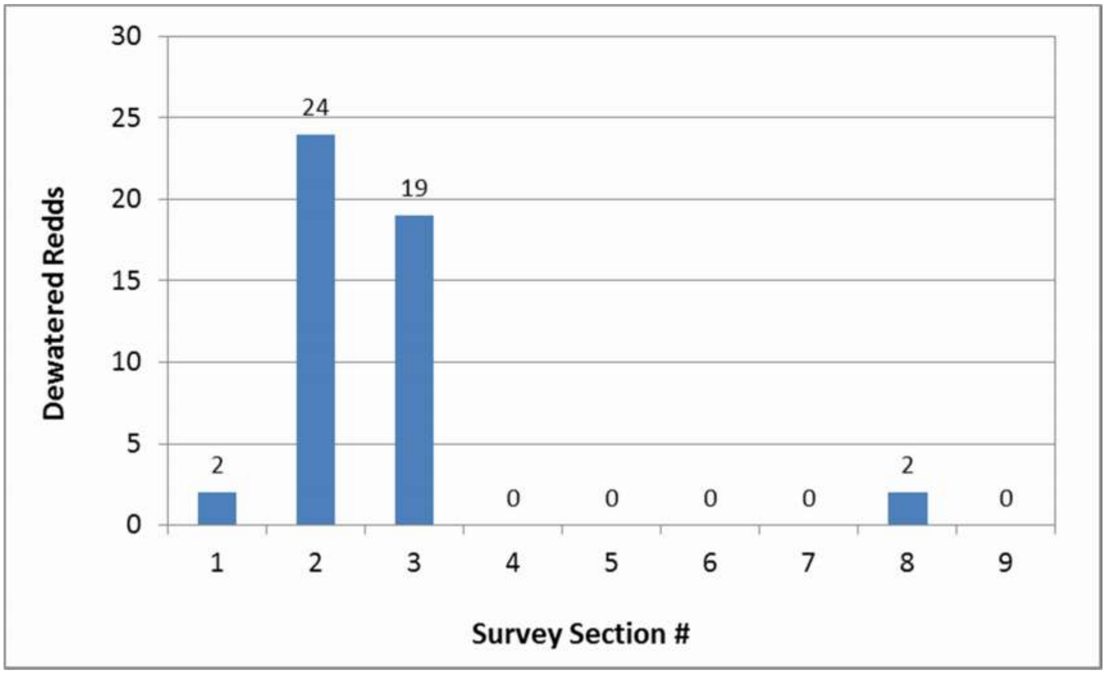

Figure 8. Graph comparing the number of dewatered redds to survey sections. Almost all redd dewatering happened in the upper three sections (14 miles) of the Sacramento River.

The depth of water over the highest point on the tailspill of the redd was measured for each redd (Figure 4 and 9). This provided data to compare water elevation at each redd with the flow in the river at each redd. This proves helpful in determining at what flow a certain area could be expected to be dewatered. For redds that had been dewatered the distance (elevation) from the redd's highest point to the nearest water surface was surveyed and reported as a negative number in the depth category for those dewatered redds.

Redd Modification

During the month of September 2014, as Keswick flow reductions were decreased due to maintain reservoir storage necessary for drought conditions, several redds came close to dewatering (3" or less water depth). As flows were scheduled to be reduced even further, redd modification became a last ditch effort implemented to lessen the impact on shallow winter-run redd dewatering.

Redd modification is a simple process where several inches of gravel are gently removed from the tailspill of a redd prior to or shortly after flow reductions occur. All substrate from the tailspill was hand removed as to not disturb any emerging fry or harm incubating eggs. A depth and water velocity measurement was recorded before and after modifying redds to document any physical changes. Fry were observed emerging from the first modified redd after several inches of gravel were removed. One dewatered, and eight shallow water (3" or less) winter-run redds were modified to prevent further dewatering in 2014. The average depth change was 2.3” with an average velocity difference of 0.4 ft/sec. Figure 9 provides an example of the redd modification process illustrating both positive and negative impacts to this novel procedure. Redd modification is a drastic, temporary solution to dewatering and may be beneficial only in certain situations when fry are close to emergence and dewatering will likely make emergence impossible unless the top of the redd is submerged.

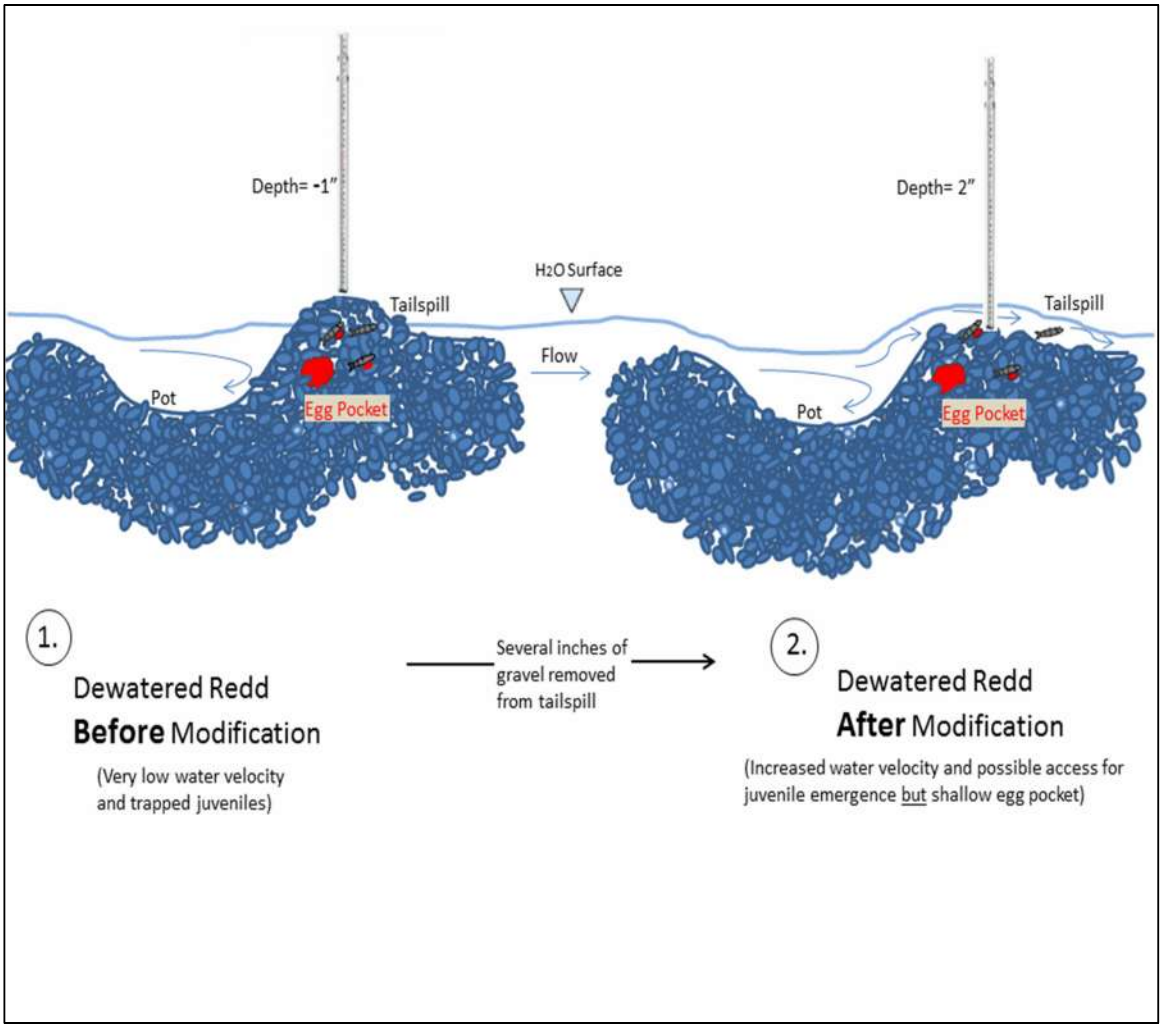

Figure 9. Diagram of the redd modification process. Redd water depths and velocities are measured before and after substrate is removed from the tailspill. Redd modification increases the water velocity over a redd and likely allows juvenile salmon to emerge successfully but decreases the egg pocket depth. Note: redd dimensions are not to scale. Egg pocket depths vary within each redd.

Redd dimensions were measured on only two redds throughout the entire study. Both measured redds were winter-run and had an average area of 34.27 ft² (3.18 m²). Although a very small sub-sample size (2) of total redds were measured, the average area for redds was significantly smaller than that of the measured fall-run redds (97.4 ft²) of 2013 (Jarrett and Killam, 2014). In addition to the redd measurements, one fall-run redd was excavated for positive identification of egg presence. An image of this redd and the dried eggs from dewatering can be seen in Appendix E Figure E9.

Percentage of Redds Dewatered

To calculate an estimate of the percentage of each run that was impacted by dewatering the overall spawning female escapement estimate for each run was divided by the number of dewatered redds observed for that run. This methodology assumes that for each spawning female there is a single redd. This method provides a minimal percentage dewatering estimate and which would increase if superimposition on the marked redds by other females occurred between survey visits by survey crew. This is most likely relevant to the fall-run salmon that spawn in large numbers during periods of reduced flows (less spawning area).

The 2014 winter-run Chinook estimate was 2,627 in-river salmon including 1,744 females (Killam and Johnson, 2015). All winter-run spawned within the boundaries of the dewatered redd survey. Additionally, a one percent unspawned female rate was observed on the winter-run carcass survey, effectively reducing the number of females digging redds to 1,727. Due to redd modifications only one dewatered winter-run redd was observed. A winter-run dewatered redd estimate of **0.05%** (1 / 1,727) was made. Redd superimposition at the site of the dewatered winter-run redds was not likely as most were in easily observable areas and redds did not appear to overlap at these sites.

The 2014 Sacramento River spring/fall-run Chinook escapement estimate included 15,923 female salmon in the population (Killam and Johnson, 2015). This estimate included both spring and fall-run Chinook since there is no means in place to separate out the Sacramento River run of these two species due to overlap in spawning times and location, (authors note: funding for genetic separation of these runs is being sought, but at present time, spring-run numbers are thought to be very low). The 15,923 estimate was used as a starting point to quantify the total number of redds in the river based on the assumption that there was one redd per spawning female. This female estimate was developed using the annual fall-run mark-recapture carcass survey as well as the aerial redd survey results. To develop the total dewatered redd percentage, the 4.8% of the aerial redds observed downstream of Tehama Bridge (23 downstream of a total 482 spring and fall-run redds observed) were removed from the 15,923 total system estimate. This resulted in an estimate of 15,163 females upstream of Tehama. Additionally, the carcass survey reported an 8.9% unspawned female figure which further reduced the spawning female estimate upstream of Tehama making redds in the dewatered redd survey area to 13,814 females. The 44 dewatered redds (spring-1 and fall-run-43) were divided by 13,814 which **resulted in a 0.3% dewatering rate for the spring and fall-run redds dewatered**. Appendix D shows examples of the marked redds and juvenile stranding sites observed in high density areas during the survey period in a series of map images starting upstream and progressing downstream. These maps also show the range of flows in which dewatering was observed at each redd.

The 2015 late-fall-run Sacramento River estimate included 1,048 female salmon. Carcass survey crews noted a 3.8% unspawned female rate (i.e, 1,008 females spawned) and redd distributions from the average (past 5 years) aerial redd surveys indicated that 2.2% of all late-fall redds (21) were below Tehama Bridge. From this, an estimated 986 female late-fall-run salmon made redds in the survey range. Crews noted two dewatered late-fall-run redds resulting in an estimate of **0.2% of the late-fall-run redds dewatered.**

Water Velocity

Water velocity measurements were conducted and monitored at several winter-run redd locations throughout the 2014-2015 season. Water velocities were measured using a SonTek FlowTracker handheld flow meter positioned near the upstream lateral of the redd tailspill (Figure 4). Velocities ranged from 0.25-4.98 ft/sec during various site visits to certain redds. The lower velocities were recorded post Keswick flow release reductions. The one dewatered winter-run redd had a velocity measurement of 0 ft/sec during its dewatering stage. Suitable water velocity preferences for winter-run chinook spawning range from 1.5-4.1 ft/sec (USFWS, 2003).

Dissolved Oxygen Monitoring

Enhanced drought monitoring on the Sacramento River prompted the deployment of several dissolved oxygen (DO) loggers in and around Chinook redds. This effort and a complete analysis of water temperature relationships in the USRB for 2014-2015 is available in Killam and Thompson, 2015 and is online at the following site:

http://www.calfish.org/ProgramsData/ConservationandManagement/CDFWUpperSacRiverBasinSalmonidMonitoring.aspx

Twelve DO loggers were positioned in close proximity to active winter-run redds. An additional 14 DO loggers were injected into active spring/fall-run redds for further monitoring. These particular loggers measured and recorded dissolved oxygen as well as water temperature every half hour for a period of up to three months. All 14 spring/fall redds experienced average water temperatures of ≥59°F for a period of 2 weeks or more. Literature suggests that in-gravel Chinook salmon eggs begin to experience mortality at temperatures above 56°F or 13.3°C (Myrick and Cech). Only one fall-run redd containing a DO logger was top dewatered while the additional 13 redds remained underwater. This single dewatered redd had corresponding low (< 5 mg/l) dissolved oxygen readings during its period of dewatering. Five other redds also experienced periods of low DO readings, likely from large rain and turbidity events. Reviewed literature proposes that embryo survival is low when dissolved oxygen contents are reduced to 5mg/l or less (Carter, 2008). Data summaries for each specific "DO" redd is located in Appendix G.

Juvenile Stranding Data Summary

There were 76 stranding surveys conducted from August 11, 2014 through April 10, 2015. Crews observed 174 potential unique stranding locations (examples shown in Appendix D) between the Tehama Bridge (RM-229) and the Keswick Dam (RM-302), a distance of 73 miles. Of the 174 potential stranding sites, 29 were both completely isolated and contained juvenile Chinook (Figure 10). Many other sites contained other unidentified juvenile fishes. The number of juvenile Chinook stranded in these locations was estimated at 798 winter-run (414 hatchery), 2,180 fall-run, 7 late-fall-run, and 3 spring-run for a total of **2,988** juveniles. Crews revisited these sites multiple times to observe and record data at different flows. Some locations containing juvenile salmon were visited up to six different times to monitor the connection status and fish health. An estimated 105 winter-run and 37 fall-run juveniles suffered mortality through either direct (stranding area drying up) or indirect means (predation, warm water, poor water quality). These numbers are only an estimation of the number of observed fish in this study's survey reach and do not represent the exact total number of stranded fish or fish mortality in this reach or throughout the whole Upper Sacramento River Basin.

Stranding locations are those in which crews observed that fish passage to the main river channel would be difficult or impassable (completely isolated) at current flows. Crews rated each stranding location by the degree of isolation to the nearest flowing channel. Ratings ranged from still connected (if flows dropped these sites would be disconnected), limited upstream or downstream connections, and completely isolated.

There were several major stranding events (flow reductions) during the 2014-2015 juvenile stranding survey. Between August 26, 2014 and September 05, 2014 flows from Keswick Dam were reduced from 8,000 cfs to 7,060 cfs (Figure 10) and resulted in 31 stranded winter-run juvenile salmon. The next significant flow reduction happened between September 5 and September 27, 2014, when Keswick flows decreased from 7,000 cfs to 5,020 cfs. After this 28% flow decrease, crews observed 278 juvenile winter-run Chinook salmon and 200 juvenile *O.mykiss* stranded at various locations. From October 30 to November 11, flows were further reduced from 5,040 cfs to 4,630 cfs and resulted in 109 stranded juveniles. Another major stranding event happened between December 15, 2014 and January 30, 2015 when flows were dropped from 4,000 cfs to 3,250 cfs and stranded 358 juvenile salmon in various locations. The last significant flow event occurred on February 8, 2015 when Keswick flows were increased to 5,140 cfs and reduced back to 3,250 cfs on February 11, 2015. This sudden flow release increase was likely triggered by a large rain event which occurred on February 6, 2015. This event was responsible for stranding 2,326 juvenile salmon including at least 414 recently released hatchery winter-run Chinook. It should be noted that the winter-run hatchery fish were released purposefully during the rain event to increase their opportunities to reach the Delta. The increased turbidity and flows in the river likely allowed many of the winter-run juveniles to migrate successfully but unfortunately the rain event was large enough to also flood into many downstream stranding sites and trap a sizable number of these fish. The majority of these stranded fish were rescued from East Sand Slough near the Red Bluff Diversion Dam. The stranding events during this survey period occurred in various habitat types (bedrock, riffles, side channels and eddies) along the entire length of the study area (Keswick Dam to the Tehama Bridge).

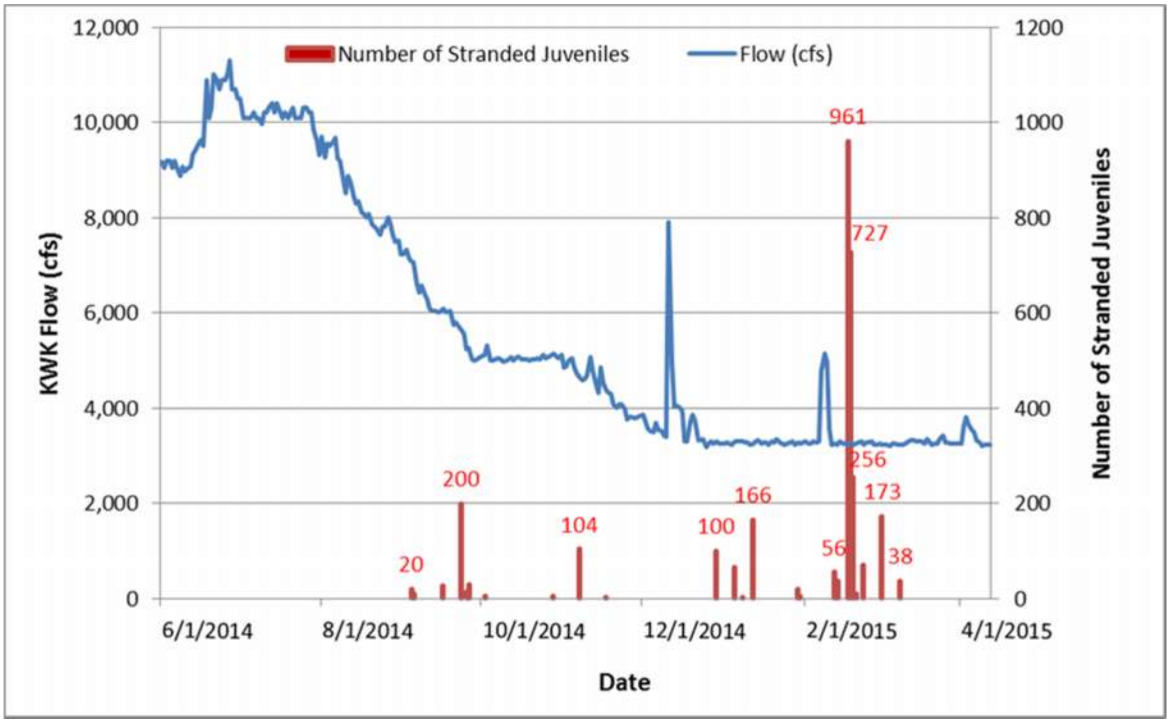

Figure 10. Graph comparing the number of stranded juvenile salmonids to Sacramento River flow (from the KWK gauge) by date for the 2014-2015 survey.

