PROGRAMMATIC BIOLOGICAL ASSESSMENT FOR THE 2013-2017 TEMPORARY BARRIERS PROJECT FOR USFWS-MANAGED SPECIES

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LIST OF ACRONYMS AND ABBREVIATIONS

ag barriers	Agricultural Barriers
ASIP	Action-Specific Implementation Plan
BA	Biological Assessment
BMPs	best management practices
BIOP	Biological Opinion
CESA	California Endangered Species Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CVP	Central Valley Project
cy	cubic yards
dB	Decibels
DFG	California Department of Fish and Game
DIDSON	Dual-Frequency Identification Sonar
DO	dissolved oxygen
DWR	California Department Water Resources
EFH	essential fish habitat
ESA	federal Endangered Species Act
FMWT	Fall mid-water trawl
Fish Facilities	Harvey O Banks Pumping Plant and John E. Skinner Fish Collection Facility
FMP	Fishery Management Plans
GLC	Grant Line Canal near Tracy Boulevard Bridge
GPS	Global Positioning System
HOR	head of Old River at the divergence from the San Joaquin River
Hz	hertz
IEP	Interagency Ecological Program
LED	light-emitting diode
LSZ	Low-Salinity Zone
MILs	Modulated Intense Lights

m	meters
mm	millimeters
MR	Middle River near Victoria Canal
MRB	MR barrier
NAVD88	North American Vertical Datum of 1988
NMFS	National Marine Fisheries Service
NPB	non-physical barrier
NTU	Nephelometric Turbidity Units
OCAP	Operations Criteria and Plan
OMR	Combined Old and Middle River (flows)
ORT	Old River near Tracy
PCEs	primary constituent elements
POD	Pelagic Organism Decline
PPT	Parts per thousand
PSU	Practical salinity unit
RBDD	Red Bluff Diversion Dam
RMS	Root mean squared
SEL	Sound exposure level
SL	Standard Length
Smolt	Downstream migrating salmonid smolt
SKT	Spring kodiak trawl
SRCSD	Sacramento Regional County Sanitation District
SWP	State Water Project
SWRCB	State Water Resources Control Board
TBP	South Delta Temporary Barriers Project
TNS	Tow-net survey
USFWS	U.S. Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
X2	Distance in kilometers from the Golden Gate Bridge to the two parts per thousand isohaline
yd^3	cubic yards

INTRODUCTION

The California Department Water Resources (DWR) initiated the South Delta Temporary Barriers Project (TBP) in 1991. The TBP involves the seasonal installation of three rock barriers in Middle River near Victoria Canal (MR), Old River near Tracy (ORT), and Grant Line Canal near Tracy Boulevard Bridge (GLC). These rock barriers are designed to act as flow control structures, "trapping" tidal waters behind them following a high tide. These barriers improve water levels and circulation for local south Delta farmers and are collectively referred to as Agricultural Barriers (ag barriers). A fourth barrier, installed at the head of Old River (HOR) at the divergence from the San Joaquin River, is designed to improve migration conditions for Central Valley fall-run Chinook salmon originating in the San Joaquin River watershed during adult and juvenile migrations, which occur annually in the fall and spring respectively. The fall HOR barrier also serves as a flow-control structure by keeping water in the San Joaquin River which improves downstream dissolved oxygen (DO) conditions. The spring barrier is intended to prevent downstream migrating salmonid smolts (smolt) in the San Joaquin River from entering Old River. The HOR barrier is often referred to as a Fish Barrier. In 2009 and 2010, DWR installed and operated a non-physical barrier (NPB) at the HOR as an alternative to the spring HOR rock barrier. The NPB employs the use of underwater bubbles, light, and sound to act as a fish behavioral deterrent which is intended to exclude smolt from entering the south Delta via Old River without having to physically block the flow of water into the channel with a rock structure. DWR retains the flexiblilty to install and operate the NPB at the HOR as an alternative to the spring HOR rock barrier.

The TBP was initiated with the intention that it would be a temporary program implemented only until permanent operable gates could be installed. However, the timing of implementation of permanent operable gates is uncertain and the TBP is proposed to continue until the permanent operable gates are implemented. Figures 1 and 2 are project vicinity and location maps.

This document is a Programmatic Biological Assessment (BA) and is intended to satisfy the Section 7 consultation requirements of the federal Endangered Species Act (ESA) of species managed by the United States Fish and Wildlife Service (USFWS). As such, this BA describes the potential effects on federally-listed fish species and their critical habitat that may result from the construction of the TBP. All operations and hydrologic impacts have been taken into account under the Central Valley Project (CVP) and State Water Project (SWP) Operations Criteria and Plan (OCAP) Biological Opinion (BIOP) which addressed the effects of operations of the TBP (USFWS, 2008).

THREATENED AND ENDANGERED SPECIES AND CRITICAL HABITAT

The following species are addressed in this BA :

- Conservancy fairy shrimp (*Branchinecta conservatio*).
- Longhorn fairy shrimp (*Branchinecta longiantenna*).
- Vernal pool fairy shrimp (*Branchinecta lynchi*).
- Vernal pool fairy shrimp designated critical habitat.
- Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*).
- Vernal pool tadpole shrimp (*Lepidurus packardi*).
- Delta smelt (*Hypomesus transpacificus*).
- Delta smelt designated critical habitat.
- California tiger salamander *(Ambystoma californiense)*.
- California red-legged frog *(Rana draytonii)*.
- California red-legged frog designated critical habitat.
- Alameda whipsnake (*Masticophis lateralis euryxanthus*).
- Giant garter snake (*Thamnophis gigas*)
- Riparian brush rabbit (Sylvilagus bachmani riparius)
- San Joaquin kit fox (*Vulpes macrotis mutica*).
- Contra Costa goldfields (*Lasthenia conjugens*)
- Contra Costa goldfields designated critical habitat.

The species analyzed in this BA are protected under the ESA and their listing status is presented in Table 1.

TABLE 1: SPECIAL-STATUS SPECIES ADDRESSED IN THIS BIOLOGICAL ASSESSMENT

Species	Status*
Conservancy fairy shrimp	FE
Longhorn fairy shrimp	FE
Vernal pool fairy shrimp	FT
Valley elderberry longhorn beetle	FT
Vernal pool tadpole shrimp	FE
Delta smelt	FT, SE
California tiger salamander	FT, ST
California red-legged frog	FT
Alameda whipsnake	FT, ST
Giant garter snake	FT, ST
Riparian brush rabbit	FE, SE
San Joaquin kit fox	FE, ST
Contra Costa goldfields	FE

* Status definitions:
FE = listed as endangered under the federal Endangered Species Act.
FT = listed as threatened under the federal Endangered Species Act.
SE = listed as endangered under the California Endangered Species Act.
ST = listed as threatened under the California Endangered Species Act.

CONSULTATION TO DATE

The regulatory permit history of the TBP begins in 1991 and includes many separate consultations, take authorizations, and permits from the U.S. Army Corps of Engineers (Corps), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), and the Regional Water Quality Control Board (RWQCB). DWR is pursuing two multi-year U.S. Clean Water Act, Section 404 / Rivers and Harbor Act, Section 10 permits from the Corps to cover the construction of the TBP through the end of 2017. The two projects of the TBP that will be subject to separate permit applications to the Corps are:

- TBP-Ag Barriers
- TBP-HOR Barrier

Below is the recent consultation history and environmental permits applicable to the TBP:

- **In 2004, the USFWS issued a Programmatic Biological Opinion (BIOP) on the Issuance of Section 10 and 404 Permits for Projects with Relatively Small Effects on the delta smelt and its Critical Habitat within the Jurisdiction of the Sacramento Fish and Wildlife Office of the USFWS, CA (USFWS File# 1-1-04-F-0345). This non-expiring Programmatic BIOP is still valid and was used in 2009 and 2010 to cover the HOR NPB, which was authorized under the Corps' Nationwide Permit 4.**
- **In 2008, the USFWS issued the Central Valley Project (CVP) and State Water Project (SWP) Operations Criteria and Plan (OCAP) BIOP which addressed the effects of operations (i.e., hydrodynamic effects) of the MR, ORT, GLC and HOR rock barriers on delta smelt *(Hypomesus transpacificus)* (USFWS File# 81420-2008-F-1481-5). This non-expiring BIOP is still valid and covers the TBP-Ag Barriers and HOR Rock Barriers.**
- In 2008, the NMFS issued a BIOP for the construction of the TBP **(NMFS # 2007/07586).**
- **In 2009, the USFWS issued a BIOP which addressed the effects of construction of the MR, ORT, GLC and HOR rock barriers on delta smelt and its designated critical habitat (USFWS File# 81420-2008-F-0522) (U.S. Fish and Wildlife Service 2008). This non-expiring BIOP is still valid and covers the TBP-Ag Barriers and HOR Rock Barriers.**
- **In 2009, the USFWS issued a BIOP which addressed the effects of construction and operation of the 2009 HOR NPB on delta smelt that appended the project covered under the Corps Nationwide Permit 4 to the 2004 Programmatic BIOP for delta smelt (USFWS File# 1-1-04-F-0345).**
- In 2009, the NMFS issued a BIOP for the construction of the non-physical barrier at the HOR **(NMFS # 2009/01239)**.
- **In 2010, the USFWS provided concurrence to the Corps that the 2010 HOR NPB would not likely adversely affect delta smelt and amended the 2009 HOR NPB BIOP with the 2010 HOR NPB project description (USFWS File# 81410-2010-F-0004).**

- In 2011, the Central Valley Regional Water Quality Control Board (RWQCB) issued Clean Water Act Section 401 Water Quality Certification for the construction and removal of the four rock barriers and construction and removal of the HOR NPB (WDID# 5B39CR00191). This permit covers all three TBP projects listed above through 2016.
- In 2011, the California Department of Fish and Game (DFG) issued a Final Lake or Streambed Alteration Agreement for the construction and removal of the four rock barriers and construction and removal of the HOR NPB (DFG tracking # 1600-2010-0375-R3). This permit covers all three TBP projects listed above through 2016.
- In 2011, DFG issued an incidental take permit for the construction and removal of the four rock barriers, construction and removal of the HOR NPB, implementation of the predator study, and implementation of the Fish Monitoring Project. (DFG tracking # 2081-2011-019-03). This permit covers all three TBP projects listed above through 2016.
- In 2011, the NMFS issued a BIOP which addressed the effects of construction of the four rock barriers and the HOR NPB (NMFS # 2010/06485). This BIOP expired on December 31, 2011.
- **In 2012, the USFWS amended the 2009 HOR BIOP with the updated 2012 project description and schedule and amended the Effects Analysis (USFWS File # 08FBDT00-2012-F-0010).**
- In 2012, the NMFS issued a BIOP for the 2012 Temporary Barriers Project (NMFS File # 2012/00152), which included the construction and removal of the four rock barriers.
- In 2012, DFG amended the 2011 Lake and Streambed Alteration Agreement with the updated 2012 project description and schedule (DFG tracking # 1600-2010-0375-R3).
- In 2012, DFG amended the 2011 Incidental Take Permit with the updated 2012 project description and schedule (DFG tracking # 2081-2011-019-03).
- In 2012, the USACE modified the 2001 Temporary Barriers Project- Agricultural Barriers, Clean Water Act Section 404 permit (SPK # 200100121) with the updated 2012 schedule for the construction of the three agricultural barriers.
- In 2012, the USACE modified the 2000 Temporary Barriers Project- HOR Rock Barriers, Clean Water Act Section 404 permit (SPK # 200000696) with the updated 2012 project description and schedule for the construction of the spring and fall HOR rock barriers.
- In 2012, the Central Valley Regional Water Quality Control Board (RWQCB) amended the Clean Water Act Section 401 Water Quality Certification for the construction and removal of the four rock barriers and construction and removal of the HOR NPB (WDID# 5B39CR00191).

DESCRIPTION OF THE PROPOSED ACTION

The proposed 2013-2017 TBP would consist of annual construction, maintenance and removal of the MR, ORT, GLC, HOR fall rock barrier, and either the spring HOR rock barrier or the spring HOR NPB. Additionally, a fish study may be conducted to gain an understanding of the HOR barrier effectiveness, to better understand the movement and behavior of salmonids and predatory fish and/or to understand how those movements and behaviors change as a result of the installation and operation of the barrier. Barriers cannot be constructed when ambient flows in the San Joaquin River are above 5000 cfs, as measured at the Vernalis monitoring station, as high flows create extremely hazardous and unsafe working conditions and cause rocks to move as they are placed.

AGRICULTURAL BARRIERS

The TBP-Agricultural Barriers (Ag Barriers) includes the annual construction, maintenance and removal of the MR, ORT, and GLC rock barriers. The design of the 2013–2017 Ag Barriers would be essentially the same as in years past. However, DWR may require modification of the weir height of the MR barrier (MRB) during some years of the permit, as was done in summer 2010 and 2012. If implemented, and after concerns for impacts to delta smelt in the south Delta have passed, the height of the MRB weir would be increased by 1 foot from the current design elevation of 3.3 feet to an elevation of 4.3 feet based on the North American Vertical Datum of 1988 (NAVD88).

MIDDLE RIVER

The MRB is located about a half mile south of the confluence of Middle River, Trapper Slough, and North Canal. The MRB is a rock barrier constructed with a center weir section that allows tidal flows to enter the Middle River upstream of the barrier by overtopping the weir crest and flowing through submerged culverts (Figure 3). The tidal flow is retained behind the barrier in part during the ebb tide by the barrier elevation and the closure of the flap-gates. This allows agricultural pumps to operate throughout each tidal cycle by maintaining a minimum water elevation of 2.6 feet (NAVD88) measured at the Howard Road Bridge station.

Each year the MRB weir section is reconstructed by placing approximately 2,300 cubic yards (cy) of rock between the two previously constructed abutments that are left in place year-round. Each abutment has three, 48-inch diameter culverts with tidally-operated flap-gates that are also left in place. Placement of rock completes the barrier that is 270-feet long and 50 feet-wide (0.31 acre). The rock weir section is 140-feet long and 18-feet wide at its crest. By September 15th, a 10 foot-wide notch (fall notch) is constructed in the weir for salmon passage. The notch allows a minimum depth of 6 inches of water to pass over the barrier during low-high tide events and shall remain in place until the barrier is removed.

Decision 1641 (D-1641), which was issued from the SWRCB, set defined salinity standards in the Delta. Raising the MRB would allow the barrier to trap more of the fresh water found below the barrier, thereby raising water quality levels above the barrier. The CVRWQCB issued a *Water Quality Control Plan for the Sacramento and San Joaquin River* (Basin Plan; revised in 2011) which set defined DO standards for the Delta. Raising the MRB in conjunction with tying open the ORT barrier culvert flapgates is intended to create net circular flow up MR and down OR which would decrease zones of stagnant water. In an effort to maintain these water quality standards DWR retains the option to raise the height of the MRB during peak irrigation months, the height of the weir may be increased from 3.3 (typical) to 4.3 feet (NAVD88). Raising the barrier height one foot will require an additional 100 cy of rock and will reduce the width of the crest to 15 feet. However, it is expected that this will result in little, if any, disturbance to the riverbed or channel and there will be no change in the footprint of the MRB. The MRB will only be raised when risks to delta smelt have passed and full barrier operations are allowed by the USFWS and DFG. DWR proposes to continue optionally raising the MRB weir because it will:

- Decrease salinity levels in the south Delta by using the tidal cycles to add additional fresh Sacramento River water into south Delta channels system via Middle River;
- Increase the circulation upstream of the barriers thereby improving water quality and agricultural diversions for crops; and
- Reduce null zones where stagnant water creates low DO levels and algae blooms.

The center weir section of the MRB is removed during the non-irrigation season (December through March). The flap-gates are tied open when the center weir section is removed. The fall notch in the MRB will remain the same elevation regardless of the 1 foot increase in weir height. The notch will be 10 feet wide and at an elevation of 2.6 feet (NAVD88).

While the culverts are left in place for most years, periodic culvert replacement (every 10-15 years) may occur in order to ensure their functionality.

OLD RIVER TRACY

The ORT barrier is located near the CVP's Tracy fish screen facility on Old River, approximately 0.5 miles east of the CVP's inlet. The structure allows tidal flows to enter the channel upstream of the barrier by overtopping the weir crest and flowing through the submerged culverts. The tidal flow is then partially retained during the ebb tide by the barrier elevation and the closure of tidal flap-gates on the upstream side of each culvert.

Each year construction of the ORT barrier begins with placement of a rock and gravel pad followed by the placement of three metal culvert frames each containing three 48-inch diameter culverts (nine culverts total) with flap-gates on the prepared pad. The culverts are then covered with approximately 5,000 cy of rock to form a 250-foot long berm that is 60 feet wide at its base (0.34 acre) (Figures 4a and 4b). The center of the barrier has a 75-foot wide weir with a crest elevation of 4.4 feet based on the NAVD88. Beneath the weir, are the nine culverts, each 60 feet long and 1 foot apart, with tidally activated flap-gates on the upstream ends. During summer months, some of the flap-gates may be tied to the open position to improve circulation in this area. Tying the flap gates open in conjunction with the Middle River raise is intended to increase net downstream flow and reduces stagnant zones in Old River. A temporary boat ramp will be constructed with riprap at the base, followed by crushed rock, and topped with articulated concrete mats. Because much of the boat ramp structure will be underwater, divers will aid in the positioning of the concrete mats. Similarly to the MRB, a 10 foot-wide notch is constructed by September 15 each fall to allow adult salmon passage.

