California Department of Fish and Wildlife

North Central Region

Colusa Basin Drain and Wallace Weir Fish Trapping and Relocation Efforts November 2013 – June 2014

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Please Note: This report is a draft and is intended for discussion purposes only.

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LIST OF ABBREVIATIONS AND ACRONYMS

CBD	Colusa Basin Drain Canal
CDEC	California Data Exchange Center
cfs	Cubic feet per second
cm	Centimeter
CVP	Central Valley Project
CWT	Coded wire tag
Delta	Sacramento-San Joaquin Delta
DFW	Department of Fish & Wildlife
DWR	Department of Water Resources
emt	Electrical metallic tubbing
°F	Degrees Fahrenheit
fps	Feet per second
FL	Fork Length
IEP	Interagency Ecological Program
KL	Knights Landing
KLOG	Knights Landing Outfall Gates
KLRC	Knights Landing Ridge Cut
LSNFH	Livingston Stone National Fish Hatchery
mm	Millimeter
NMFS	National Marine Fisheries Services
NTU	Nephelometric Turbidity Units
QAQC	Quality assurance and quality control
USFWS	U.S. Fish and Wildlife Service

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INTRODUCTION

In April 2013, large numbers of adult Chinook salmon were observed within Colusa Basin Drain (CBD) in various agricultural diversions and drainages. Out of concern that these salmon were threatened or endangered and would parish in the absence of intervention, in early May of 2013 the Department of Fish and Wildlife (DFW) implemented multiple rescue efforts within the Colusa Basin watershed. The total number of live salmon recovered during these operations was 312. This included 235 salmon that were tagged with external T-bar anchor tags, of which 13 salmon also received an internal acoustic transmitter tags. Tissue samples were collected from a subset (10) to determine genetic identification. To identify hatchery of origin 11 adipose fin-clipped salmon were taken to DFW's Region 2 office to extract and read coded wire tags. An additional 18 mortalities/carcasses were observed during the rescue operations. After determining stranded fish were largely composed of federally endangered winter-run Chinook, 48 salmon recovered between 20 May and 5 June, 2013, and were sent directly to Livingston Stone National Fish Hatchery (LSNFH) to spawn. It was speculated that more than a hundred Chinook salmon were not recovered during rescue operations and the total number entrained into CBD during 2013 was undetermined. As Central Valley winter and spring-run Chinook salmon are listed as federally endangered and threatened respectively, loss of adults from these races on this scale is very concerning.

There has been a great deal of effort put into identifying environmental conditions and water operations which may have caused Chinook salmon to become entrained in CBD during 2013. Stranded anadromous fish species have been documented in the Yolo Bypass on numerous occasions following high flow events that overtop Fremont Weir. This is likely a consequence of attraction to the large volume of water that can be conveyed through the bypass during a weir over-topping event. The rescues that occurred in spring of 2013 occurred during a period of below average flows in the Sacramento River. Stage height in the Sacramento River during this time period was insufficient to result in over-topping the Fremont Weir. This suggests there may be strong attraction cues into the CBD for anadromous species occurring during periods outside of flood conditions.

Following the 2013 rescue, much effort was given to examining potential routes for salmon to become entrained in the CBD. Possible entry points in the CBD watershed include the Knights Landing Ridge Cut which drains into the Tule Canal which subsequently drains into the Cache Slough Complex in the northern Sacramento - San Joaquin Delta as well as the Sacramento River through the Knights Landing Outfall Gates.

To address the issue of anadromous species entrainment in the CBD and to better understand environmental conditions resulting in entrainment, DFW designed and installed a resistance board style fish weir and an associated fish trap in the CBD approximately 14 miles upstream of the town of Knights Landing in the fall of 2013. This location was selected primarily because it could allow fish to be trapped prior to moving further up into the network of agricultural diversions and drainages further upstream in the CBD. The weir was designed to handle the variable flow and debris conditions present in the CBD.

To better document utilization of the two entry points for fish into the CBD and increase the ability to capture anadromous species, other locations in Yolo Bypass were evaluated for capturing entrained fish. The DFW, in coordination with the California Department of Water Resources (DWR), installed a 10’ by 20’ fyke trap in the KLRC, downstream from Wallace Weir in the Yolo Bypass on 22 January 2014. This site was selected primarily as a location to target and rescue fish entering the CBD through the KLRC because of good access for staff to the KLRC and the ability to capture fish across a wide range of flow conditions in the Yolo Bypass. By examining catch at each site independently over time, it was hoped that utilization of entry points to the CBD could be identified for entrained fish.

The primary goals for both rescue efforts:

1. Detect and enumerate the presence of salmonids, sturgeon, and other fish species within the bypass.
2. Minimize the loss of state and federally listed salmonids through rescue/relocation.
3. Examine the timing, size, and species composition of entrained fish.

Secondary goals:

1. Identifying how fish enter the CBD.
2. Identifying conditions and operations that result in attracting and entraining fish into the CBD.

In addition to the primary goals it was hoped that trapping data could allow for inferences to be made into attraction cues for fish during non-flood periods. It was speculated that KLOG operations influence fish entrainment into the CBD as fish can enter the drain directly through KLOG or by regulating attraction flows in the KLRC and subsequently down into the Cache Slough Complex.

BACKGROUND

Historically Chinook salmon (*Oncorhynchus tshawytscha*) were naturally abundant and widely distributed in almost all major streams of California's Central Valley (Yoshiyama et al., 1998, 2001). Central Valley Chinook salmon numbers have been greatly reduced by anthropogenic changes to the environment from loss of historical spawning habitat through construction of large dams, changes to the natural hydrology of rivers, altering and channelizing rivers and streams, and construction of unscreened diversions. It is well recognized that protection during the adult life stage of Chinook salmon is crucial for maintaining Central Valley salmonid stocks.

> *"Adult anadromous fish returning from the ocean and migrating upstream to spawning grounds face a variety of hazards. Protecting adult anadromous fish from time of entry into freshwater until successful reproduction in the upstream spawning habitats is critical. Those adults attaining the reproductive phase are the fewest in number among all the prior life stages. Fish reaching the spawning grounds are the oldest among all prior life stages and have already survived the vast majority of density-independent and density-dependent factors exerting the most influence on the population. Significant changes in the numbers of these adult fish can have resulting profound impacts on subsequent generations. Given the complexity of the anadromous fishes' life cycle, the upstream migrating adult fish should be the easiest to protect."* (Vogel 2011).

Irrigation returns and flood runoff from the west side of the Central Valley drain into CBD which conveys water to KLOG where a portion of these flows can be discharged into the Sacramento River under most conditions. The remainder of the water drains into the KLRC. If stage height of the Sacramento River at Knights Landing is greater that approximately 27 feet, then the outfall gates are closed and all flows in the CBD are directed into the KLRC which ultimately discharges into the north Sacramento-San Joaquin Delta. It is believed that both flow routes have the potential to attract anadromous species into the CBD though KLOG and has been identified as far back as the 1970's as an entry point into the CBD.

> *"Significant numbers of upstream migrant adult Chinook salmon have been known to enter the Colusa Basin Drain Outfall at Knights Landing [KLOG]. Because salmon spawning and rearing habitat in the Drain is essentially non-existent, those fish are lost from Sacramento River production. Salmon runs are presently depressed, stressing the importance of ensuring the safety of those salmon returning to spawn. The California Department of Fish and Game attempted to exclude salmon from entry into the Drain during the 1970s, but failed to do so for a variety of reasons. Presently adult salmon can migrate up into the Drain and many may perish."* (CH2M HILL 1991).

In October 1975, a U.S. Fish and Wildlife Service (USFWS) employee working at Delevan National Wildlife Refuge estimated that approximately 200 salmon were stranded below a refuge operated canal dam, at least 35 miles upstream from the mouth of CBD (Lassen, 1975). Inclusive in the memorandum was information from a DFW warden reporting that it was an annual problem, though not knowing the magnitude of the loss; it appeared that the problem was limited to fall-run Chinook during the months of September through November. Because of the numbers of salmon regularly observed at the Delavan NWR, it was determined that a significant salmon loss must be occurring in the CBD on the order of 200 to 400 fish per year. Preliminary evaluations at the time indicated that an electric barrier immediately downstream of KLOG would be an appropriate method to discourage adult salmonids from entering the CBD. In the fall 1977, the DFW installed an electric barrier, however the device was destroyed during heavy flows through the KLOG in early January 1978 (pers. com., Dave Rose) and no physical or behavioral fish barrier has been installed since.

The problem persisted and correspondence between Reclamation District of Colusa, the DFW, DWR, and the California Fish and Game Commission on the entrainment issue continued from the 60’s through the 90’s. In the 90’s, Reclamation District No. 2047 stated that CBD salmon entrainment had been an issue for at least 20 years. The magnitude of the numbers of salmon varied from year to year depending on rainfall and water flows in CBD relative to the Sacramento River. Reclamation District No. 2047 requested fish screens or another electric fish barrier to resolve the issue.

> *“The reasons adult Chinook salmon choose to enter the Drain rather than migrate up the Sacramento River is not entirely understood. … Once at the Drain Outfall [KLOG], salmon are further “enticed” by high velocity water exiting the Outfall Gates. Their attraction to high velocity water is a well-known behavioral trait (Bell 1973).”*
>
> *“The mechanism for entry at the Outfall Gates occurs when water velocity is sufficient to attract the fish but low enough for the fish to overcome when migrating in an upstream direction. Experience at the Red Bluff Diversion Dam and the Tehama-Colusa Fish Facilities has shown that adult salmon readily swim through flows from hydraulic control structures when the hydraulic head differential between the upstream and downstream water bodies is less than about four feet* (Vogel et al. 1988).”

Reclamation District No. 2047 requested that a fish exclusion device or electric fish barrier be constructed to resolve the issue and that DWR take the lead in preparing and implementing a plan to exclude salmon from the CBD. However, DWR suggested that DFW take the lead with their technical and potential financial support in the event a project was developed.

> *"The migration of adult Chinook salmon into the Colusa Basin Drain has been widely reported for many years by personnel of the District [2047], the Glenn-Colusa Irrigation District (GCID), CDFW, DWR [Department of Water Resources], the U.S. Bureau of Reclamation, local farmers, and sportsman groups. The number of adult salmon ascending the Drain appears to vary from year to year and is estimated to range up to thousands of fish in some years; however, no annual counts or comprehensive records of adult salmon in the Drain have been maintained by CDFG." (Paul Ward and Pat O'Brien, CDFG, personal communications)*
>
> *"Generally, more adult salmon are reported as seen in the Drain during years of high salmon run abundance than during years of low salmon run abundance."* (Pat O'Brien, CDFG, personal communication)

Considering the magnitude of adult Chinook salmon loss over the years, the issues of attraction and entrainment into the CBD has major implications on management of threatened and endangered fish populations and commercial and sport fishing opportunities.

Colusa Basin Drain

The CBD is a man-made structure containing multiple canals that drain runoff and irrigation return flows of public and private lands. Farmers built CBD in the 1920's as rice production in the Central Valley expanded (Leavenworth, 2004). The CBD was designed to collect and convey flows from agricultural lands and 32 ephemeral streams during the irrigation season and during winter storm water flows. It terminates at two locations; the KLOG where it empties into the Sacramento River through control gates and at KLRC, a canal that carries excess flood water into the Yolo Bypass. The Colusa Basin watershed, includes both Glenn and Yolo Counties and extends from the Stony Creek watershed in the north to the Cache Creek watershed to the south, and from the Sacramento River in the east to the foothills of the inner Coast Ranges to the west, and covers over one million acres (Colusa County Resources Conservation District, 2012).