Figure 11 reveals that the majority of observed juvenile stranding sites occurred in Section 8. This section alone had 12 sites containing stranded juvenile salmon (41% of total stranding sites). Ten of these sites are located in East Sand Slough upstream of Red Bluff Diversion Dam (RBDD). Section 8 (RBDD to Bend Bridge) contains a total of 45 possible stranding sites. Many of these sites were observed in bedrock pools located near "China Rapids" from RM-253 to 255.

Crews recorded various data for each stranding site including water temperature, substrate size, site shelter data, and pool dimensions (see Appendix C Figure C3). Many physical stream site properties such as substrate size and natural stream shelter data were collected and used for prioritizing fish rescues and future restoration efforts. The dominate substrates found at most sites were cobble and multiple substrates that included a combination of some or all categories (sand, silt, cobble, gravel) with the exception of Section 8, where the dominate substrate consisted of basalt (lava) bedrock. Most sites had aquatic vegetation, tree branches or both for shelter.

River discharge was calculated using the same procedure as was used for the dewatered redds (Appendix F Table F1). This information was utilized to relate flow to the river stage that stranding sites became isolated and prevented fish passage. Resulting electronic data from these monitoring efforts is available upon request. Please contact the authors at doug.killam@wildlife.ca.gov or pjarrett@psmfc.org .

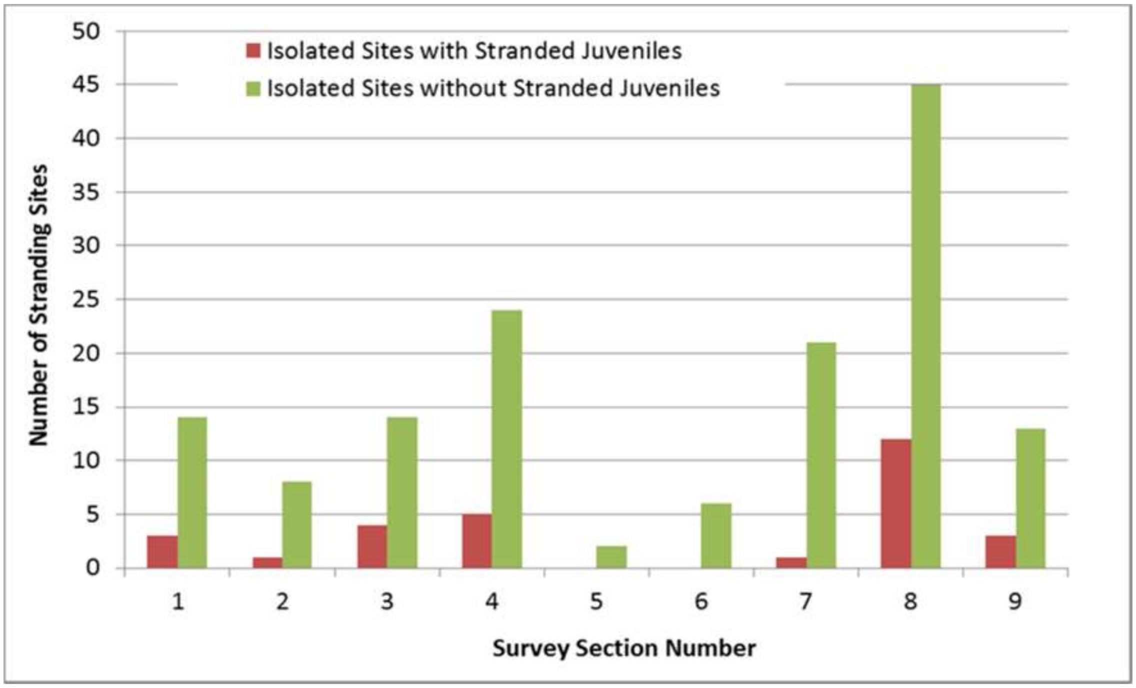

Figure 11. Number of isolated stranding sites with juvenile salmon compared to the number of stranding sites without juvenile salmon for each survey section during the 2014-2015 survey period.

Fish Rescue Effort Results

Stranded juvenile fish rescue efforts (example shown in Figure 12) using seine nets were conducted from August 21, 2014, through March 30, 2015. Backpack electrofishing and dip nets were also used where seining was not feasible. A total of 7,536 fish were observed and rescued from 31 stranding locations on the Sacramento River during this period. Of these fish, there were 693 winter-run and 2,143 fall-run sized salmon (based on data in Appendix B Table B3) and 515 rainbow trout (*Oncorhynchus mykiss*) rescued. Of the 693 rescued winter-run, 414 were adipose fin clipped (Figure 5).

During one of the rescue efforts on East Sand Slough near Red Bluff Diversion Dam, a largemouth bass (*Micropterus salmoides*) was rescued and stomach contents checked out of concern of predation on stranded juvenile salmonids. The stomach contents confirmed its diet of winter-run and a Coded Wire Tag (CWT) was retrieved from the partially digested salmon. The tag code later identified the salmon as a Livingston Stone Fish Hatchery winter-run that was released from Caldwell Park on February 6, 2015; 1 day before a large rain event had occurred (see Figure 14). A total of 26 adipose-fin clipped steelhead smolts (suspected to originate from Coleman National Fish Hatchery) were also rescued from the same area on the Sacramento River near Red Bluff Diversion Dam and were suspected to have been stranded during the same flood event.

Another 4,177 fishes of other families were also rescued during the 2014-2015 salmonid rescues (i.e. Cyprinidae, Cottidae, Petromyzontidae, Centrarchidae, Catostomidae, etc.). Beach seining and other rescue methods proved very successful and safe during these rescue attempts. A small number of fish mortalities resulted during or from these rescues but overall, a seine net proved most effective at removing juvenile salmonids from stranding sites.

Figure 12. Stranding Survey crew seine a stranding pool to relocate juvenile salmon on February 17, 2015, near Red Bluff Diversion Dam.

DISCUSSION

The overall objective of this monitoring effort is to investigate and provide mangers with information on the extent and nature of impacts of river flow reductions and fluctuations to salmon populations in the upper Sacramento River. The monitoring effort provides data to water and fishery agency managers that allow them to better understand how flow changes affect salmonid resources. It also provides opportunities to protect these resources using real time information.

The 2014-2015 survey occurred during another period of extreme drought, (Killam and Thompson, 2015). Concern over diminishing water resources led to a significant increase in use by mangers of the data collected on the survey. Additionally the 2014-2015 survey began earlier than scheduled when concern over winter-run redd dewatering led to crews actively marking all spawning winter-run salmon redds in June 2014.

Survey crews identified some 32 winter-run redds that were thought to be susceptible to future dewatering before the eggs and juveniles within them had a chance to emerge from the gravel. These redds were carefully monitored as seasonal flow reductions began to threaten nine of them in early September (Figure 2). As the effects of this historical drought became more severe, Lake Shasta water storage became the main priority. This decision led to continued flow reductions and "top dewatered" the first winter-run redd. With limited options, this redd was modified to allow water to re-flow over the top part that had been dewatered. In support of this novel effort, the authors noted the emergence of several winter-run fry immediately following the removal of the top inches of a dewatered redd. Another eight shallow water redds were also later modified to prevent dewatering with the continued flow reductions. Fisheries and water agency managers met regularly in conference calls and decided to hold further flow reductions until the beginning of November to allow the last of the juvenile winter-run time to clear the redds. Redd "emergence" dates were calculated from comparison of the redd "born-on-date" (when the redd was first observed by crews) to the water temperature. A direct relationship between Chinook salmon egg hatching/fry emergence and water temperature is well known and was used to predict when the last of the winter-run juveniles had emerged, (see USGS, 2013). As a direct result of the monitoring from this survey, flows were stabilized for protection of these shallow winter-run redds.

Unfortunately, and despite suitable flows, water temperatures in the Upper Sacramento River climbed above 56^{o}F and significant mortality to winter-run eggs and fry and later spring and fall-run eggs occurred in early September of 2014. Detailed in Killam and Thompson, 2015, these increased water temperatures were considered to impact up to 95% of the juvenile winter-run survival. In short the increased water temperatures resulted from low reservoir storage and the inability of the Shasta Dam operators to control the amount of warm water released from the reservoir.

Thirty of the 32 winter-run redds were downstream of the ACID dam which creates a deep water pool in the Sacramento River in Redding (RM-298). Nearly 56 percent of the winter-run spawned upstream of the ACID dam based on aerial redds survey data in 2014. An additional management action taken to protect these upstream winter-run redds was to request that the ACID dam be kept in place until at least November 1, in order to prevent dewatering of those winter-run redds above the dam. The seasonal flashboard dam is normally taken out in early October but by keeping the dam in place through the start of November, the redds upstream remained submerged. This allowed winter-run juveniles the opportunity to emerge from their redds without difficulties. One management recommendation of this study for future years is to investigate regularly leaving the ACID dam in place until November during dry years when redd dewatering is predicted.

Observations during the 2014-2015 and prior studies indicate that oscillating river flows have the potential to dewater redds and strand juvenile salmonids repeatedly in the same locations. Juvenile salmon naturally move between shallow slow moving waters to rest before venturing into swifter food carrying waters. This tendency makes them particularly susceptible to stranding as flows recede isolating the shallow river margin areas. Appendix D contains maps displaying some of the different dewatered redd and stranding sites discussed in this report. During typical winter dry periods with steady or decreasing tributary inputs, small flow changes (up or down) from Keswick Dam can result in repeated flooding and dewatering of pool and side channels throughout the upper Sacramento River. Images of these areas are shown in Appendix E. This year (2014-2015) experienced a few major winter rain events that resulted in flooding and major tributary stream influences downstream of Keswick Dam. These rain events resulted in high flows downstream as measured at the CDEC BND gauge in Figure 13. Shasta Lake captured much of this rain upstream so the Keswick Dam releases (KWK) remained relatively uninfluenced by rains, (Figure 13). Although the increased tributary inputs substantially reduced redd dewatering below Clear Creek, many new and existing stranding sites became inundated then swiftly isolated. These flood events combined with decreased Keswick flow releases resulted in the bulk of observed stranded juvenile salmonids.

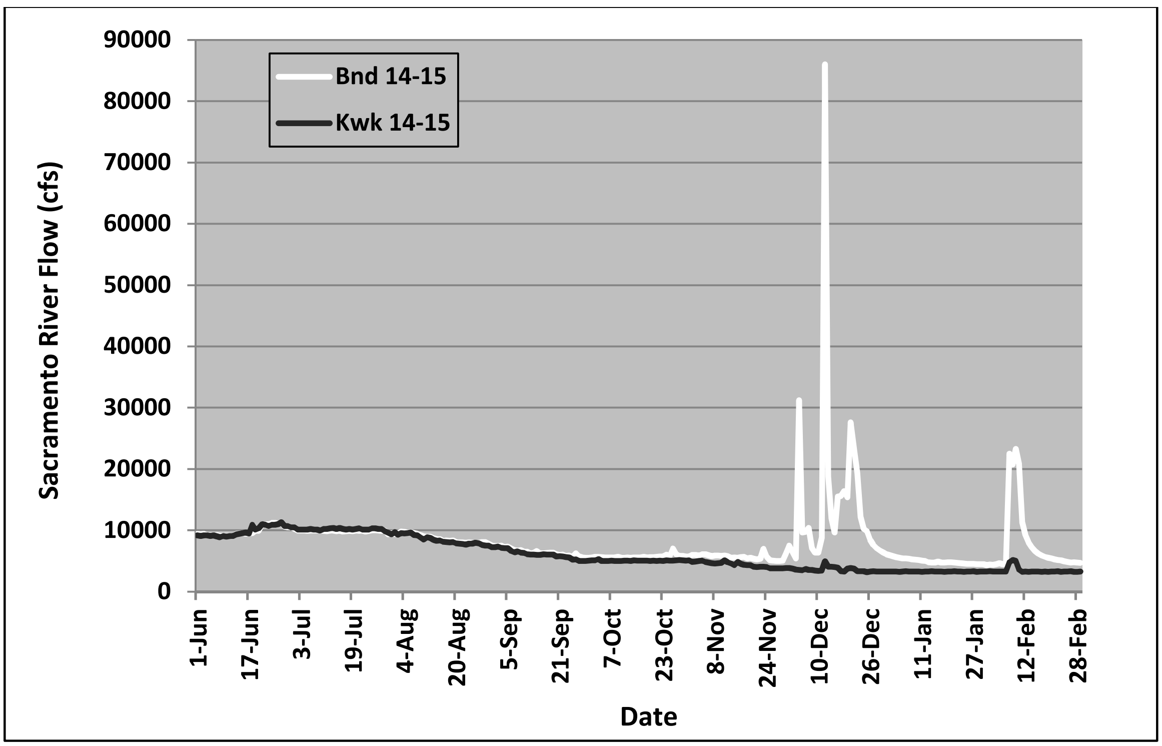

Figure 13. Graph of Sacramento River flow at KWK (below Keswick Dam) and at Bend Bridge (located 44 miles downstream of KWK) during study year 2014-2015.

The main objectives of the 2014-2015 juvenile stranding survey were to identify new stranding sites and to monitor the known sites for stranded juvenile salmonids. Juvenile fish rescues became an essential component of the stranding surveys during the latter part of the 2013-2014 survey period. These rescues are currently expected to continue during each survey when stranded juvenile salmonids are present. Although these rescues proved to have limited success they are not a long term answer to the stranding problem. Future efforts should shift focus towards implementing preventive actions such as habitat restoration work by developing strategies for reconnecting (grading, contouring, excavating, etc.) certain stranding sites back to the main river channel. Many stranding sites contain juvenile salmonids due to their rearing preferences. A portion of these sites would make ideal rearing habitat if inundated or not completely isolated during the mandated lowest river flow (i.e. 3,250 cfs) from Keswick Dam.

Summary of Five Year Study and Future Plans

We know that constant river flows for a period of nearly 3 months following redd construction will prevent dewatering and stranding. During dry years it seems increasingly difficult to balance fisheries needs with the water needs of California's human population. A goal of this study was to provide information on the impacts that redd dewatering and juvenile stranding caused by flow changes can have on the early life stages of naturally produced Chinook salmon. The complexity of the Sacramento River below Keswick Dam makes determination of the impacts to juvenile salmon difficult to judge. Some of the issues this study could focus on in the future are as follows:

a.) Determining the total percentage of redds dewatered and the impacts of superimposition to this percentage,
b.) Determining the impacts of salmon mortality from redd dewatering,
c.) Determining future restoration sites based on observed juvenile stranding locations,
d.) Determining the relationships between Keswick Dam flows and rain events that increase tributary flows and the impacts to stranding locations.

The total percentage of dewatered redds depends on the ability to closely monitor both the dewatered redds and the total number of redds. The CDFW aerial redd count survey was not designed to count all redds so another method was developed. Beginning in 2013, the Sacramento River escapement survey results were utilized to obtain an estimated dewatering percentage for each salmon run. For the large fall-run numbers difficulties arose when unusually high spring-run numbers proved inseparable from the fall-run. Another difficulty was redd superimposition in areas over previously marked redds. During the previous survey season we observed that in areas of high superimposition the later spawning fish would bury the existing redd markers and make it difficult to determine exact numbers of dewatered redds in those locations. This proved to be true during the 2014-2015 season as well, although to a much lesser extent.

Superimposition was observed in a variety of different high density spawning locations throughout the entire survey reach. Redd superimposition occurs when early constructed redds are imposed upon by late spawning salmon that construct redds on top of or near the preexisting redds. This usually occurs in areas of high quality spawning habitat with adequate subsurface water flow and loose gravel provided by previous redds that are no longer guarded (S.J.R.P, 2008). Superimposition has been documented in many other streams and is known to have negative effects on previously deposited eggs (Fukushima M, et.1998). Redd superimposition in the Upper Sacramento River may be attributed to the lack of high quality spawning grounds (substrate, flow) which are necessary to support the chinook population in this system. Counting redds in these high density areas during past study seasons was problematic due to the common occurrence of superimposed redds. Many redds were constructed in close proximity to one another and difficult to distinguish.

Salmon mortality in dewatered redds is variable and each redd is unique based on location and physical and environmental conditions around the redd. Dewatering of redds can occur due to small changes in flows and knowing the impacts (see Becker, et al., 1983) to the developing fish will need focused study. Determining what allows some salmon in dewatered redds to survive and others to perish could be a focus of future efforts. Water velocity reduction and temperature increases are key components of the risks to salmon in redds during dewatering. Salmonid redds have water velocity, dissolved oxygen, and temperature requirements for optimal embryo survival. Intragravel water flow transports dissolved oxygen, to the eggs while removing silt and metabolic waste (Cordone and Kelley 1961). The observed ideal velocity requirements for Chinook salmon redds are 1-2.6 ft/sec (30-80 cm/sec) while optimal temperatures range from 41-55°F (5-13°C) (Moyle, 2002). Although surface water levels and velocities may fall well below these ranges, sub-surface flow in the hyporheic zone may (or may not) be sufficient in providing dissolved oxygen for egg incubation. During this year's study, DO meters deployed in fall-run redds resulted in the correlation between top dewatering and low DO readings. One dewatered redd was excavated with a shovel for egg presence and condition and contained many desiccated, un-hatched eggs. These findings display the variation and importance of subsurface flow to salmon redds. Further efforts to determine impacts to survival in the redds may focus on surface water flows and water quality in and around dewatered redds.

Survival of juveniles in stranding sites depends on many factors. The connectivity to the river changes as Keswick Dam flows change or as tributary flows (e.g. Cow Creek) change so each stranding site is a dynamic balance of environmental inputs at any given time. The further upstream the site, the less likely that downstream tributary flows will contribute to connectivity changes. Fish in some stranding locations are not necessarily lost as many even completely isolated sites are large and deep enough to support fish life for weeks or even months and eventually would reconnect as flows increase in the spring for agricultural purposes. While fish may survive in some stranding pools their growth and ability to migrate is impaired and may lead to further survival problems later in life due to reduced growth or migration delays. Depressed low flow areas along river margins are a common natural occurrence and provide much needed rearing and resting habitat in the Sacramento River. They can however become stranding sites when conditions (flows) are managed opposite of the naturally occurring conditions. As natural flows increase from rainfall and flows from Keswick Dam are reduced, salmon in the upper river may become stranded and miss the opportunity to out migrate during peak flows. Salmon out-migration during peak flows assists in predator avoidance and ensures the salmon can find their way to the Ocean past the confusion of alternate pathways in the Sacramento-San Joaquin Delta. Management options such as Keswick pulse flows during dry years timed to rain events may trigger a migratory response in naturally spawned fish and allow stranded fish a chance to escape. Figure 13 compares the Keswick flows and the flows 42 miles downstream at the Bend site. Figure 13 reveals that even in a critically dry year such as the 2014-2015 season there may be opportunities to help move juvenile salmon out of the stranding sites and upper river with a pulse flow that could be timed to naturally mimic the Bend gauge hydrograph shown in Figure 13.