GRANT LINE CANAL

Each year the GLC barrier is constructed with approximately 12,600 cy of rock that is placed between the existing south abutment and the north canal bank to create a 300-foot long barrier that is up to 100 feet wide at its base (0.34 acre) (Figures 5a and 5b). The center of the barrier has a weir section with a crest at 3.3 feet elevation (NAVD88) that is 125 feet long and 24 feet wide. The existing south abutment contains six 48-inch diameter, 60-foot long culverts with flap-gates on the upstream end. A catwalk structure is affixed to the top of each culvert with a winch and hand crank allowing access to and operation of the flap-gates attached to the upstream end of each culvert. A 10 foot wide flashboard structure is also built at the south abutment, which can be adjusted to allow delta smelt passage in spring and salmon passage in the fall. Similarly to the ORT barrier, a ramped boat portage facility is also provided at the north levee. The boat ramp is constructed with riprap at the base, followed by crushed rock, and topped with articulated concrete mats. Because much of the boat ramp structure will be underwater, divers will aid in the positioning of the concrete mats.

While the culverts are left in place for most years, periodic culvert replacement (every 10-15 years) may occur in order to ensure their functionality.

HEAD OF OLD RIVER BARRIER

The HOR barrier is located at the divergence of Old River from the San Joaquin River near the City of Lathrop. The HOR barrier serves a dual purpose and may be installed in the spring and in the fall. In the spring, the barrier acts as a fish barrier to decrease the number of salmonid smolts entering Old River. This can be accomplished by installing a rock barrier or a Non Physical Barrier (NPB). In the fall, the barrier may be needed to increase flows and dissolved oxygen levels downstream in the San Joaquin River including the Stockton deepwater shipping channel; therefore, a rock barrier must be used.

SPRING ROCK BARRIER

The spring HOR rock barrier is intended to prevent downstream-migrating salmon smolts in the San Joaquin River from entering Old River, which would expose them to State Water Project (SWP) and Central Valley Project (CVP) diversion operations and unscreened agricultural diversions. The spring HOR rock barrier is constructed with approximately 12,500 cy of rock to form a 225-foot long and 85-foot wide (at the base) berm (0.44 acre) (Figures 6a and 6b) and it has a crest elevation of 12.3 feet (NAVD88). Construction at the south end of the barrier includes the placement of six to eight, 48-inch diameter culverts with slide-gates into the barrier abutment. The middle section includes a 75-foot weir at an elevation of 8.3 feet that is capped with clay up to the barrier crest elevation (12.3 feet, NAVD88). Unlike the ORT and GLC barriers, there is no boat portage facility at this barrier. A ramp and dock may be secured to the shore in order to allow storage and safe access to small boats that may be used for construction, maintenance and research purposes.

FALL ROCK BARRIER

Installation of the fall HOR rock barrier may be needed to increase flows and dissolved oxygen levels downstream in the San Joaquin River. The fall HOR rock barrier is constructed similarly to the spring barrier, but using approximately 7,500 cy of rock to form a smaller 225-foot long and 65-foot wide (at the base) berm (0.34 acre) that is constructed to a crest elevation of 8.3 feet and includes a 30-foot wide notch at elevation 2.3 feet (NAVD88; Figures 7a and 7b) to allow the passage of adult salmonids.

SPRING NON-PHYSICAL BARRIER

The HOR NPB is a multi-stimulus fish barrier that combines high-intensity light-emitting diode (LED) Modulated Intense Lights (MILs), an air bubble "curtain," and sound at frequencies and levels that are repellent to Chinook salmon (Bowen et al. 2009; Bowen and Bark 2010). The sound system and MIL flash rate can be tuned to known sensitivities of various fish species. Investigations have indicated that the most effective acoustic deterrents for multiple fish species fall within the sound frequency range of 5 to 600 hertz (Hz) (Bowen and Bark 2010). Studies with Chinook salmon and delta smelt have shown that when the sound and strobe light flash rate were tuned according to these species' sensitivities, the barrier was particularly effective as a deterrent for Chinook salmon smolts (Bowen et al. 2008). Based on these studies, it has been hypothesized that the sound is the deterrent. The sound is trapped by refraction within the bubble curtain, producing a sharply defined sound field that fish do not detect until within a few meters of the barrier. The flashing MILs are aligned such that the light beam projects onto the bubble curtain. This helps identify the bubbles so that the source of the sound can be determined by the fish. A narrow, vertical MIL beam minimizes light saturation within the experimental area.

Modifications to the length and orientation of the HOR NPB may be made each year based on acoustic telemetry data obtained during operation. The 2009 HOR NPB was approximately 367 linear feet and spanned across the mouth of the Old River. The 2010 HOR NPB was 450 linear feet and was oriented further out in San Joaquin River than the 2009 NPB. Future HOR NPB's, if constructed, may have varying orientations in order to improve the barriers effectiveness on deterring and protecting smolts.

Current ideas on barrier design have been refined based on information collected in 2009 and 2010. The barrier may be up to 700 feet long and may be comprised of as many as 30 metal framed sections. The sections will be positioned along the barrier line such that, during average annual flow conditions, as much of the barrier as possible is at a depth where the height of the bubble curtain is less than 12 feet. The frames will be placed approximately 18 inches from the channel bottom. The top of the frame sections will be at 5–10 feet below the water surface elevation at low tide during average annual flow conditions. The barrier frames will be supported and secured with steel piles and concrete pier blocks. The NPB will require as many as 8 piles (including one scientific pile) and 30 pier blocks. Figures 9 a-d show plan and profile views of one option for a HOR NPB.

Each barrier frame section will have approximately four sound projectors spaced 6.5 feet apart, eight strobe lights, and a perforated "bubble" pipe. The bubble pipe will be positioned along each frame below and upstream of the sound projectors. A bubble curtain will be created by passing compressed air into the perforated pipe. The air flow rate will typically be 1.38 cubic feet per minute (cfm) per linear foot for the length of the barrier. The MILs will be powered from an "accumulator" positioned on each frame section. A mounting plate will be attached to the support tray to house the accumulators. The junction of each frame section can pivot with the adjacent section, and where needed, each frame section will be supported at either end with a piling or pier block.

Light cables, sound cables, and air lines will run from generators and air compressors located on the water side berm along the south bank of the San Joaquin River adjacent to the NPB, where a portion of the stockpile for the HOR rock barrier is stored. Approximately 120 amps (115 volts) of an inductively –rated power supply will be required to run the complete electrical system. A small trailer will house the control units, signal generators and amplifiers. A temporary floating dock will be installed near the trailer to tether a small boat used for operation, maintenance, and monitoring. See Figure 9e, for an example of placement locations of air lines, cables, and onshore equipment. All generators, air compressors, trailers and fuel storage containers will be placed such that it can be removed quickly and most equipment will be readily towable while staged.

In addition to the NPB structure, warning signs, lighted warning buoys, high visibility float rope, and ball buoys will be deployed around the barrier to alert boaters of its location. Up to 40 concrete anchors would be placed on the river bottom or on river banks to anchor the warning buoys and signs in place. Figure 9d show an example of the buoy layout and Figure 9f shows details of the example buoys, signs, and concrete anchors and pier blocks.

TEMPORARY BARRIERS PROJECT FISH STUDY

In general, the program includes tagging and releasing salmon and steelhead in the south Delta, installing an acoustic receiver network including a two-dimensional (2-D) biotelemetry system, implementing a mobile monitoring effort to find acoustic tags on the river bottom using global positioning system (GPS), monitoring fish using Dual-Frequency Identification Sonar (DIDSON) cameras, placement of hydroacoustic and other scientific instrumentation and sampling, tagging and releasing predatory fish. Scientific equipment will be affixed to several types of mounting brackets depending on equipment type, barrier type and location. Up to 50 anchors made from sections of railroad track will be used to anchor floating scientific equipment, such as hydrophones (Figure 10 and Figure 11) in the water column using tensioned lines. Additionally, up to 10 weighted stands and one scientific pile will be used for placing stationary equipment such as ADCP's and DIDSON cameras. A scientific pile will only be placed if the NPB is used at the HOR. The minimum required number of railroad track anchors and weighted stands will be placed each year and scientific equipment will be placed using barrier related structure, as much as possible. All scientific equipment will be affixed to anchors and stands similar in nature and impacts to those used for ADCP's, DIDSON cameras and hydrophones. Additional studies of salmonid smolts and predatory fish may occur, however, techniques used to capture predatory fish will be limited to electrofishing, hook and line sampling and fyke trapping.

Study techniques used in the past and likely to be used for future studies include 2-D tracking of acoustically tagged Chinook salmon and steelhead smolts, 2-D tracking of acoustically tagged predatory fish, acoustic tagging of salmonid smolts and predatory fish, capture of predatory fish using multiple techniques, placement of a 2-D hydrophone array within ½ mile of barrier locations, placement of hydrophone nodes at strategic locations within the south Delta (e.g. peripheral nodes to determine migration paths; See Figure 13), placement of ADCP's within ½ mile of barrier locations, placement of DIDSON cameras within ½ mile of barrier locations, and mobile hydroacoustic monitoring within the south Delta. Advanced technologies and monitoring techniques may be used in the future, as they are developed. A study plan will be prepared and submitted to the FWS for comment and approval for each year a study is planned.

CONSTRUCTION AND REMOVAL

Construction activities for all of the barriers would begin as early as March 1 and removal would be completed no later than November 30 of each year. Any rock barrier operating on or after September 15 will be notched beginning September 15 to allow for passage of adult salmon. At GLC, flashboards will be removed to create the notch in the barrier. Historic information on the actual construction schedules of the barriers since 1968 are included in Appendix B and approximate construction durations are included in Table 2.

TABLE 2: CONSTRUCTION AND REMOVAL REQUIREMENTS FOR EACH OF THE TEMPORARY BARRIERS.

		Construction (Days)	Removal (Days)
HORB	Spring Rock	24	24
	Spring NPB	20	15
	Fall Rock	18	18
Ag Barriers	MR	5 (+5 if culverts are replaced)	5 (+5 if culverts are replaced)
	ORT	20	20
	GLC	24 (+10 if culverts are replaced)	21 (+10 if culverts are replaced)

AGRICULTURAL BARRIERS

Construction of the ag barriers entails the placement of rock barriers in the spring within the channels of the Middle River, Old River, and Grant Line Canal. At the ORT barrier, quarry rock is stockpiled about ½ mile upstream of the barrier site on the inland side of the levee crown. The rock materials for MR are stockpiled adjacent to the barrier site on the water side of the levee crown and rock for the GLC barrier is stockpiled offsite at the Howard Road (2.0 miles) storage area. Each spring, heavy construction equipment is mobilized to move the stockpiled rock from its storage location into the channel to form the barriers. Large front loaders, dump trucks, off-road haulers, cranes, long reach excavators and drag lines are used to move and place the materials. Typically, machinery works from one or both banks of the channel to place the rock, as well as any additional materials such as culverts, articulating concrete mats, or other structures. Depending on the individual design of each barrier, the 48-inch diameter steel pipes used as culverts are placed by crane after the gravel pad of the barrier is constructed. At the MR and GLC barriers the abutments and the culverts remain in place over the winter. As the rock barrier is extended into the channel, machinery can utilize the crown of the barrier to move farther into the channel on top of the barrier to place additional materials. Each of the barriers is adequately marked with navigational aids and warning signs approved for placement by the U.S. Coast Guard (Private Aids Permit #s 2832-2839).

Barrier installation, including in-water work, and associated construction activities such as mobilization and site clean-up, typically takes approximately 5 working days for the MRB, 20 working days for the ORT barrier and 24 working days for the GLC barrier. However, extreme weather, tide and river flow conditions may impact the barriers construction schedules.

While the culverts are left in place for most years at MR and GLC, periodic culvert replacement may occur in order to ensure their functionality. Removal of the culverts would occur during the fall barrier removal. The removal of the culverts and the abutments at MR and GLC would add approximately 10 days for GLC and 5 days for MR to the removal schedule. The culverts and their associated structures would then be repaired or replaced and reset into the normal position using similar techniques to the culvert placement at ORT. The replacement would occur the following spring add approximately 10 days of work for GLC and 5 days for MR. The normally permanent rock abutments in each of these locations would be rebuilt as they have been previously constructed. The culverts at MR and GLC barriers have been replaced in recent years and are not likely to be replaced during the 2013-2017 period.

Removal of the barriers will occur in the fall and the installation procedure is reversed. Barrier removal, including in-water work, and associated construction activities such as mobilization and site clean-up, typically takes approximately 5 working days for the MRB, 20 working days for the ORT barrier and 21 working days for the GLC barrier. The rock barriers will be removed with an excavator and a dragline. An excavator will remove the majority of the rock down to the underwater pad of the culvert frames. Because the culvert pad is longer and wider than the "reach" of the excavator, a dragline with a bucket will be necessary to remove the remainder of the underwater rock associated with the barriers. The removed rock is stockpiled outside of the waterway until used again. At the barrier sites, the channel bottom is restored to pre-project conditions after the barriers are removed. Confirmation that the channel bottom has been restored to pre-project conditions is accomplished via bathymetric surveys which are conducted each year before construction (pre-project) and after removal. The barrier culverts and abutments at MR will remain in place throughout the year, as will the culverts and south barrier abutment at GLC.

HEAD OF OLD RIVER ROCK BARRIERS

Construction of the HOR rock barrier may entail the placement of a rock barrier in the spring and/or fall within the channel of Old River. Minor sediment removal may be required in order to prepare the area for barrier installation. The removal of sediment in the vicinity to the HOR barrier will be limited to the minimum amount necessary that will allow for the installation of the crushed rock bed for the culverts and will not extend beyond 200 feet in any direction from the barrier footprint. All removed sediment will be deposited and retained in an area that has no connection to waters of the United States. The culverts and articulated mats for the HOR rock barriers are stockpiled offsite at Howard Road storage area, while the rock is stockpiled adjacent to the HOR site. Heavy construction equipment will be mobilized to move the stockpiled culverts, articulated mats and rock from its storage location into the channel to form the barrier. Large front loaders, dump trucks, long reach excavators and barges with spuds and tug boat are used to move and place the materials. Typically, machinery works from both banks of the channel and from a barge within the channel to place the rock, as well as any additional materials such as culverts, concrete reinforcing mats, clay or other structures or materials. Depending on the design of the barrier, the 48-inch diameter steel pipes used as culverts are placed by crane from shore or from a barge after the gravel pad of the barrier is constructed. As the rock barrier is extended into the channel, machinery can utilize the crown of the barrier to move farther into the channel on top of the barrier to place additional materials. The barrier will be adequately marked with navigational aids and warning signs approved for placement by the U.S. Coast Guard (Private Aids Permit #s 2832-2839).

Barrier installation, including in-water work, and associated construction activities such as mobilization and site clean-up, typically takes approximately 24 working days for the spring HOR rock barrier and 18 working days for the fall HOR rock barrier. However, extreme weather, tide, and river flow conditions may impact the barriers construction schedule.

Removal of the barriers can occur in the spring and/or fall and the installation procedure is reversed. Removal of the spring HOR rock barrier can take up to 24 days and the removal of the fall HOR rock barrier can take up to 18 working days. The rock barriers will be removed with an excavator and a dragline or a crane with clamshells. Equipment will work both from shore and from a barge with spuds and a tug boat. The excavator and/or crane will remove the majority of the rock down to the underwater pad of the culvert frames. A dragline with a bucket may be necessary to remove the remainder of the underwater rock associated with the barriers. The removed rock is stockpiled outside of the waterway until used again. At the barrier site, the channel bottom is restored to pre-project conditions after the barrier is removed. Confirmation that the channel bottom has been restored to pre-project conditions is accomplished via bathymetric surveys which are conducted each year before construction (pre-construction) and after removal.

HEAD OF OLD RIVER NON-PHYSICAL BARRIER

In 2010 construction of the barrier took a total of 11 days including pile driving, assembly and installation. However, the nature of in-water work makes it highly dependent on weather and flow conditions. Wet weather, high river flows, and increased pile driving requirements have the potential to make in-water work conditions unsafe during the construction period, thus halting work and delaying the construction completion date. Installation will be completed in approximately 20 days including up to 10 days of in-water work. Removal of the NPB and piles will take approximately 15 days including up to 5 days of in water work. Construction and related site cleanup activities may occur during daylight hours, up to 12 hours per day, 7 days per week.

Construction vehicles will access the project site using existing roads, including those on the levee crown, that are typically used during installation and removal of the HOR rock barriers. It is anticipated that the following equipment will be used during construction and installation of the non-physical barrier: flatbed tractor/trailer; off-road forklift; barge with spuds and tug boat; barge-mounted crane; vibratory hammer pile driver; work boat; diesel or liquid petroleum gas generator; and air compressors.

The pile foundation and concrete pier blocks for the non-physical barrier frames will be installed first. Up to eight, 8- to 12-inch diameter steel piles will be driven with a vibratory driver in the wetted channel from a barge. It is anticipated it will take about 30 minutes to position each pile and the driving will occur in one to two days resulting in less than 80 minutes total driving time. Each pile will be driven approximately 15 to 30 feet into the river bed. It will require approximately one hour between pile driving to position the barge and load the next pile.

The NPB frame sections will be assembled on land, in sets of two, with pier blocks positioned between adjacent frame modules. The pier blocks and frame sets are then lowered into the water with the crane. Divers will attach the frame sets to the piles and pier blocks and then attach the air lines and power cords to the non-physical barrier.