Knights Landing Ridge Cut

In 1930 the Army Corps of Engineers, partnering with the State of California, constructed KNRC by digging a 7 mile long canal through the Knights Landing Ridge to regulate water flowing either to the Sacramento River through KLOG or through KLRC into the Yolo Bypass. The Yolo Bypass conveys water for both agricultural needs and flood control purposes. During the irrigation season, water in the Yolo Bypass is controlled and directed through the use of weirs before eventually draining into the Cache Slough Complex. Two of the more prominent control structures in the Yolo Bypass are Wallace and Lisbon weirs. KLRC runs from the CBD and enters the northwest corner of the Yolo Bypass, downstream of Fremont Weir. Wallace Weir is an earthen berm that is constructed annually at the downstream end of KLRC to allow the retention and regulations of irrigation flows to help meet agricultural irrigation needs.

During the irrigation season at low-flow, Wallace Weir is in place and KLRC cuts across the Yolo Bypass into the east side toe drain of the Yolo Bypass. At times of high flow, all gates in KLOG are closed and water is diverted through the KLRC where it overtops Wallace Weir, and flows into the Yolo Bypass, incidentally allowing unimpeded fish passage into the CBD watershed.

The Knights Landing Outfall Gates

Originally known as Sycamore Slough Outfall Gates, KLOG was constructed around 1914 (Figure 1). The structure was modified again in 1929, 1930, and in 1949. The outfall gates were updated most recently in 2012. However, these updates did not include any measures to reduce the likelihood of fish entrainment.

The KLOG structure is operated by the DWR and consists of a concrete barrier wall at the terminus of CBD canal with 10 automated round gated openings. These gates allow water to drain from the CBD to the Sacramento River during river flows of up to approximately 27 feet and also prevent water from the Sacramento River from entering the CBD during periods of river flow with stage height greater than 27 feet. During high flows in the Sacramento River (with gates closed), all CBD water is shunted through the KLRC into the Yolo Bypass (Navigant Consulting, 2004). Eight of the KLOG gate openings are 5.5 feet in diameter and two are 3.5 feet in diameter. All have a centerline elevation of 21 feet and are equipped with automated slide gates on the upstream (canal) side and a flap gate on the downstream (river) side. Automated slide gates allow water level in the canal to be regulated at an elevation above the river level and flap gates prevent Sacramento River water from passing into CBD when the river is higher than the water level in the canal. The gate structure has a concrete slab at an elevation of 17 feet extending downstream of the gate openings for a distance of approximately 40 feet to prevent bed erosion from water discharging through the gates (Heise, 2014). Operations at KLOG additionally allow for regulation of CBD water elevations for irrigation use in the agricultural lands around the CBD and ridge cut. Stage height is kept at a relatively constant water level elevation of approximately 25 feet above the U.S. Army Corps of Engineers geodetic datum upstream in CBD (Yolo Bypass Working Group 2001) (Figure 2).

It is assumed that adult Chinook salmon are attracted to KLOG when water is being actively discharged into the Sacramento River. For entrainment to actually occur, water elevation over the concrete slab needs to be at a sufficient depth and water velocities through the gates have to be within the burst swimming speed of adult Chinook salmon. For example, at a river elevation of 20 feet, there would be 3 feet of water over the slab and the bottom of the gate opening would be submerged by 1.7 feet. This condition was assumed to facilitate passage of fish through the gate openings as long as the head differential in CBD is not exceeding more than 6 fps. Discharge velocities greater than 6 fps are assumed to be greater than the burst swimming speed for adult Chinook salmon.

As Sacramento River stage level continues to decrease below 19 feet, the depth over the slab becomes less than 2 feet, likely decreasing the ability for adult Chinook salmon entrainment. Upstream fish passage through KLOG is assumed to be blocked when Sacramento River stage level drops below 17 feet exposing the concrete slab at KLOG.

Figure 1. Knights Landing outfall gates under construction in 1914.

Figure 2. Knights Landing outfall gates on April 8, 2014. Downstream (top picture) and upstream (lower picture).

Yolo Bypass

The Yolo Bypass is a leveed basin which is designed to convey excess flood flows from the Sacramento Valley including the Sacramento River, Feather River, Sutter Bypass, and west side streams (Appendix B, Figure1). The bypass is considered the primary floodplain of the Delta (Sommer et al., 2001). The 40 mile long floodplain is designed to convey up to 343,000 cfs and under typical flood event conditions, water spills into the Yolo Bypass via Fremont Weir when the stage height of the Sacramento River surpasses 33.5 feet (CDWR 2010). After overtopping the weir, water flows initially pass along the eastern edge of the Yolo Bypass through the Tule Canal before spreading throughout the floodplain.

At high flows in Sacramento River flow, the Sacramento Weir can convey additional flows into the Yolo Bypass. In addition, west side streams such as Cache and Putah creeks are also sources of inflow to the bypass. During the dry season, the Tule Canal and toe drain channel along the east side of Yolo Bypass remain inundated as a result of irrigation runoff and tidal action from the north Delta.

Personnel from DWR and DFW have been conducting fish studies in the Yolo Bypass for several years (Sommer et al. 1997; Sommer et al. 2001). Studies by the Interagency Ecological Program (IEP) Yolo Bypass Project Work Team have demonstrated that the shallow water habitat of the Cache slough complex and toe drain support at least 40 fish species including Delta smelt, Sacramento splittail, white and green sturgeon, striped bass, American shad, assorted races of Chinook salmon, and steelhead trout (Sommer et al. 2003).

METHODS

Colusa Basin Drain Resistance Weir

On 2 November 2013, the DFW installed a 125 feet wide resistance board style weir and associated fish trap in CBD (38°54'10.78"N, 121°54'54.71"W) approximately 14 miles upstream from Knights Landing (Appendix A, Figure 1; Appendix D, Figure 1). This trapping site was operated through 22 May 2014. The site was selected based on security, access, stable bank characteristics, and a uniform channel. Methods for design, construction, and installation of the weir were based on methods developed by the Alaska Department of Fish and Game, and the United States Fish and Wildlife Service (Stewart 2002, Stewart 2003, and Tobin 1994). The weir had three major components: panels, an anchored substrate platform, and a fixed picket section (Appendix C, Figure 1).

Forty-two panels (3' X 12') were made of schedule 40 capped polyvinyl chloride (PVC) irrigation pipe and affixed with boat fenders (10" X 30") at the top of each panel to provide buoyancy to the upper portion of the panels. Each panel was attached along its edges until the span of the channel was reached. A cable anchored to the substrate with earth anchors and t-posts was used to attach both the panel bottoms and live trap to the canal bottom.

Approximately 47 feet and 31 feet of fixed-picket weir sections were used on the west and east banks respectively (Appendix C, Figure 1). To prevent fish from escaping between the weir and each bank, fixed-picket sections (3 on the west bank, 2 on the east bank) were made of ¾ emt conduit placed vertically through holes spaced 2 inches apart in 2" X 4" angle iron.

A 10' X 20' live trap also constructed of emt conduit was attached to the fixed-pickets on the east bank. The entrance to the live trap was fitted with a stationary passage chute approximately 15 feet from the east bank made of 5' X 6' perforated flat iron and rounded at the top to allow the weir to pivot at various flow rates and water elevations. The 24" x 8" angle iron had holes placed in them to allow ¾ emt conduit placement vertically, completing the fixed picket section. The sections formed a trapezoid-like shape on both banks. A bump rack was constructed at the entrance to the live trap from ¾ emt conduit placed 2 inches apart and individually hinged at the top of 2" by 4" angle iron. It was constructed in a fashion to allow fish upstream passage by placing a grooved piece of 2" by 4" angle iron affixed to the bottom of the live trap entrance which allowed for the individual hinged pieces of conduit to recess between the grooves and to prevent fish from escaping the live trap.

The weir was checked daily to check for fish tightness, debris build up and catch. Two to four personnel were assigned to check the weir depending upon catch g and maintenance needs.

All data was recorded on water-proof datasheets. Data included abiotic conditions, catch for the day, and comments. Any salvaged Chinook salmon was externally marked with anchor tags; anchor tags were individually numbered and printed with return information (DFW, region 2 phone number), salmonids were sexed if possible and fork length recorded. A genetic sample was collected from all Chinook salmon. Salmonids were then placed in a cradle and carried to a transport trailer for transport to Elkhorn Boat Launch and then released in the Sacramento River. Datasheets were taken to a DFW office and checked for quality assurance and quality control (QAQC). Once all datasheets were checked for QAQC, data were entered into an Excel spreadsheet using the Julian year calendar and again checked for QAQC.

Wallace Weir Fyke Trap

A 10' X 20' fyke trap was installed a few hundred yards downstream Wallace Weir on 22 January 2014, in the KLRC (38°43'4.353"N, 121°39'35.4672"W) (Appendix A, Figure 1; Appendix D, Figure 2). The fyke trap was constructed of 2" X 4" wood cross beams, circular piping, and 2" diameter plastic and wire mesh. The trap was open at one end and contained two funnels which act as behavioral one-way shoots within the trap. Once passing the funnels, fish were held in the enclosed spaces between the funnels inside the trap. Additionally, the trap was constructed with three openings covered with strap-on doors which allowed staff to access the holding area to gather catch. The trap was fished with the back or open end facing downstream (Appendix d, Figure 2). To increase capture efficiency the trap was positioned in the KLRC between two wing wall structures that were 33' X 9' and constructed from ¼" gauge galvanized steel hog wire paneling with 2" X 4" openings on the downstream end of the trap to prevent fish from bypassing the trap (Appendix C, Figure 2).

Upstream of the fyke trap, a 75' X 9' debris weir was constructed consisting of ¼" gauge galvanized steel hog wire paneling with 2" X 4" openings and ¾" emt conduit to further reduce the chance of fish passing the sampling site.

The fyke trap was secured to shore in three locations with t-bar stakes driven into the levee; a lead at the top end of the trap, a tail at the bottom end, and a centrally located cable primarily used for trap retrieval. The central cable was wrapped around the middle of the fyke and during trap service events, was attached to a truck mounted winch which allowed the trap to be pulled and rolled onto shore to check for catch.

To check for catch, the fyke trap was rolled up the side of the levee enough to leave approximately two to three feet of water in the holding areas. Captured fish were removed from the trap with a dip net and placed in a 250 gallon tub filled with canal water for processing and tagging.

The fyke trap was checked daily to check for fish tightness, debris build up, and catch. Two to four personnel were typically assigned to check the weir for catch and maintenance needs. Data was recorded on water-proof datasheets. Data was recorded and fish were processed in an identical fashion to the CBD weir. Salmonids were then placed in a cradle and carried to a transport trailer for transport to Sacramento River release locations. Datasheets were taken to a DFW office and checked for quality assurance and quality control (QAQC). Once all datasheets were checked for QAQC, data were entered into an Excel spreadsheet using the Julian year calendar and again checked for QAQC. From 22 January through 17 March 2014, DWR operated the Wallace Weir fyke trap Monday through Friday and checked it once daily. On 18 March 2014, DFW began operating the trap, checking it daily seven days a week until 6 June 2014.

Fish Specific Data

All fish captured at both sites were identified to species, and enumerated. All fish except salmonids and sturgeon were released on-site, upstream of the trap to minimize recapture. Each captured Chinook salmon received two external, individually-numbered t-bar anchor tags. The tags were placed into the muscle tissue adjacent to the dorsal fin on both sides of the fish prior to transport to the release location. Captured sturgeon were measured to the nearest cm total length (TL), but were not externally marked (no anchor tag was applied) and then transported to the release location.

Physical and morphological data (sex, condition, fork length, adipose fin status, tissue samples, and presence of any external mark) were collected from all salmonids and sturgeon captured at both sites. Tissue samples were collected from the upper corner of the caudal fin of Chinook salmon and preserved using either the Dry or Wet tissue sample method (Appendix E). Tissue

samples were transferred to the DFW Tissue Archive in Sacramento. Wet tissue samples were transferred to the USFWS, Abernathy Fish Technology Center in Longview, Washington.