Fish rescues are a major component to juvenile stranding surveys but are limited by staff time and resources. Rescues will be carried out after significant flow reductions from Keswick Dam if juvenile fish are observed stranded in disconnected pools and survival in these pools is unlikely due to dewatering or long term expected dry conditions. Rescuing every stranding site with juvenile salmon by hand is not a viable long-term solution. Other options should be investigated such as deepening connections to known stranding sites to allow connection with the main channel at the current (agency established) minimum low flow from Keswick Dam of 3,250 cfs.

The past five years of this study have demonstrated the need for flexibility and adaptability when studying the dewatering and stranding of redds and juveniles in the upper Sacramento River. Figure 14 shows the flow releases from Keswick Dam for all five study seasons. Figure 14 reveals the typical variability that occurs from year-to-year during the study period of interest. To continue this effort in future years, staff should be in place in early summer but because of rainfall variability the study may or may not be able to occur on any given year. Flow releases from Keswick Dam in year 2010-2011 jumped above 15,000 cfs in early-December, (Figure 14), thus effectively canceling the ability to conduct the study after early-December. In year 2011-2012 the steady flows from mid-October to mid-November resulted in few dewatering events, but this was not the case in 2012-2013 when flows were slightly decreasing but large numbers of salmon were spawning for long periods of time. The variability experienced each year points to the challenge of managing river flows, predicting precipitation timing, and staffing for this project. In some future years crews will be busy all year (i.e. years similar to this dry 2013-2014 and 2014-2015 seasons), while in others the river might be flooding for months and crews will have little opportunity to collect data. In many years natural rainfall can swell the tributaries downstream of Keswick Dam. These natural inflows raise and lower the river levels and can both prevent, and lead to, dewatering and juvenile stranding depending on timing and salmon numbers.

This 2014-2015 study season was a very dry season with the exception of major rain events during the months of December 2014 and February 2015. Keswick flows were reduced earlier than typical in the year despite being held around 5,000 cfs until the first of November. These earlier flow reductions likely saved many fall-run redds from becoming dewatered. Figure 15 compares the difference in flow reduction timing with the number of observed dewatered redds between the 2013-14 and 2014-15 seasons. This season's dewatered redd percentage (0.3% or 47 redds) was significantly lower than that of the previous 2013-14 season (3% or 573 redds). Early fall flow reductions proved to be beneficial to the spawning success of fall-run Chinook salmon. The smaller Keswick flow reductions from November to December 2014 (5,000 to 3,900 cfs) when compared to these months of 2013 (7,000 to 3,900 cfs) show a considerable decrease in redd dewatering.

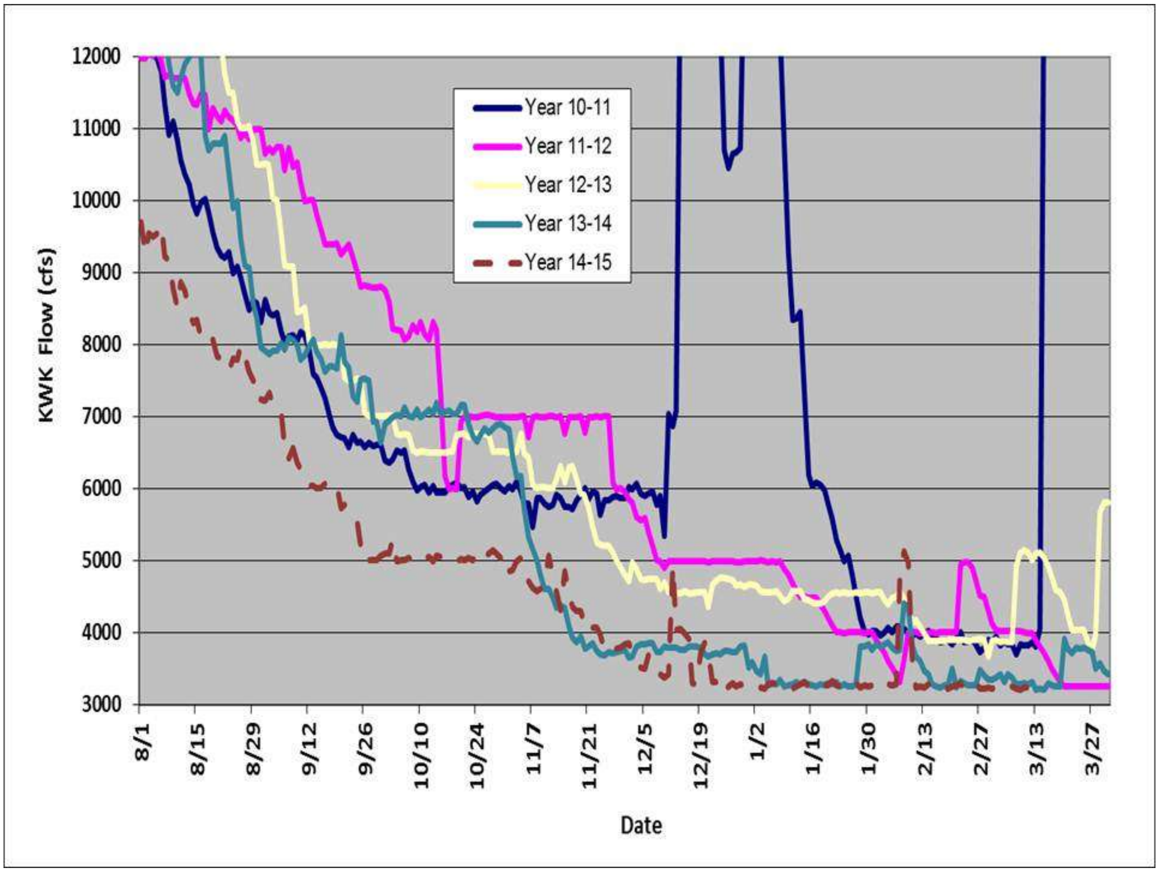

Figure 14. Graph of five years of Keswick Dam flows to the Sacramento River for the dates of interest to the dewatered redds and juvenile stranding study. Years 2013-2015 use the KWK flow gauge, other years use KES.

The fifth year of the dewatered redd and juvenile stranding study made many improvements due to additional funding and resources. A fully funded and dedicated staff made it possible to increase the distance downstream the study could monitor and gain valuable data that normally is not available in these areas due to typical tributary high flows in winter. Additional data and measurements such as water temperatures, dissolved oxygen, velocity, and egg viability were also conducted in thanks to the new resources. Crews were able to utilize and combine the field methods that were developed during the last four years of the pilot redd dewatering study with new techniques. The analysis and information in Appendix F Table F1 made possible the ability to calculate flows at almost any site along the river.

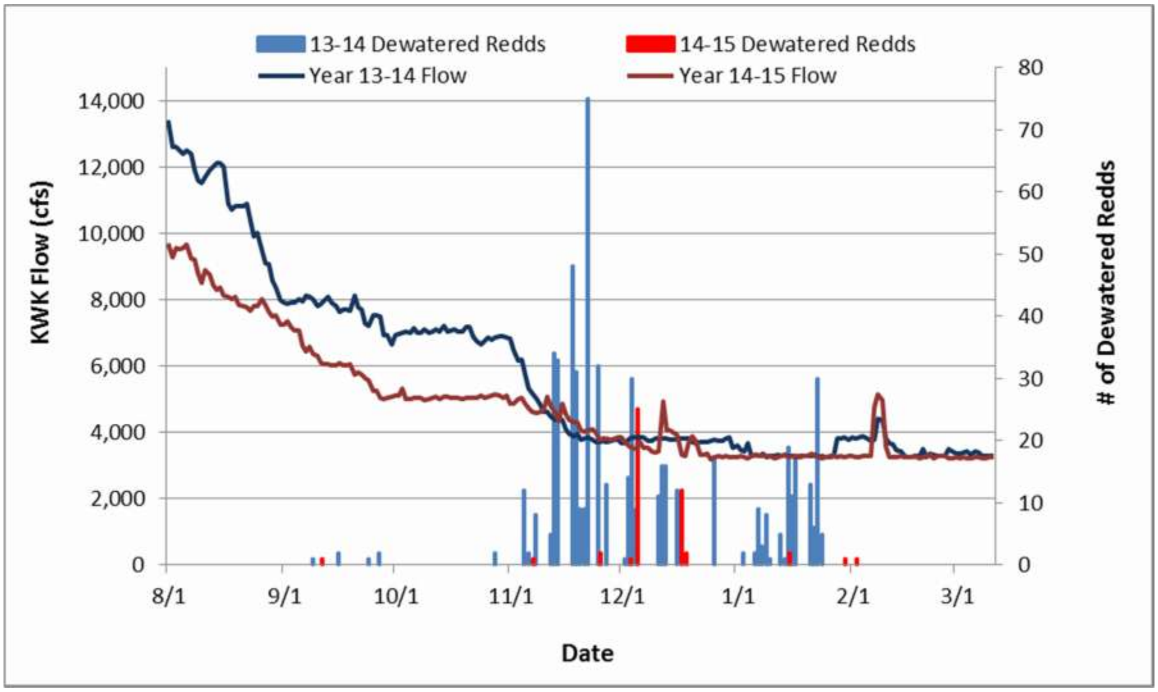

Figure 15. A comparison between water years 2013 and 2014. Significantly more fall-run redds were dewatered during the 2013-2014 season than in 2014-2015. The graph illustrates a much greater Keswick flow reduction after the peak spawn time during the month of November 2013 than in 2014.

Based on the data collected during this study, it is known that Sacramento River flow reductions and flow oscillations have the potential to increase the mortality of naturally produced salmonids by dewatering and/or stranding thousands of juvenile Chinook. It appears that the issue of stranding can affect juveniles of all runs, and can occur throughout the year at many different flows. It is now apparent that redd dewatering and stranding of juveniles impacts occurs in all types of habitat and has the potential to have a major impact on juvenile salmonid survival throughout the upper Sacramento River.

Future efforts will allow extensive coverage of the study areas as well as almost real-time reporting of redd dewatering and juvenile stranding. Most notably this includes further monitoring of juvenile stranding sites to provide insight on future fish rescues and river restoration. Water quality parameters such as water velocity, water temperatures, and dissolved oxygen in and near redds and in stranding sites will be analyzed to gain a better understanding of egg, and juvenile survival during dewatering and stranding events. In addition, coordinating this study with other studies (such as gravel injections, habitat typing, restoration projects, etc.) will provide mutually beneficial data collection and management options. Future efforts can also begin to assess the presence of superimposition in high density spawning grounds and its impact on the total number of Chinook redds being dewatered, as a proportion of the entire spawning population. With the use of advanced technology, further studies will provide resource managers with real-time data to make educated decisions on future flow allocations and based on the impacts these decisions will have on Central Valley Chinook Salmon.

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APPENDIX A

Relevant excerpts from the National Marine Fisheries Service (NMFS)-Operations and Criteria Plan (OCAP) Biological Opinion.

Page 587: Project operations of the Sacramento River Division affect winter-run, spring-run, CV steelhead, the Southern DPS of green sturgeon. In addition, project operations affect fall-run, which are not listed. Fall-run salmon are considered in developing the actions as a prey base for Southern Residents. This Division section of the RPA includes actions related to minimizing adverse effects to spring-run and steelhead spawning and rearing in Clear Creek and all species in the main stem Sacramento River. Actions include those necessary to reduce the risk to temperature effects to egg incubation in the upper river, especially to winter-run and spring-run spawning below Shasta Dam.

Page 590: Action Suite I.2. Shasta Operations, Introduction to Shasta Operations: Maintaining suitable temperatures for egg incubation, fry emergence, and juvenile rearing in the Sacramento River is critically important for survival and recovery of the winter-run ESU. The winter-run ESU has been reduced to a single population, which has been blocked from its historical range above Shasta Dam. Consequently, suitable temperatures and habitat for this population must be maintained downstream of Shasta Dam through management of the cold water pool behind the dam in the summer. Maintaining optimum conditions for this species below Shasta is crucial until additional populations are established in other habitats or this population is restored to its historical range. Spring-run are also affected by temperature management actions from Shasta Reservoir.

The effects analysis in this Opinion highlights the very challenging nature of maintaining an adequate cold water pool in critically dry years, extended dry periods, and under future conditions, which will be affected by increased downstream water demands and climate change. This suite of actions is designed to ensure that Reclamation uses maximum discretion to reduce adverse impacts of the projects to winter-run and spring-run in the Sacramento River by maintaining sufficient carryover storage and optimizing use of the cold water pool. In most years, reservoir releases through the use of the TCD are a necessity in order to maintain the bare minimum population levels necessary for survival (Yates et al. 2008, Angilletta et al. 2008).

The effects analysis in this Opinion, and supplemental information provided by Reclamation, make it clear that despite Reclamation's best efforts, severe temperature-related effects cannot be avoided in some years. The RPA includes exception procedures to deal with this reality. Due to these unavoidable adverse effects, the RPA also specifies other actions that Reclamation must take, within its existing authority and discretion, to compensate for these periods of unavoidably high temperatures. These actions include restoration of habitat at Battle Creek that may be support a second population of winter-run, and a fish passage program at Keswick and Shasta dams to partially restore winter-run to their historical cold water habitat.

Objectives*: The following objectives must be achieved to address the avoidable and unavoidable adverse effects of Shasta operations on winter-run and spring-run:*

> *Ensure a sufficient cold water pool to provide suitable temperatures for winter-run spawning between Balls Ferry and Bend Bridge in most years, without sacrificing the potential for cold water management in a subsequent year. Additional actions to those in the 2004 CVP/SWP operations Opinion are needed, due to increased vulnerability of the population to temperature effects attributable to changes in Trinity River ROD operations, projected climate change hydrology, and increased water demands in the Sacramento River system.*
>
> *Ensure suitable spring-run temperature regimes, especially in September and October. Suitable spring-run temperatures will also partially minimize temperature effects to naturally-spawning, non-listed Sacramento River fall-run, an important prey base for endangered Southern Residents.*
>
> *Establish a second population of winter-run in Battle Creek as soon as possible, to partially compensate for unavoidable project-related effects on the one remaining population.*
>
> *Restore passage at Shasta Reservoir with experimental reintroductions of winter-run to the upper Sacramento and/or McCloud rivers, to partially compensate for unavoidable project-related effects on the remaining population.*

Page 592: ***Action 1.2.1 Performance Measures.***

Objective*: To establish and operate to a set of performance measures for temperature compliance points and End-of-September (EOS) carryover storage, enabling Reclamation and NMFS to assess the effectiveness of this suite of actions over time. Performance measures will help to ensure that the beneficial variability of the system from changes in hydrology will be measured and maintained.*

Action: *The following long-term performance measures shall be attained. Reclamation shall track performance and report to NMFS at least every 5 years. If there is significant deviation from these performance measures over a 10-year period, measured as a running average, which is not explained by hydrological cycle factors (e.g., extended drought), then Reclamation shall reinitiate consultation with NMFS.*
Performance measures for EOS carryover storage at Shasta Reservoir:

87 percent of years: Minimum EOS storage of 2.2 MAF
82 percent of years: Minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Balls Ferry compliance point)
40 percent of years: Minimum EOS storage 3.2 MAF (to maintain potential to meet Jelly's Ferry compliance point in following year)

Measured as a 10-year running average, performance measures for temperature compliance points during summer season shall be:

Meet Clear Creek Compliance point 95 percent of time
Meet Balls Ferry Compliance point 85 percent of time
Meet Jelly's Ferry Compliance point 40 percent of time
Meet Bend Bridge Compliance point 15 percent of time

Rationale: *Evaluating long-term operations against a set of performance measures is the only way to determine the effectiveness of operations in preserving key aspects of life history and run time diversity. For example, maintaining suitable spawning temperatures down to Bend Bridge in years when this is feasible will help to preserve the part of winter-run distribution and run timing that relies on this habitat and spawning strategy. This will help to ensure that diversity is preserved when feasible. The percentages are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, and NMFS technical memo on historic Shasta operations.*

P 592: ***Action I.2.2*****.** **November through February Keswick Release Schedule (Fall Actions)**

Objective: *Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir.*

Action*: Depending on EOS carryover storage and hydrology, Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.*

Action I.2.2.A Implementation Procedures for EOS Storage at 2.4 MAF and Above
If the EOS storage is at 2.4 MAF or above, by October 15, Reclamation shall convene a group including NMFS, USFWS, and CDFG, through B2IT or other comparable process, to consider a range of fall actions. A written monthly average Keswick release schedule shall be developed and submitted to NMFS by November 1 of each year, based on the criteria below. The monthly release schedule shall be tracked through the work group. If there is any disagreement in the group, including NMFS technical staff, the issue/action shall be elevated to the WOMT for resolution per standard procedures.
The workgroup shall consider and the following criteria in developing a Keswick release schedule:

1) *Need for flood control space: A maximum 3.25 MAF end-of-November storage is necessary to maintain space in Shasta Reservoir for flood control.*

2) *Need for stable Sacramento River level/stage to increase habitat for optimal spring-run and fall-run redds/egg incubation and minimization of redd dewatering and juvenile stranding.*

3) *Need/recommendation to implement USFWS' Delta smelt Fall X2 action as determined by the Habitat Study Group formed in accordance with the 2008 Delta*

smelt Opinion. NMFS will continue to participate in the Habitat Study Group (HSG) chartered through the 2008 Delta smelt biological opinion. If, through the HSG, a fall flow action is recommended that draws down fall storage significantly from historical patterns, then NMFS and USFWS will confer and recommend to Reclamation an optimal storage and fall flow pattern to address multiple species' needs.