TEMPORARY BARRIERS PROJECT FISH STUDY

Construction activities associated with the fish studies are minimal due to the nature of these studies designs, however, yearly placement of anchors, weighted stands, cabling and one temporary pile may occur. DWR may study the "no barrier", NPB, or the rock barrier condition at the HOR depending on the barrier used in any given year. Additionally DWR may conduct other studies using the aforementioned tools anywhere within the projects action area. Fish studies may not occur in all years.

ACOUSTIC TELEMETRY TRACKING SYSTEM

An acoustic telemetry tracking system consisting of hydrophone arrays will be used to monitor juvenile salmonids and predatory fish. Juvenile salmonids obtained from local hatcheries (e.g., Mokulumne River Fish Hatchery) will be surgically implanted with bio-acoustic tags and then released upstream from the HOR. Each acoustic tag transmits an underwater sound signal (i.e., acoustic "ping") that sends identification information about the tagged fish to strategically placed hydrophones, onshore receivers, data loggers, and data processing computers that listen for, and record the location of the tagged fish as they move through the study area. Up to 50 hydrophones will be deployed in the rivers to detect the tagged fish. Each hydrophone would be secured to an anchor made from a short section of railroad track with a section of rope and a floating buoy (See Figure 10 and 11). The data will be analyzed to determine the barrier's effectiveness and predatory fish behavior. The hydrophone placement will likely include an array to collect 2-D tracks around the HORB and several other hydrophone node placements further from the barriers to determine the fates of tagged fish (See Figure 12 and 13) .

VISUAL TRACKING SYSTEM

DIDSON cameras may be installed with weighted stands or attached to structures associated with the installed barrier. One temporary pile may be installed adjacent to the HORB on years that a NPB is constructed to support components of a visual tracking system consisting of a DIDSON camera and/or other scientific equipment. DIDSON cameras are intended to regularly monitor fish behavior around the barrier and will be operated to obtain data to achieve defined study objectives. The objectives may include gaining a better understanding of how predatory fish interact with the barrier, how other fish interact with the barriers, predation events near the barriers, and juvenile salmonid response to the barriers. DIDSON cameras are likely to be placed within ½ mile of the HORB, however, no more than 10 weighted stands will be placed during any study year.

SCHEDULE FOR INSTALLATION

Barrier installation, including in-water work, and associated construction activities such as mobilization and site clean-up, typically takes approximately 24 working days for the spring HOR rock barrier, 18 working days for the fall HOR rock barrier, 20 working days for the HOR NPB, 5 working days for the MRB, 20 working days for the ORT barrier and 24 working days for the GLC barrier. However, extreme weather, tide and river flow conditions may impact the barriers completion date. Construction activities for all of the barriers would begin as early as March 1 and removal would be completed no later than November 30 of each year. Any rock barrier operating on or after September 15 will be notched beginning September 15 to allow for passage of adult salmon. At GLC, flashboards will be removed to create the notch in the barrier. The HORB cannot be constructed when ambient flows in the San Joaquin River are above 5000 cfs, as measured at Vernalis monitoring station. Historic information on the actual construction schedules of the barriers since 1968 are included in Appendix B.

HEAD OF OLD RIVER BARRIER

The HORB serves a dual purpose. In the spring, the barrier acts as a fish barrier to decrease the number of salmonid smolts entering Old River. This can be accomplished by installing a rock barrier or a NPB. In the fall the barrier may be needed to increase flows and dissolved oxygen levels downstream in the San Joaquin River including the Stockton deepwater shipping channel, therefore, a rock barrier must be used.

The spring HORB can be operated from April 1 through May 31 and installation of the fall HORB will be at the timing and discretion of the DFG, NMFS and FWS based on DO levels in the San Joaquin River. The Spring and Fall HORB will be installed and operated following the criteria listed in Table 3.

TABLE 3: INSTALLATION AND OPERATION OF THE HORB

	HORB
October 1 of preceding year	Spring barrier type (rock barrier or NPB) to be used must be determined in coordination with DFG, NMFS and USFWS. Default barrier type is the rock barrier if no determination is made by this date.
March 1	Spring installation of rock barrier or NPB may begin.
April 1-May 31	Full closure and/or operation of the spring barrier may occur.
	If a physical HORB is used and 1) the GLC is breached due to Delta Smelt concerns **OR:** 2) the GLC cannot be closed when the need is clearly demonstrated by DWR, the HORB must be breached and removed as soon as possible, unless otherwise instructed by the DFG, NMFS and USFWS.
May 15-May 31	Full closure and/or operation may continue, at the discretion of the DFG, NMFS and USFWS.
On or after September 1	Fall barrier installation may begin at the discretion of DFG, NMFS and USFWS.
November 30	Barrier must be completely removed.

The ag barriers are installed and operated based on the spring HOR barrier installation. If the spring HOR barrier is not installed the ag barriers will be installed and operated following **Table 4**. If the spring HOR barrier is installed the ag barriers will be installed and operated following **Table 5**.

TABLE 4: AGRICULTURAL BARRIER INSTALLATION AND OPERATION SCHEDULE, FOR YEARS WHEN THE SPRING HORB IS NOT INSTALLED

	MR	ORT	GLC
May 1	Installation may begin.	Installation may begin.	Installation may begin.
May 15 to May 31	Full operation and closure may occur if: • the need for MR full operation is clearly demonstrated by DWR through forecasting water levels by delta modeling and by actual stage data collected in the field (such data shall be provided to the DFG, NMFS and USFWS one week in advance of closing the flapgates).	Full operation and closure may occur if: • the need for ORT full operation is clearly demonstrated by DWR through forecasting water levels by delta modeling and by actual stage data collected in the field (such data shall be provided to the DFG, NMFS and USFWS one week in advance of closing the flapgates).	Full operation of flapgates and/or closure of the center rock section may occur if: 1) the need for GLC full operation is clearly demonstrated by DWR through forecasting water levels by delta modeling and by actual stage data collected in the field (such data shall be provided to the DFG, NMFS and USFWS two weeks in advance of closing the flapgates and center sections of the barrier). **AND:** 1) the incidental take concern level for delta smelt at the SWP/CVP facilities has not been reached. If the incidental take concern limit is reached at the SWP/CVP facilities and if reductions in project exports are determined to be inadequate to protect delta smelt, the DFG, NMFS and USFWS may require the flap gates to be tied in the open position and the center section to be removed.
June 1 to November 30	Full operation and closure may occur. Barrier elevation can be raised from 3.3 feet NAVD to 4.3 feet NAVD with DFG and USFWS approval.	Full operation and closure may occur.	Full operation of flapgates and/or closure of the center rock section may occur if: If the incidental take concern limit is reached at the SWP/CVP facilities and if reductions in project exports are determined to be inadequate to protect delta smelt, the DFG, NMFS and USFWS may require the flap gates to be tied in the open position and the center section to be removed.
September 15	Barrier must be notched to allow passage of adult salmon.	Barrier must be notched to allow passage of adult salmon.	Barrier must have enough flashboards removed to allow passage of adult salmon.
November 30	Barrier must be completely removed.	Barrier must be completely removed.	Barrier must be completely removed.

TABLE 5: AGRICULTURAL BARRIER INSTALLATION AND OPERATION SCHEDULE, FOR YEARS WHEN THE SPRING HORB IS INSTALLED

	MR	**ORT**	**GLC**
March 1	Installation may begin.	Installation may begin.	Installation may begin.
April 1 to May 31, after HORB is fully operational	Full operation and closure may occur. If HORB is breached, flap gates must be tied in open position.	Full operation and closure may occur. If HORB is breached, flap gates must be tied in open position.	Full operation of flapgates and/or closure of the center rock section may occur if: 1) the need for GLC full operation is clearly demonstrated by DWR through forecasting water levels by delta modeling and by actual stage data collected in the field (such data shall be provided to the DFG, NMFS and USFWS two weeks in advance of closing the flap gates and center sections of the barrier). **AND:** 2) the DFG, NMFS and USFWS, in coordination with DWR, approves closure. If HORB is breached, flap gates must be tied in open position. If HORB is breached due to Delta Smelt concerns, flap gates must be tied in the open position and the center section shall be removed until concerns have passed.
June 1 to November 30	Full operation and closure may occur. Barrier elevation can be raised from 3.3 feet NAVD to 4.3 feet NAVD with DFG and USFWS approval.	Full operation and closure may occur.	Full operation of flapgates and/or closure of the center rock section may occur if: 2) the need for GLC full operation is clearly demonstrated by DWR through forecasting water levels by delta modeling and by actual stage data collected in the field (such data shall be provided to the DFG and USFWS two weeks in advance of closing the flap gates and center sections of the barrier). **AND:** 3) the incidental take concern level for delta smelt at the SWP/CVP facilities has not been reached. If the incidental take concern limit is reached at the SWP/CVP facilities and if reductions in project exports are determined to be inadequate to protect delta smelt, the DFG and USFWS may require the flap gates to be tied in the open position and the center section to be removed.
September 15	Barrier must be notched to allow passage of adult	Barrier must be notched to allow passage of adult	Barrier must have enough flashboards removed to allow passage of adult salmon.

	salmon.	salmon.	
November 30	Barrier must be completely removed.	Barrier must be completely removed.	Barrier must be completely removed.

ACTION AREA

The action area is defined as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR § 402.02). The action area, for the purposes of this biological assessment includes the southern Sacramento-San Joaquin Delta and generally comprises the lands and waterways of the Delta southwest of the City of Stockton. Major waterways within the south Delta include the San Joaquin River, Old River, Middle River, Woodward and North Victoria canals, Grant Line and Fabian canals, Italian Slough, Tom Paine Slough and the adjoining canals of the CVP and SWP. However, due to the anticipated effects of the TBP, the action area for this consultation not only encompasses the lands and waterways described above but includes lands and waterways of the central Delta including the lower San Joaquin downstream of Old River, Columbia Cut and Turner Cut, and all reaches of Middle River and Old River and adjoining sloughs and canals (Figure 1).

SPECIES ACCOUNTS

Construction activities are occurring on heavily disturbed levies and banks and in wetted portions of the large riverine channels. Terrestrial vegetation will not be impacted by construction activities, therefore, Direct and Indirect impacts are not anticipated to occur to any listed vernal pool species (Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, vernal pool tadpole shrimp, California tiger salamander and Contra Costa goldfields) to San Joaquin kit fox, valley elderberry longhorn beetle, California red-legged frog, Alameda whipsnake, giant garter snake or to the riparian brush rabbit. Direct and Indirect impacts are likely to occur to delta smelt and its critical habitat and the remainder of this BA will focus on these impacts.

SPECIES LIFE HISTORY AND POPULATION DYNAMICS

DELTA SMELT

GENERAL LIFE HISTORY

The delta smelt life cycle is completed within the freshwater and brackish Low-Salinity Zone (LSZ) of the Bay-Delta. Delta smelt are moderately euryhaline (Moyle 2002). However, salinity requirements vary by life stage. Delta smelt are a pelagic species, inhabiting open waters away from the bottom and shore-associated structural features (Nobriga and Herbold, 2008). Although delta smelt spawning has never been observed in the wild, clues from the spawning behavior of related osmerids suggests delta smelt use bottom substrate and nearshore features during spawning. However, apart from spawning and egg-embryo development, the distribution and movements of all life stages are influenced by transport processes associated with water flows in the estuary, which also affect the quality and location of suitable open water habitat (Dege and Brown 2004; Feyrer et al. 2007; Nobriga et al. 2008).

Delta smelt are weakly anadromous and undergo a spawning migration from brackish water to freshwater annually (Moyle 2002). In early winter, mature delta smelt migrate from brackish, downstream rearing areas in and around Suisun Bay and the confluence of the Sacramento and San Joaquin rivers upstream to freshwater spawning areas in the Delta. Delta smelt historically have also spawned in the freshwater reaches of Suisun Marsh. In winters featuring high Delta outflow, the spawning range of delta smelt shifts west to include the Napa River (Hobbs et al. 2007).

The upstream migration of delta smelt, which ends with their dispersal into river channels and sloughs in the Delta (Radtke 1966; Moyle 1976, 2002; Wang 1991), seems to be triggered or cued by abrupt changes in flow and turbidity associated with the first flush of winter precipitation (Grimaldo et al, 2009) but can also occur after very high flood flows have receded. Grimaldo et al (2009) noted salvage often occurred when total inflows exceeded 25,000 cfs or when turbidity elevated above 12 NTU (Nephelometric Turbidity Units) at Clifton Court Forebay station. Delta smelt spawning may occur from mid-winter through spring; most spawning occurs when water temperatures range from about 12^{0}C to 18^{0}C (Moyle 2002). Most adult delta smelt die after spawning (Moyle 2002), however, some fraction of the population may hold over as two-year-old fish and spawn in the subsequent year.

During and after a variable period of larval development, the young fish migrate downstream until they reach the LSZ where they reside until the following winter (Moyle 2002). The location of the delta smelt population follows changes in the location of the LSZ which depends primarily on delta outflow.

BIOLOGY AND LIFE HISTORY

SPAWNING

Adult delta smelt spawn during the late winter and spring months, with most spawning occurring during April through mid-May (Moyle 2002). Spawning occurs primarily in sloughs and shallow edge areas in the Delta. Delta smelt spawning has also been recorded in Suisun Marsh and the Napa River (Moyle 2002). Most spawning occurs at temperatures between 12-18°C. Although spawning may occur at temperatures up to 22°C, hatching success of the larvae is very low (Bennett 2005).

Fecundity of females ranges from about 1,200 to 2,600 eggs, and is correlated with female size (Moyle 2002). Moyle et al. (1992) considered delta smelt fecundity to be “relatively low.” However, based on Winemiller and Rose (1992), delta smelt fecundity is fairly high for a fish its size. In captivity, females survive after spawning and develop a second clutch of eggs (Mager et al. 2004); field collections of ovaries containing eggs of different size and stage indicate that this also occurs in the wild (Adib-samii 2008). Captive delta smelt can spawn up to 4-5 times. While most adults do not survive to spawn a second season, a few (<5 percent) do (Moyle 2002; Bennett 2005). Those that do survive are typically larger (90-110 mm SL) females that may contribute disproportionately to the population’s egg supply (Moyle 2002 and references therein). Two-year-old females may have 3-6 times as many ova as first year spawners. Most of what is known about delta smelt spawning habitat in the wild is inferred from the location of spent females and young larvae captured in the spring Kodiak trawl (SKT) and 20-millimeter (mm) survey, respectively. In the laboratory, delta smelt spawned at night (Baskerville-Bridges et al. 2000; Mager et al. 2004). Other smelts, including marine beach spawning species and estuarine populations and the landlocked Lake Washington longfin smelt, are secretive spawners, entering spawning areas during the night and leaving before dawn. If this behavior is exhibited by delta smelt, then delta smelt distribution based on the SKT, which is conducted during daylight hours in offshore habitats, may reflect general regions of spawning activity, but not actual spawning sites. Delta smelt spawning has only been directly observed in the laboratory and eggs have not been found in the wild. Consequently, what is known about the mechanics of delta smelt spawning is derived from laboratory observations and observations of related smelt species. Delta smelt eggs are 1 mm diameter and are adhesive and negatively buoyant (Moyle 1976, 2002; Mager et al. 2004; Wang 1986, 2007). Laboratory observations indicate that delta smelt are broadcast spawners, discharging eggs and milt close to the bottom over substrates of sand and/or pebbles in current (DWR and Reclamation 1994; Brown and Kimmerer 2002; Lindberg et al. 2003; Wang 2007). The eggs of surf smelts and other beach spawning smelts adhere to sand particles, which keeps them negatively buoyant but not immobile, as the sand may move ("tumble") with water currents and turbulence (Hay 2007; slideshow available at http://www.science.calwater.ca.gov/pdf/workshops/workshop_smelt_presentation _Hay_111508.pdf). It is not known whether delta smelt eggs "tumble incubate" in the wild, but tumbling of eggs may moderately disperse them, which might reduce predation risk within a localized area.

Presence of newly hatched larvae likely indicates regions where spawning has occurred. The 20-mm trawl has captured small (~5 mm Standard Length [SL]) larvae in Cache Slough, the lower Sacramento River, San Joaquin River, and at the confluence of these two rivers (e.g., 20-mm trawl survey 1 in 2005). Larger larvae and juveniles (size > 23 mm SL), which are more efficiently sampled by the 20-mm trawl gear, have been captured in Cache Slough (Sacramento River) and the Sacramento Deep Water Channel in July (e.g. 20-mm trawl survey 9 in 2008). Because they are small fish inhabiting pelagic habitats with strong tidal and river currents, delta smelt larval distribution depends on both the spawning area from which they originate and the effect of transport processes caused by flows. Larval distribution is further affected by water salinity and temperature. Hydrodynamic simulations reveal that tidal action and other factors may cause substantial mixing of water with variable salinity and temperature among regions of the Delta (Monson et al 2007). This could result in rapid dispersion of larvae away from spawning sites.

Sampling of larval delta smelt in the Bay-Delta in 1989 and 1990 suggested that spawning occurred in the Sacramento River; in Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs; in the San Joaquin River adjacent to Bradford Island and Fisherman's Cut; and possibly other areas (Wang 1991). However, in recent years, the densest concentrations of both spawners and larvae have been recorded in the Cache Slough/Sacramento Deepwater Ship Channel complex in the North Delta. Some delta smelt spawning occurs in Napa River, Suisun Bay and Suisun Marsh during wetter years (Sweetnam 1999; Wang 1991; Hobbs et al. 2007). Early stage larval delta smelt have also been recorded in Montezuma Slough near Suisun Bay (Wang 1986).