Data gathered specific to the performance of the CBD weir and the Wallace Weir fyke trap were acquired at every opportunity when personnel visited each site. Data obtained specific to each trapping site included: total hours fished, water velocity entering live trap or fyke trap, and depth water. Water velocity was evaluated using a Global Water flow probe (model FP111) and water depth was read using fixed staff gauges placed in the upper left corner of the CBD live trap (facing upstream) and on the ¾" emt conduit support by the fyke opening at the Wallace Weir site.

Environmental Conditions

Environmental data collected and recorded during each site check included: water temperature, water turbidity, and flow rate. Water temperature was evaluated over time using an electronic Onset HOBO temperature logger and during each trap service an instantaneous temperature was taken with a handheld H-B USA standard liquid thermometer. Two water samples were collected during each site and analyzed using a LaMotte 2020 Turbidity Meter, then averaged and reported in Nephelometric Turbidity Units (NTU). Flow rate for CBD was obtained from the California Data Exchange Center gauge at Colusa Drain near HWY 20 (CDR) (CDEC 2013-'15). Wallace Weir fyke trap flow rate was obtained from the California Data Exchange Center gauge at KLRC (RCS) (CDEC, 2013-'15).

Fish Transport

All salmonids were transported in a trailer-mounted, 400 gallon fish transport tank. Transport tanks were designed to reduce stress associated with fish handling and transport by outfitting them with an oxygen delivery system to deliver 1.5 pounds per-square-inch pure oxygen, a water circulation system, and a large release gate to facilitate release. Fish were transported and released at either Tisdale Boat Launch or Elkhorn Boat Launch release sites (Appendix A, Figures 2 and 3).

To minimize stress to fish, water used in the transport tanks was always gathered from locality of where the fish were captured. Once a transport tank was filled with water, an initial water temperature reading was recorded. Water temperatures were re-evaluated every half hour when fish were being held in the transport tank and water temperature was adjusted accordingly by adding water. Prior to use between CBD and Wallace Weir sites, tanks were decontaminated with a heated pressure wash >140˚F to avoid any potential to spread aquatic invasive species.

Fish were transported by hand from the trap to the transport tank with a purse-style fish cradle that allowed the fish to remain in water during transport.

As an operating guideline, DFW personnel were instructed to place no more than 12 fish in a transport tank as per the USFWS recommendation of one fish per 34 gallons (USFWS, personal communication).

Upon arrival at either release site, water temperature was measured and recorded for both the transport water and the receiving water. When there was a difference greater than two degrees ºF between the transport and receiving water temperatures, water circulation systems and oxygen delivery systems were shut off and receiving water was transferred into the tank until the transport water was equal to the receiving water temperature.

Once water temperature was equalized between the transport tank and receiving water, the transport trailer was backed down the boat launch to a point where the lift gate could be submerged in the river. The release gate was then opened allowing fish to volitionally swim from the tank to the Sacramento River.

RESULTS

Environmental Conditions observed at the Colusa Basin Drain

The CBD resistance weir operated for a total of 172 days from 2 November 2013, through 22 May 2014. Mean weekly flow ranged from a high of 674.7 cfs (week 10) to 30.0 cfs (week 44) during the entire trapping period (Figure 3 and Table 1). Peak flow was observed on 1 March 2014, at 1,322 cfs which occurred during week 14. Mean weekly water temperature in CBD ranged from 38°F on 12 December 2013, to 72°F on 15 May 2014, and averaged 57°F during the trapping period (Figure 3 and Table 1).

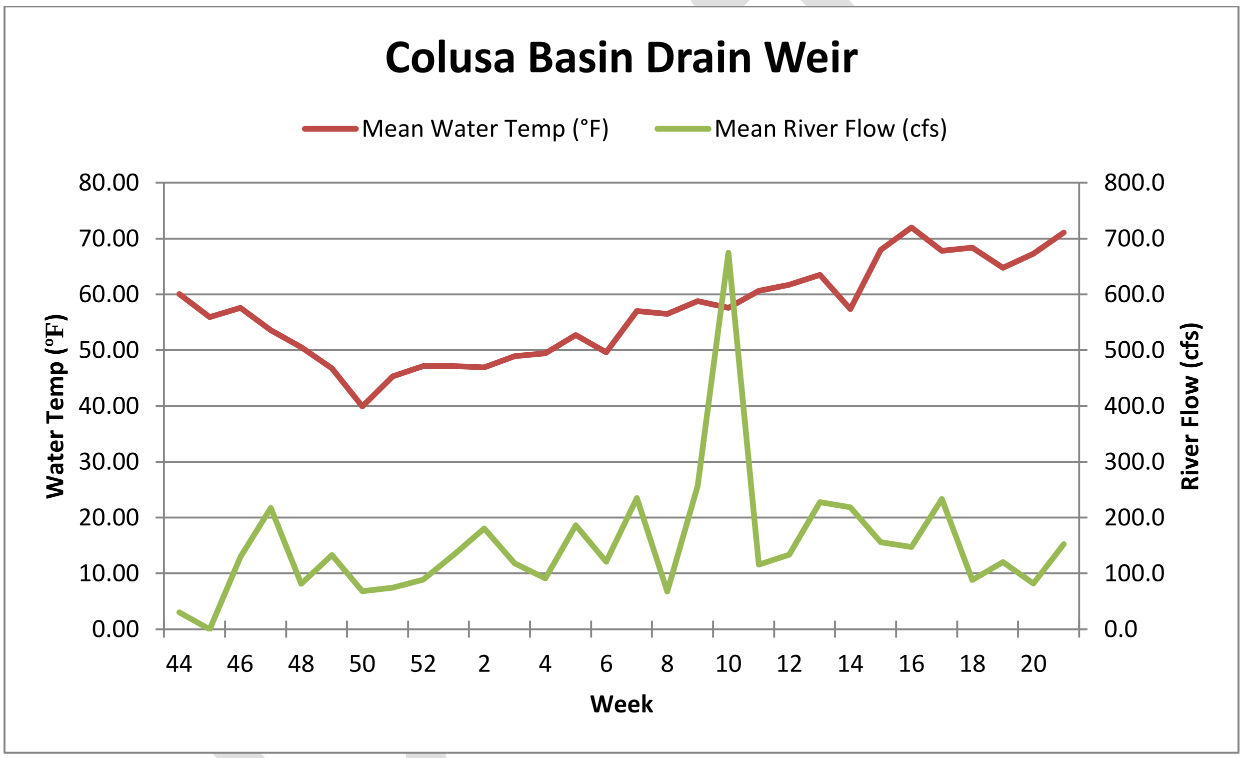

Figure 3. Mean weekly water temperature and mean weekly river flow in the Colusa Basin Drain during the trapping period of 2 November 2013, through 22 May 2014. Water flow was reported by CDEC, Colusa Drain near HWY 20 gauge (CDR).

Table 1. Weekly summaries of environmental conditions recorded for Colusa Basin Drain Weir from 2 November 2013 through 22 May 2014.

Week	Date	Mean Water Temp (°C)	Mean Water Temp (°F)	Mean River Flow (cfs)	Mean Water Trubity (NTU)
44	10/27/13	15.6	60.08	30.0	N/A
45	11/3/13	13.3	55.94	N/A	N/A
46	11/10/13	14.2	57.56	129.8	N/A
47	11/17/13	12.0	53.60	217.5	N/A
48	11/24/13	10.3	50.54	81.4	N/A
49	12/1/13	8.2	46.76	132.7	39.2
50	12/8/13	4.4	39.92	68.2	15.4
51	12/15/13	7.4	45.32	74.4	19.3
52	12/22/13	8.4	47.12	88.6	25.3
1	12/29/13	8.4	47.12	133.4	15.3
2	1/5/14	8.3	46.94	180.4	25.0
3	1/12/14	9.4	48.92	117.9	21.5
4	1/19/14	9.7	49.46	91.1	31.1
5	1/26/14	11.5	52.70	186.1	32.3
6	2/2/14	9.8	49.64	120.7	33.8
7	2/9/14	13.9	57.02	235.3	52.7
8	2/16/14	13.6	56.48	67.6	52.4
9	2/23/14	14.9	58.82	257.1	44.7
10	3/2/14	14.2	57.56	674.7	118.2
11	3/9/14	15.9	60.62	115.7	47.2
12	3/16/14	16.5	61.70	133.3	41.4
13	3/23/14	17.5	63.50	227.9	31.1
14	3/30/14	14.1	57.38	218.6	53.4
15	4/6/14	20.0	68.00	155.7	34.1
16	4/13/14	22.2	71.96	147.6	33.5
17	4/20/14	19.9	67.82	233.2	28.9
18	4/27/14	20.2	68.36	88.1	28.6
19	5/4/14	18.2	64.76	120.3	31.8
20	5/11/14	19.6	67.28	82.2	23.6
21	5/18/14	21.7	71.06	152.3	35.8

Environmental Conditions observed at the Wallace Weir Sampling Location

Wallace Weir fyke trap operations were conducted for a total of 136 days from 22 January through 6 June 2014. Mean weekly flow measurements at Wallace Weir ranged from 134.0 cfs (week 22) to 8.5 cfs (week 11) and water temperatures ranged from 48°F on 4 February 2014 to 76°F 5 June 2014 during the trapping period (Figure 4 and Table 2).

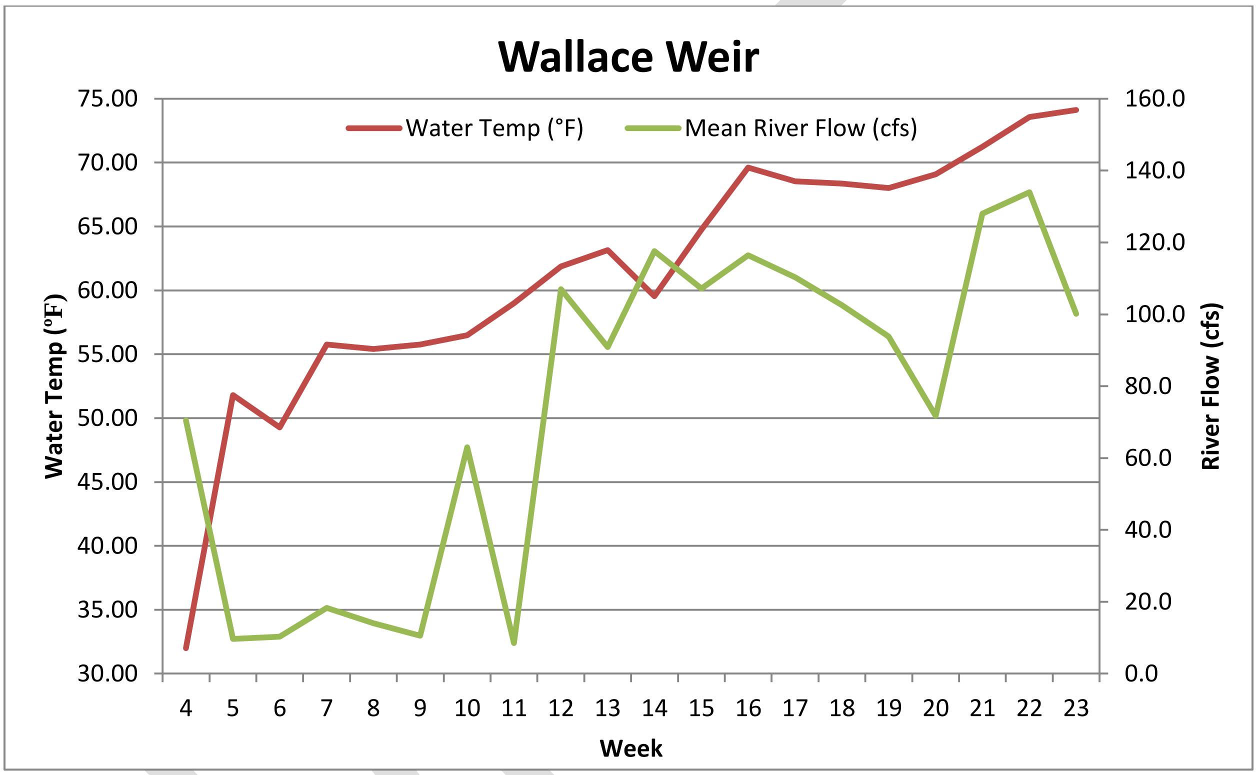

Figure 4. Mean weekly water temperature and mean weekly river flow for the Knights Landing Ridge Cut measured at the Wallace Weir sampling location from 22 January through 6 June 2014 (week 4 through week 23). Water flow was reported by CDEC, Ridge Cut Slough (RCS) gauge and reported in cubic feet per second.