If there is a disagreement at the workgroup level, actions may be elevated to NMFS Sacramento Area Office Supervisor and resolved through the WOMT's standard operating procedures.
Rationale: *2.2 MAF EOS storage is linked to the potential to provide sufficient cold water to meet the minimum Balls Ferry Compliance point in the following year, and it is achievable approximately 85 percent of the time. Based on historical patterns, EOS storage will be above 2.4 MAF 70 percent of the time. The 2.4 MAF storage value provides a reasonable margin above the 2.2 level to increase the likelihood that the Balls Ferry Compliance Point will be reached while also implementing fall releases to benefit other species and life stages. Therefore, in these circumstances, actions should target the fall life history stages of the species covered by this Opinion (i.e., spring-run spawning, winter-run emigration). The development of a Keswick release schedule is a direct method for controlling storage maintained in Shasta Reservoir. It allows Reclamation to operate in a predictable way, while meeting the biological requirements of the species. The B2IT workgroup has been used in the past to target actions to benefit fall-run during this time of year using b(2) resources, and, because of its expertise, may also be used by Reclamation to develop this flow schedule. In the past, the B2IT group has used the CVPIA AFRP guidelines to target reservoir releases. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.*

Action I.2.2.B Implementation Procedures for EOS Storage Above 1.9 MAF and Below 2.4 MAF
If EOS storage is between 1.9 and 2.4 MAF, then Reclamation shall convene a group including NMFS, USFWS, and CDFG, through B2IT or other comparable workgroup, to consider a range of fall actions. Reclamation shall provide NMFS and the work group with storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February, and develop a monthly average Keswick release schedule based on the criteria below. The monthly release schedule shall be submitted to NMFS by November 1. Criteria for the release schedule shall include:

1) Maintain Keswick releases between 7000 cfs and 3250 cfs to reduce adverse effects on main stem spring-run and conserve storage for next year's cold water pool.

2) Consider fall-run needs per CVPIA AFRP guidelines, through January, including stabilizing flows to keep redds from de-watering.

3) Be more conservative in Keswick releases throughout fall and early winter if hydrology is dry, and release more water for other purposes if hydrology becomes wet. For example, release no more than 4,000 cfs if hydrology remains dry.

Reclamation, in coordination with the work group, shall review updated hydrology and choose a monthly average release for every month (November, December, January, February), based on the release schedule. In the event that the updated hydrology indicates a very dry pattern and consequent likely reduction in storage, the work group may advise Reclamation to take additional actions, including export curtailments, if necessary to conserve storage

If there is a disagreement at the work group level, actions may be elevated to NMFS and resolved through the WOMT's standard operating procedures.

***Rationale**: It is necessary to be reasonably conservative with fall releases to increase the likelihood of adequate storage in the following year to provide cold water releases for winter-run. This action is intended to reduce adverse effects on each species without compromising the ability to reduce adverse effects on another species. A work group with biologists from multiple agencies will refine the flow schedule, providing operational certainty while allowing for real-time operational changes based on updated hydrology. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.*

Action I.2.2.C. Implementation and Exception Procedures for EOS Storage of 1.9 MAF or Below

If the EOS storage is at or below 1.9 MAF, then Reclamation shall:

1) In early October, reduce Keswick releases to 3,250 cfs as soon as possible, unless higher releases are necessary to meet temperature compliance points (see action I.2.3).

2) Starting in early October, if cool weather prevails and temperature control does not mandate higher flows, curtail discretionary water deliveries (including, but not limited to agricultural rice decomposition deliveries) to the extent that these do not coincide with temperature management for the species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition, and any other discretionary purposes at this time of year, may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS, USFWS, and CDFG.

3) By November 1, submit to NMFS storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February. In coordination with NMFS, Reclamation shall: (1) develop a monthly average Keswick release schedule similar in format to that in Action I.2.2.B, based on the criteria below and including actions specified below; and (2) review updated hydrology and *choose a monthly average release for every month, based on the release schedule. November releases shall be based on a 90 percent hydrology estimate.*

Criteria and actions: 1) Keswick releases shall be managed to improve storage and maintained at 3,250 cfs unless hydrology improves. 2) November monthly releases will be based on 90 percent hydrology. 3) Consider fall-run needs through January as per CVPIA AFRP guidelines, including stabilizing flows to keep redds from dewatering. 4) Continue to curtail discretionary agricultural rice decomposition deliveries to the extent that these do not coincide with temperature management for the species, or impact other ESA-listed species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS. USFWS, and CDFG. 5) If operational changes are necessary to meet Delta outflow, X2, or other legal requirements during this time, then: a) CVP/SWP Delta combined exports shall be curtailed to 2,000 cfs if necessary to meet legal requirements while maintaining a 3,250 cfs Keswick release (or other planned release based on biological needs of species); and b) if it is necessary to curtail combined exports to values more restrictive than 2000 cfs in order to meet Delta outflow, X2, or other legal requirements, then Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom; and c) in general, Reclamation shall increase releases from Keswick as a last resort. d) Based on updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence. 6) If the hydrology and storage have not improved by January, additional restrictions apply – see Action I.2.4.

Rationale: *Per actions I.2.3 and I.2.4 below, Reclamation is required to meet 1.9 MAF EOS. The BA's CALSIM modeling shows that during a severe or extended drought, 1.9 EOS storage may not be achievable. In this circumstance, Reclamation should take additional steps in the fall and winter months to conserve Shasta storage to the maximum extent possible, in order to increase the probability of maintaining cold water supplies necessary for egg incubation for the following summer's cohort of winter-run. Assessment of the hydrologic record and CALSIM modeling shows that operational actions taken during the first year of a drought sequence are very important to providing adequate storage and operations in subsequent drought years. The biological effects of an extended drought are particularly severe for winter-run. Extended drought conditions are predicted to increase in the future in response to climate change. While it is not possible to predict the onset of a drought sequence, in order to ensure that project operations avoid jeopardizing listed species, Reclamation should operate in any year in which storage falls below 1.9 MAF EOS as potentially the first year of a drought sequence. The curtailments to discretionary rice decomposition deliveries and combined export curtailment of 2,000 cfs are necessary to conserve storage when EOS storage is low. This action is consistent with comments from the Calfed Science Peer Review panel. That panel recommended that Shasta be operated on a two-year (as opposed to single year) hydrologic planning cycle and that Reclamation take additional steps to incorporate planning for potential drought and extended drought into its operations.*

APPENDIX B

Reference tables of salmon biological life history traits.

Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	0.9%
9000																2.2%	5.5%
8000															2.6%	6.6%	11.5%
7500														0.8%	4.4%	9.1%	14.1%
7000													0.9%	2.0%	6.6%	11.8%	17.3%
6500												1.3%	2.6%	4.2%	9.8%	15.6%	21.1%
6000											1.2%	2.8%	4.6%	6.5%	12.9%	19.7%	25.8%
5500										1.4%	3.2%	5.4%	7.7%	10.3%	17.6%	24.9%	31.0%
5250									0.7%	2.1%	4.2%	6.8%	9.4%	12.3%	19.8%	27.2%	33.1%
5000								0.7%	1.3%	3.2%	5.6%	8.6%	11.6%	14.7%	22.6%	30.2%	36.0%
4750							0.8%	1.6%	2.5%	4.8%	7.6%	10.8%	14.2%	17.6%	25.8%	33.2%	38.8%
4500						0.8%	1.7%	2.8%	4.0%	6.9%	10.4%	14.2%	18.2%	22.1%	30.9%	38.8%	44.2%
4250					0.8%	1.6%	2.7%	4.0%	5.4%	8.9%	13.0%	17.2%	21.6%	25.8%	34.9%	42.8%	48.0%
4000				0.9%	1.7%	2.8%	4.1%	5.7%	7.3%	11.4%	15.8%	20.3%	24.8%	29.0%	38.0%	45.7%	50.7%
3750			0.9%	1.6%	2.6%	3.9%	5.5%	7.3%	9.2%	13.6%	18.4%	23.1%	28.0%	32.4%	41.5%	48.7%	53.6%
3500		1.0%	2.1%	3.2%	4.6%	6.2%	8.1%	10.1%	12.2%	17.0%	22.2%	27.4%	29.2%	37.0%	45.9%	52.8%	57.3%
3250	1.0%	2.0%	3.4%	4.8%	6.6%	8.4%	10.6%	12.9%	15.3%	20.6%	26.2%	31.7%	37.0%	41.5%	50.2%	56.3%	60.4%

USFWS, SFWO, Energy Planning and Instream Flow Branch
Sacramento River (Keswick Dam to Battle Creek) Redd Dewatering and Juvenile Stranding Final Report
June 22, 2006
55

Appendix B Table B1. Example of a relationship table developed in Gard's USFWS 2006 report between salmon spawning flows and redd development flows shown in percentage of total redds dewatered, if development flows less than spawning flows.

Percentage and cumulative percentages

		Based on years--82-86		1970-1988		1970-1988		1970-1986		1970-1988	
		Winter Run		**Spring Run**		**Fall Run**		**Late-Fall**		**Steelhead**	
	Week	%	cum.%	%	cum.%	%	cum.%	%	cum.%	%	cum.%
	1	1.70	3.45					6.50	55.39	0.97	91.84
JAN	2	1.78	5.23					6.32	61.71	0.80	92.64
	3	0.35	5.57					3.07	64.77	0.61	93.25
	4	1.28	6.85					2.91	67.69	0.50	93.75
	5	2.38	9.23					3.58	71.26	0.29	94.05
FEB	6	3.12	12.35					4.08	75.34	0.45	94.50
	7	3.08	15.44					4.19	79.54	0.56	95.06
	8	0.97	16.41					4.38	83.91	0.53	95.59
	9	6.35	22.76					3.29	87.20	0.49	96.09
MAR	10	7.72	30.48					2.14	89.34	0.46	96.54
	11	9.23	39.70	start				1.74	91.08	0.38	96.92
	12	7.79	47.49	0.10	0.10			3.39	94.47	0.30	97.22
	13	4.91	52.40	0.25	0.35			2.08	96.55	0.28	97.50
	14	7.64	60.04	0.59	0.93			1.82	98.37	0.35	97.85
APR	15	8.26	68.29	0.96	1.89			1.39	99.76	0.28	98.12
	16	9.19	77.48	1.38	3.27			0.24	100.00	0.19	98.31
	17	3.47	80.95	1.63	4.90			end		0.17	98.48
	18	2.02	82.98	1.60	6.50					0.16	98.63
MAY	19	1.60	84.58	1.71	8.21					0.17	98.80
	20	2.17	86.75	2.16	10.37					0.23	99.03
	21	3.09	89.84	2.63	13.00	start				0.18	99.20
	22	2.03	91.87	2.86	15.86	0.01	0.01			0.20	99.40
JUN	23	1.63	93.50	2.61	18.47	0.00	0.02			0.13	99.54
	24	1.84	95.34	2.93	21.40	0.01	0.03			0.14	99.68
	25	0.51	95.85	3.50	24.89	0.03	0.06			0.15	99.82
	26	0.76	96.61	3.10	27.99	0.08	0.14			0.18	100.00
	27	1.60	98.20	3.67	31.66	0.10	0.24			0.13	0.13
JUL	28	0.31	98.52	6.02	37.68	0.29	0.53			0.18	0.31
	29	1.04	99.55	4.75	42.44	0.49	1.02			0.18	0.49
	30	0.44	99.99	3.21	45.65	0.70	1.72			0.22	0.72
	31	0.01	100.00	4.12	49.77	0.96	2.68			0.26	0.98
AUG	32	end		6.97	56.74	1.68	4.36			0.39	1.36
	33			6.07	62.81	2.95	7.31			0.68	2.04
	34			6.75	69.55	3.53	10.84			1.12	3.16
	35			5.74	75.29	3.91	14.75			2.36	5.52
	36			7.22	82.51	4.54	19.29			3.82	9.34
SEP	37			6.68	89.19	5.59	24.88			5.80	15.14
	38			5.23	94.42	8.58	33.46			7.54	22.67
	39			3.70	98.12	9.24	42.70			8.95	31.63
	40			1.19	99.31	10.49	53.19	start		11.75	43.37
OCT	41			0.69	100.00	10.59	63.78	0.26	0.26	11.27	54.65
	42			end		8.97	72.75	2.06	2.32	9.79	64.44
	43					6.99	79.74	2.33	4.65	6.51	70.95
	44					6.70	86.44	3.27	7.92	5.17	76.12
NOV	45					4.68	91.12	4.24	12.16	4.04	80.17
	46					2.71	93.83	3.42	15.58	2.44	82.61
	47					2.23	96.06	3.65	19.23	2.21	84.82
	48	start				1.68	97.74	5.37	24.60	2.05	86.87
DEC	49	0.17	0.17			0.90	98.64	5.27	29.87	1.44	88.31
	50	0.38	0.55			0.66	99.30	5.27	35.14	1.04	89.35
	51	0.49	1.04			0.51	99.81	6.94	42.08	0.69	90.04
	52	0.71	1.75			0.19	100.00	6.81	48.89	0.83	90.87

Appendix B Table B2. Average migration timing for the various salmonid runs passing the Red Bluff Diversion Dam 1970-1988.

— · Fork Lengths by day sampled not SID

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

	FALL	SPRING	WINTER	LATE-FALL	FALL	
1-Jan	0-41	42-55	56-111	112-202	203-270	1-Jan
2-Jan	0-41	42-55	56-112	113-230	231-270	2-Jan
3-Jan	0-41	42-56	57-112	113-205	206-270	3-Jan
4-Jan	0-41	42-56	57-113	114-206	207-270	4-Jan
5-Jan	0-42	43-56	57-114	115-207	208-270	5-Jan
6-Jan	0-42	43-57	58-115	116-209	210-270	6-Jan
7-Jan	0-42	43-57	58-115	116-210	211-270	7-Jan
8-Jan	0-43	44-58	59-116	117-211	212-270	8-Jan
9-Jan	0-43	44-58	59-117	118-213	214-270	9-Jan
10-Jan	0-43	44-58	59-118	119-214	215-270	10-Jan
11-Jan	0-43	44-59	60-119	120-216	217-270	11-Jan
12-Jan	0-44	45-59	60-119	120-217	218-270	12-Jan
13-Jan	0-44	45-59	60-120	121-218	219-270	13-Jan
14-Jan	0-44	45-60	61-121	122-220	221-270	14-Jan
15-Jan	0-45	46-60	61-122	123-221	222-270	15-Jan
	FALL	SPRING	WINTER	LATE-FALL	FALL	
16-Jan	0-45	46-61	62-123	124-223	224-270	16-Jan
17-Jan	0-45	46-61	62-123	124-224	225-270	17-Jan
18-Jan	0-45	46-61	62-124	125-226	227-270	18-Jan
19-Jan	0-46	47-62	63-125	126-227	228-270	19-Jan
20-Jan	0-46	47-62	63-126	127-229	230-270	20-Jan
21-Jan	0-46	47-63	64-127	128-230	231-270	21-Jan
22-Jan	0-47	48-63	64-127	128-232	233-270	22-Jan
23-Jan	0-47	48-64	65-128	129-233	234-270	23-Jan
24-Jan	0-47	48-64	65-129	130-235	236-270	24-Jan
25-Jan	0-48	49-64	65-130	131-236	237-270	25-Jan
26-Jan	0-48	49-65	66-131	132-238	239-270	26-Jan
27-Jan	0-48	49-65	66-132	133-239	240-270	27-Jan
28-Jan	0-49	50-66	67-133	134-241	242-270	28-Jan
29-Jan	0-49	50-66	67-133	134-243	244-270	29-Jan
30-Jan	0-49	50-67	68-134	135-244	245-270	30-Jan
31-Jan	0-50	51-67	68-135	136-246	247-270	31-Jan
	FALL	SPRING	WINTER	LATE-FALL	FALL	
1-Feb	0-50	51-67	68-136	137-247	248-270	1-Feb
2-Feb	0-50	51-68	69-137	138-249	250-270	2-Feb
3-Feb	0-50	51-68	69-138	139-251	252-270	3-Feb
4-Feb	0-50	51-69	70-139	140-252	253-270	4-Feb

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Appendix B Table B3. Example of juvenile salmon fork length table allowing run classification by date and length developed for use in California Central Valley investigations.

APPENDIX C

Example of field datasheets used in 2014-2015 Redd Dewatering and Stranding Study.

SACRAMENTO RIVER REDD DEWATERING STUDY DATA SHEET

Date:____/_____/ 2014 Use new data sheet for each section
River temp:_______
Crew:_____,______,_____

River Section ____________
Water clarity:______ (nearest 1/2 foot)
GPS #_________

Boat ____________
Weather:__________ 1-clear, 2-pt cloudy, 3-cloudy, 4-rain, 5-snow

carcass survey boat = 1 (and 2 if both doing redds), 3= specific boat redd survey, 4= redds only 2nd boat, 5= walking to redd areas
SURVEY ID# from computer___________

COMMENTS:

REDD INFORMATION

	Redd #	Time	Pict #'s	Salmon Present	Dewatered	Action	Depth	Comments
1				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
2				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
3				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
4				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
5				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
6				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
7				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
8				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
9				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
10				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
11				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
12				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
13				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
14				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
15				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
16				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
17				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
18				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
19				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
20				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
21				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
22				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
23				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
24				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
25				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
26				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
27				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
28				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
29				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
30				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
31				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
32				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
33				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
34				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
35				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
36				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
37				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
38				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
39				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
40				0 1 2 3	0 1 2 3 4	0 1 2 3 4		

Codes:
Redd # = Disc Tag number and GPS waypoint #
Salmon Present = 0-none, 1-on redd, 2-seen in area, 3-redd dewatered
Dewatered ? = 0-No, 1-Top only, 2-Mostly, 3-Pot still wet, 4-Pot dry
Action = 0- depth and photo, 1-measured, 2-egg check, 3-Combination/other-use comments, 4-Mark expired (use back if measuring)

River Sections- 1= up from ACID, 2= up from Hwy 44, 3=up from Clear Pwr
4=up from Balls, 5=up from Battle, 6=up from Jellys, 7=up from Bend
8=up from RBDD, 9=up from Los Mo, 10=all down from Los Mo
DEPTH is inches of H20 of top of redd, can be negative (99 is no data collected)

Appendix C Figure C1. Front side of redd dewatering field datasheet.

REVERSE SIDE of SACRAMENTO Dewatered REDD DATA SHEET DATE:____/____/____ Section_____ Boat # _________

REDD INFORMATION (CONTINUED)

	REDD #	Time	Picture #	Salmon Present	Dewatered	Action	Depth	Comments
41				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
42				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
43				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
44				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
45				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
46				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
47				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
48				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
49				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
50				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
51				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
52				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
53				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
54				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
55				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
56				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
57				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
58				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
59				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
60				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
61				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
62				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
63				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
64				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
65				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
66				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
67				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
68				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
69				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
70				0 1 2 3	0 1 2 3 4	0 1 2 3 4		

Codes: Redd # = Disc Tag number and GPS waypoint #, Salmon Present = 0-none, 1-on redd, 2-seen in area, 3-redd dewatered
Dewatered ? = 0-No, 1-Top only, 2-Mostly, 3-Pot still wet, 4-Pot dry, Depth is in inches and 99 is not taken
Action = 0- depth and photo, 1-measured, 2-egg check, 3-Combination/other-use comments, 4-Mark expired

REDD MEASUREMENTS in inches (use for both new or previously marked redds)

	Redd #	Total length	Pot length	Pot wide	Pot Depth	Tail wide 1st-2nd	Flow avg (ft/sec) (4spots = frt,side,side,back)	Substrate	H20 temp (f°) (pot)
1						,	, , , , avg =	1 2 3 4	
2						,	, , , , avg =	1 2 3 4	
3						,	, , , , avg =	1 2 3 4	
4						,	, , , , avg =	1 2 3 4	
5						,	, , , , avg =	1 2 3 4	
6						,	, , , , avg =	1 2 3 4	
7						,	, , , , avg =	1 2 3 4	
8						,	, , , , avg =	1 2 3 4	
9						,	, , , , avg =	1 2 3 4	
10						,	, , , , avg =	1 2 3 4	
11						,	, , , , avg =	1 2 3 4	
12						,	, , , , avg =	1 2 3 4	
13						,	, , , , avg =	1 2 3 4	
14						,	, , , , avg =	1 2 3 4	
15						,	, , , , avg =	1 2 3 4	
16						,	, , , , avg =	1 2 3 4	
17						,	, , , , avg =	1 2 3 4	
18						,	, , , , avg =	1 2 3 4	
19						,	, , , , avg =	1 2 3 4	
20						,	, , , , avg =	1 2 3 4	

Substrate codes (circle predominant): 1- normal spawn size (3-5") cobble; 2-smaller gravel (trout1-3"), 3-larger cobble- (5-12"), 4-sandy

Pot depth is to surrounding undistrubed river bed

Appendix C Figure C2. Rear side of redd dewatering field datasheet.