LARVAL DEVELOPMENT

Mager et al. (2004) reported that embryonic development to hatching takes 11-13 days at 14-16° C for delta smelt, and Baskerville-Bridges et al. (2000) reported hatching of delta smelt eggs after 8-10 days at temperatures between 15-17° C. Lindberg et al. (2003) reported high hatching rates of delta smelt eggs in the laboratory at 15° C, and Wang (2007) reported high hatching rates at temperatures between 14-17° C. Bennett (2005) showed hatching success peaks near 15° C. Swim bladder inflation occurring at 60-70 days post-hatch at 16-17° C (Mager et al. 2004). At hatching and during the succeeding three days, larvae are buoyant, swim actively near the water surface, and do not react to bright direct light (Mager et al. 2004). As development continues, newly hatched delta smelt become semi-buoyant and sink in stagnant water. However, larvae are unlikely to encounter stagnant water in the wild. In the laboratory, a turbid environment (>25 NTU) was necessary to elicit a first feeding response (Baskerville-Bridges et al. 2000; Baskerville-Bridges 2004). Successful feeding seems to depend on a high density of food organisms and turbidity, and increases with stronger light conditions (Baskerville-Bridges *et al.* 2000; Mager et al. 2004; Baskerville-Bridges *et al.* 2004).

Growth rates of wild-caught delta smelt larvae are faster than laboratory-cultured individuals. Mager et al. (2004) reported growth rates of captive-raised delta smelt reared at near-optimum temperatures (16°C-17°C). Their fish were about 12 mm long after 40 days and about 20 mm long after 70 days. In contrast, analyses of otoliths indicated that wild delta smelt larvae were 15-25 mm, or nearly twice as long at 40 days of age (Bennett 2005). By 70 days, most wild fish were 30-40 mm long and beyond the larval stage. This suggests there is strong selective pressure for rapid larval growth in nature, a situation that is typical for fish in general (Houde 1987). Laboratory-cultured delta smelt larvae have generally been fed rotifers at first-feeding (Baskerville-Bridges et al. 2004; Mager et al. 2004). However, rotifers rarely occur in the guts of wild delta smelt larvae (Nobriga 2002). The most common first prey of wild delta smelt larvae is the larval stages of several copepod species. These copepod 'nauplii' are larger and have more calories than rotifers. This difference in diet may enable the faster growth rates observed in wild-caught larvae. The food available to larval fishes is constrained by mouth gape and status of fin development. Larval delta smelt cannot capture as many kinds of prey as larger individuals, but all life stages have small gapes that limit their range of potential prey.

Prey availability is also constrained by habitat use, which affects what types of prey are encountered. Larval delta smelt are visual feeders. They find and select individual prey organisms and their ability to see prey in the water is enhanced by turbidity (Baskerville-Bridges et al. 2004). Thus, delta smelt diets are largely comprised of small crustacea that inhabit the estuary's turbid, low-salinity, open-water habitats (i.e., zooplankton). Larval delta smelt have particularly restricted diets (Nobriga 2002). They do not feed on the full array of zooplankton with which they co-occur; they mainly consume three copepods, *Eurytemora affinis*, *Pseudodiaptomus forbesi*, and freshwater species of the family Cyclopidae. Further, the diets of first-feeding delta smelt larvae are largely restricted to the larval stages of these copepods; older, larger life stages of the copepods are increasingly targeted as the delta smelt larvae grow, their gape increases, and they become stronger swimmers.

The triggers for and duration of delta smelt larval movements from spawning areas to rearing areas are not known. Hay (2007) noted that eulachon larvae are probably flushed into estuaries from upstream spawning areas within the first day after hatching, but downstream movement of delta smelt larvae occurs much later. Most larvae gradually move downstream toward the two parts per thousand (ppt) isohaline (X2; Dege and Brown 2004). X2 is scaled as the distance in kilometers from the Golden Gate Bridge (Jassby et al. 1995). It is a physical attribute of the Bay-Delta that is used as a habitat indicator and as a regulatory standard in the SWRCB D-1641. At all life stages, delta smelt are found in greatest abundance in the water column and usually not in close association with the shoreline. They inhabit open, surface waters of the Delta and Suisun Bay, where they presumably aggregate in loose schools where conditions are favorable (Moyle 2002). In years of moderate to high Delta outflow (above normal to wet water years), delta smelt larvae are abundant in the Napa River, Suisun Bay and Montezuma Slough, but the degree to which these larvae are produced by locally spawning fish and the degree to which they originate upstream and are transported by tidal currents to the bay and marsh is uncertain.

JUVENILES

Young-of-the-year delta smelt rear in the LSZ from late spring through fall and early winter. Once in the rearing area growth is rapid, and juvenile fish are 40-50 mm SL long by early August (Erkkila *et al.* 1950; Ganssle 1966; Radtke 1966). They reach adult size (55-70 mm SL) by early fall (Moyle 2002). Delta smelt growth during the fall months slows considerably (only 3-9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila *et al*. 1950; Radtke 1966). Nobriga et al. (2008) found that delta smelt capture probabilities in the TNS are highest at specific conductance levels of 1,000 to 5,000 μS cm^{-1} (approximately 0.6 to 3.0 practical salinity unit [psu]). Similarly, Feyrer et al. (2007) found a decreasing relationship between abundance of delta smelt in the FMWT and specific conductance during September through December. The location of the LSZ and changes in delta smelt habitat quality in the San Francisco Estuary can be indexed by changes in X2. The LSZ historically had the highest primary productivity and is where zooplankton populations (on which delta smelt feed) were historically most dense (Knutson and Orsi 1983; Orsi and Mecum 1986). However, this has not always been true since the invasion of the overbite clam (Kimmerer and Orsi 1996). The abundance of many local aquatic species has tended to increase in years when winter-spring outflow was high and X2 was pushed seaward (Jassby et al. 1995), implying that the quantity and quality (overall suitability) of estuarine habitat increases in years when outflows are high. However, delta smelt is not one of the species whose abundance has statistically covaried with winter-spring freshwater flows (Stevens and Miller 1983; Moyle et al. 1992; Kimmerer 2002; Bennett 2005). There is evidence that X2 in the fall influences delta smelt population dynamics (FWS OCAP BiOp). Delta smelt seem to prefer water with high turbidity, based on a negative correlation between the frequency of delta smelt occurrence in survey trawls during summer, fall and early winter and water clarity. For example, the likelihood of delta smelt occurrence in trawls at a given sampling station decreases with increasing Secchi depth at the stations (Feyrer et al. 2007, Nobriga et al. 2008). This is very consistent with behavioral observations of captive delta smelt (Nobriga and Herbold 2008). Few daylight trawls catch delta smelt at Secchi depths over one half meter and capture probabilities for delta smelt are highest at 0.40 meter depth or less. The delta smelt's preference for turbid water may be related to increased foraging efficiency (Baskerville-Bridges et al. 2004) and reduced risk of predation.

Temperature also affects delta smelt distribution. Swanson and Cech (1995) and Swanson et al. (2000) indicate delta smelt tolerate temperatures (<8° C to >25° C), however warmer water temperatures >25° C restrict their distribution more than colder water temperatures (Nobriga and Herbold 2008). Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures are usually less than 25° C in summer (Nobriga et al. 2008).

FORAGING ECOLOGY

Delta smelt feed primarily on small planktonic crustaceans, and occasionally on insect larvae (Moyle 2002). Juvenile-stage delta smelt prey upon copepods, cladocerans, amphipods, and insect larvae (Moyle 2002). Historically, the main prey of delta smelt was the euryhaline copepod *Eurytemora affinis* and the euryhaline mysid *Neomysis mercedis*. The slightly larger *Pseudodiaptomus forbesi* has replaced *E. affinis* as a major prey source of delta smelt since its introduction into the Bay-Delta, especially in summer, when it replaces *E. affinis* in the plankton community (Moyle 2002). Another smaller copepod, *Limnoithona tetraspina*, which was introduced into the Bay-Delta in the mid-1990s, is now one of the most abundant copepods in the LSZ, but not abundant in delta smelt diets. *Acartiella sinensis*, a calanoid copepod species that invaded the Delta at the same time as *L. tetraspina*, also occurs at high densities in Suisun Bay and in the western Delta over the last decade. Delta smelt eat these newer copepods, but *Pseudodiaptomus* remains a dominant prey (Baxter et al. 2008).

River flows influence estuarine salinity gradients and water residence times and thereby affect both habitat suitability for benthos and the transport of pelagic plankton upon which delta smelt feed. High tributary flow leads to lower residence time of water in the Delta, which generally results in lower plankton biomass (Kimmerer 2004). In contrast, higher residence times, which result from low tributary flows, can result in higher plankton biomass but water diversions, overbite clam grazing (Jassby et al. 2002) and possibly contaminants (Baxter et al. 2008) remove a lot of plankton biomass when residence times are high. These factors all affect food availability for planktivorous fishes that utilize the zooplankton in Delta channels. Delta smelt cannot occupy much of the Delta anymore during the summer (Nobriga et al. 2008). Thus, there is the potential for mismatches between regions of high zooplankton abundance in the Delta and delta smelt distribution now that the overbite clam has decimated LSZ zooplankton densities.

The delta smelt compete with and are prey for several native and introduced fish species in the Delta. The introduced inland silverside may prey on delta smelt eggs and/or larvae and compete for copepod prey (Bennett and Moyle 1996; Bennett 2005). Young striped bass also use the LSZ for rearing and may compete for copepod prey and eat delta smelt. Centrarchid fishes and coded wire tagged Chinook salmon smolts released in the Delta for survival experiments since the early 1980s may potentially also prey on larval delta smelt (Brandes and McLain 2001; Nobriga and Chotkowski 2000). Studies during the early 1960s found delta smelt were only an occasional prey fish for striped bass, black crappie and white catfish (Turner and Kelley 1966). However, delta smelt were a comparatively rare fish even then, so it is not surprising they were a rare prey. Striped bass appear to have switched to piscivorous feeding habits at smaller sizes than they historically did, following severe declines in the abundance of mysid shrimp (Feyrer et al. 2003). Nobriga and Feyrer (2008) showed that inland silverside, which is similar in size to delta smelt, was only eaten by subadult striped bass less than 400 mm fork length. While largemouth bass are not pelagic, they have been shown to consume some pelagic fishes (Nobriga and Feyrer 2007).

HABITAT

The existing physical appearance and hydrodynamics of the Delta have changed substantially from the environment in which native fish species like delta smelt evolved. The Delta once consisted of tidal marshes with networks of diffuse dendritic channels connected to floodplains of wetlands and upland areas (Moyle 2002). The in-Delta channels were further connected to drainages of larger and smaller rivers and creeks entering the Delta from the upland areas. In the absence of upstream reservoirs, freshwater inflow from smaller rivers and creeks and the Sacramento and San Joaquin

Rivers were highly seasonal and more strongly and reliably affected by precipitation patterns than they are today. Consequently, variation in hydrology, salinity, turbidity, and other characteristics of the Delta aquatic ecosystem was greater in the past than it is today (Kimmerer 2002b). For instance, in the early 1900s, the location of maximum salinity intrusion into the Delta during dry periods varied from Chipps Island in the lower Delta to Stockton along the San Joaquin River and Merritt Island in the Sacramento River (DWR Delta Overview). Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows (Knowles 2002), though Delta outflows have been tightly constrained during late summer-fall for several decades.

Channelization, conversion of Delta islands to agriculture, and water operations have substantially changed the physical appearance, water salinity, water clarity, and hydrology of the Delta. As a consequence of these changes, most life stages of the delta smelt are now distributed across a smaller area than historically (Arthur et al. 1996, Feyrer et al. 2007). Wang (1991) noted in a 1989 and 1990 study of delta smelt larval distribution that, in general, the San Joaquin River was used more intensively for spawning than the Sacramento River. Though not restricting spawning *per se*, based on particle tracking modeling, export of water by the CVP and SWP would usually restrict reproductive success of spawners in the San Joaquin River by entraining most larvae during downstream transport from spawning sites to rearing areas (Kimmerer and Nobriga 2008). There is one, non-wet year exception to this generalization: in 2008, delta smelt entrainment was managed under a unique system of restrictions imposed by the Court in NRDC v Kempthorne. In 2008, CVP/SWP operations were constrained in accordance with recommendations formulated by the Service expressly to limit entrainment of delta smelt from the Central Delta.

Persistent confinement of the spawning population of delta smelt to the Sacramento River increases the likelihood that a substantial portion of the spawners will be affected by a catastrophic event or localized chronic threat. For instance, large volumes of highly concentrated ammonia released into the Sacramento River from the Sacramento Regional County Sanitation District may affect embryo survival or inhibit prey production. Further, agricultural fields in the Yolo Bypass and surrounding areas are regularly sprayed by pesticides, and water samples taken from Cache Slough sometimes exhibited toxicity to Hyalella azteca (Werner et al. 2008). The thresholds of toxicity for delta smelt for most of the known contaminants have not been determined, but the exposure to a combination of different compounds increases the likelihood of adverse effects. The extent to which delta smelt larvae are exposed to contaminants varies with flow entering the Delta. Flow pulses during spawning increase exposure to many pesticides (Kuivila and Moon 2004) but decrease ammonia concentrations entering the Delta from wastewater treatment plants.

The distribution of juvenile delta smelt has also changed over the last several decades. During the years 1970 through 1978, delta smelt catches in the TNS survey declined rapidly to zero in the Central and South Delta and have remained near zero since. A similar shift in FMWT catches occurred after 1981 (Arthur et al. 1996). This portion of the Delta has also had a long-term trend increase in water clarity during July through December (Arthur et al. 1996; Feyrer et al. 2007; Nobriga et al. 2008).

The position of the LSZ where delta smelt rear has also changed over the years. Summer and fall environmental quality has decreased overall in the Delta because outflows are lower and water transparency is higher. These changes may be due to increased upstream water diversions for flooding rice fields (Kawakami et. al. 2008). The confluence of the Sacramento and San Joaquin rivers has, as a result, become increasingly important as a rearing location for delta smelt, with physical environmental conditions constricting the species range to a relatively narrow area (Feyrer et al. 2007; Nobriga et al. 2008). This has increased the likelihood that most of the juvenile population is exposed to chronic and cyclic environmental stressors, or catastrophic events. For instance, all seven delta smelt collected during the September 2007 FMWT survey were captured at statistically significantly higher salinities than what would be expected based upon historical distribution data generated by Feyrer et al. (2007). During the same year, the annual bloom of toxic cyanobacteria (*Microcystis aeruginosa*) spread far downstream to the west Delta and beyond during the summer (Peggy Lehman, pers comm). This has been suggested as an explanation for the anomaly in the distribution of delta smelt relative to water salinity levels (Reclamation 2008).

DELTA SMELT POPULATION DYNAMICS AND ABUNDANCE TRENDS

The FMWT provides the best available long-term index of the relative abundance of delta smelt (Moyle et al. 1992; Sweetnam 1999). The indices derived from these surveys closely mirror trends in catch per unit effort (Kimmerer and Nobriga 2005), but do not at present support statistically reliable population abundance estimates, though substantial progress has recently been made (Newman 2008). FMWT derived data are generally accepted as providing a reasonable basis for detecting and roughly scaling interannual trends in delta smelt abundance. The FMWT derived indices have ranged from a low of 17 in 2009 to 1,653 in 1970. For comparison, TNS-derived indices have ranged from a low of 0.3 in 2005 and 2009 to a high of 62.5 in 1978. Although the peak high and low values have occurred in different years, the TNS and FMWT indices show a similar pattern of delta smelt relative abundance; higher prior to the mid-1980s and relatively low since with a low point from around 2000 to 2010.

From 1969-1981, the mean delta smelt TNS and FMWT indices were 22.5 and 894, respectively. Both indices suggest the delta smelt population declined abruptly in the early 1980s (Moyle et al. 1992). From 1982-1992, the mean delta smelt TNS and FMWT indices dropped to 3.2 and 272 respectively. The population rebounded somewhat in the mid-1990s (Sweetnam 1999); the mean TNS and FMWT indices were 7.1 and 529, respectively, during the 1993-2002 period. However, delta smelt numbers have trended precipitously downward since about 2000 until 2011 where a small increase in population occurred, presumably due to a high precipitation during that year.

Currently, the 2011 delta smelt population TNS and FMWT indices are 2.2 and 323 respectively, up from the historic lows of 0.3 and 17 in 2009. From 2000 through 2011 the median FMWT index was 41. The lowest FMWT abundance indices ever obtained were recorded during 2005-2010 (27, 41, 28, 23, 17, and 29, respectively). The median TNS index during the period from 2000 through 2011 fell similarly to 1.6, and has also dropped to its lowest levels from 2005-2010 with indexes of 0.3, 0.4, 0.4, 0.6, 0.3 and 0.8 respectively.