Table 2. Weekly summaries of environmental conditions recorded for Wallace Weir fyke trap from 22 January through 6 June 2014.

Week	Date	Water Temp (°C)	Water Temp (°F)	Mean River Flow (cfs)	Mean Turbidity (NTU)
4	1/19/14	N/A	N/A	70.5	N/A
5	1/26/14	11.0	51.80	9.7	N/A
6	2/2/14	9.6	49.28	10.3	N/A
7	2/9/14	13.2	55.76	18.3	N/A
8	2/16/14	13.0	55.40	14.0	N/A
9	2/23/14	13.2	55.76	10.5	N/A
10	3/2/14	13.6	56.48	63.0	N/A
11	3/9/14	15.0	59.00	8.5	N/A
12	3/16/14	16.6	61.88	107.0	28.6
13	3/23/14	17.3	63.14	90.9	16.0
14	3/30/14	15.3	59.54	117.6	20.8
15	4/6/14	18.2	64.76	107.1	15.0
16	4/13/14	20.9	69.62	116.4	12.8
17	4/20/14	20.3	68.54	110.3	13.6
18	4/27/14	20.2	68.36	102.6	12.5
19	5/4/14	20.0	68.00	93.9	10.3
20	5/11/14	20.6	69.08	71.8	11.1
21	5/18/14	21.8	71.24	128.0	9.9
22	5/25/14	23.1	73.58	134.0	7.5
23	6/1/14	23.4	74.12	100.2	5.9

Summary of Fish Catch

A total of 2,687 fish were captured from both sites during the period of trapping operations (Table 3). Most fish (2,562) were captured at Wallace Weir and the remaining 125 fish from the CBD site. Catch consisted of a total of nineteen species; eight native and eleven non-native species.

Table 3. Summary of fish species recovered from 2 November 2013 through 6 June 2014. *California native fish species.

Common Name	Scientific Name	Number Captured Wallace Weir	Number Captured CBD
Common Carp	*Cyprinus carpio*	2249	111
Sacramento Sucker*	*Catostomus occidentalis*	154	3
Sacramento Pikeminnow*	*Ptychocheilus grandis*	59	0
Channel Catfish	*Ictalurus punctatus*	39	5
Largemouth Bass	*Mirocpterus salmoides*	13	0
Chinook Salmon*	*Oncorhynchus tshawytscha*	**9**	**2**
Striped Bass	*Morone saxatilis*	9	0
Black Crappie	*Pomoxis nigromaculatus*	8	0
Goldfish	*Carassius auratus*	6	1
White Catfish	*Ameiurus catus*	5	1
Sacramento Splittail*	*Pogonichthys macrolepidotus*	4	0
American Shad	*Alosa sapidissima*	2	0
Big Scale Log Perch	*Percina macrolepida*	1	0
Sacramento Blackfish*	*Orthodon microlepidotus*	1	0
Steelhead*	*Oncorhynchus mykiss*	**1**	0
White Crappie	*Pomoxis annularis*	**1**	0
White Sturgeon*	*Acipenser transmontanus*	1	0
Tule Perch*	*Hysterocarpus traskii*	0	1
Western Mosquitofish	*Gambusia affinis*	0	1

A total of nine Chinook salmon were recovered at the Wallace Weir fyke trap and relocated to the Sacramento River. A total of two salmon were recovered at the CBD weir; the first salmon was observed on 8 November 2013 was dead and the second salmon was observed on 18 March 2014 and was also found dead. All salmon gathered from both sites had a tissue removed from the upper caudal fin for later race designation. Results from genetic analysis indicate that of the total recovered from both sites there were 3 fall-run, 3 winter-run, and 5 spring-run Chinook salmon that ascended KLRC and CBD during the sampling period (Table 4). Genetic analysis further indicated that all recoveries were from either upper Sacramento River or Butte Creek.

Table 4. Summary of salmon trapped and DNA analysis results from both sites; 2 November 2013 through 6 June 2014 (HW = hatchery winter-run; Rsp = spring run)

ID	Sex	Sample Date	Fork Length (mm)	Assignment	PosProb1	Group	Best	AD Clip
CBDC1301	M	11/8/2013	805	Non-winter	1.00	Spring	Upper Sac. HW	No
WW1	M	2/4/2014	900	Non-winter	1.00	Fall	Butte Creek	No
WW2	M	2/7/2014	860	Non-winter	1.00	Fall	Butte Creek	No
WW3	F	2/7/2014	870	Winter	0.98	Winter	Upper Sac. HW	Yes
WW4	F	2/28/2014	830	Winter	1.00	Winter	Upper Sac. HW	No
WW5	F	3/4/2014	790	Non-winter	1.00	Spring	Upper Sac Rsp	No
WW6	M	3/5/2014	960	Winter	1.00	Winter	Upper Sac. HW	No
CBCD01	F	3/18/2014	800	Non-winter	1.00	Spring	Upper Sac Rsp	No
WW7	F	3/25/2014	750	Non-winter	1.00	Fall	Butte Creek	No
WW8	F	4/17/2014	810	Non-winter	0.99	Spring	Upper Sac Rsp	No
WW11	M	4/22/2014	770	Non-winter	1.00	Spring	Upper Sac Rsp	No

DISCUSSION

Results from the pilot trapping year indicate that Central Valley Chinook salmon have the ability to migrate into the CBD via the Yolo Bypass or KLOG during non-flood periods. Other native anadromous species such as steelhead and white sturgeon similarly appear to be attracted into and use these canals during non-flood periods though possibly to a lesser extent. The single observations of each species respectively may just be a function of smaller population sizes or slightly different migration timing, ability and or attraction cues then those of Chinook salmon. Observation of non-native anadromous species such as striped bass and American shad at the Wallace Weir site is an indication that these migratory species are also attracted into KLRC from the Yolo Bypass during non-flood periods and have access to CBD under some conditions. Other non-native warm water and resident fish species collected at both sites may reside in the trapping locations as they are typically found in various waterbodies throughout the Central Valley.

During fall of 2013 and spring of 2014, there were three periods from February through April with suitable conditions for salmon attraction and passage through the KLOG gate structure (Figures 5 and 6). Only one of the two salmon recovered at the CBD weir overlapped with these periods. Though KLOG can't be conclusively identified as the entry point for either of the two fish recovered at the CBD trap, the low numbers suggest entrainment through KLOG was minimal during the sampling period.

The critically dry water year during 2013/'14 sampling season may have influenced the numbers of anadromous fish collected at both trapping sites. Drought and low flows may have influenced numbers of anadromous fishes through affecting attraction cues as well as passage conditions either into the KLRC or through KLOG. Adult Chinook salmon escapement in Sacramento Valley tributaries during fall of 2013 and spring of 2014 was slightly depressed compared to the previous season. Relative to the number of Chinook salmon recovered during early spring of 2013 (312 adult Chinook salmon), the numbers observed in spring of 2014 were minimal. This suggests that attraction cues into the KLRC and KLOG may have been different between the two consecutive seasons though attraction cues during both seasons were non-flood related. In evaluating attraction cues, factors of interest occurring during periods when adult Chinook salmon are present in the Delta and Sacramento River includes, Sacramento River flow, tidal action in the Delta, CBD flows (either flood runoff and irrigation return flows), KLOG operations and KLRC flows.

Of interest in evaluating attraction cues for recovered fish, was that the recoveries at both CBD and Wallace Weir trap sites occurred shortly before and after new or full moon phases and associated monthly high tides (Table 5, Figure 7). Though correlative, it suggests an association between tidal fluctuations at the mouth of the Cache Slough complex and fish attraction into the complex and subsequently into the toe drain during non-flood periods. The mechanism for this is likely the ebb cycle following flood tides magnifying the flow signal of water coming down the toe drain. If water moving through KLRC and Tule Canal is sufficient for fish passage, tidal action may provide greater attraction to these flows for anadromous fish. Low Sacramento River flows most likely amplify this affect by decreasing attraction to the main stem Sacramento River for adults passing through the North Delta. Sacramento River flows were below average in March through June of 2013 overlapping with the adult migration period for winter and spring-run Chinook and coinciding with observed of stranded Chinook salmon in the CBD. Similarly, Sacramento River flows were below average in winter and early spring of 2014 (Figure 8).

Also of interest in evaluating attraction cues into the CBD are KLOG operations. KLOG operations have a substantial influence on attraction cues to the outfall gates from the Sacramento River and conversely in attracting fish into the CBD through KLRC by regulating flows in the KLRC. The extent to which KLOG can influence flows KLRC was clearly displayed in the hydrograph for the ridge cut (Figure 8). Reverses flows followed by a spike in flows observed in the KLRC in early March, 2014 suggest that the outfall gates have the capacity to pass all CBD flows out to the Sacramento River during some conditions and rapidly change conditions in the KLRC. This has direct implications on attraction cues into KLRC and downstream.

Fish rescue efforts during fall of 2013 and spring of 2014 provided insight into mechanisms resulting in fish entrainment into the CBD. Fish can enter the CBD via two separate routes and entrainment can occur during periods of relatively low Sacramento River flows. As rescues are resource intensive and stressful on fish, it is crucial to further refine our understanding of conditions resulting in fish attraction to both the KLOG and the KLRC. As migratory fish can pass through the Yolo Bypass during high flows when the Fremont Weir is overtopped, finding ways to minimize fish attraction during non-flood periods could largely eliminate the potential for entrainment in the CBD and contribute significantly to protection of listed stocks.

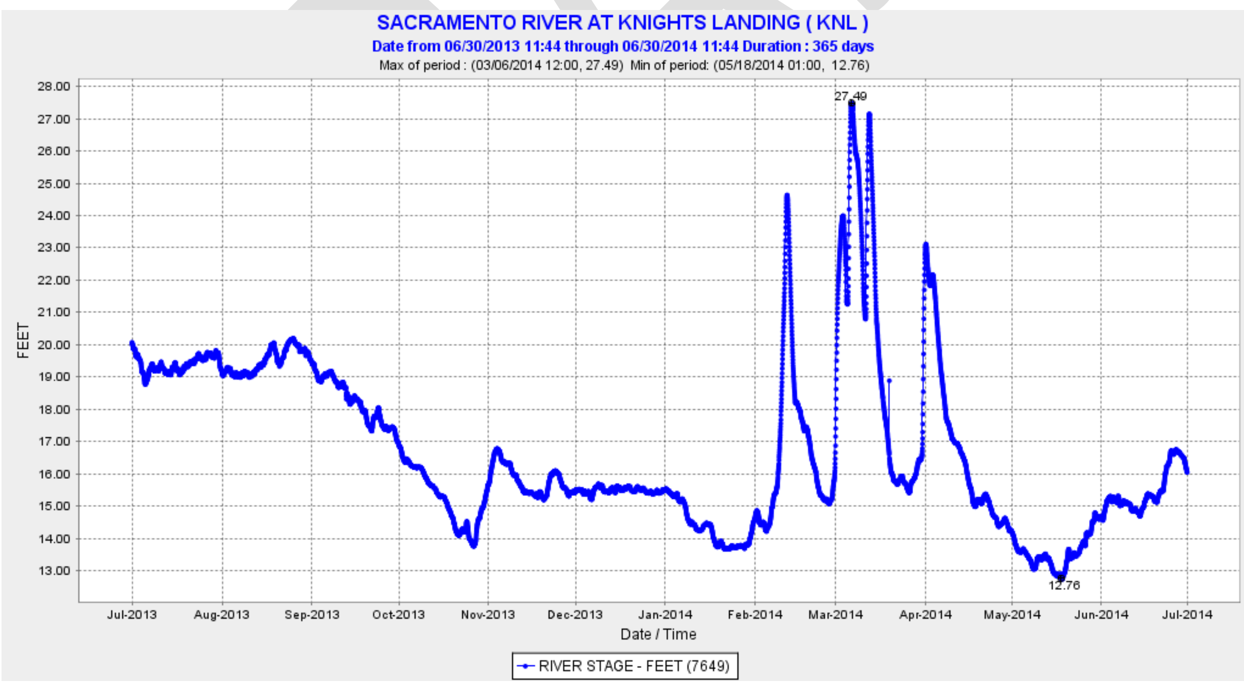

Figure 5. Sacramento River elevations at Knights Landing 1 July 2013 to 30 June 2014. Data source CDEC, accessed 10/24/15.