SAC RIV JUVENILE FISH STRANDING SURVEY DATA

USE NEW Pg per SECTION see reverse for more section codes, fish lengths

Date:____/____/____ **River temp:**_______ **Weather:**_______ **GPS #**_______ SURVEY ID _______

River Section _______ 1-clear, 2-pt cloudy, 3-cloudy, 4-rain, 5-snow fill in at office

Boat _______ **Water clarity:**_______ **Crew:**____,____,____ **Agency (s)**_______

carcass survey boat = 1 (and 2 if both doing stranding), 3= specific boat stranding survey, 4= stranding only 2nd boat, 5= walking (no boat) to standing areas

COMMENTS: Fill out fish fork cutoffs before the survey based on date. Take pics of all stranding locations surveyed

	Time	Waypoint #	Picture #'s	Riv Mile	Connection	Winter run #	Fall run #	Late Fall #	Habitat	Survival	Substrate	Pool Temp	DO2	Length-ft	Width-ft	Depth-ft	Shelter	Reconnect	Rescue	Comments
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				

CODES: **Time**:-military **Waypoint #** is with gps zoomed to 80'- can have multiple small pools with same waypoint, if long take wp in middle

Pics- take mult pics show all, underwater fish, list numbers **Connection** = **0**-open both up and down, **1**-up open only, **2**-down only, **3** = Isolated completely

Habitat = **0**-Pool, **1**-Riffle, **2**-Combo Both **Survival** = judgement and forecast of future conditions = **0**-Survival likely, **1**-Death likely, **2**- Survival is uncertain

Substrate = **0**-Bedrock, **1**-Cobble, **2**-small rocks-sand, **3**-sand-silt-mud, **4**-multiple **Shelter** = **0**-tree branches, **1**-submerged wood, **2**-aquatic veg, **3**-none, **4**-mult

Reconnect= **0**-by Hand, **1**-by Power, **2**-by machine, **3**-not possible **Rescue** = **0**-easy, **1**-moderate, **2**-difficult, **3**-not possible

Appendix C Figure C3. Front side of juvenile stranding field datasheet.

FILL OUT FRONT FIRST this is Reverse side of JUVENILE FISH STRANDING SURVEY DATA

River Sections- 1= up from ACID, 2= up from Hwy 44, 3= up from Clear 4= up from Balls, 5= up from Battle, 6= up from Jellys, 7= up from Bend 8= up from RBDD, 9= up from Los Mo, 10= all down from Los Mo	Winter run size = Fall run size = Late fall size =	Date:_____/______/_______ River Section ___________ Boat ______________

	Time	Waypoint #	Picture #'s	Riv Mile	Connection	Winter run #	Fall run #	Late Fall #	Habitat	Survival	Substrate	Pool Temp	DO2	Length-ft	Width-ft	Depth-ft	Shelter	Reconnect	Rescue	Comments
19																				
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
32																				
33																				
34																				
35																				
36																				
37																				
38																				

CODES: **Time**:-military **Waypoint #** is with gps zoomed to 80'- can have multiple small pools with same waypoint, if long take wp in middle

Pics- take mult pics show all, underwater fish, list numbers **Connection = 0**-open both up and down, **1**-up open only, **2**-down only, **3 =** Isolated completely

Habitat = **0**-Pool, **1**-Riffle, **2**-Combo Both **Survival =** judgement and forecast of future conditions = **0**-Survival likely, **1**-Death likely, **2**- Survival is uncertain

Substrate = **0**-Bedrock, **1**-Cobble, **2**-small rocks-sand, **3**-sand-silt-mud, **4**-multiple **Shelter** = **0**-tree branches, **1**-submerged wood, **2**-aquatic veg, **3**-none, **4**-mult

Reconnect= 0-by Hand, **1**-by Power, **2**-by machine, **3**-not possible **Rescue** = **0**-easy, **1**-moderate, **2**-difficult, **3**-not possible

Appendix C Figure C4. Rear side of juvenile stranding field datasheet.

SAC RIV JUVENILE FISH RESCUE DATA see reverse for more section codes, fish lengths, codes

Date:_____/______/________

SURVEY ID __________

River Section ___________

Datasheet for rescued fish only. Observed fish recorded on SAC RIV JUVENILE FISH STRANDING SURVEY DATASHEET

COMMENTS: Fill out fish fork cutoffs before the survey based on date. Take pics of all stranding locations surveyed

	Time	Waypoint #	Picture #'s	W-CHISAL	S-CHISAL	F-CHISAL	L-CHISAL	RAITRO adult	RAITRO juvenile	THRSTI	SAKPIK	RIFSCU	SACSUC	WESMOS	HARDHE	CALROA	Other Species Comments
1																	
2																	
3																	
4																	

Appendix C Figure C5. Front side of juvenile rescue field datasheet.

FILL OUT FRONT FIRST this is Reverse side of JUVENILE FISH RESCUE DATA

River Sections- 1= up from ACID, 2= up from Hwy 44, 3= up from Clear 4= up from Balls, 5= up from Battle, 6= up from Jellys, 7= up from Bend 8= up from RBDD, 9= up from Los Mo, 10= all down from Los Mo	Winter run size = Fall run size = Late fall size =	Date:______/______/______ River Section __________ Boat __________

Waypoint #	W-CHISAL	S-CHISAL	F-CHISAL	L-CHISAL	RAITRO adult	RAITRO juvenile	Other Species Comments

Blue Gill	BLUEGI	Lamprey Spp.	LAMSPP	Sacramento Sucker	SACSUC	catfish spp.	CATSPP	mosquito fish	WESMOS	Notes:
California Roach	CALROA	Largemouth Bass	LARBAS	Sculpin Spp.	SCUSPP	green sunfish	GRESUN	goldfish	GOLDFI	
Chinook Salmon	CHISAL	Minnow Spp.	MINSPP	Smallmouth Bass	SMABAS	largemouth bass	LARBAS	common carp	COMCAR	
Dace Species	DACSPP	ainbow Trout (Steelhea	RAITRO	Threespine Stickleback	THRSTI	riffle sculpin	RIFSCU	brown trout	BRWTRO	
Hardhead	HARDHE	Sacramento Pikeminnov	SACPIK	Unknown	FISUKN	prickly sculpin	PRISCU	american shad	AMESHA	

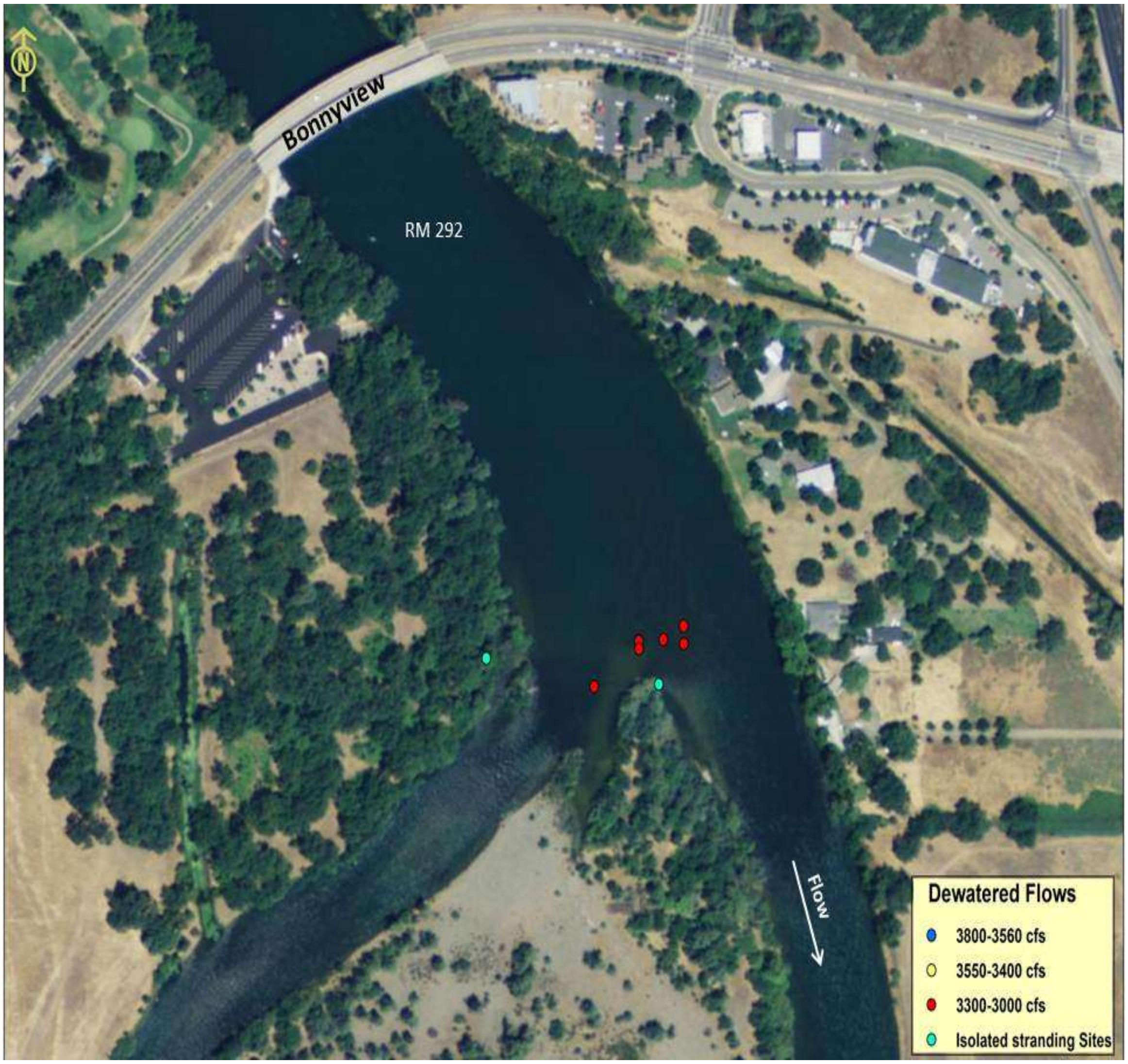
Appendix C Figure C6. Rear side of juvenile rescue field datasheet.

APPENDIX D

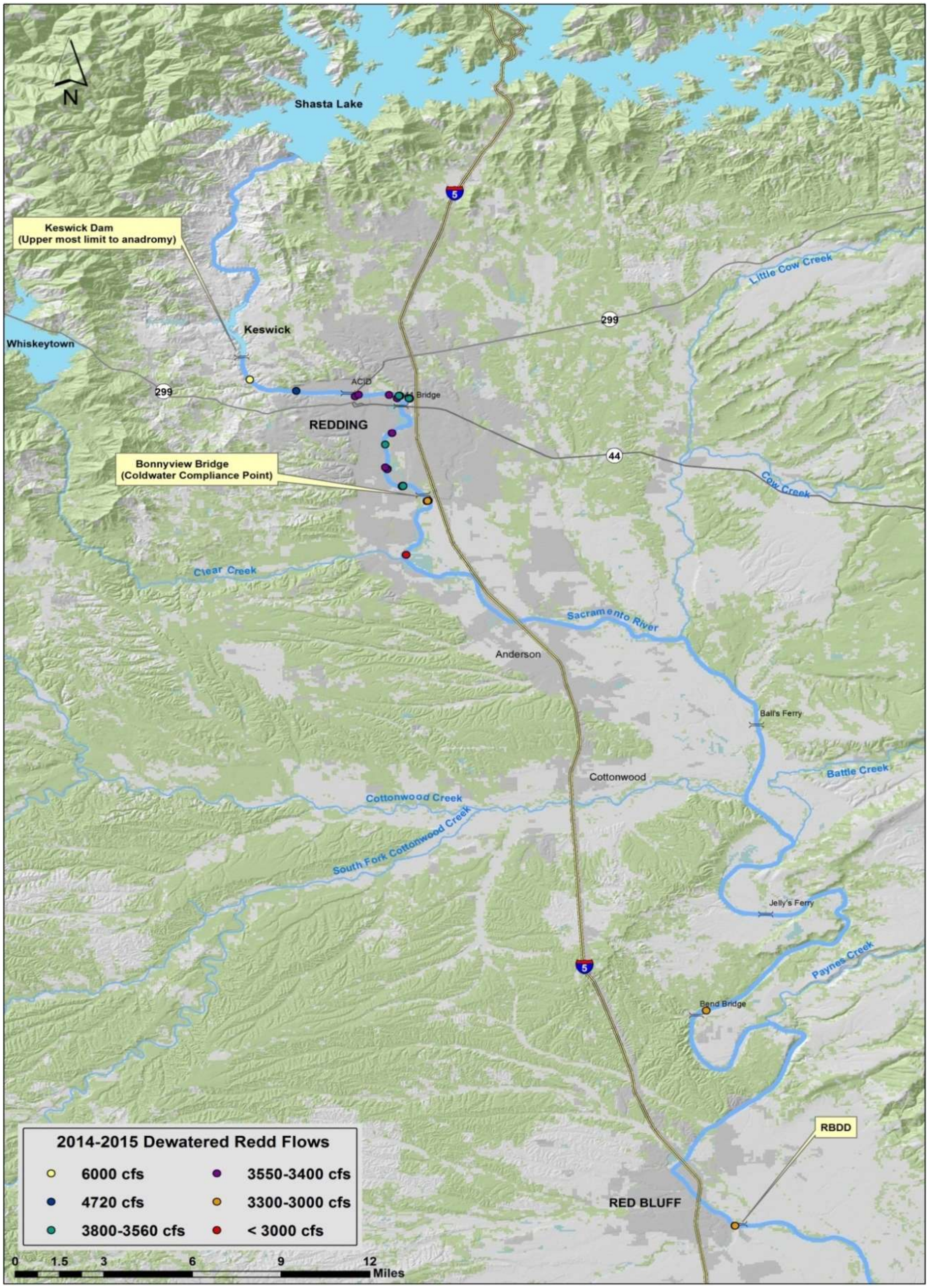
Example locations of stranding sites and Chinook redds marked during the 2014-2015 monitoring effort. Maps and site locations for entire river survey reach are available upon request.

Appendix D Figure D1. Location of dewatered redds and stranding sites at RM-297 in Redding. Redds are color coded based on range of flows.

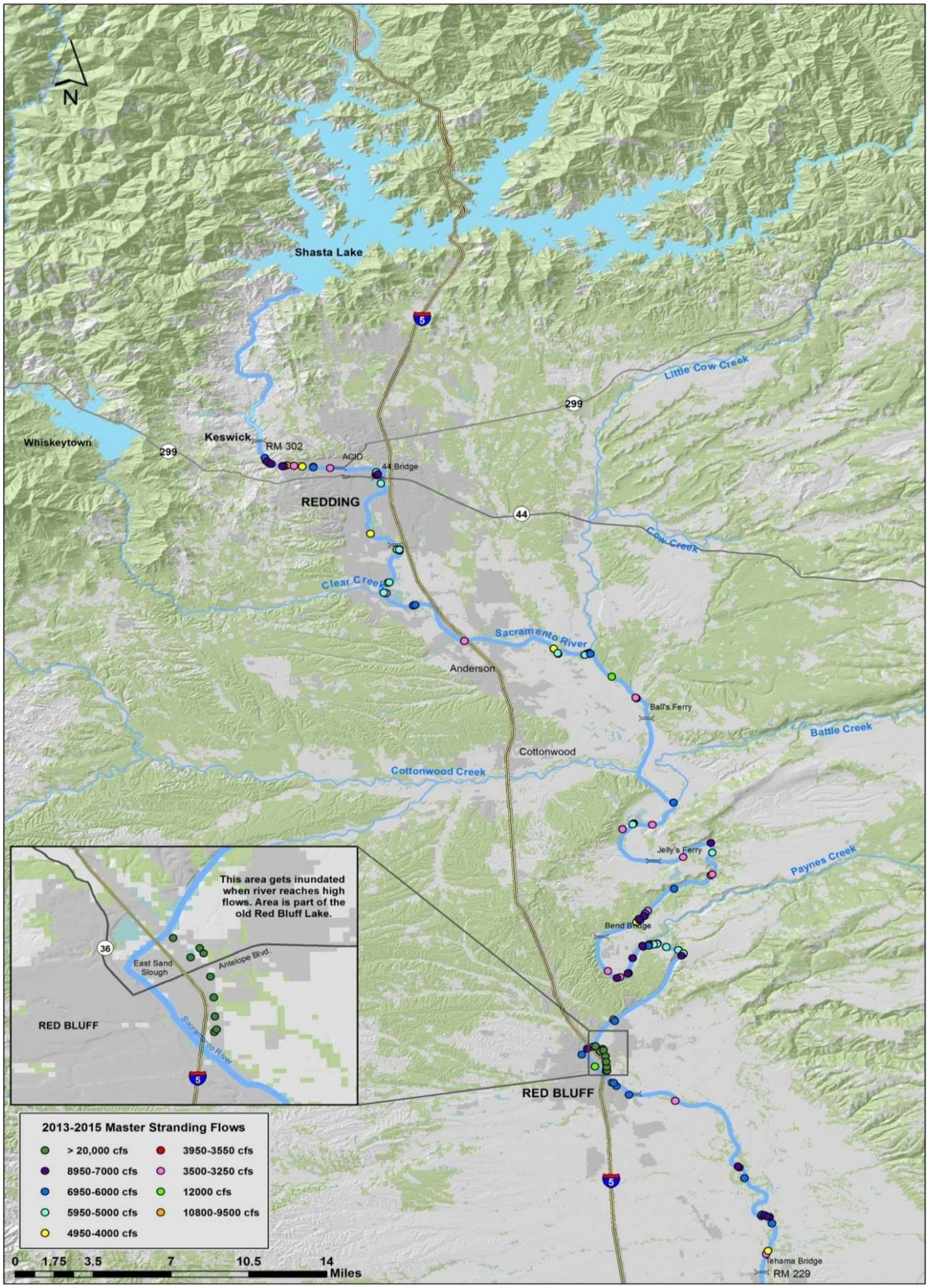
Appendix D Figure D2. Dewatered redds at river mile 292.5 in Redding, CA. An area of high density spawning.