The total number of delta smelt collected in the 20-mm Survey decreased substantially during the years from 2002 to 2008 (4917 to 587 fish) compared to the period 1995 through 2001 (98 to 1084 fish). Similarly, the number of delta smelt caught in the SKT decreased steadily from when the survey started in 2002 until 2010. Since about 2002, delta smelt is one of four pelagic fish species subject to what has been termed the Pelagic Organism Decline or POD (Sommer et al. 2007). The POD denotes the sudden, overlapping declines of San Francisco Estuary pelagic fishes first recognized in data collected from 2002-2004. The POD species include delta smelt, longfin smelt, threadfin shad (*Dorosoma petenense*), and (age-0) striped bass (*Morone saxatillis*), which together account for the bulk of the resident pelagic fish biomass in the tidal water upstream of X2. The year 2002 is often recognized as the start of the POD because of the striking declines of three of the four POD species between 2001 and 2002; however, statistical review of the data (e.g., Manly and Chotkowski 2006) has revealed that for at least delta smelt, the POD downtrend really began earlier (around 1999). Post-2001 abundance indices for the POD species have included record lows for all but threadfin shad. The causes of the POD and earlier declines are not fully understood, but appear to be layered and multifactorial (Baxter et al. 2008). Several analyses have concluded that the shift in pelagic fish species abundance in the early 1980s was caused by a decrease in habitat carrying capacity or production potential (Moyle et al. 1992, Bennett 2005; Feyrer et al. 2007).

There is some evidence that the recruitment of delta smelt may have sometimes responded to springtime flow variation (Herbold et al. 1992; Kimmerer 2002). However, the weight of evidence suggests that delta smelt abundance does not (statistically) respond to springtime flow like the abundance of the species mentioned above (Stevens and Miller 1983; Jassby et al. 1995; Bennett 2005). The number of days of suitable spawning temperature during spring is correlated with subsequent abundance indices in the autumn (Bennett 2005). This is evidence that cool springs, which allow for multiple larval cohorts, can contribute to population resilience. However, these relationships do not explain a large proportion of variance in autumn abundance. Depending on which abundance index is used, the r_2 are 0.24-0.29.

The relationship between numbers of spawning fish and the numbers of young subsequently recruiting to the adult population is known as a stock-recruit relationship. Analysis of stock-recruit relationships using delta smelt survey data indicate that a weak density dependent effect has occurred during late summer/fall (Bennett 2005, Reclamation 2008), suggesting that delta smelt year-class strength has often been set during late summer and fall. This is supported by studies suggesting that the delta smelt is food limited (Bennett 2005; IEP 2005) and evidence for density dependent mortality has been presented by Brown and Kimmerer (2001). However, the number of days during the spring that water temperature remained between 15 °C and 20 °C, with a density-dependence term to correct for the saturating TNS-FMWT relationship (described above), predicts FMWT indices fairly well ($r2 \approx 0.70$; $p < 0.05$; Bennett, unpublished presentation at the 2003 CALFED Science Conference). This result shows that of the quantity of young delta smelt produced also contributes to future spawner abundance. Bennett (2005) analyzed the relationship between delta smelt spawner population and spawner recruits using data before and after the 1980s decline. He concluded that density dependence pre-1982 may have occurred at FMWT values of 600 to 800 and at FMWT values of 400 to 500 for the period 1982 through 2002. Bennett (2005) also conducted extensive stock-recruit analyses using the TNS and FMWT indices. He provided statistical evidence that survival from summer to fall is nonlinear (= density-dependent). He also noted that carrying capacity had declined. Bennett (2005) surmised that density-dependence and lower carrying capacity during the summer and fall could happen in a small population if habitat space was smaller than it was historically. This hypothesis was recently demonstrated to be true (Feyrer et al. 2007). Reduced Delta outflow during autumn has led to higher salinity in Suisun Bay and the Western Delta while the proliferation of submerged vegetation has reduced turbidity in the South Delta. Together, these mechanisms have led to a long-term decline in habitat suitability for delta smelt. High summer water temperatures also limit delta smelt distribution (Nobriga et al. 2008) and impair health (Bennett et al. 2008).

A minimum amount of suitable habitat during summer-autumn may interact with a suppressed pelagic food web to create a bottleneck for delta smelt (Bennett 2005; Feyrer et al. 2007; Bennett et al. 2008). Prior to the overbite clam invasion, the relative abundance of maturing adults collected during autumn was unrelated to the relative abundance of juveniles recruiting the following summer (i.e., the stock-recruit relationship was density-vague). Since the overbite clam became established, autumn relative abundance explains 40 percent of the variability in subsequent juvenile abundance (Feyrer et al. 2007). When autumn salinity is factored in, 60 percent of the variance in subsequent juvenile abundance is accounted for statistically.

Since 2000, the stock-recruit relationship for delta smelt has been stronger still (r^2 = 0.88 without autumn habitat metrics factored in; Baxter et al. 2008). This has led to speculation about Allee effects. Allee effects occur when reproductive output per fish declines at low population levels (Allee 1931, Berec et al. 2006). Below a certain threshold the individuals in a population can no longer reproduce rapidly enough to replace themselves and the population spirals to extinction. For delta smelt, possible mechanisms for Allee effects include mechanisms directly related to reproduction and genetic fitness such as difficulty finding enough males to maximize egg fertilization during spawning (e.g., Purchase et al. 2007). Genetic problems arising from small population sizes like inbreeding and genetic drift also can contribute to Allee effects, but genetic bottlenecks occur after demographic problems like the example of finding enough mates (Lande 1988). Other mechanisms related to survival such as increased vulnerability to predation are also possible based on studies of other species. These data provide evidence that factors affecting juvenile delta smelt during summer and autumn are also impairing delta smelt reproductive success. Thus, the interaction of warm summer water temperatures, suppression of the food web supporting delta smelt, and spatially restricted suitable habitat during autumn affect delta smelt health and ultimately survival and realized fecundity. Another possible contributing driver of reduced delta smelt survival, health, fecundity, and resilience that occurs during winter is the "Big Mama Hypothesis" (Bill Bennett, UC Davis, pers. comm. and various oral presentations). As a result of his synthesis of a variety of studies, Bennett proposed that the largest delta smelt (whether the fastest growing age-1 fish or fish that manage to spawn at age-2) could have a large influence on population trends. Delta smelt larvae spawned in the South Delta have high risk of entrainment under most hydrologic conditions (Kimmerer 2008), but water temperatures often warm earlier in the South Delta than the Sacramento River (Nobriga and Herbold 2008). Thus, delta smelt spawning often starts and ends earlier in the Central and South Delta than elsewhere. This differential warming may contribute to the "Big Mama Hypothesis" by causing the earliest ripening females to spawn disproportionately in the South Delta, putting their offspring at high risk of entrainment. Although water diversion strategies have been changed to better protect the 'average' larva, the resilience historically provided by variable spawn timing may be reduced by water diversions and other factors that co-vary with Delta inflows and outflows.

Substantial increases in winter salvage at Banks and Jones that occurred contemporaneously with recent declines in delta smelt and other POD species (Kimmerer 2008, Grimaldo et al. 2009) support the interpretation that entrainment played a role in the POD-era depression of delta smelt numbers. Increased winter entrainment of delta smelt represents a loss of pre-spawning adults and all their potential progeny (Sommer et al. 2007). Note that winter salvage levels subsequently decreased to very low levels for all POD species during the winters of 2005-2006 and 2006-2007, possibly due to the very low population sizes during those periods. Reduced pumping for protection of delta smelt also substantially reduced OMR flow towards the pumps and subsequently reduced number of delta smelt entrained during the winters of 2006-2007 and 2007-2008.

The hydrologic and statistical analyses of relationships between Old and Middle River (OMR) flows and salvage suggest a reasonable mechanism by which winter entrainment increased with increased exports during the POD years; however, entrainment is not a substantial source of mortality every year. Manly and Chotkowski (2006; IEP 2005) found that monthly or semi-monthly measures of exports or Old and Middle rivers flow had a reliable, statistically significant effect on delta smelt abundance; however, individually they explained a small portion (no more than a few percent) of the variability in the fall abundance index of delta smelt across the entire survey area and time period. Kimmerer (2008) addressed delta smelt entrainment by means of particle tracking, and estimated historical entrainment rates for larvae and juvenile delta smelt to be as high as 40 percent; however, he concluded that non-entrainment mortality in the summer had effects on FMWT delta smelt numbers. Hence, there are other factors that often mask the effect of entrainment loss on delta smelt fall abundance in these analyses. Among them, availability and quality of summer and fall habitat are clearly affected by CVP/SWP operations.

It was concluded that entrainment and habitat availability/quality jointly contribute to downward pressure on spawner recruitment and one or both of these general mechanisms is operating throughout the year. The intensity of constraints of the other threats affecting the delta smelt carrying capacity varies between years, and the importance of contributing stressors changes as outflow, export operations, weather, and the abundances of other ecosystem elements vary. For instance, Bennett (2005) noted that seasonally low outflow and warmer water temperatures may concentrate delta smelt and other planktivorous fishes into relatively small patches of habitat during late summer. This would increase competition and limit food availability during low outflow. Higher outflow that expands and moves delta smelt habitat downstream of the Delta is expected to improve conditions for delta smelt (Feyrer et al. 2007). The high proportion of the delta smelt population that has been entrained during some years (Kimmerer 2008) would be expected to reduce the ability of delta smelt to respond to the improved conditions, thereby limiting the potential for increased spawner recruitment. Further, the smaller sizes of maturing adults during fall may have affected delta smelt fecundity (Bennett, 2005). This would further reduce the species' ability to respond to years with improved conditions.

DEFINITION OF CRITICAL HABITAT CONDITION AND FUNCTION FOR SPECIES' CONSERVATION

CRITICAL HABITAT FOR DELTA SMELT

The Service designated critical habitat for the delta smelt on December 19, 1994 (59 FR 65256). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (USFWS 1994).

Primary Constituent Elements (PCEs) for delta smelt include:

PHYSICAL HABITAT

Physical habitat is defined as the structural components of habitat. Because delta smelt is a pelagic fish, spawning substrate is the only known important structural component of habitat. It is possible that depth variation is an important structural characteristic of pelagic habitat that helps fish maintain position within the estuary's LSZ (Bennett et al. 2002).

WATER

Water is defined as water of suitable quality to support various delta smelt life stages with the abiotic elements that allow for survival and reproduction. Delta smelt inhabit open waters of the Delta and Suisun Bay. Certain conditions of temperature, turbidity, and food availability characterize suitable pelagic habitat for delta smelt. Factors such as high entrainment risk and contaminant exposure can degrade this PCE even when the basic water quality is consistent with suitable habitat.

RIVER FLOW

River flow is defined as transport flow to facilitate spawning migrations and transport of offspring to LSZ rearing habitats. River flow includes both inflow to and outflow from the Delta, both of which influence the movement of migrating adult, larval, and juvenile delta smelt. Inflow, outflow, and OMR influence the vulnerability of delta smelt larvae, juveniles, and adults to entrainment at Banks and Jones. River flow interacts with the fourth primary constituent element, salinity, by influencing the extent and location of the highly productive LSZ where delta smelt rear.

SALINITY

Salinity is defined as the LSZ nursery habitat. The LSZ is where freshwater transitions into brackish water; the LSZ is defined as 0.5-6.0 psu (Kimmerer 2004). The 2 psu isohaline is a specific point within the LSZ where the average daily salinity at the bottom of the water is 2 psu (Jassby et al. 1995). By local convention the location of the LSZ is described in terms of the distance from the 2 psu isohaline to the Golden Gate Bridge (X2); X2 is an indicator of habitat suitability for many San Francisco Estuary organisms and is associated with variance in abundance of diverse components of the ecosystem (Jassby et al. 1995; Kimmerer 2002). The LSZ expands and moves downstream when river flows into the estuary are high. Similarly, it contracts and moves upstream when river flows are low.

During the past 40 years, monthly average X2 has varied from as far downstream as San Pablo Bay (45 km) to as far upstream as Rio Vista on the Sacramento River (95 km). At all times of year, the location of X2 influences both the area and quality of habitat available for delta smelt to successfully complete their life cycle (see Biology and Life History section above). In general, delta smelt habitat quality and surface area are greater when X2 is located in Suisun Bay. Both habitat quality and quantity diminish the more frequently and further the LSZ moves upstream, toward the confluence of the Sacramento and San Joaquin Rivers.

ENVIRONMENTAL BASELINE

The environmental baseline "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50 CFR §402.02).

The environmental baseline for the action area is described in detail in the USFWS BiOp (81420-2008-F-1481-5) on the Operation Criteria and Plan (OCAP) for the SWP and the CVP.

STATUS OF THE SPECIES AND CRITICAL HABITAT IN THE ACTION AREA

STATUS OF THE SPECIES WITHIN THE ACTION AREA

The action area functions as a migratory corridor and as spawning habitat for delta smelt. Given the long list of stressors discussed in the OCAP BiOp, the rangewide status of the delta smelt is currently declining and abundance levels were the lowest ever recorded in 2009. Although there was a spike in the population in 2011 the declining abundance of delta smelt is clear. This abundance trend has been influenced by multiple factors, some of which are affected or controlled by CVP and SWP operations and others that are not. Although it is becoming increasingly clear that the long-term decline of the delta smelt was very strongly affected by ecosystem changes caused by non-indigenous species invasions and other factors influenced, but not controlled by CVP and SWP operations, The CVP and SWP have played an important direct role in that decline, especially in terms of entrainment and habitat-related impacts that add increments of additional mortality to the stressed delta smelt population. Further, past CVP and SWP operations have played an indirect role in the decline of the delta smelt by creating an altered environment in the Delta that has fostered both the establishment of non-indigenous species and habitat conditions that exacerbate their adverse influence on delta smelt population dynamics. Past CVP and SWP operations have been a primary factor influencing delta smelt abiotic and biotic habitat suitability, health, and mortality.

STATUS OF CRITICAL HABITAT WITHIN THE ACTION AREA

The action area is defined as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR § 402.02). The action area, for the purposes of this biological opinion includes the southern Sacramento-San Joaquin Delta and generally comprises the lands and waterways of the Delta southwest of the City of Stockton. Major waterways within the south Delta include the San Joaquin River, Old River, Middle River, Woodward and North Victoria canals, Grant Line and Fabian canals, Italian Slough, Tom Paine Slough and the adjoining canals of the CVP and SWP. However, due to the anticipated effects of the TBP, the action area for this consultation not only encompasses the lands and waterways described above but includes lands and waterways of the central Delta including the lower San Joaquin downstream of Old River, Columbia Cut and Turner Cut, and all reaches of Middle River and Old River and adjoining sloughs and canals.

As discussed in the biology and life history section above, the existing physical appearance and hydrodynamics of the action area have changed substantially from the environment in which native fish species like delta smelt evolved. The action area once consisted of tidal marshes with networks of diffuse dendritic channels connected to floodplains of wetlands and upland areas (Moyle 2002). The in-Delta channels were further connected to drainages of larger and smaller rivers and creeks entering the action area from the upland areas. In the absence of upstream reservoirs, freshwater inflow from smaller rivers and creeks and the Sacramento and San Joaquin Rivers were highly seasonal and more strongly and reliably affected by precipitation patterns than they are today. Consequently, variation in hydrology, salinity, turbidity, and other characteristics of the Delta aquatic ecosystem was greater in the past than it is today (Kimmerer 2002b). For instance, in the early 1900s, the location of maximum salinity intrusion into the Delta during dry periods varied from Chipps Island in the lower Delta to Stockton along the San Joaquin River and Merritt Island in the Sacramento River (DWR Delta Overview). Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows (Knowles 2002), though Delta outflows have been tightly constrained during late summer-fall for several decades.

Channelization, conversion of Delta islands to agriculture, and water operations have substantially changed the physical appearance, water salinity, water clarity, and hydrology of the action area. As a consequence of these changes, most life stages of the delta smelt are now distributed across a smaller area than historically (Arthur et al. 1996, Feyrer et al. 2007). Wang (1991) noted in a 1989 and 1990 study of delta smelt larval distribution that, in general, the San Joaquin River was used more intensively for spawning than the Sacramento River. Though not restricting spawning per se, based on particle tracking modeling, export of water by the CVP and SWP would usually restrict reproductive success of spawners in the San Joaquin River by entraining most larvae during downstream transport from spawning sites to rearing areas (Kimmerer and Nobriga 2008). There is one, non-wet year exception to this generalization: in 2008, delta smelt entrainment was managed under a unique system of restrictions imposed by the Court in NRDC v Kempthorne. In 2008, CVP/SWP operations were constrained in accordance with recommendations formulated by the Service expressly to limit entrainment of delta smelt from the Central Delta.

Introduced species have also impacted the action area in several ways including added predation to adult and juvenile delta smelt from introduced piscivorous fish, changes in prey composition due to the introduction of several copepod species and added competition for food resources from introduced filter feeders.

CUMULATIVE EFFECTS

For purposes of the ESA, cumulative effects are defined as the effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR §402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultations pursuant to section 7 of the ESA.

Other future State, local, tribal or private projects combined with the TBP have the potential to result in significant adverse effects on delta smelt, however, many of the factors that contribute to these adverse effects have been addressed in the USFWS OCAP BiOp, which includes measures to avoid, minimize, or compensate for effects of CVP and SWP operations. Additionally, the TBP construction does not make a considerable contribution to any adverse cumulative effects because it would affect only a small area of the total delta smelt critical habitat, is not likely to affect many individuals, and would not result in any permanent changes to the environment.

On-going non-Federal diversions of water within the action area (e.g., municipal and industrial uses, as well as diversions through intakes serving numerous small, private agricultural lands) are not likely to entrain very many delta smelt based on the results of a study by Nobriga et al. (2004). Nobriga et al. reasoned that the littoral location and lowflow operational characteristics of these diversions reduced their risk of entraining delta smelt. A study of the Morrow Island Distribution System by DWR produced similar results, with one demersal species and one species that associates with structural environmental features together accounting for 97-98 percent of entrainment; only one delta smelt was observed to be entrained during the two years of the study (DWR 2007). State or local levee maintenance may also destroy or adversely affect delta smelt spawning or rearing habitat and interfere with natural, long term spawning habitat through maintenance processes. Operation of flow-through cooling systems on the Mirant electrical power generating plants that draw water from and discharges water into the action area may also adversely affect delta smelt in the form of entrainment and locally increased water temperatures.