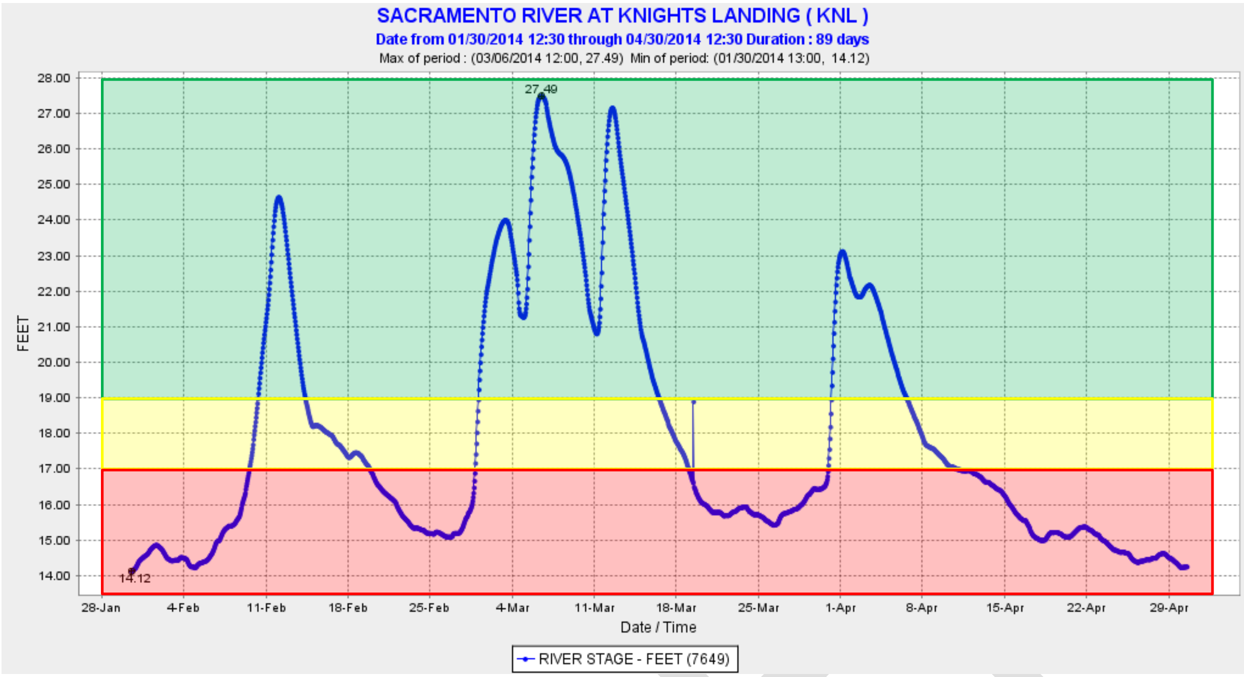

Figure 6. Sacramento River stage height at KL for the period from 1 February to 20 April 2014. Zones have been shaded to indicate the potential of fish passage through the outfall gates based on Sacramento River stage height at Knights Landing. There were three periods that provided suitable conditions for salmon entrainment from the river into the Colusa Basin Drain through the KLOG gate structure (Heise, 2014). Red indicates no potential for passage; Green and yellow show potential for fish passage. Data source CDEC, accessed 10/24/15.

Table 5. Moon phases in relation to salmon recovered.

Moon Phase	Moon Phase Date	Dates Salmon collected	Sex	Fork Length	Group	Best	AD Clip
New moon	1/30/2014	2/4/2014	M	900	Fall	Butte Creek	No
		2/7/2014	M	860	Fall	Butte Creek	No
		2/7/2014	F	870	Winter	Upper Sac. HW	Yes
New moon	3/1/2014	2/28/2014	F	830	Winter	Upper Sac. HW	No
		3/4/2014	F	790	Spring	Upper Sac Rsp	No
		3/5/2014	M	960	Winter	Upper Sac. HW	No
Full moon	3/16/2014	3/18/2014*	F	800	Spring	Upper Sac Rsp	No
		3/25/2014	F	750	Fall	Butte Creek	No
Full moon	4/15/2014	4/17/2014	F	810	Spring	Upper Sac Rsp	No
		4/22/2014	M	770	Spring	Upper Sac Rsp	No

* Salmon was recovered dead at CBD weir. Exact arrival timing is unknown.

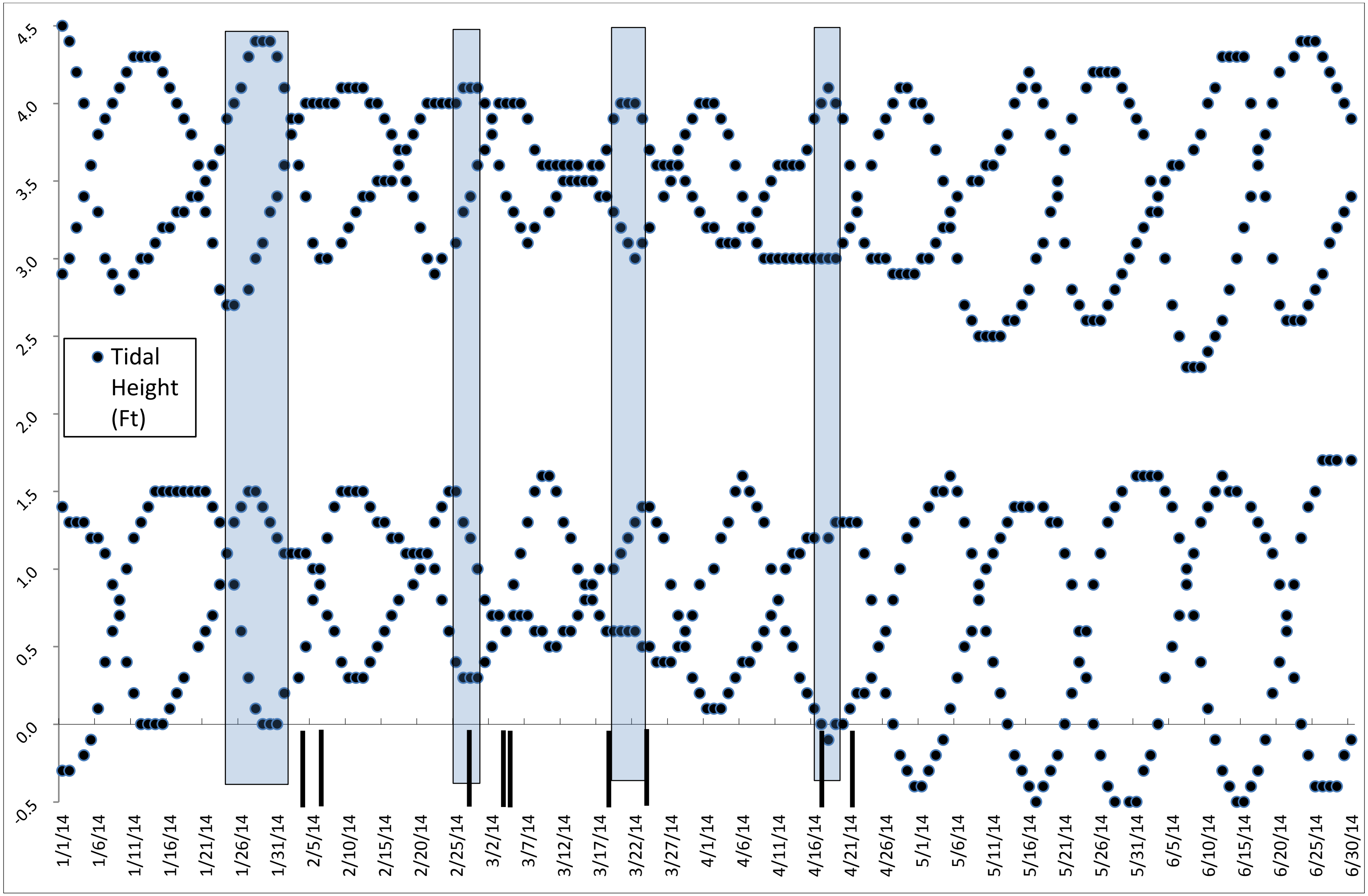

Figure 6. Tide height at Rio Vista. Data downloaded from NOAA Tides & Currents website 10/24/15 for station 9415316. Lines denote Chinook salmon catch. Boxes denote peak high tide periods in relation to observations of Chinook salmon.

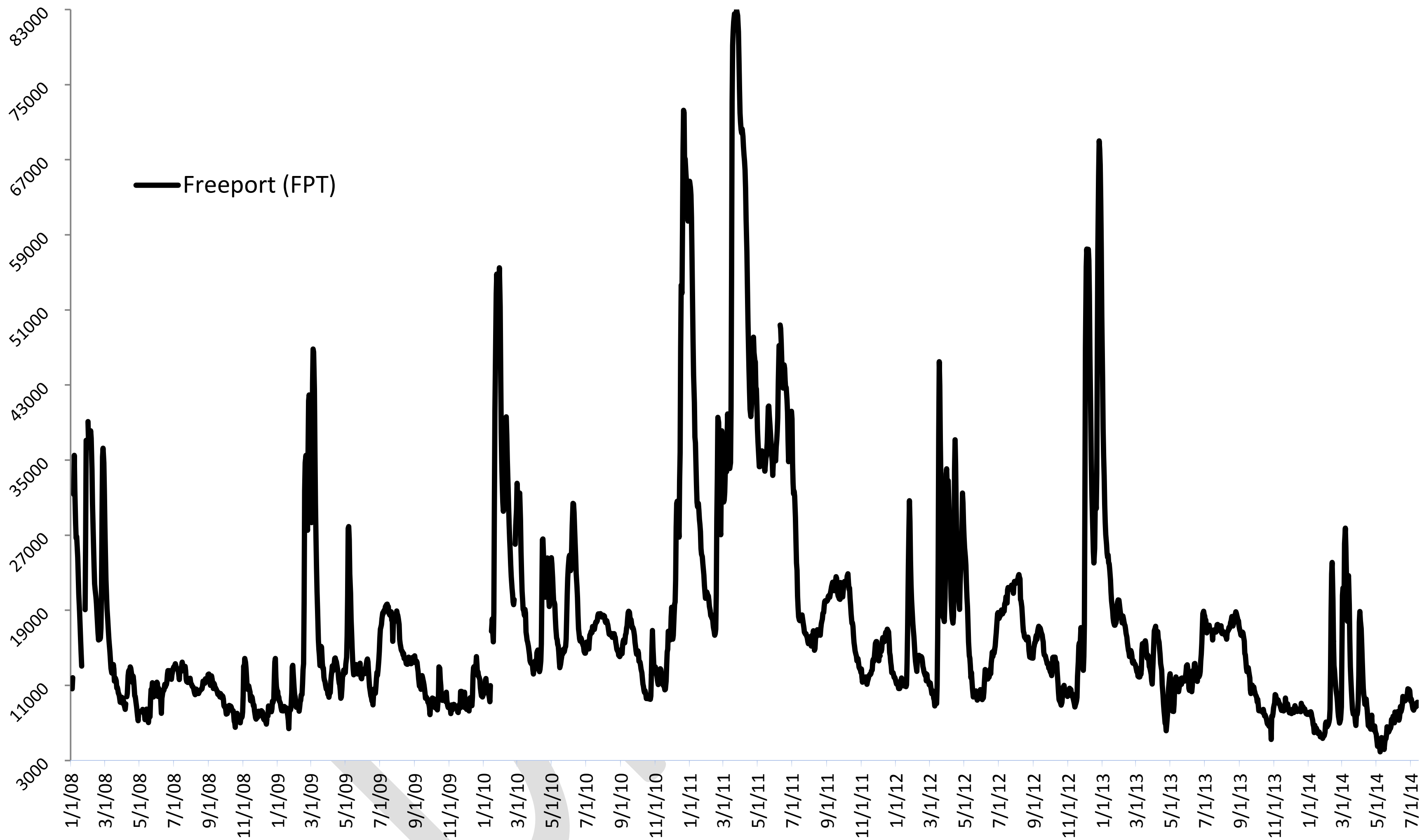

Figure 7. Sacramento River flows in cubic feet per second at Freeport. Data downloaded from California Data Exchange Center. Accessed on 10/24/15