Appendix D Figure D3. Location of isolated stranding sites and dewatered fall-run Chinook redds below Bonnyview bridge in Redding, CA. Stranding sites contained winter-run Chinook.



Appendix D Figure D4. Map of all 2014-2015 dewatered redds with corresponding Keswick flow range.



Appendix D Figure D5. Map of all 2013-2015 isolated stranding site locations. Sites are color coded based on the corresponding stranding flow range.

APPENDIX E

Photographs of redd dewatering and juvenile stranding from the 2014-2015 study on the Sacramento River.

Appendix E Figure E1. Rainbow trout/steelhead smolt swimming out of a very shallow stranding site, after a high water event. Located in East Sand Slough on the Sacramento River; February 13, 2015.

Appendix E Figure E2. Bedrock and cobble stranding pool, Sacramento River, February 4, 2015. Keswick Dam flow: 3,280 cfs.

Appendix E Figure E3. Exposed cobble stranding pool, Sacramento River, January 5, 2015. Keswick Dam flow: 3,240 cfs.

Appendix E Figure E4. Stranding pool containing fall-run Chinook. Sacramento River, February 19, 2015. Keswick Dam flow: 3,270 cfs.

Appendix E Figure E5. Stranding site in East Sand Slough, located in side channel above Antelope Blvd. bridge in Red Bluff, CA. Contained an estimated 273 hatchery winter-run and wild fall-run juvenile Chinook on March 2, 2015.

Appendix E Figure E6. Dewatered Chinook redd (top only dewatering), Sacramento River, December 05, 2014. Keswick Dam flow: 3,540 cfs.

Appendix E Figure E7. Dewatered Fall-run redd (mostly dewatered). Sacramento River, December 05, 2014. Keswick Dam flow: 3,540 cfs.

Appendix E Figure E8. Dewatered fall-run Chinook redd (pot still wet), Sacramento River January 13, 2014.

Appendix E Figure E9. Decomposed Chinook eggs excavated from a completely dewatered redd. Sacramento River November 11, 2014.

APPENDIX F

Relationship between distance and time and flows for the Sacramento River between Keswick Dam (RM-302) and Tehama Bridge (RM-229).

Note to use this table: use recorded time of day and the river mile of your point of interest (redd, stranding site, etc). River miles are divided into half miles and segments begin at downstream edge. Subtract the time from this table from the actual time at site location. Compare this calculated time to the closest (15 minute) corresponding KWK or KES gauge time and use CDEC site to obtain a river flow value for the calculated time. This flow value is the actual flow at your point of interest, minus any tributary inputs.

Appendix F Table F1. Times for Sacramento River flows to travel downstream from Keswick Dam to Tehama CA. by half-river miles (RM). Green highlight indicates locations with flow measuring sites.

Miles	RM	KES Time	KWK Time	Location
0.0	302	0:00		KESWICK DAM (KES Gauge)
0.5	301.5	0:06		
1.0	301	0:11	0:02	KWK Gauge is 0.75 miles downstream
1.5	300.5	0:17	0:08	
2.0	300	0:23	0:14	
2.5	299.5	0:28	0:20	
3.0	299	0:34	0:25	Diestelhorst Bridge-Redding CA
3.5	298.5	0:40	0:31	
4.0	298	0:46	0:37	
4.5	297.5	0:51	0:43	
5.0	297	0:57	0:49	Turtle Bay-Redding CA
5.5	296.5	1:03	0:54	
6.0	296	1:09	1:00	
6.5	295.5	1:15	1:06	
7.0	295	1:20	1:12	Cypress Street Bridge-Redding CA
7.5	294.5	1:26	1:17	
8.0	294	1:32	1:23	
8.5	293.5	1:38	1:29	
9.0	293	1:43	1:35	
9.5	292.5	1:49	1:40	
10.0	292	1:55	1:46	Bonnyview Bridge-Redding CA
10.5	291.5	2:01	1:52	
11.0	291	2:06	1:58	
11.5	290.5	2:12	2:04	
12.0	290	2:18	2:09	
12.5	289.5	2:24	2:15	
13.0	289	2:30	2:21	Clear Creek mouth
13.5	288.5	2:35	2:27	
14.0	288	2:41	2:32	
14.5	287.5	2:47	2:38	
15.0	287	2:53	2:44	I5 close below Burbon Island

Appendix F Table F1. Continued.

Miles	RM	KES Time	KWK Time	Location
15.5	286.5	2:58	2:50	
16.0	286	3:04	2:55	
16.5	285.5	3:10	3:01	
17.0	285	3:16	3:07	I5 Bridge-Anderson CA
17.5	284.5	3:21	3:13	
18.0	284	3:27	3:19	Airport Road Bridge- Anderson CA
18.5	283.5	3:33	3:24	
19.0	283	3:39	3:30	
19.5	282.5	3:45	3:36	
20.0	282	3:50	3:42	
20.5	281.5	3:56	3:47	
21.0	281	4:02	3:53	Deschutes Road Bridge-
21.5	280.5	4:08	3:59	
22.0	280	4:13	4:05	Cow Creek mouth
22.5	279.5	4:19	4:10	
23.0	279	4:25	4:16	
23.5	278.5	4:31	4:22	
24.0	278	4:36	4:28	
24.5	277.5	4:42	4:34	
25.0	277	4:48	4:39	Ash Creek-Mouth
25.5	276.5	4:54	4:45	
26.0	276	5:00	4:51	Balls Ferry Bridge-Cottonwood CA
26.5	275.5	5:05	4:57	
27.0	275	5:11	5:02	
27.5	274.5	5:17	5:08	
28.0	274	5:23	5:14	
28.5	273.5	5:28	5:20	
29.0	273	5:34	5:25	Cottonwood Creek mouth
29.5	272.5	5:40	5:31	
30.0	272	5:46	5:37	
30.5	271.5	5:51	5:43	
31.0	271	5:57	5:49	Battle Creek mouth
31.5	270.5	6:03	5:54	
32.0	270	6:09	6:00	Barge Hole Fishing Access
32.5	269.5	6:15	6:06	
33.0	269	6:20	6:12	Lake California Area side channel
33.5	268.5	6:26	6:17	
34.0	268	6:32	6:23	
34.5	257.5	6:38	6:29	
35.0	267	6:43	6:35	Jellys Ferry Road Bridge
35.5	266.5	6:49	6:40	
36.0	266	6:55	6:46	
36.5	265.5	7:01	6:52	
37.0	265	7:06	6:58	
37.5	264.5	7:12	7:04	
38.0	264	7:18	7:09	Inks Creek mouth
38.5	263.5	7:24	7:15	

Appendix F Table F1. Continued.

Miles	RM	KES Time	KWK Time	Location
39.0	263	7:30	7:21	Massacre Flat BLM camp
39.5	262.5	7:35	7:27	
40.0	262	7:41	7:32	
40.5	261.5	7:47	7:38	
41.0	261	7:53	7:44	
41.5	260.5	7:58	7:50	BEND Gauge is at RM 260.4
42.0	260	8:05	7:57	
42.5	259.5	8:12	8:03	
43.0	259	8:19	8:10	
43.5	258.5	8:26	8:17	
44.0	258	8:33	8:24	Bend District Road Bridge
44.5	257.5	8:39	8:31	
45.0	257	8:46	8:38	
45.5	256.5	8:53	8:45	
46.0	256	9:00	8:51	
46.5	255.5	9:07	8:58	
47.0	255	9:14	9:05	China Rapids
47.5	254.5	9:21	9:12	
48.0	254	9:27	9:19	
48.5	253.5	9:34	9:26	
49.0	253	9:41	9:33	Paynes Creek mouth
49.5	252.5	9:48	9:39	
50.0	252	9:55	9:46	
50.5	251.5	10:02	9:53	
51.0	251	10:09	10:00	
51.5	250.5	10:15	10:07	
52.0	250	10:22	10:14	Powerlines in Iron Canyon
52.5	249.5	10:29	10:21	
53.0	249	10:36	10:27	
53.5	248.5	10:43	10:34	
54.0	248	10:50	10:41	
54.5	247.5	10:57	10:48	
55.0	247	11:03	10:55	Dibble Creek mouth
55.5	246.5	11:10	11:02	
56.0	246	11:17	11:09	
56.5	245.5	11:24	11:15	
57.0	245	11:31	11:22	Antelope Ave. Bridge-Red Bluff CA
57.5	244.5	11:38	11:29	
58.0	244	11:45	11:36	
58.5	243.5	11:51	11:43	Red Bank Creek mouth
59.0	243	11:59	11:51	RBD Gauge is at RM 242.9
59.5	242.5	12:07	11:58	
60.0	242	12:15	12:06	
60.5	241.5	12:22	12:14	
61.0	241	12:30	12:21	
61.5	240.5	12:38	12:29	
62.0	240	12:46	12:37	mouth of Salt Creek

Appendix F Table F1. Continued.

Miles	RM	KES Time	KWK Time	Location
62.5	239.5	12:53	12:45	
63.0	239	13:01	12:52	mouth of Craig Creek
63.5	238.5	13:09	13:00	
64.0	238	13:16	13:08	
64.5	237.5	13:24	13:15	
65.0	237	13:32	13:23	
65.5	236.5	13:40	13:31	
66.0	236	13:47	13:39	
66.5	235.5	13:55	13:46	Butler Slough mouth
67.0	235	14:03	13:54	
67.5	234.5	14:10	14:02	
68.0	234	14:18	14:10	Antelope Creek mouth
68.5	233.5	14:26	14:17	
69.0	233	14:34	14:25	Coyote Creek mouth
69.5	232.5	14:41	14:33	
70.0	232	14:49	14:40	Dye Creek mouth
70.5	231.5	14:57	14:48	
71.0	231	15:05	14:56	
71.5	230.5	15:12	15:04	Elder Creek mouth
72.0	230	15:20	15:11	Mill Creek mouth
72.5	229.5	15:28	15:19	TEH Gauge is at RM 229.3
73.0	229	15:35	15:27	Tehama CA

Readers should take note that in mid-2013 the "KES" CDEC gauge historically used to record Keswick Dam outflows for numerous databases, reports and studies malfunctioned and was not repaired (it continued reporting inaccurate readings) as of the time of this report. Fortunately three quarters of a mile downstream from Keswick Dam is the "KWK" CDEC gauge that records similar flow data. Readers interested in further analysis should use the KWK gauge for all flow related data needs, until such time that the KES and KWK gauges report similar results.

APPENDIX G – Dissolved Oxygen Logger Data

Catalog of dissolved oxygen (DO) meters in fall-run redds: average weekly DO, temperature, flows and water depth by date.

The following figures display measured parameters specific to each of the dissolved oxygen meter loggers placed inside 14 fall-run redds during the 2014-2015 season. Water depth was measured by survey crew members during each site visit to a specific redd. Both Keswick and Bend flow data was obtained from the California Data Exchange Center (CDEC) for the dates of interest. The tables and graphs were designed to illustrate the various environmental factors affecting the overall health of chinook salmon redds and how they influence one another.

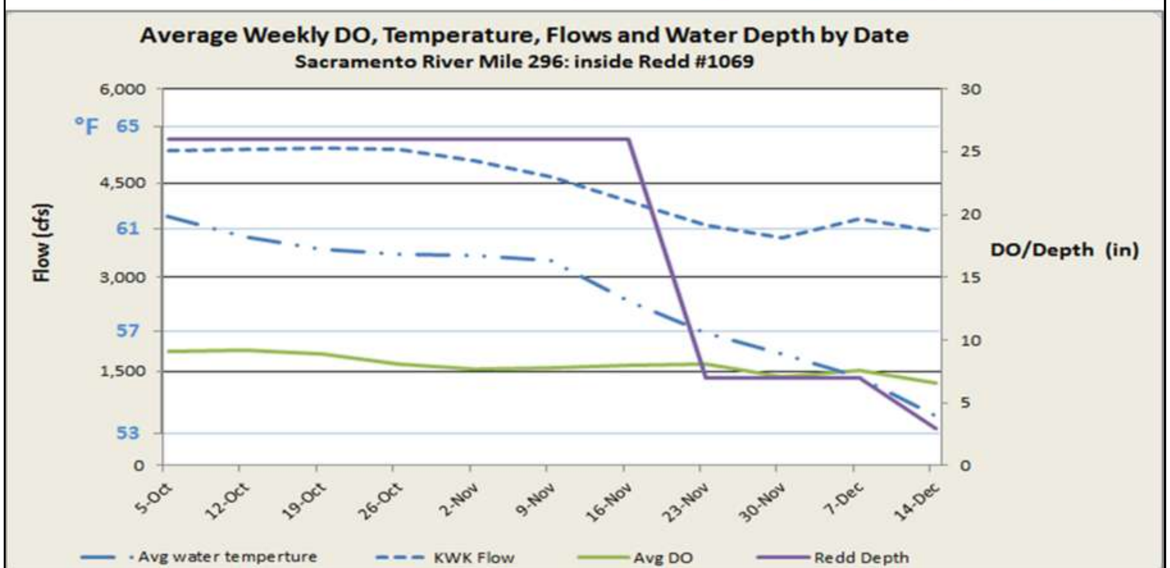
The data tables included in this appendix contain a hot-cold, gradient color scheme to display the temperature ranges measured in each redd. The blue color represents cooler temperatures while the red indicates warmer temperatures that are harmful to incubating eggs and fry. The orange and brown colors indicate intermediate temperatures measured between the two extreme temperatures. Water below 56°F is not impacting egg and fry survival while water temperatures above 62°F are fatal to most eggs and fry.

The graphs show water quality parameter fluctuations over time. The y-axis on the right shares the same scale for both dissolved oxygen (mg/l) measurements and water depth in inches. The y-axis located on the left side of the graph represents the river flow as well as water temperature (blue).

Each DO meter logger was injected into a fall-run redd using a fabricated “redd injector” as described in the Drought Monitoring of Water Quality for Spawning Chinook Salmon 2014 report (Killam and Thompson, 2015). The DO loggers recorded both dissolved oxygen and temperature while survey crews measured the water depth of the redd during each site visit.

Redd #1069

Redd #1069 was located north of Turtle Bay at RM 296 and contained DO logger #15. It was not dewatered but was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/18/2014.

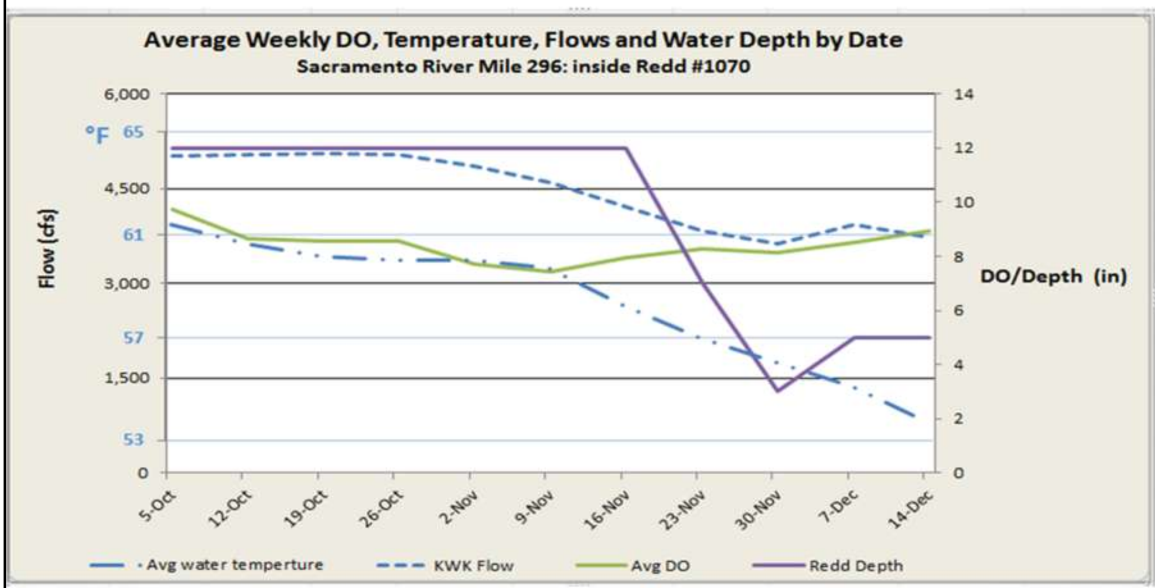


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1069	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	9	26	61
42	10/12/2014	10/18/2014	5026	9	26	61
43	10/19/2014	10/25/2014	5061	9	26	60
44	10/26/2014	11/1/2014	5038	8	26	60
45	11/2/2014	11/8/2014	4858	8	26	60
46	11/9/2014	11/15/2014	4597	8	N/A	60
47	11/16/2014	11/22/2014	4216	8	N/A	58
48	11/23/2014	11/29/2014	3831	8	7	57
49	11/30/2014	12/6/2014	3630	7	7	56
50	12/7/2014	12/13/2014	3933	8	N/A	55
51	12/14/14	12/20/14	3722	7	3	54

Appendix G Figure G1. Summary of information specific to each fall-run redd containing a DO logger. Loggers were placed inside of redds thought to be most susceptible to dewatering.

Redd #1070

Redd #1070 was located north of Turtle Bay at RM 296.5 and contained DO logger #14. It was not dewatered but was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/18/2014.

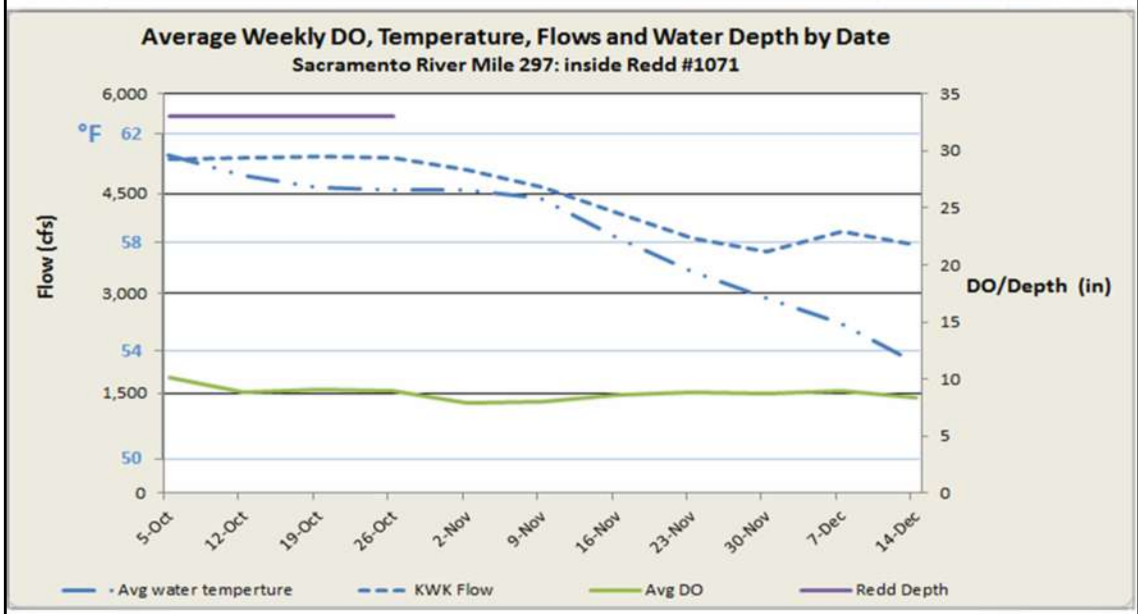


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1070	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	12	61
42	10/12/2014	10/18/2014	5026	9	12	61
43	10/19/2014	10/25/2014	5061	9	12	60
44	10/26/2014	11/1/2014	5038	9	12	60
45	11/2/2014	11/8/2014	4858	8	12	60
46	11/9/2014	11/15/2014	4597	7	N/A	60
47	11/16/2014	11/22/2014	4216	8	N/A	58
48	11/23/2014	11/29/2014	3831	8	7	57
49	11/30/2014	12/6/2014	3630	8	3	56
50	12/7/2014	12/13/2014	3933	9	N/A	55
51	12/14/14	12/20/14	3722	9	5	54

Appendix G Figure G1. Continued.