Adverse effects to delta smelt and its critical habitat may result from point and non-point source chemical contaminant discharges within the action area. These contaminants include, but are not limited to ammonia and free ammonium ion, numerous pesticides and herbicides, and oil and gasoline product discharges. Oil and gasoline product discharges may be introduced into Delta waterways from shipping and boating activities and from urban activities and runoff. Implicated as potential stressors of delta smelt, these contaminants may adversely affect fish reproductive success and survival rates. Two wastewater treatment plants (one located on the Sacramento River near Freeport and the other on the San Joaquin River near Stockton) have received special attention because of their discharge of ammonia. The Sacramento Regional County Sanitation District (SRCSD) wastewater treatment facility near Freeport discharges more than 500,000 cubic meters of treated wastewater containing more than 10 tons of ammonia into the Sacramento River each day (http://www.sacbee.com/378/story/979721.html).

Preliminary studies commissioned by the Interagency Ecological Program (IEP) POD investigation and the Central Valley Regional Water Quality Control Board are evaluating the potential for elevated levels of Sacramento River ammonia associated with the discharge to adversely affect delta smelt and the Delta ecosystem. The Freeport location of the SRCSD discharge places it upstream of the confluence of Cache Slough and the mainstem Sacramento River, a location just upstream of where delta smelt have been observed to congregate in recent years during the spawning season. The potential for exposure of a substantial fraction of delta smelt spawners to elevated ammonia levels has heightened the importance of this investigation. Ammonia discharge concerns have also been expressed with respect to the City of Stockton Regional Water Quality Control Plant, but its remoteness from the parts of the Estuary frequented by delta smelt and its recent upgrades suggest that it is more a potential issue for migrating salmonids than for delta smelt.

Other future, non-Federal actions within the action area that are likely to occur and may adversely affect delta smelt and its critical habitat include: the dumping of domestic and industrial garbage that decreases water quality; construction and maintenance of golf courses that reduce habitat and introduce pesticides and herbicides into the aquatic environment; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the water; agricultural activities, including burning or removal of vegetation on levees that reduce riparian and wetland habitats that contribute to the quality of habitat used by delta smelt; and livestock grazing activities that may degrade or reduce riparian and wetland habitats that contribute to the quantity and quality of habitat used by delta smelt.

EFFECTS OF THE ACTION

This section describes the anticipated effects of implementing the 2013-2017 TBP on the delta smelt and its critical habitat

CONSTRUCTION IMPACTS ON DELTA SMELT

TEMPORARY ROCK BARRIERS

Adult migrating and spawning delta smelt are likely to be adversely affected by construction activities associated with implementing the 2013-2017 Temporary Rock Barriers. Migrating and spawning adult delta smelt may be present in the action area during the construction of the rock barriers as construction activities in March and April coincide with the peak of delta smelt spawning. Sommer et al. (2011) reports that delta smelt have been observed in the south delta from January to July in recent years, however, historically they were present throughout the year.

Juvenile and larval delta smelt are unlikely to be impacted by the construction activites associated with the TBP. Most spawning occurs after the barriers installation and juveniles are rearing in the LSZ during the normal barrier removal timing, therefore, it would be unlikely that juvenile and larval delta smelt would be in the vicinity of the construction activities.

Adult delta smelt are rare near the HORB as Mossdale trawl data from 1994 to 2011 reports that only 44 delta smelt have been captured during these 17 years with 40 of these captures occurring from April to June. As installation of the spring HORB is likely to be installed in March, when only one delta smelt has been captured during Mossdale trawl surveys, take of delta smelt is likely to be low. The removal of the spring HORB will likely occur during June. This work coincides with the height of delta smelt occurrences in the area, however, take is still likely to be low as only 22 delta smelt have been captured in June throughout the 17 years of Mossdale trawl surveys. The fall HORB may be installed in September and if installed it would be notched by September 15 and removed by November 30. No delta smelt have been captured during these months during Mossdale trawl surveys and, as such, take is not likely to occur due to the installation, notching, and removal of the fall HORB.

Salvage data from the State and Federal Fish Facilities shows that the majority of delta smelt are in the south Delta near the ag barriers in May and June, with 73.4 percent of all delta smelt salvage occurring during these two months. In March and April, during the normal installation period, salvage data suggests that delta smelt are quite rare, with 4.8 percent of delta smelt salvage occurring in March and 1.7 percent occurring in April. Notching and removal of the barriers would occur from September to November and delta smelt salvage during this time period comprises 0.1 percent of the total salvage or a total of 17 fish from 1993 to 2012.

The installation of the four rock barriers in the south Delta has the potential to harass and displace delta smelt present in the general area of the construction activity, however due to the timing and locations of the construction activities, take will likely be low. Additionally, the increased turbidity levels associated with construction may negatively impact fish populations temporarily through reduced availability of food, reduced feeding efficiency, and exposure to toxic sediments released into the water column, however, due to low delta smelt occurrences near the barriers during construction activities, take will likely be low. The notching and removal of the ag barriers and the installation, notching, and removal of the fall HORB would not likely impact delta smelt.

DWR anticipates that raising the MRB by one foot will have few, if any, impacts to delta smelt. The MRB raise will trap more water above the MRB, thereby raising stage levels and increasing flow down GLC. If the ORT flapgates are tied open when the MRB has been raised, than the flow down OR will also increase. These increases in flows down OR and GLC are expected to improve circulation which is intended to reduce areas with high salinity levels.

The construction of the barriers may take delta smelt, however, take is expected to be low because:

- few delta smelt are expected to be in this area during construction,
- Sound data taken during the 2012 installation of the rock barriers showed that noise levels at 100m from construction were below the NMFS criteria for adverse behavioral effects (Shields, 2012) indicating that the area of affects from construction would be relatively small,
- the effects would be temporary (from 10 to 42 days for installation and removal, depending on the barrier),
- the effects of noise on fish would be likely be limited to avoidance behavior in response to movements, noises, and shadows caused by construction personnel and equipment operating in or adjacent to the water body,
- only a very small channel area would be disturbed or affected by construction, and
- most fish are expected to move away from the area of disturbance.

NON-PHYSICAL BARRIER

In the years in which DWR opts to install the NPB in place of the spring HORB, the installation and removal of up to eight, 8- or 12-inch diameter steel piles and the bubble curtain structure at the head of Old River has the potential to harass and displace fishes present in the general area of the construction activity. NMFS has established interim criteria for evaluating underwater noise impacts from pile driving on fish. These criteria are defined in the document entitled "Agreement in Principal for Interim Criteria for Injury to Fish from Pile Driving Activities" dated June 12, 2008 (National Marine Fisheries Service 2008). This agreement identifies a peak sound pressure level of 206 decibels (dB) and an accumulated sound exposure level (SEL)[1] of 187 dB as thresholds for injury to fish. For fish less than 2 g, the accumulated SEL threshold is reduced to 183 dB. Although there has been no formal agreement on a "behavioral" threshold, NMFS uses 150 dB-RMS as the threshold for adverse behavioral effects (National Marine Fisheries Service 2009c).

Pile driving noise modeling, using NMFS Underwater Noise Calculation Spreadsheet model (National Marine Fisheries Service 2009c), indicates that the installation of the piles would not result in peak sounds greater than 171 dB. The Compendium of Pile Driving Sound Data (California Department of

[1] Sound exposure level (SEL) is defined as the constant sound level acting for one second, which has the same amount of acoustic energy as the original sound. Expressed another way, the sound exposure level is a measure of the sound energy in a single pile driver strike. Accumulated SEL (SEL accumulated) is the cumulative SEL resulting from successive pile strikes. $SEL_{accumulated}$ is based on the number of pile strikes and the SEL per strike; the assumption is made that all pile strikes are of the same SEL.

Transportation, 2007) provides sound level data on a variety of pile sizes and driver types. Data on vibratory driving of 12-inch piles is available but none is available for 8-inch piles. The 12-inch pile data is considered to be representative for both of the potential sizes of piles (8" or 12") to be used and indicates the following source levels as measured at 10 meters from the pile:

Peak[2] = 171 dB

RMS = 155 dB

Sound exposure level (SEL [for 1 second of vibratory driving]) = 155 dB.

In the absence of site-specific data, NMFS recommends using an underwater attenuation rate of 4.5 dB per doubling of distance (National Marine Fisheries Service 2009c). It also supports the notion that sound levels of less than 150 dB do not contribute the accumulated SEL for the purposes of assessing injury (National Marine Fisheries Service 2009c). Using this assumption and attenuation rate the calculated distance to each of the applicable thresholds is as follows:

Distance to 206 dB-peak = less than 1 meter

Distance to 150 dB-RMS = 22 meters

Distance to 187 dB-$SEL_{accumulated}$ = 21 meters (for fish > 2 g)

Distance to 183 dB-$SEL_{accumulated}$ = 22 meters (for fish < 2 g)

Results of sound monitoring conducted for a similar project at Georgiana Slough in the Delta have shown that distances to 183 dB- $SEL_{accumulated}$ were significantly less than levels calculated in the NMFS Underwater Pile Driving Sound Level Excel spreadsheet (Shields, 2012, Appendix C) and sound levels predicted for HOR are significantly less than those at Georgiana Slough. These low sound levels measured at Georgiana Slough are despite the fact that piles driven at Georgiana Slough are driven deeper than those at HOR (a maximum of 25 feet vs 20 feet deep) and that the substrate at Georgiana Slough was more difficult for the piles to penetrate than the substrate at HOR (J. Persoeni 2012, Pers. Comm., 9 Aug.). The 12" piles at Georgiana Slough took from 55 seconds to 490 seconds to place and one to ten piles were placed per day. Accumulated SEL's for stationary fish 10 meters from the pile driving at Georgiana Slough never exceeded 175 dB.

The increased turbidity levels associated with construction may negatively impact fish populations temporarily through reduced availability of food, reduced feeding efficiency, and exposure to toxic sediment released into the water column. These potential effects would be minimal because:

- the effects would be temporary (4 days for installation and 5 days for removal);
- a vibratory method of pile installation would be used which minimizes disturbances to fish over other impact-type pile driving methods;
- for most activities, the effects of pile driving noise on fish would likely be limited to avoidance behavior in response to movements, noises, and shadows caused by construction personnel and equipment operating in or adjacent to the water body. Additionally, the duration of pile driving would be minimal and would require less than 80 minutes to complete;

[2] Peak sound pressure refers to the highest absolute value of a measured waveform (i.e., sound pressure pulse as a function of time).

- There is an extremely low likelihood of delta smelt being in the vicinity of the HOR during March construction, as Mossdale Trawl reports only 1 delta smelt capture in March during 17 years of data collection;
- only a very small channel area would be disturbed or affected by construction; and
- most fish are expected to move away from the area of disturbance.

The placement of the NPB with the signage, concrete anchors and pier blocks associated with it will temporarily impact a maximum of 288 ft^2 of the river bed (8-12" piles, 30-2'x2' pier blocks and 40-2'x2' concrete anchors). These temporary impacts from the placement of this equipment will be for no more than 4 months and the substrate is expected to return to pre-project conditions after removal of the anchors, stands and piles.

BARRIER CULVERT REPLACEMENT

Delta smelt could potentially occur in the project area during the necessary replacement of the GLC and MR barrier culverts and associated structures. The effects of construction-related activities associated with the replacement of the barrier culverts and associated structures on delta smelt would be similar to that described above for the installation of the temporary rock barriers. These potentially adverse effects would be minimal because:

- The culverts only need replacement every 10 to 15 years and will not likely be replaced from 2013-2017,
- culverts would be replaced by completely removing the barrier, culverts and abutments in October and November along with the regular barrier removal. The following year new culverts and abutments would be placed immediately preceding the barrier construction,
- few delta smelt are expected to be in this area during construction,
- the effects would be temporary (less than 10 additional days for removal and 5 additional days for placement),
- the effects of noise on fish would be likely be limited to avoidance behavior in response to movements, noises, and shadows caused by construction personnel and equipment operating in or adjacent to the water body,
- only a very small channel area would be disturbed or affected by construction, and
- most fish are expected to move away from the area of disturbance.

TEMPORARY BARRIERS PROJECT FISH STUDY

Impacts from the TBP fish study will be relatively small in area and will be comprised of placement of up to 50 anchors made from sections of railroad track, up to 10 weighted stands and one scientific pile. These anchors will be used for placing equipment such as hydrophones, ADCP's and DIDSON cameras. Each railroad track anchor is approximately 24 inches x 6 inches, each weighted stand is approximately 3 feet by 3 feet and the scientific pile would be at most a 12 inch diameter steel pipe. The total substrate impacted by the placement of the maximum number of all of these structures would be 141 ft^2 and all structures would temporarily affect the river bottom at the location placed. The placement of the scientific equipment on these anchors will have no effects on listed fish species as they will be affixed to the anchors so they would point in a specific direction (ADCP's and DIDSON cameras) or float freely in the water column (Hydrophones). As no impacts from the scientific equipment are anticipated, other different technologies may be utilized if the need arises to obtain data on and improve the understanding of listed species or predatory fish in the vicinity of the TBP. Scientific equipment will be placed for no more than five months and the substrate is expected to return to pre-project conditions after removal of the anchors, stands and pile. The scientific pile will only be placed in years that the NPB is installed and impacts associated with the vibratory driving have been assessed in the "Non-Physical Barrier" effects section of this document.

PREDATORY FISH CAPTURE IMPACTS ON DELTA SMELT

ELECTROFISHING IMPACTS ON DELTA SMELT

As previously described, there is the potential for delta smelt to be present in the predatory fish sampling areas near the temporary barriers during the 3-month spring sampling period. Should delta smelt be inadvertently shocked by the electrofishing equipment, incidental take would occur. However, the likelihood of take is low because:

- prior to the start of sampling each day, water temperature and conductivity measurements will be taken to evaluate electroshocker settings and adjustments will be made if necessary,
- electrofishing would not be conducted when EC is above 1500 μS/cm,
- electrofishing would not occur when 600 Volts (V) produces less than 6 amps,
- in areas where large amounts of aquatic vegetation interfere with the electrical field, electrofishing would range from 200 V to 600 V at 60 pulses per second and settings would be adjusted to maintain approximately 8 amps,
- in areas without large amounts of aquatic vegetation electrofishing would range from 200 V to 400 V at 60 pulses per second and settings would be adjusted to maintain approximately 6 amps,
- the electrofishing equipment would use pulse DC (PDC) only,
- it is unlikely that delta smelt would be in the immediate vicinity of the predatory fish due to extremely low densities of delta smelt. Mossdale Trawl data from 1994 to 2011 showed only 44 delta smelt captures near the HOR,
- if present, delta smelt are unlikely to be affected by the electrofishing equipment because the voltage drop on small fish is much less than that of large predatory fish, and
- electrofishing would be conducted only occasionally, occurring at most once per week near each of the study sites for a three-month period.

If delta smelt were inadvertently shocked by the electrofishing equipment measures will be put in place to reduce mortality of these individuals. These measures are:

- field staff will be trained to quickly identify listed species and would release live fish to minimize handling stress,
- any listed species will be measured, recorded and released at the location caught, and
- Delta smelt will be placed in a black bucket full of water until they recover and then they will be released.

FYKE NETTING IMPACTS ON FISH

As previously described, there is the potential for delta smelt to be present in the predatory fish sampling areas near the temporary barriers during the 3-month spring sampling period. Delta smelt are highly unlikely to be trapped by fyke netting as the fish would be able to fit through the mesh in the traps. If delta smelt are trapped efforts would be made to minimize trapping and handling mortality by:

- following procedures used by the DFG Adult Striped Bass Monitoring Project,
- removing accumulated debris from the fyke net,
- using a live well, coolers, or quickly sorting fish into wet containers,
- making efforts to remove listed species before other non-listed fish,
- measuring and immediately releasing delta smelt trapped in the fyke nets to minimize handling stress,
- keeping hands or surgical gloves wet to minimize disruption of the mucous layer,
- soaking fyke traps for less than 24 hours before retrieving the catch, and
- leaving a portion of the fyke net in the water to minimize fish stress during catch processing.

Although every effort may be made to return all fish back to the site alive, some mortality is inevitable, however, fyke netting has been shown to cause significantly less stress to fish than other netting methods such as gill netting (Hopkins, 2011). Fyke netting mortality to striped bass from the past five years of the DFG Adult Striped Bass Monitoring Project ranged between 0 to 16 fish per year, which is a 0% to 0.24% mortality rate. No delta smelt captures were recorded from DFG Fyke netting. Capture and mortality to delta smelt will be documented and reported to the FWS and all sampling will stop when take levels are reached.

HOOK AND LINE FISHING IMPACTS ON FISH

As previously described, there is the potential for delta smelt to be present in the predatory fish sampling areas near the temporary barriers during the 3-month spring sampling period. Delta smelt would not likely be impacted from hook and line fishing because:

- Fishing methods will be chosen to target larger predatory fish,
- Delta smelt are highly unlikely to be captured through any hook and line fishing method, and
- Hook and line sampling has been conducted for the past 3 years at the HOR and no delta smelt were captured.