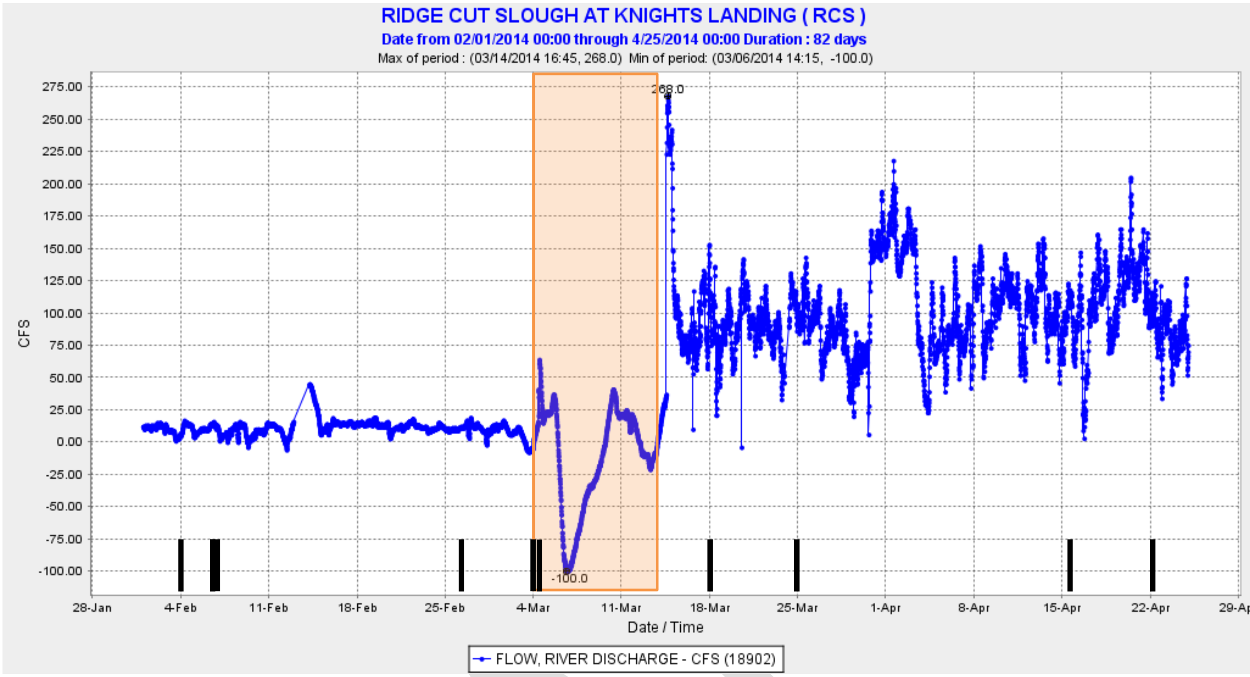

Figure 8. Ridge Cut Slough flow 28 January 2014 to 29 April 2014. The red box highlights the time period where nights Landing outfall gate operations likely resulted in reverse flows with in the ridge cut. Lines denote periods when Chinook salmon were observed at Wallace Weir. Note, fish recovered on 18 March 2014 was from CBD trapping site and was dead. Migration route for this fish in undetermined. Data source CDEC, accessed 10/24/15.

ACKKNOWLEDGEMENTS

The authors would like to express apparition to both John Brennan and Jacob Katz for providing access and support for the fish rescue efforts at Wallace Weir. The authors would also like to express appreciation to Luis Bair of RD 108 for access and support at the weir site in the CBD. Additionally, we want to acknowledge the support of CDFW staff from the Region 2, Fisheries and Water Branches including, Kevin Thomas, Tom Schroyer, Hideaki Kubo, Josef Lehr and George Heise as well as CDWR staff for their support in rescue efforts at Wallace Weir during the season Jared Frantzich and James Newcomb. Finally, we want express our appreciation to Jim Smith and the USFWS for providing the specialized transport tanks required to transport fish to release locations.

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Appendix A.

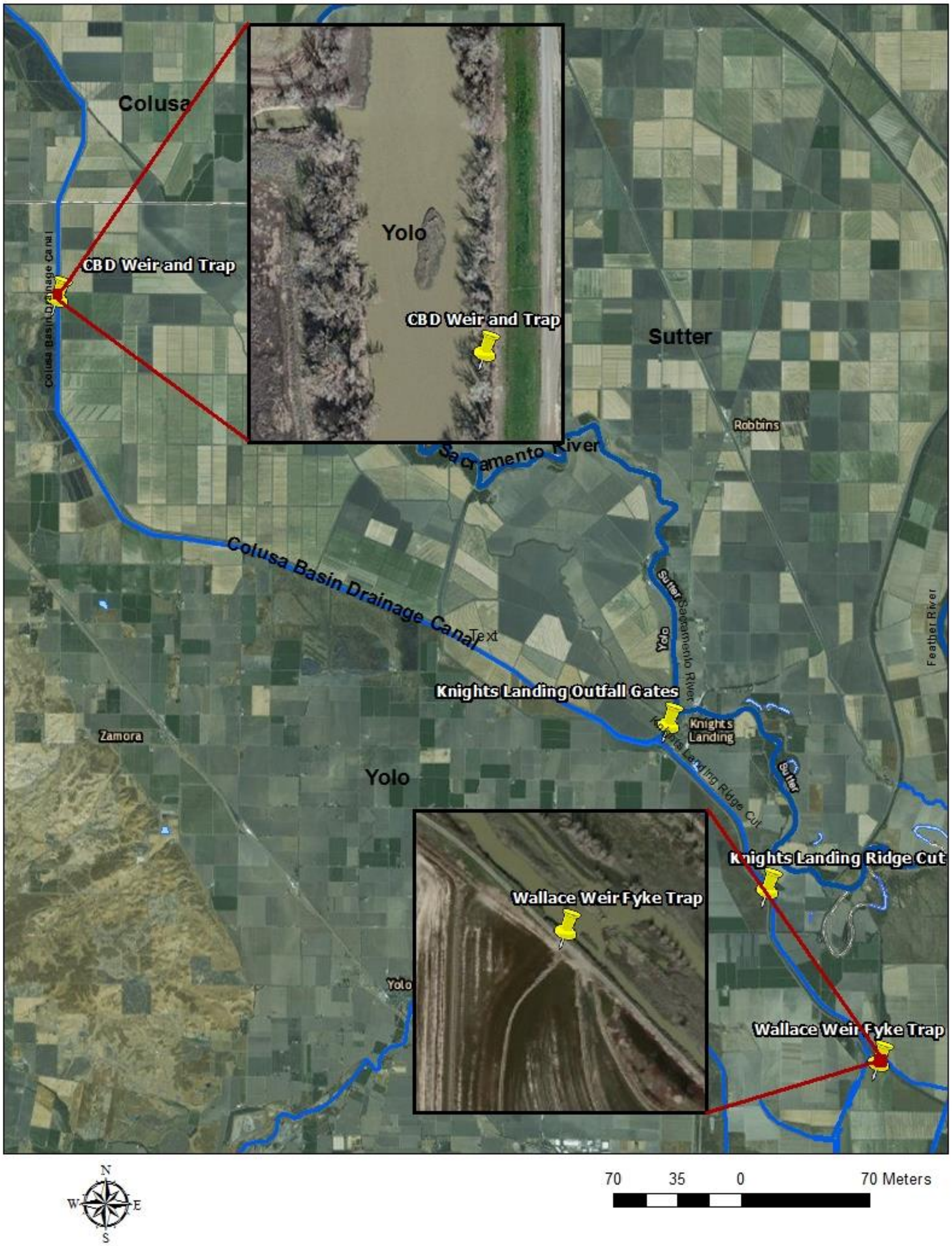

Figure 1. Map of Wallace Weir Fyke Trap Site and Colusa Basin Drain Canal Resistance Weir Site.

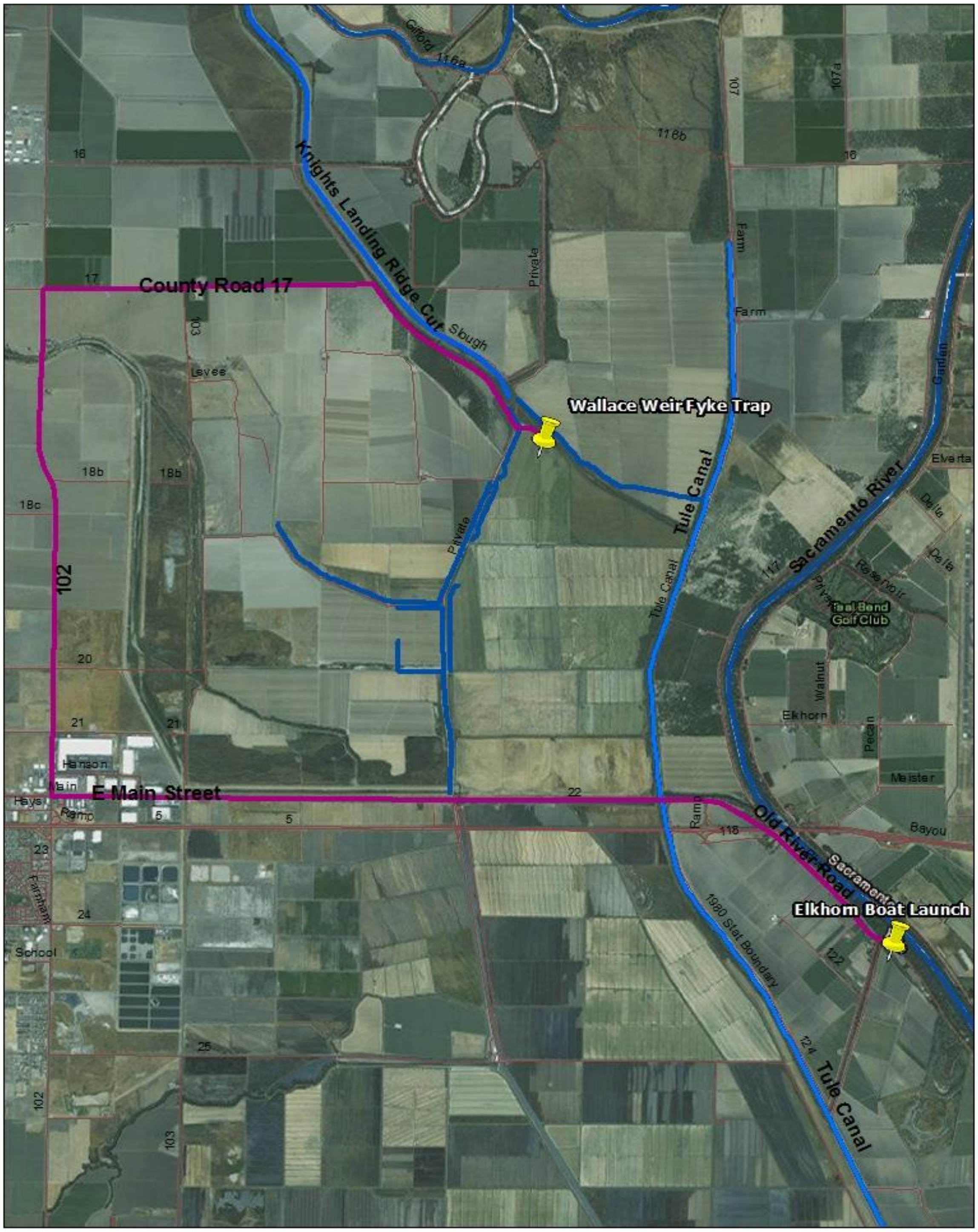

Figure 2. Map of Wallace Weir trap site, with route to the Elkhorn Boat Ramp on the Sacramento River indicated as a purple line.