Redd #1071

Redd #1071 was located at RM 297 in Redding and contained DO logger #9. It was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/18/2014.

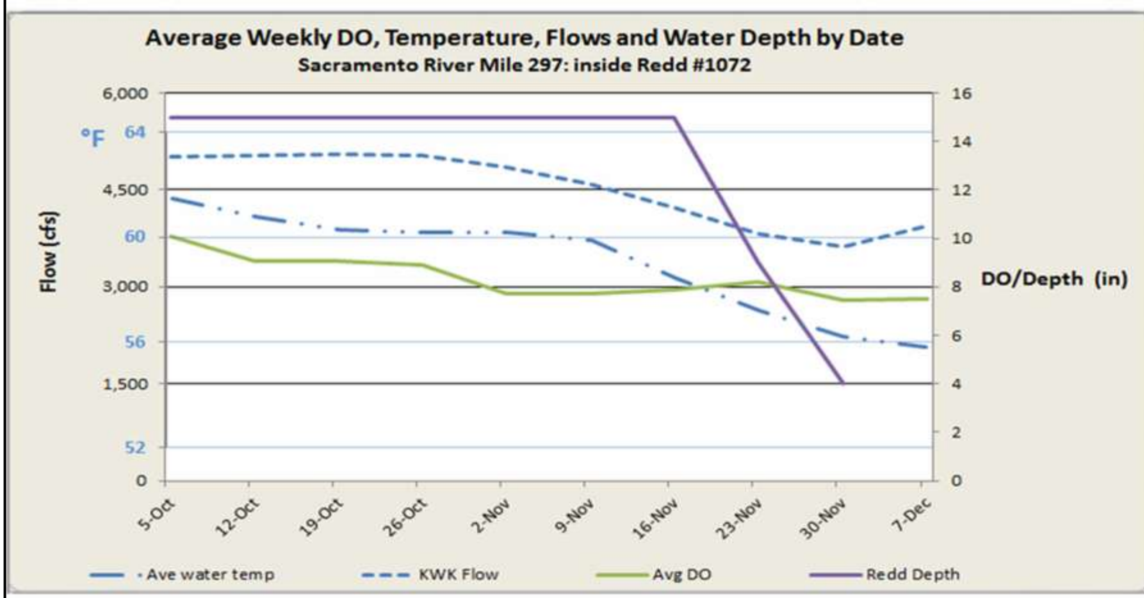


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1071	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	33	61
42	10/12/2014	10/18/2014	5026	9	33	60
43	10/19/2014	10/25/2014	5061	9	33	60
44	10/26/2014	11/1/2014	5038	9	33	60
45	11/2/2014	11/8/2014	4858	8	N/A	60
46	11/9/2014	11/15/2014	4597	8	N/A	60
47	11/16/2014	11/22/2014	4216	9	N/A	58
48	11/23/2014	11/29/2014	3831	9	N/A	57
49	11/30/2014	12/6/2014	3630	9	N/A	56
50	12/7/2014	12/13/2014	3933	9	N/A	55
51	12/14/14	12/20/14	3722	8	N/A	54

Appendix G Figure G1. Continued.

Redd #1072

Redd #1072 was located at RM 297 and contained DO logger #8. It was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/18/2014.

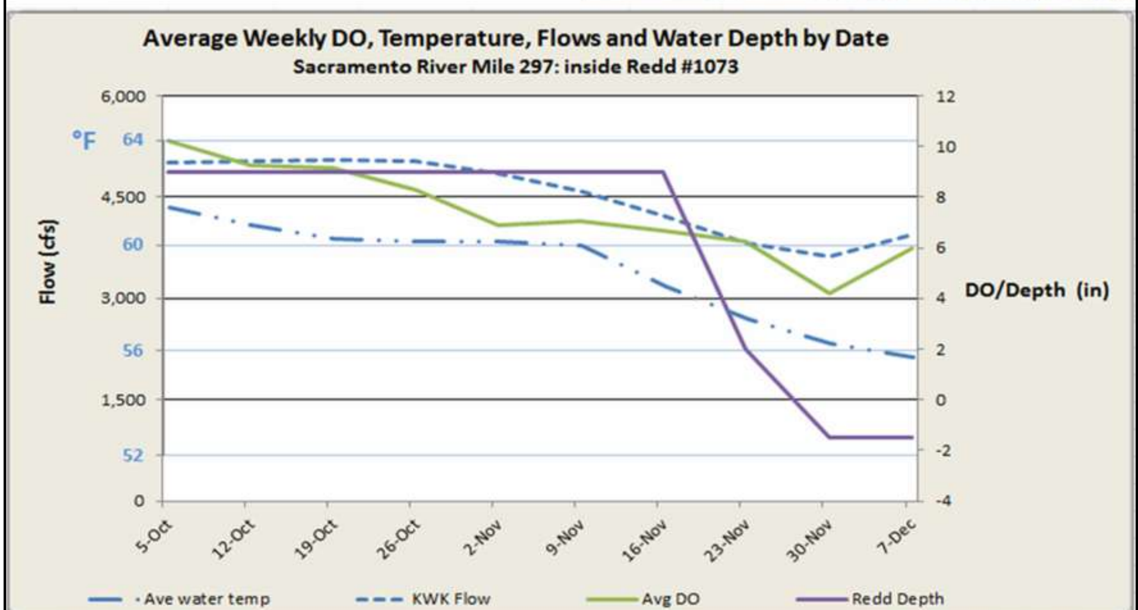


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1072	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	15	61
42	10/12/2014	10/18/2014	5026	9	15	61
43	10/19/2014	10/25/2014	5061	9	15	60
44	10/26/2014	11/1/2014	5038	9	15	60
45	11/2/2014	11/8/2014	4858	8	15	60
46	11/9/2014	11/15/2014	4597	8	N/A	60
47	11/16/2014	11/22/2014	4216	8	N/A	58
48	11/23/2014	11/29/2014	3831	8	9	57
49	11/30/2014	12/6/2014	3630	7	4	56
50	12/7/2014	12/13/2014	3933	8	N/A	56

Appendix G Figure G1. Continued.

Redd #1073

Redd #1073 was located at RM 297 and contained DO logger #2. It was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/18/2014. Keswick flow reductions during 12/2/2014 resulted in "top dewatering" this redd and further reducing its DO content to 4 mg/l.

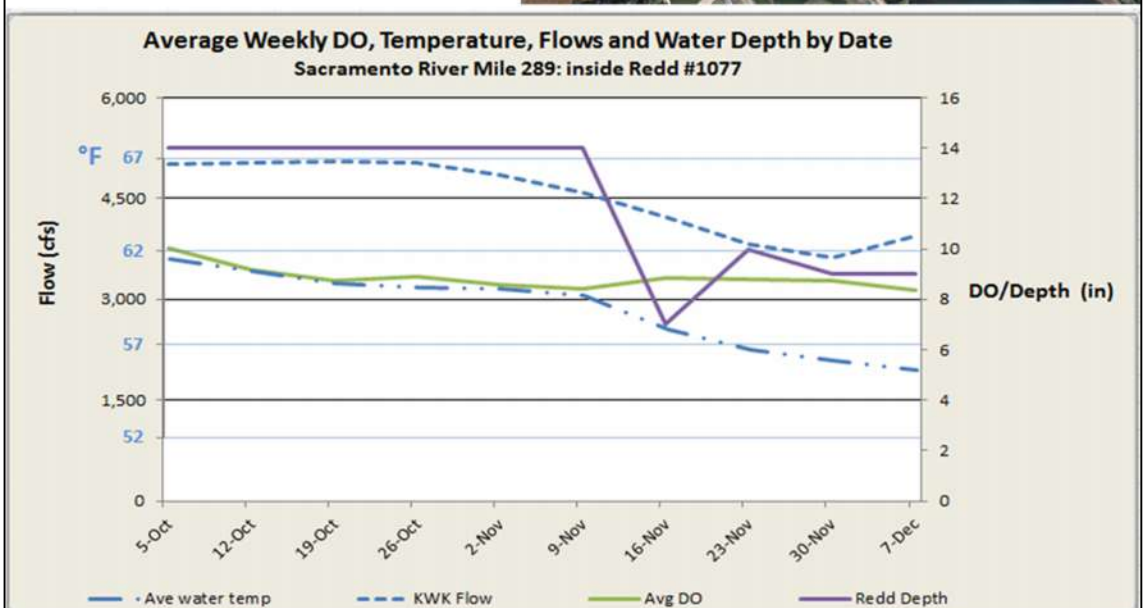


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1073	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	9	61
42	10/12/2014	10/18/2014	5026	9	9	61
43	10/19/2014	10/25/2014	5061	9	9	60
44	10/26/2014	11/1/2014	5038	8	9	60
45	11/2/2014	11/8/2014	4858	7	9	60
46	11/9/2014	11/15/2014	4597	7	N/A	60
47	11/16/2014	11/22/2014	4216	7	N/A	58
48	11/23/2014	11/29/2014	3831	6	2	57
49	11/30/2014	12/6/2014	3630	4	-1.5	56
50	12/7/2014	12/13/2014	3933	6	N/A	56

Appendix G Figure G1. Continued.

Redd #1077

Redd #1077 was located at RM 289 and contained DO logger #3. It was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/27/2014.

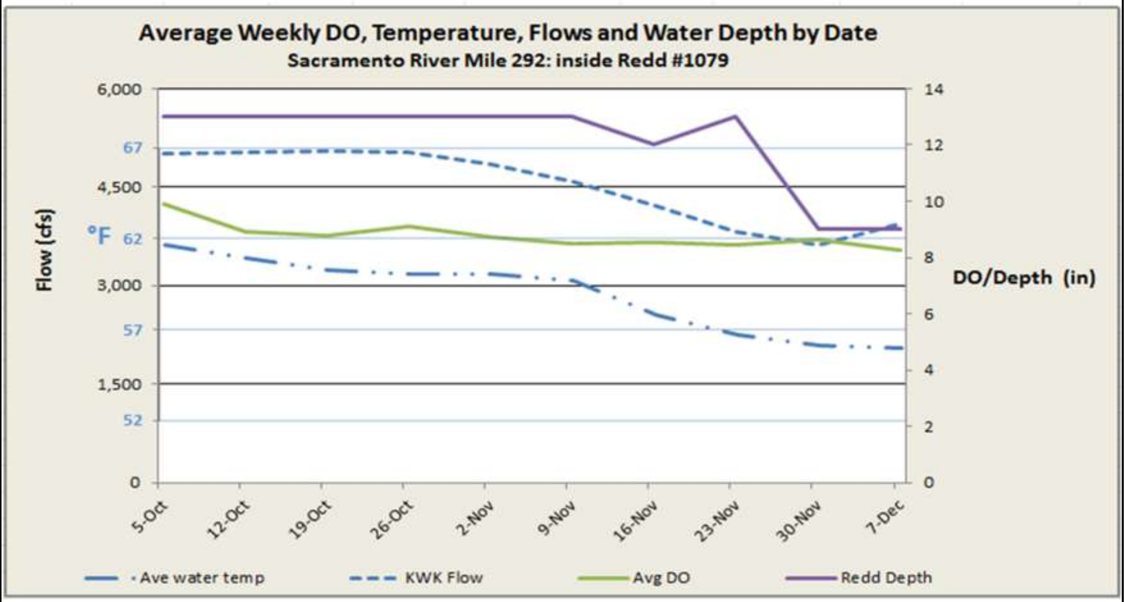


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1077	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	14	62
42	10/12/2014	10/18/2014	5026	9	14	61
43	10/19/2014	10/25/2014	5061	9	14	60
44	10/26/2014	11/1/2014	5038	9	14	60
45	11/2/2014	11/8/2014	4858	9	14	60
46	11/9/2014	11/15/2014	4597	8	N/A	60
47	11/16/2014	11/22/2014	4216	9	7	58
48	11/23/2014	11/29/2014	3831	9	10	57
49	11/30/2014	12/6/2014	3630	9	9	56
50	12/7/2014	12/13/2014	3933	8	N/A	56

Appendix G Figure G1. Continued.

Redd #1079

Redd #1079 was located at RM 293 and contained DO logger #4. It was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/27/2014.

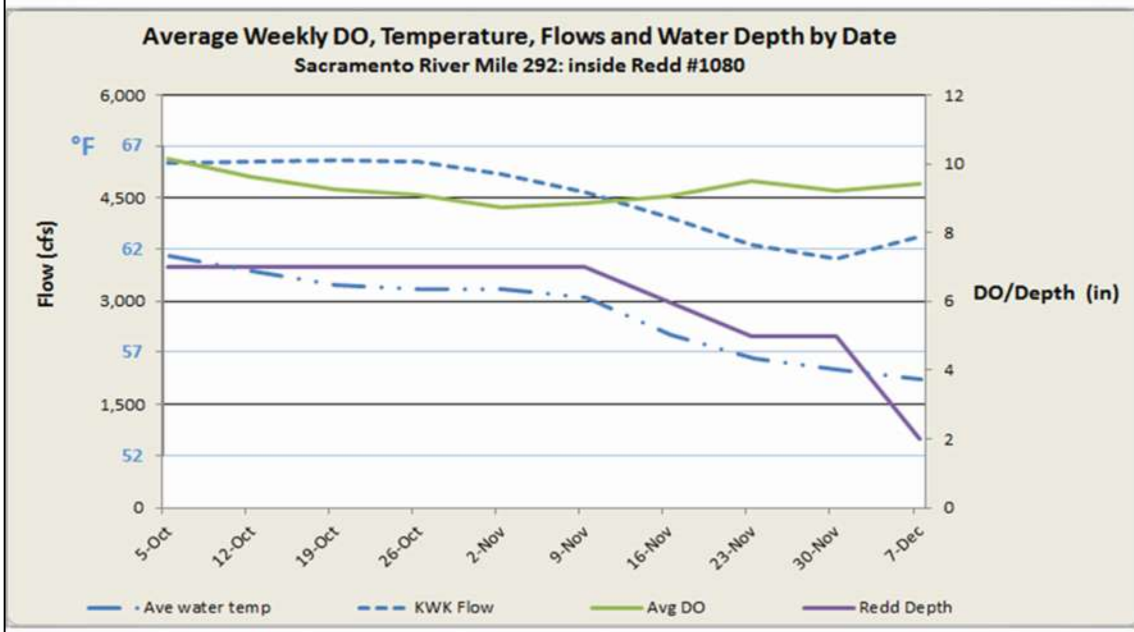


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1079	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	13	62
42	10/12/2014	10/18/2014	5026	9	13	61
43	10/19/2014	10/25/2014	5061	9	13	60
44	10/26/2014	11/1/2014	5038	9	13	60
45	11/2/2014	11/8/2014	4858	9	13	60
46	11/9/2014	11/15/2014	4597	9	13	60
47	11/16/2014	11/22/2014	4216	9	12	58
48	11/23/2014	11/29/2014	3831	8	13	57
49	11/30/2014	12/6/2014	3630	9	9	56
50	12/7/2014	12/13/2014	3933	8	N/A	56

Appendix G Figure G1. Continued.

Redd #1080

Redd #1080 was located at RM 292 and contained DO logger #5. It was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/27/2014.

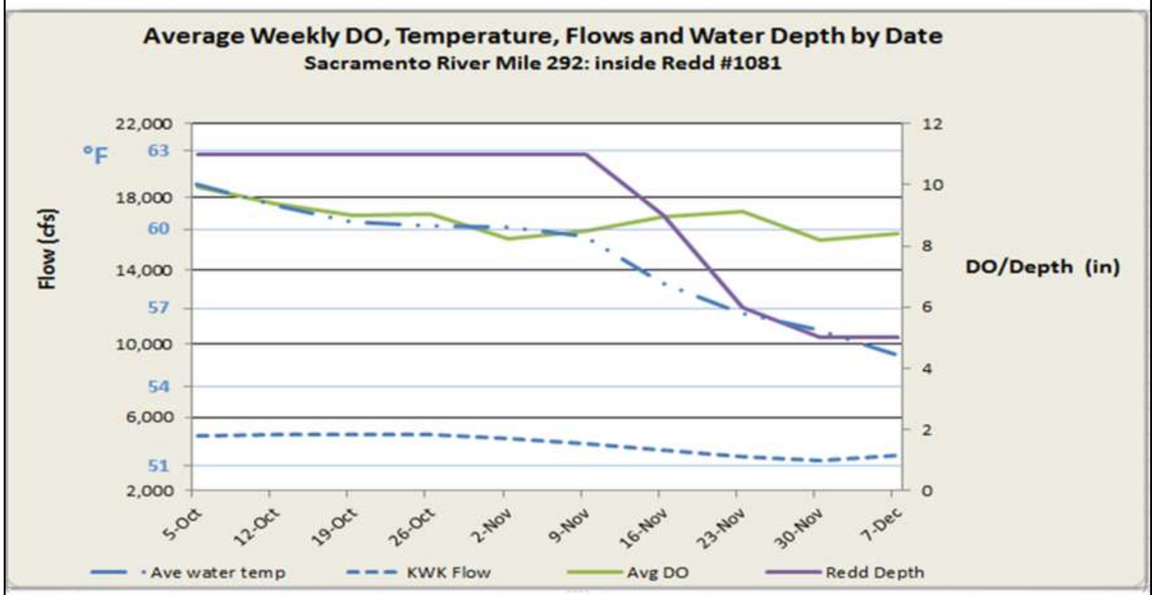


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1080	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	7	62
42	10/12/2014	10/18/2014	5026	10	7	61
43	10/19/2014	10/25/2014	5061	9	7	60
44	10/26/2014	11/1/2014	5038	9	7	60
45	11/2/2014	11/8/2014	4858	9	N/A	60
46	11/9/2014	11/15/2014	4597	9	N/A	60
47	11/16/2014	11/22/2014	4216	9	6	58
48	11/23/2014	11/29/2014	3831	10	5	57
49	11/30/2014	12/6/2014	3630	9	5	56
50	12/7/2014	12/13/2014	3933	9	N/A	56

Appendix G Figure G1. Continued.