IMPACTS ON DELTA SMELT CRITICAL HABITAT

The Service designated critical habitat for the delta smelt on December 19, 1994 (59 FR 65256). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (USFWS 1994). The designation was based on 4 PCEs: physical habitat, water, river flow, and salinity.

NON-PHYSICAL BARRIER

The only PCE that would be affected by the NPB is physical habitat, and this effect would be limited to the footprint of the NPB, because there would be no changes in hydrodynamics that would result in changes in water quality, flows, or salinity.

The footprint of the NPB includes the area occupied by up to 8 piles, concrete piers, concrete anchors, and the area affected by the bubbles, sound, and lights. Each pile would be approximately 1 square foot, each concrete pier block would occupy approximately 4 square feet, and each concrete anchor would occupy approximately 4 square feet, so a total area of 288 square feet (0.01 acre) of channel bottom would be temporary lost. The bubbles, sound, and light are not expected to cause any disturbance to smelt or their habitat, and are therefore not considered an impact to critical habitat. The piles would be removed upon completion of use and there would be no permanent changes in the physical habitat. As such, no adverse effects on delta smelt critical habitat would occur.

TEMPORARY ROCK BARRIERS

Physical habitat, and potentially water quality, would be affected by construction of the TBP. River flow and salinity would not be affected by the construction of the TBP, however these PCE's would be affected by the hydrologic changes caused by the operation of the barriers. These hydrologic changes and their impacts to delta smelt critical habitat have been addressed in the OCAP BIOP (Service File # 81420-2008-F-1481-5) and will not be addressed in this document. The effect of construction activities on physical habitat in areas where the rock barriers are installed would be limited to the footprint area of each of the four rock barriers as shown in Table 5.

Table 6: Barrier Footprints

Barrier	Footprint (acres)
Spring Head of Old River[1]	0.44
Old River at Tracy	0.34
Grant Line Canal	0.34
Middle River	0.31
Total	**1.43**

[1] The footprint of the fall HORB is approximately 0.34 acres.

These footprints are the historical site of the TBP and have been repeatedly disturbed for many years. As such, the quality of the habitat is low and would continue to be low as a result of continued construction of the TBP. However, it is habitat utilized by delta smelt, and the continued disturbance of these areas would result in a continued loss of this habitat. As shown in Table 1, approximately 1.43 acres of delta smelt critical habitat, in the form of physical habitat, would be adversely affected by the TBP. Additionally, construction activities could potentially impair water quality if hazardous chemicals (e.g., fuels and petroleum-based lubricants) or other construction materials are spilled or enter the south Delta channels. This risk is limited to the construction period and is not likely to occur. Regardless, DWR will implement a spill prevention and control plan to ensure avoidance of any accidental spills or releases. As such, there would be no effects on the water PCE.

PREDATORY FISH SAMPLING

Electrofishing, Fyke netting and hook and line fishing for predatory fish in areas near the temporary barriers are not expected to have an adverse effect on these PCEs. Delta smelt that may be utilizing the area are unlikely to be affected, as described previously.

HYDRODYNAMICS OF BARRIER OPERATIONS

Operations of the TBP and the hydrodynamic effects associated with these operations have been addressed in the OCAP BIOP (Service File # 81420-2008-F-1481-5). As such, the hydrodynamic effects described below are for information purposes only.

FARFIELD EFFECTS

Installation of the three agricultural barriers creates alterations in the circulation of water in the south Delta. The barriers create a delay in the tidal signal between the channels upstream of the barriers and the downstream sections of the channels below the barriers. The barriers also create differences in water elevations between the upstream segments above the barriers and those segments below the barriers. In addition to the increases in water elevations, alterations in the net flows and their direction within the channels of the south Delta occur with the installation of the temporary barriers. DWR has modeled these flows using its Delta Simulation Model (DSM2-Hydro). In general, the average net flows in the south Delta channels are reduced or reversed when the barriers are in place. Prior to barrier installation, net flows in Old River and Grant Line/Fabian-Bell

Canals are downstream and directly influenced by flows entering the Old River channel from the mainstem San Joaquin River at HOR as well as pumping rates at the CVP and SWP facilities. Flows in MR are harder to predict. When flows in the mainstem San Joaquin River at Vernalis are high, then flows entering the south Delta channels are higher and Middle River tends to have a net positive flow downstream along its entire length. Conversely, when San Joaquin River flows are low, then the net flow in lower MR tends to be negative and the flows entering from Old River near Undine Road are "balanced" by this inflow of water from downstream. Once the ORT, MR and HOR barriers are installed, the net flows above the ORT and MR barriers generally become negative and flow proceeds in an upstream direction. Flows in GLC remain positive and net flows proceed in a downstream direction towards the CVP and SWP water intakes. Once the HOR barrier is removed, net positive flows resume in the upper portion of Old River and flow enters both the lower Old River channel and Middle River channel below their split. Flows from upstream may become "balanced" by net negative flows originating from downstream creating areas of null flows in the interior sections of the channels. This condition is more pronounced as the demand for irrigation water increases within the interior of the south Delta and inflow from the San Joaquin River is low (*i.e.*, flows below approximately 2,000 cfs). The flow patterns in the interior of the south Delta under these parameters creates a "hydraulic trap" for particles (or fish) moving with the river's flow. These alterations in the flow patterns in the south Delta reduce the ability of migrating fish, to successfully travel through the region towards the western edge of the Delta. These changes will create a confusing flow signal for any migrating fish within the affected areas. Increases in travel time through the south Delta channels are expected to expose fish to higher levels of predation, raise the risk of entrainment into any one of the hundreds of small agricultural water diversions found in the area, and prolong the time that fish are exposed to reaches with degraded water quality.

During the period when all of the barriers are installed in the south Delta, the hydrodynamics of the Delta interior to the north are also affected. Under the influence of pumping at the CVP and SWP, water is drawn southwards from the lower San Joaquin River near McDonald, Mandeville and Medford Islands down the channels of Old River, MR, Columbia Cut, and Turner Cut. This creates net negative flows in these channels and water moves upstream towards the CVP and SWP diversion points in the south Delta. Any fish that was successful in staying in the main channel of the San Joaquin River past the HOR still has the possibility of being drawn back into the south Delta through these aforementioned waterways under the influence of the pumping actions of the CVP and SWP and tidal oscillations (Vogel 2004). For fish that are drawn into these channels, the risk of predation, entrainment by agricultural diversions, and exposure to degraded water quality increases. These factors are expected to reduce their chances of survival.

The barriers also impact water quality parameters, although to varying degrees. Based on the data provided by the annual reports submitted by DWR (2001 through 2005), specific conductance is generally higher upstream of the barriers than below. Typically, Old River has the highest specific conductance while Middle River has the lowest. In 2005, this relationship did not hold, as flows from the San Joaquin River were much higher than in previous years, and the south Delta channels were all well flushed throughout the summer period. Dissolved oxygen and water temperature also appear to show a strong correlation with season as represented by ambient air temperature. As ambient air temperature increases, water temperature also increases, while DO levels decline. Barrier effects may contribute to the creation of DO sags around the barriers (ORT and GLC) and within the interior sections of the south Delta channels due to flow conditions (null zones), input of irrigation return water, input of waste waters from sanitation plants, nutrient loading, and excessive primary productivity depleting nighttime DO levels through respiration. These decreases in ambient water quality parameters would have negative impacts on the survival of any fish found in the affected waterways.

NEARFIELD EFFECTS

The three agricultural barriers will function as open channel weirs within the waterways of the south Delta. In general, water will flow over the crest of the three agricultural barriers and create a turbulent flow field downstream of the barriers. The characteristics of the flow field, however, will not remain static as water elevation and flow direction will change with the tidal cycle. Flow will typically be bi-directional, and water elevation will have both an ascending limb and descending limb, based on the point of the tidal cycle in which the observations are made.

The following is a generalization of the complex hydraulic environment created by the agricultural barriers within the channels of the south Delta. Concepts are based on information provided in the introductory reference text for open channel hydraulics by Chanson (2004). On an incoming tide, the water elevation downstream of the structures will be below the elevation of the weir crest and hence the upstream water surface elevation. The incoming tide will encounter the rock barrier and water surface levels will increase in elevation on the downstream side of the barrier. At the point of contact with the barrier, net water velocity will diminish to zero, since upstream flow is negated by the barriers.

Flow from upstream of the barrier will continue to flow over the weir, creating a "riffle" over the downstream slope of the rock barrier before dissipating its energy in the "plunge pool" below the rock barrier. Depending on the differential in head between the upstream and downstream sides of the rock barrier, a significant hydraulic jump can be formed when energy in the faster velocity flow coming over the weir is dissipated by the downstream water mass in the plunge pool. It is expected that a complex circulation pattern will be set up by the formation of the hydraulic jump at the interface of the downstream water body and the flow of higher velocity water coming over the weir crest (and through the submerged culverts when they are tied open). The tongue of water flowing over the weir (the weirs are less than the width of their respective channels) will create counter circulating flow cells below the water surface and to either side of the main flow line. It is expected that these circulation patterns to concentrate fish immediately downstream of the barrier structures. In addition to the downstream conditions described, flow over the top of the weir is likely to create a hydraulic "cushion" on the upstream side of the rock barriers below the elevation of the weir crest. It is expected that these areas of reduced velocity will also serve to concentrate fish prior to their passage over the top of the weir. In addition, these areas of reduced flow velocities serve as ambush points for predatory fish to prey on the concentrated schools of smaller fish in front of the barrier. These hydraulic conditions are expected to have adverse effects upon delta smelt traveling through the reaches occupied by the agricultural barriers.

In addition to flow over the top of the barrier's weir, additional flow from upstream can pass downstream through the submerged culverts during the early portion of the barrier's installation season. During this early stage of the barrier season, the agricultural barriers have their culverts tied open to allow tidal flow to pass through them. Normally, the tidal flap gates would close and prevent the ebb tide from flowing through the culverts in the downstream direction. As the tide reaches full flood and its elevation matches the water level upstream of the barriers, water is expected to move upstream through both the submerged culverts, and across the top of weir. In order for water movement to pass upstream through the 48-inch diameter culverts, the elevation head has to be higher on the downstream side than the upstream side of the barrier. This only occurs when the downstream surface elevations are above the height of the weir crest and the surface elevations upstream of the barriers. It is expected that fish below the weir will move with the upstream flow, passing through both the culverts and across the top of the barrier's weir with the incoming tide. Similar to the circulation conditions already described for water flowing downstream over the weir crests, it is expected that water flowing upstream over the weirs during the flood stage of the tide to exhibit turbulent characteristics. Fish passing through this turbulent tongue of water will experience disorientation and become more susceptible to predation.

In summary, it is expected that the installation of the physical barriers will create hydraulic conditions that will impede free passage of fish through the channels of the south Delta. Water flow through the channels will be redirected, and the residency time of fish passing through the channels of the south Delta will be increased due to the changes in flow patterns. Furthermore, after passing through the San Joaquin River reach adjacent to the Port of Stockton and lower Roberts Island, a proportion of the fish in the main stem San Joaquin River will subsequently be entrained into the channels leading southwards under the influence of the CVP/SWP water diversion pumps. In addition, the barriers will create nearfield hydraulic conditions that will subject migrating fish to increased turbulence and disorientation than is normal for an unobstructed channel. The barriers will also create obstructions that will concentrate fish into confined areas of the channel prior to passing through the reach with the barrier structure. These effects will increase their risk of predation by larger fish such as striped bass and largemouth bass.

CONSERVATION MEASURES

CONTINUE EXISTING MEASURES

DWR will continue implementation of all applicable monitoring, avoidance, minimization, and compensation measures required as part of the Action-Specific Implementation Plan (ASIP) BIOPs issued in 2001 for the TBP and referenced by the current BIOPs (U.S. Fish and Wildlife Service 2008 USFWS # 81420-2008-F-1481-5, 2009a USFWS # 81420-2008-F-0522, and 2009b USFWS # 1-1-04-F-0345; National Marine Fisheries Service 2008, 2009a, 2009b, 2011 and 2012).

PREVIOUS CONSERVATION

In accordance with requirements issued in the 2011-2015 DFG ITP (ITP # 2801-2011-019-03) DWR purchased 6.0 acres of shallow water habitat credits covering the South Delta TBP. DWR utilized a credit of 1.25 acres left over from the Kimball Island Mitigation Bank and an additional 4.75 acres of shallow water habitat credits was purchased at the Liberty Island Conservation Bank. DWR also purchased 1.0 acre of Floodplain Riparian Habitat credit at the Cosumnes Floodplain Mitigation Bank to mitigate impacts to Swainson's Hawks.

WORKER ENVIRONMENTAL AWARENESS PROGRAM

Construction personnel will participate in a USFWS-approved worker environmental awareness program. Under this program, workers will be informed about the presence of USFWS-listed fish species and habitat associated with the species and that unlawful take of the animal or destruction of its habitat is a violation of the ESA. Prior to construction activities, a qualified biologist(s) approved by USFWS will instruct all construction personnel about the life history of delta smelt. Proof of this instruction will be submitted to the USFWS SFBay-Delta Fish and Wildlife Office.

CONDUCT PILE DRIVING WITH A VIBRATORY DRIVER

DWR is committed to conducting all pile driving using a vibratory hammer to minimize to the extent possible the noise generated from pile-driving activities. Compared to the standard impact driving method, vibratory driving reduces the distance that noise exceeds NMFS thresholds by almost 1,000 feet from the area of impact, substantially reducing or avoiding the potential to cause take of listed species.

SPILL PREVENTION AND CONTROL PROGRAM

DWR will prepare a spill prevention and control program prior to the start of construction to minimize the potential for hazardous, toxic, or petroleum substances release into the project area during construction and project operation. In addition, DWR will place sand bags, bio-logs, or other containment features around the areas used for fueling or other uses of hazardous materials to ensure that these materials do not accidentally leak into the rivers or channels.

TEMPORARY BARRIERS PROJECT FISH STUDY

The fish study will be developed to avoid take of delta smelt. Specific conservation measures will be developed in due course. Consistent with the previous Fish Monitoring Programs, the following measures will be used to minimize the effects of loss and disturbance of habitat on delta smelt:

- Any listed species caught alive will be handled as little as possible, have length and condition/coloration estimated visually and recorded, and immediately released at the location caught;
- Any dead listed species will be disposed according to procedures listed under the take authorization. Take information will be reported as a supplemental report at the end of the sampling period;
- Field staff will be trained to quickly identify listed species and release live fish to minimize handling stress.

Measures to minimize take of listed fish during passive sampling, i.e., fyke trapping, will follow procedures used by the DFG Adult Striped Bass Monitoring Project. These measures include:

- Soaking fyke traps for less than 24 hours before retrieving the catch;
- Ensuring that a portion of the fyke trap remains in the water to minimize fish stress during catch processing;

If sampling is likely to produce a variance of expected take, project staff will notify and consult with the appropriate regulatory agencies (USFWS and DFG). If actual take exceeds estimated take, project staff will cease sampling and await ESA consultation.