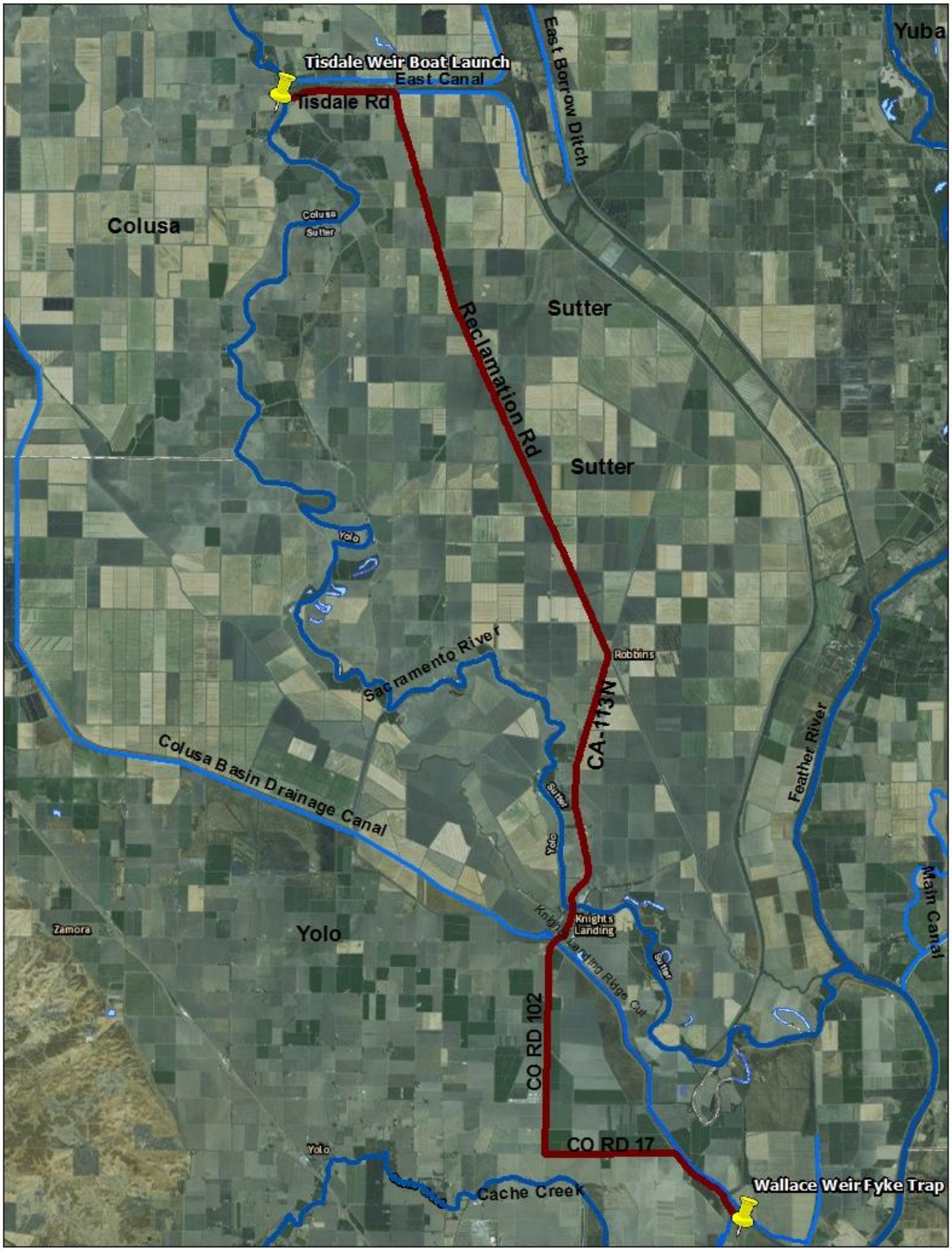

Figure 3. Map of Wallace Weir trap site, with route to the Tisdale Boat Ramp on the Sacramento River indicated as a red line.

Appendix B.

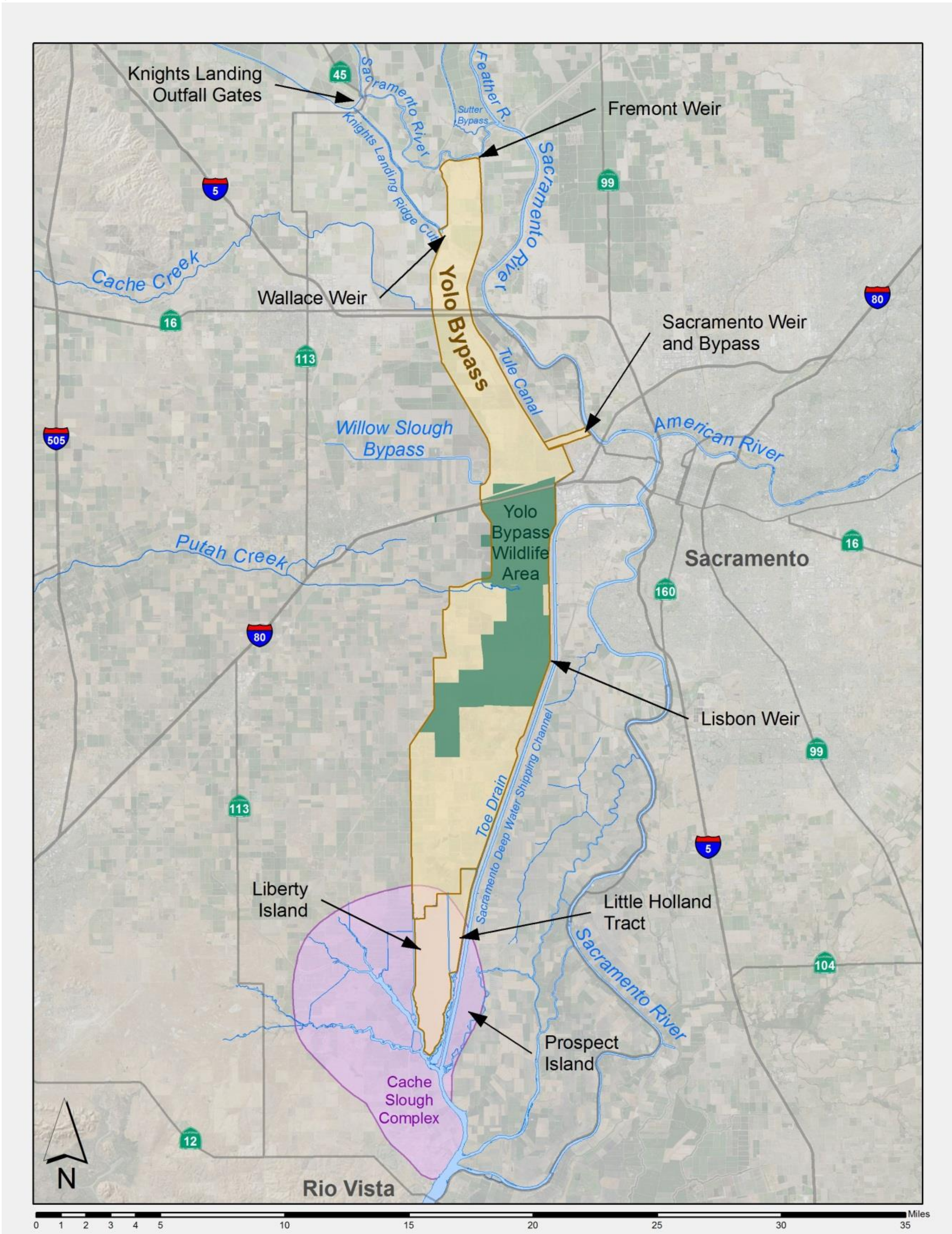

Figure 1. Map of the Yolo Bypass. The Cache Slough Complex extends from approximately Little Holland Tract down to the confluence with Sacramento Deep Water Ship Channel.

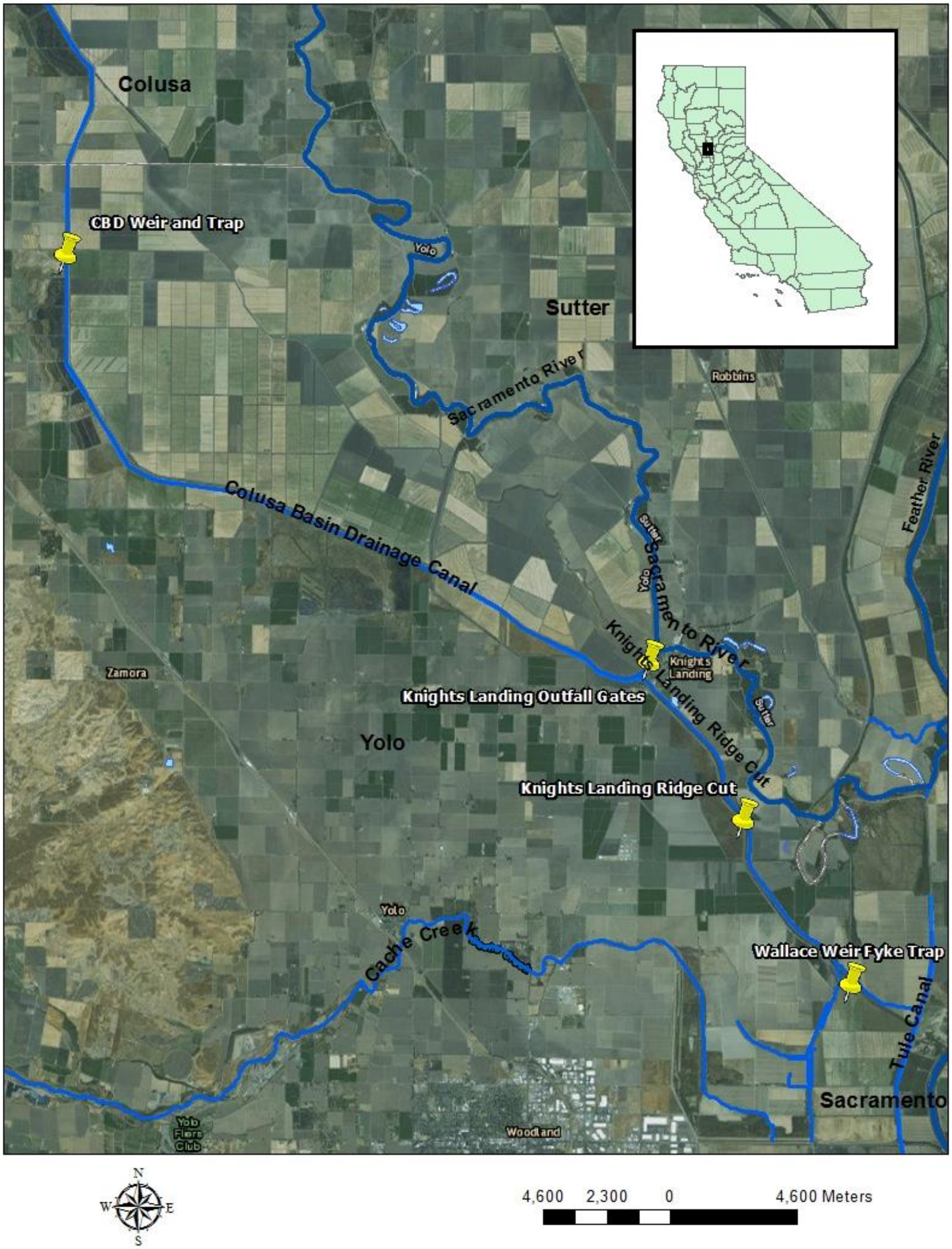

Figure 2: Map showing the Colusa Basin Drain weir and trap, Knights Landing Outfall Gates, Knights Landing Ridge Cut and Wallace Weir.