Redd #1081

Redd #1081 was located at RM 292 and contained DO logger #11. It was exposed to lethal temperatures for an extended period during October and November. The estimated fry emergence date was 12/28/2014.

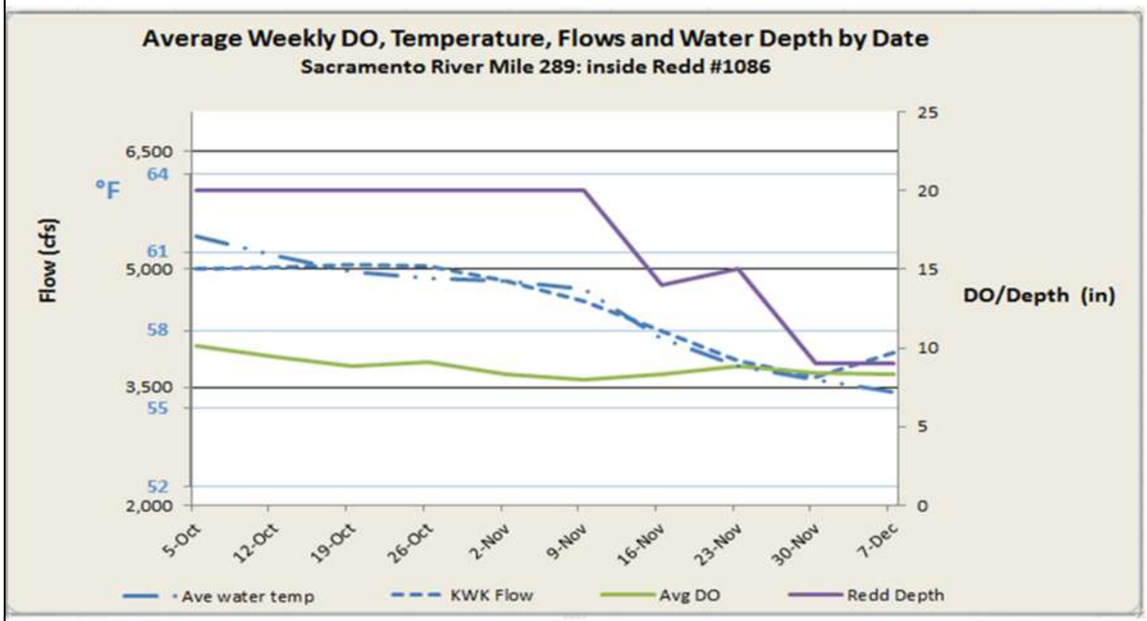


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1081	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	11	62
42	10/12/2014	10/18/2014	5026	9	11	61
43	10/19/2014	10/25/2014	5061	9	11	60
44	10/26/2014	11/1/2014	5038	9	11	60
45	11/2/2014	11/8/2014	4858	8	11	60
46	11/9/2014	11/15/2014	4597	8	11	60
47	11/16/2014	11/22/2014	4216	9	9	58
48	11/23/2014	11/29/2014	3831	9	6	57
49	11/30/2014	12/6/2014	3630	8	5	56
50	12/7/2014	12/13/2014	3933	8	5	55
51	12/14/2014	12/20/2014	3722	9	4	54

Appendix G Figure G1. Continued.

Redd #1086

Redd #1086 was located at RM 289 and contained DO logger #6. It was exposed to lethal temperatures for an extended period during October and November. The average DO concentration was also reduced to 5 during week 46. The estimated fry emergence date was 12/27/2014.

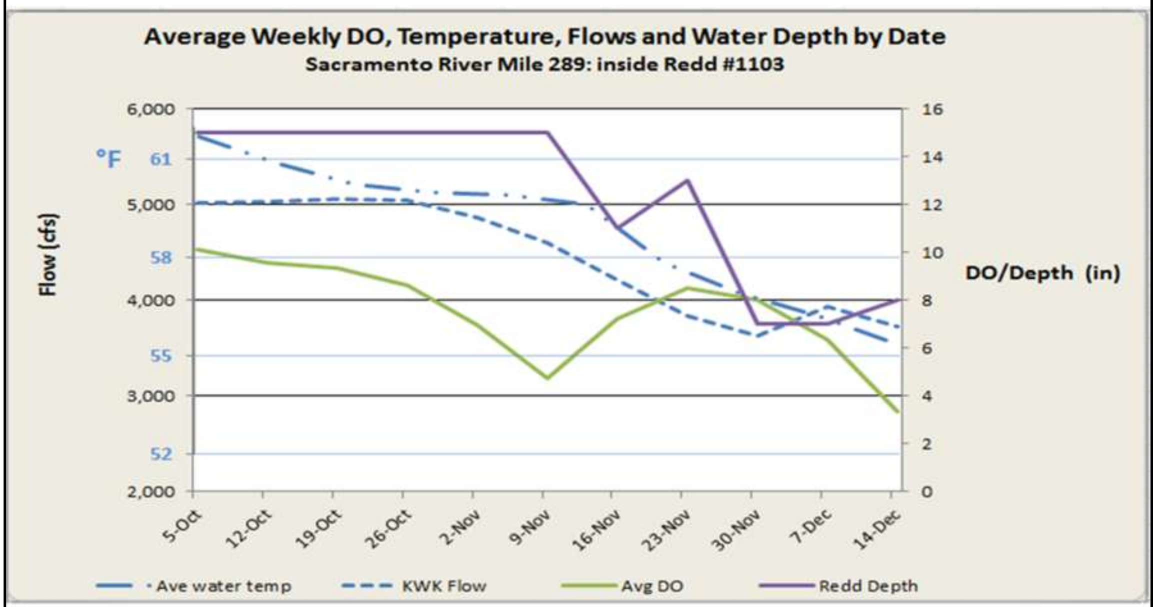


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1086	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	15	62
42	10/12/2014	10/18/2014	5026	10	15	61
43	10/19/2014	10/25/2014	5061	9	15	60
44	10/26/2014	11/1/2014	5038	9	15	60
45	11/2/2014	11/8/2014	4858	7	15	60
46	11/9/2014	11/15/2014	4597	5	15	60
47	11/16/2014	11/22/2014	4216	7	11	58
48	11/23/2014	11/29/2014	3831	9	13	57
49	11/30/2014	12/6/2014	3630	8	7	56
50	12/7/2014	12/13/2014	3933	6	7	56

Appendix G Figure G1. Continued.

Redd #1103

Redd #1103 was located at RM 289 and contained DO logger #10. It was exposed to lethal temperatures for an extended period during October and November. It also experienced low DO levels during week 46 and 51. The estimated fry emergence date was 12/27/2014.

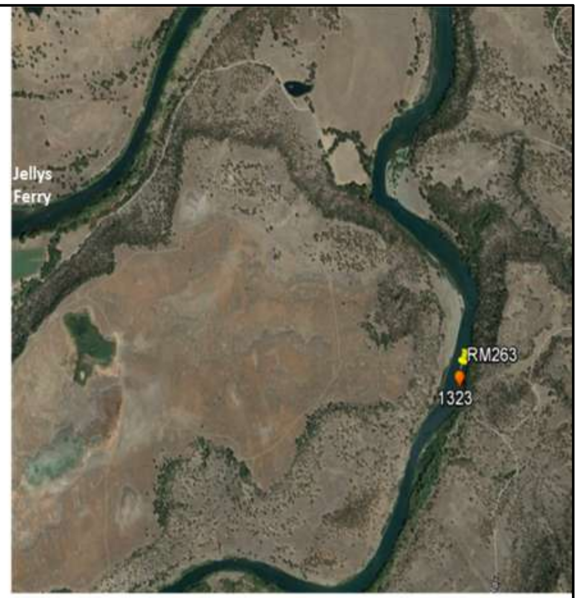


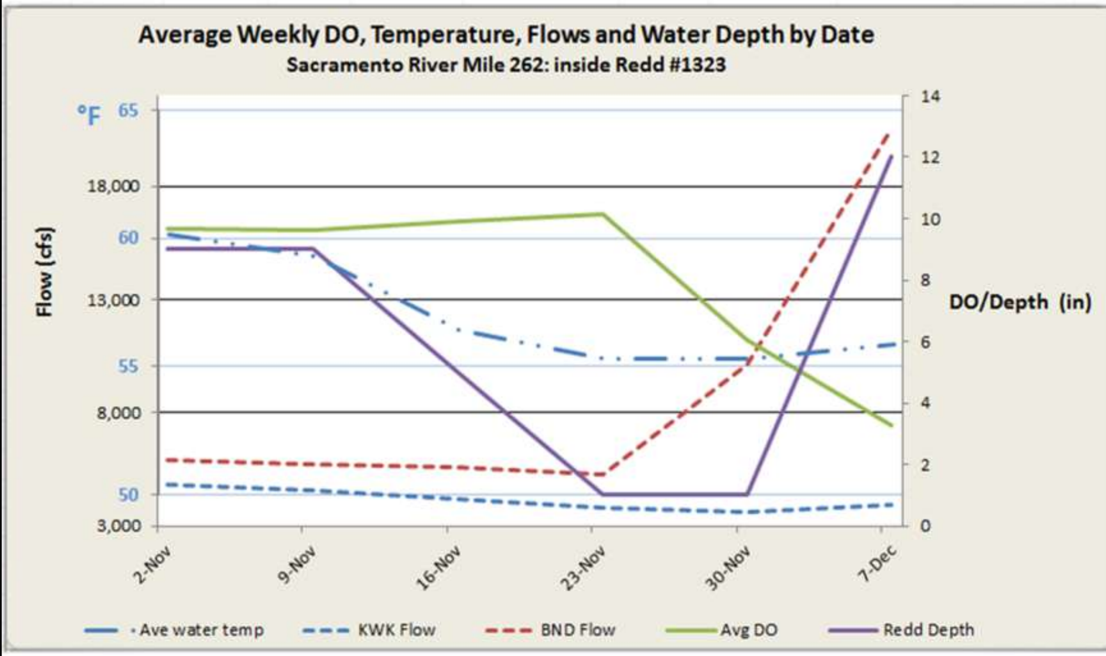
Average Weekly DO, Temperature, Flows and Redd Depth of Logger:					Redd #1103	
Week	Begin	End	KWK Flow	Avg DO	Redd Depth	Avg F°
41	10/5/2014	10/11/2014	5009	10	15	62
42	10/12/2014	10/18/2014	5026	10	15	61
43	10/19/2014	10/25/2014	5061	9	15	60
44	10/26/2014	11/1/2014	5038	9	15	60
45	11/2/2014	11/8/2014	4858	7	N/A	60
46	11/9/2014	11/15/2014	4597	5	N/A	60
47	11/16/2014	11/22/2014	4216	7	11	58
48	11/23/2014	11/29/2014	3831	9	13	57
49	11/30/2014	12/6/2014	3630	8	7	56
50	12/7/2014	12/13/2014	3933	6	N/A	55
51	12/14/2014	12/20/2014	3722	3	8	54

Appendix G Figure G1. Continued.

Redd #1323

Redd #1323 was located near RM 263 and contained DO logger #17. It was exposed to warmer temperatures during the first 2 weeks of November and experienced very low DO levels during week 50. The redd depth increased during week 50 due to heavy rain events and likely contributed to low DO levels from high turbidity. The estimated fry emergence date was 1/23/2015.



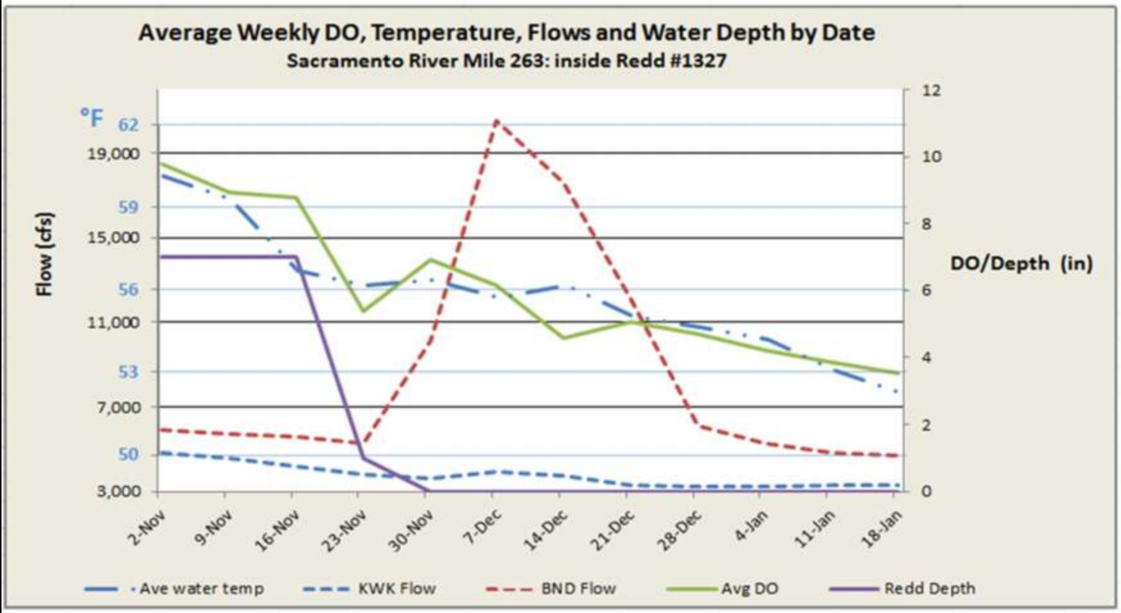


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:						Redd #1323	
Week	Begin	End	KWK Flow	BND Flow	Avg DO	Redd Depth	Avg F°
45	11/2/2014	11/8/2014	4858	5882	10	9	60
46	11/9/2014	11/15/2014	4597	5697	10	9	59
47	11/16/2014	11/22/2014	4216	5579	10	5	56
48	11/23/2014	11/29/2014	3831	5282	10	1	55
49	11/30/2014	12/6/2014	3630	10107	6	1	55
50	12/7/2014	12/13/2014	3933	20530	3	12	56

Appendix G Figure G1. Continued.

Redd #1327

Redd #1327 contained DO logger #12 and was located at RM 263 across from Massacre Flat Campground. It was exposed to warm temperatures during the first 2 weeks of November and experienced low DO levels during January. It was close to becoming dewatered during week 48 with a water depth of 1". The estimated fry emergence date was 1/23/2014.

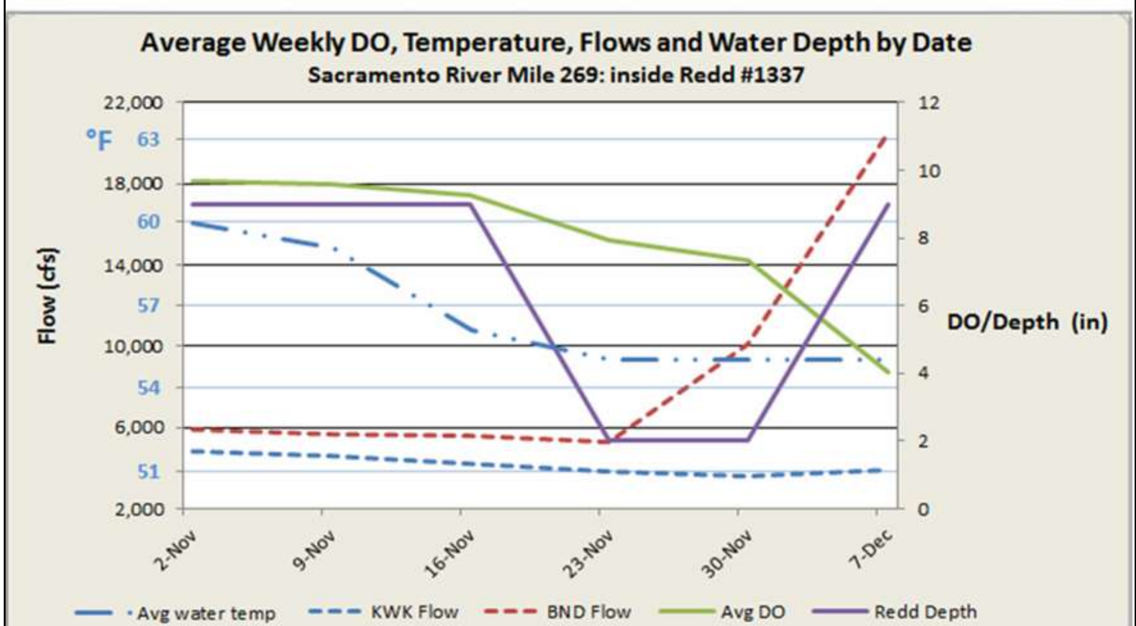


Average Weekly DO, Temperature, Flows and Redd Depth of Logger:						Redd #1327	
Week	Begin	End	KWK Flow	BND Flow	Avg DO	Redd Depth	Avg F°
45	11/2/2014	11/8/2014	4858	5882	10	7	60
46	11/9/2014	11/15/2014	4597	5697	9	7	59
47	11/16/2014	11/22/2014	4216	5579	9	7	57
48	11/23/2014	11/29/2014	3831	5282	5	1	56
49	11/30/2014	12/6/2014	3630	10107	7	N/A	56
50	12/7/2014	12/13/2014	3933	20530	6	N/A	56
51	12/14/2014	12/20/2014	3722	17580	5	N/A	56
52	12/21/2014	12/27/2014	3321	12099	5	N/A	55
53	12/28/2014	1/3/2015	3260	6125	5	N/A	55
1	1/4/2015	1/10/2015	3262	5298	4	N/A	54
2	1/11/2015	1/17/2015	3265	4818	4	N/A	53
3	1/18/2015	1/24/2015	3275	4698	4	N/A	52

Appendix G Figure G1. Continued.

Redd #1337

Redd #1337 was located at RM 269 and contained DO logger #269. It was exposed to warm water temperatures during the first 2 weeks of November and experienced low DO levels during week 50. The estimated fry emergence date was 1/23/2015.



Average Weekly DO, Temperature, Flows and Redd Depth of Logger:						Redd #1337	
Week	Begin	End	KWK Flow	BND Flow	Avg DO	Redd Depth	Avg F°
45	11/2/2014	11/8/2014	4858	5882	10	9	60
46	11/9/2014	11/15/2014	4597	5697	10	9	59
47	11/16/2014	11/22/2014	4216	5579	9	9	56
48	11/23/2014	11/29/2014	3831	5282	8	2	55
49	11/30/2014	12/6/2014	3630	10107	7	2	55
50	12/7/2014	12/13/2014	3933	20530	4	9	55

Appendix G Figure G1. Continued.