Appendix C. Trap Designs

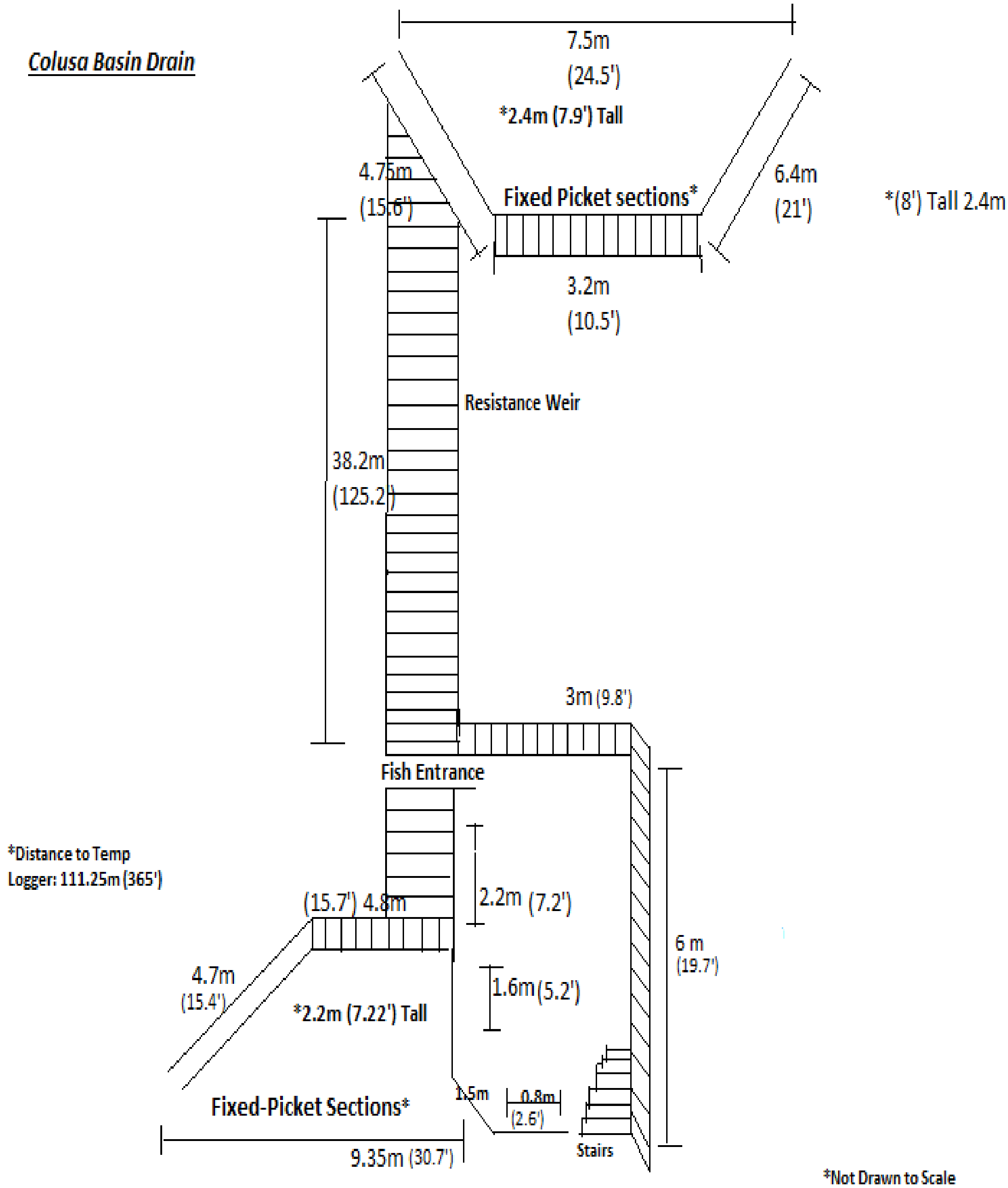

Figure 1. Colusa Basin Drain weir site measurements.

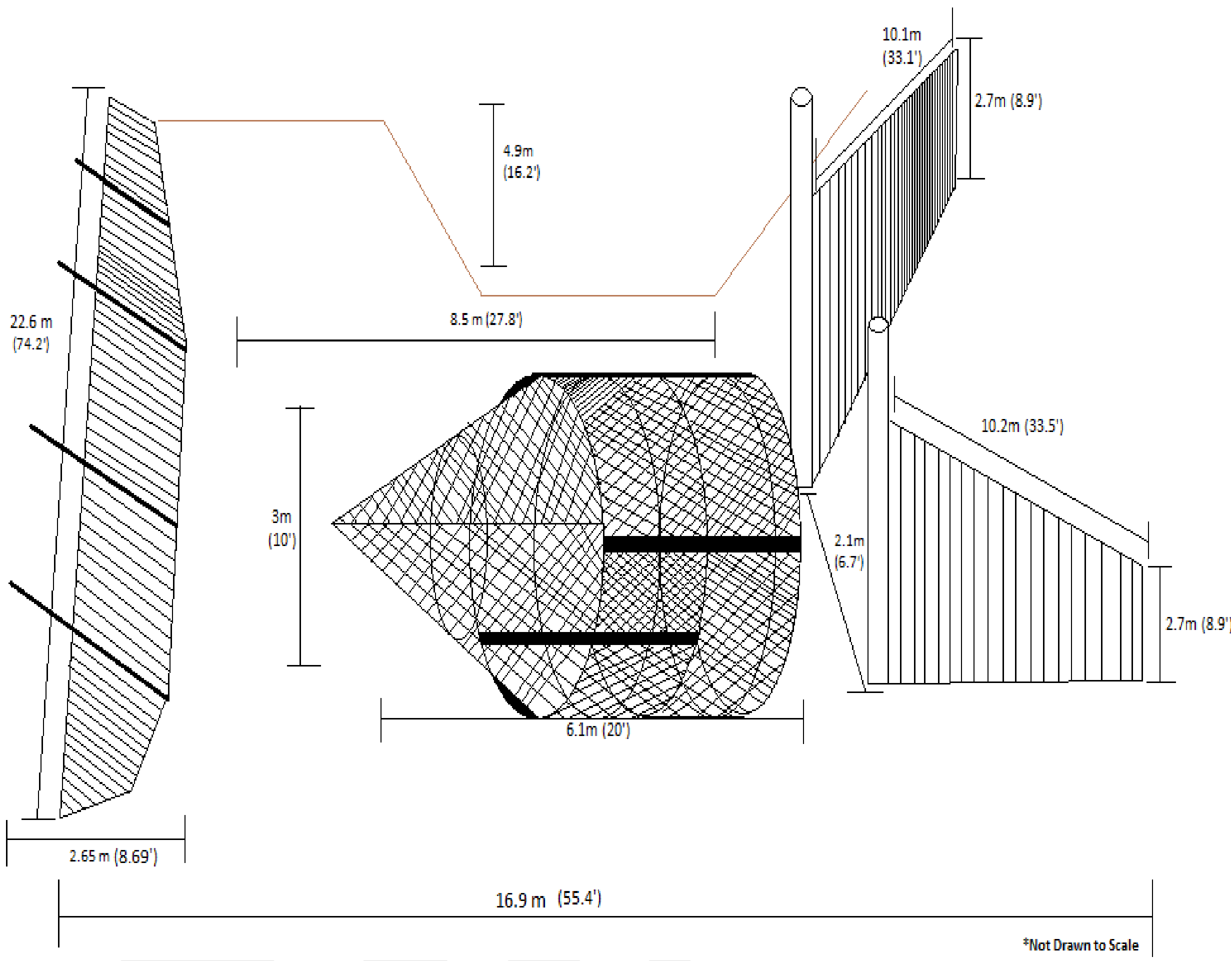

Figure 2. Wallace Weir fyke trap site measurements

Appendix D

Figure 1. Photo of the Colusa Basin Drain weir and trap entrance.

Figure 2: Photo of the Wallace Weir fyke trap.

Appendix E. Guidelines for sample collection of dry and wet genetic sampling

Protocol for Taking Dry Genetic Samples

I. Select a fresh carcass suitable to obtain a tissue sample. A fresh carcass will have clear eyes (not cloudy) and/or pink gills. **Record all data on the coin envelope**. Use only one envelope per fish. If the envelope is not pre-stamped, include the following data: date, location with landmarks, sample ID number, GPS coordinates (if available), fork length (mm), sex of fish, collector's name, fin which sample was taken from, species of fish, adipose fin present or absent, and any other information pertaining to the sample.

II. From each fish, choose a fin (caudal, pectoral, dorsal, etc.) in the best condition. Take a fin clip (size indicated in Figure 1) from the base of the fin (Figure 2). Do not take tissue from the adipose fin as there is little DNA provided in that sample.

III. Place the tissue sample on one piece of filter paper and fold paper over to cover the sample. Place filter paper into the coin envelope.

IV. Vigorously agitate scissors in water between samples to prevent cross contamination.

V. Cut open each fish and examine the gonad tissue to confirm the sex of the fish. Write any remarks concerning the sample in the notes section of the data sheet (e.g. the fish looks like a male, but has female gonads)

VI. Either in the field after collection, or in the office immediately upon return from the field, air-dryall samples on the same filter paper. The samples are dry when all mucous and moisture has evaporated and the tissue feels dry to the touch. Sun drying in the field works best and can be done quickly. Drying fins indoors usually takes 24 hours.

VII. Record the appropriate field and lab preservation methods (both will normally be noted in the "other" column as "air dried") on the data sheet.

VIII. When completely dry, repackage tissue into its original, **dry**, envelope and attach to field notes for shipment to our lab. Please make arrangements with the Tissue Archive before shipping. Check all envelopes to ensure that the data is filled out completely and legibly

Protocol for Taking Wet Genetic Samples

Equipment you will need:

1) Screw cap tubes filled with 95% NON-denatured ethanol

2) Surgical scissors and forceps

3) Biological Data Sheet

Procedure:

1) Ensure that tubes are labeled in a way that will not wash off if ethanol leaks (laser-jet printed labels in the tubes work well).

2) To avoid sample contamination keep your hands, sampling instruments and work area clean. Rinse / wash scissors and forceps in fresh water prior to taking each genetic sample.

3) Use the scissors to cut a small piece of tissue off of the caudal fin (approximately 0.5 cm^2 each).

4) Place the tissue sample into the screwcap tube filled with alcohol and tightly screw on the cap (If the cap is not tight, the alcohol will evaporate).

5) Place the sample back in the plastic box. Samples should be stored at room temperature.

6) Contact Christian Smith via e-mail before sending samples to the USFWS genetics repository.

Christian Smith, U.S. Fish and Wildlife Service, Abernathy Fish Technology Center, 1440 Abernathy Creek Rd, Longview, WA 98632, Phone (360) 425-6072, e-mail: Christian_Smith@fws.gov

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