CONCLUSION

Based on the information presented within this BA, the California Department of Water Resources has determined that the Temporary Barriers Project, with all of the components described in the "Description of Proposed Action" section of this document is likely to have the following effects on USFWS regulated ESA listed species and their Critical Habitats:

TABLE 7: EFFECT DETERMINATIONS OF USFWS REGULATED SPECIES FOR THE TEMPORARY BARRIERS PROJECT

Species	Status*	Effect Determination
Delta smelt (*Hypomesus transpacificus)*	FT, SE	May Affect, Likely to Adversely Affect
Delta smelt designated critical habitat	X	May Affect, Likely to Adversely Affect
Conservancy fairy shrimp (*Branchinecta conservatio*)	FE	No effect
Longhorn fairy shrimp (*Branchinecta longiantenna*)	FE	No effect
Vernal pool fairy shrimp (*Branchinecta lynchi*)	FT	No effect
Vernal pool fairy shrimp designated critical habitat	X	No effect
Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)	FT	No effect
Vernal pool tadpole shrimp (*Lepidurus packardi*)	FE	No effect
California tiger salamander *(Ambystoma californiense)*	FT, ST	No effect
California red-legged frog *(Rana draytonii)*.	FT	No effect
California red-legged frog designated critical habitat.	X	No effect
Alameda whipsnake (*Masticophis lateralis euryxanthus*)	FT, ST	No effect
Giant garter snake (*Thamnophis gigas*)	FT, ST	No effect
Riparian brush rabbit (*Sylvilagus bachmani riparius*)	FE, SE	No effect
San Joaquin kit fox (*Vulpes macrotis mutica*)	FE, ST	No effect
Contra Costa goldfields (*Lasthenia conjugens)*	FE	No effect
Contra Costa goldfields designated critical habitat	X	No effect

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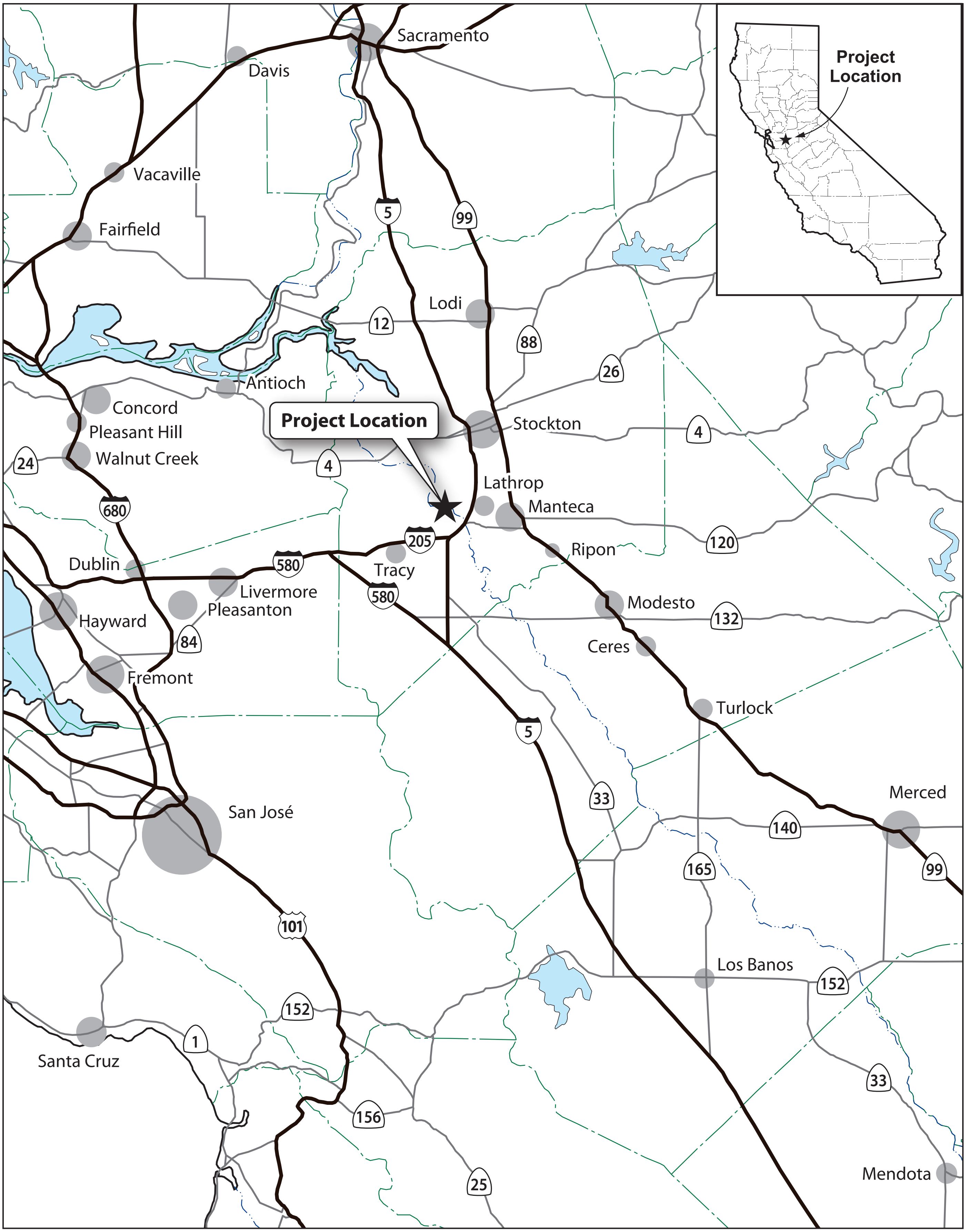
Personal Communications

John Personeni, Department of Water Resources, Pers comm. August 2012.

Matthew Young, University of California, Davis. Pers comm August and September, 2012.

APPENDIX A

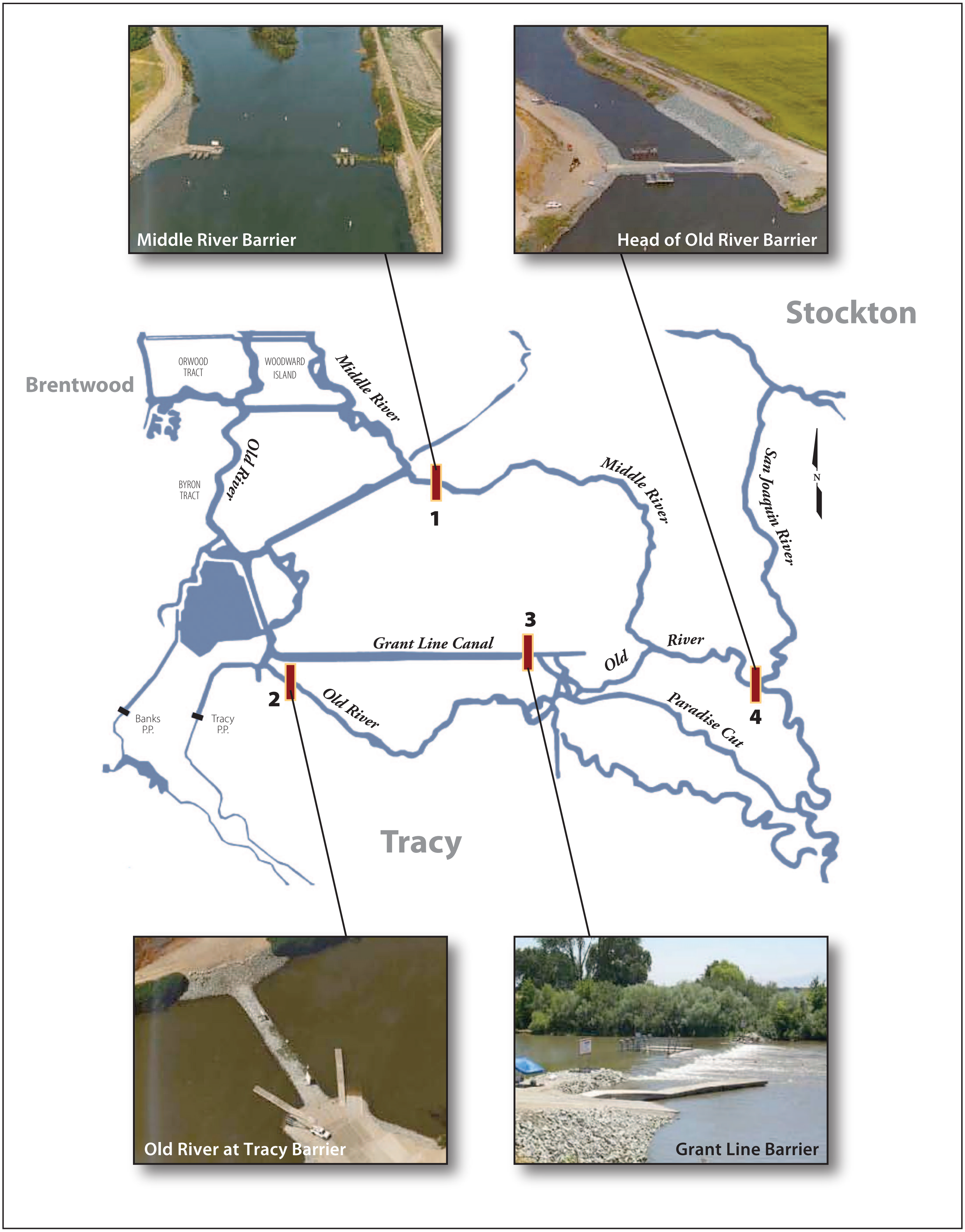
APPENDIX A: FIGURES



Graphics/Projects/00135.10 Permitting TBP (11-11) JD

ICF INTERNATIONAL

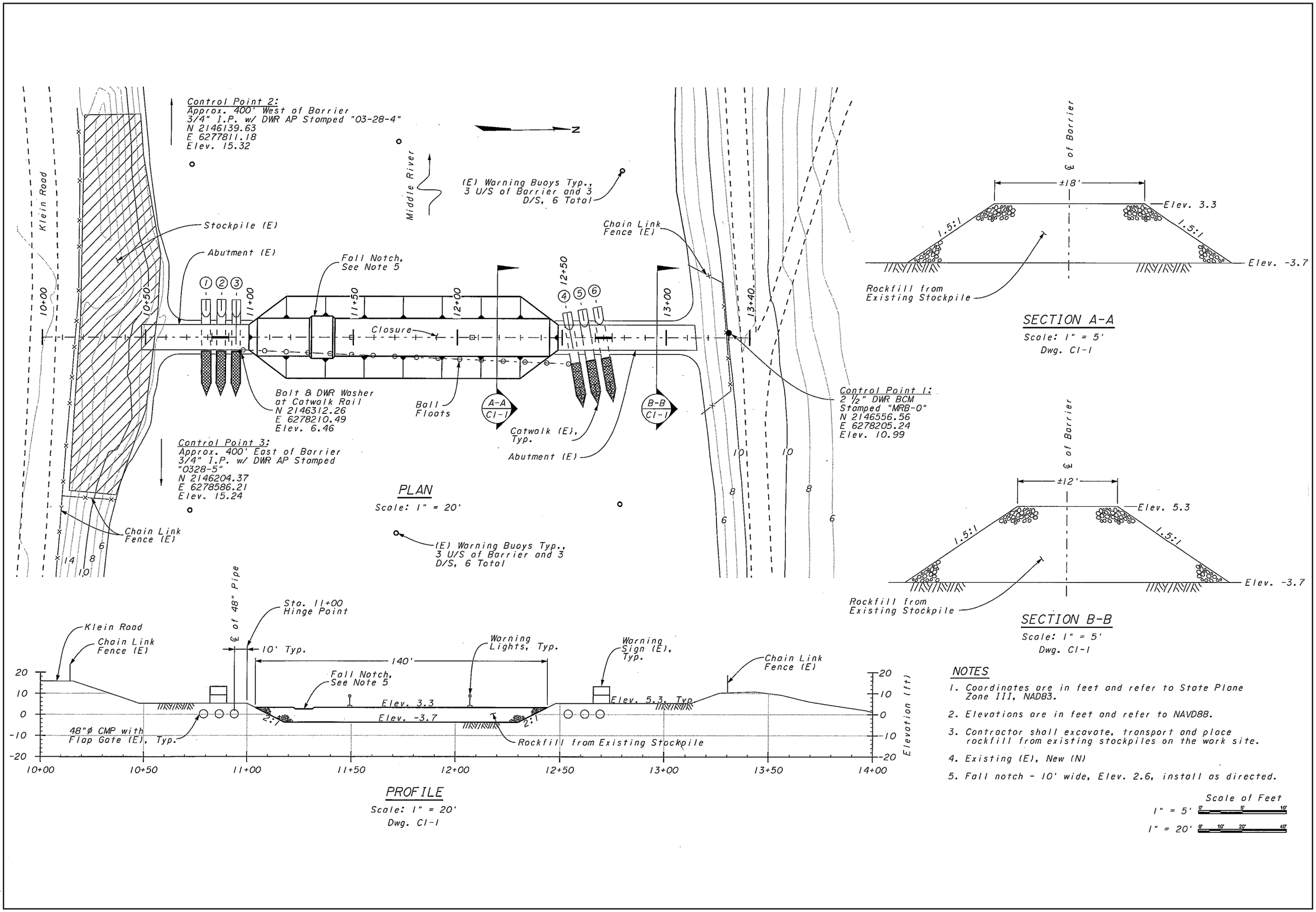
Figure 1
Project Vicinity



Graphics/Projects/00135.10 Permitting TBP (11-11) JD

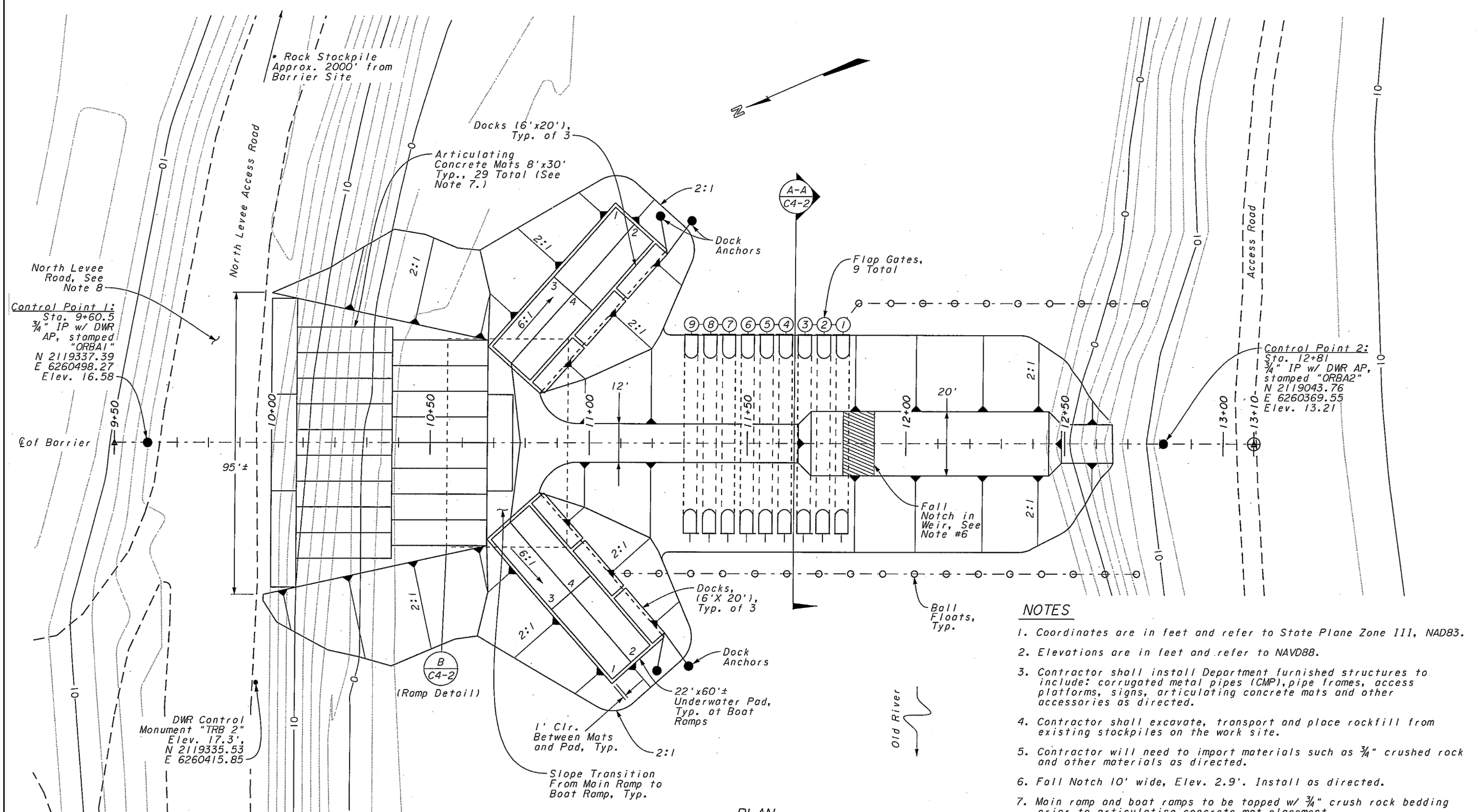
ICF INTERNATIONAL

Figure 2
Project Location Map



Graphics... 00135.10 Permits TPB (11-2011) JD

Figure 3
Middle River Barrier
Plan, Profile, and Sections



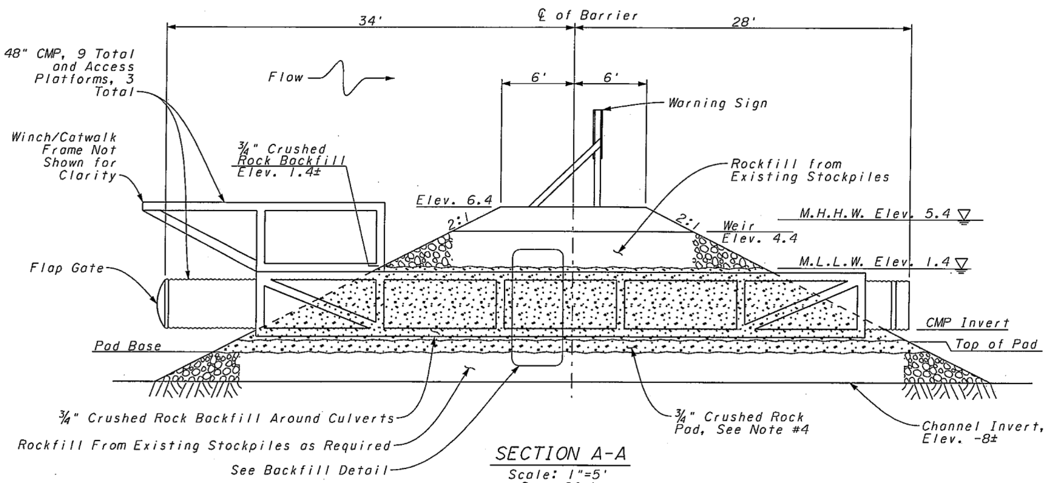
NOTES

1. Coordinates are in feet and refer to State Plane Zone III, NAD83.
2. Elevations are in feet and refer to NAVD88.
3. Contractor shall install Department furnished structures to include: corrugated metal pipes (CMP), pipe frames, access platforms, signs, articulating concrete mats and other accessories as directed.
4. Contractor shall excavate, transport and place rockfill from existing stockpiles on the work site.
5. Contractor will need to import materials such as ¾" crushed rock and other materials as directed.
6. Fall Notch 10' wide, Elev. 2.9'. Install as directed.
7. Main ramp and boat ramps to be topped w/ ¾" crush rock bedding prior to articulating concrete mat placement.
8. North levee road to be repaired to conform to existing roadway 75' upstream and 75' downstream of barrier centerline, as directed.

Scale of Feet
1"=15' 0' 15' 30'

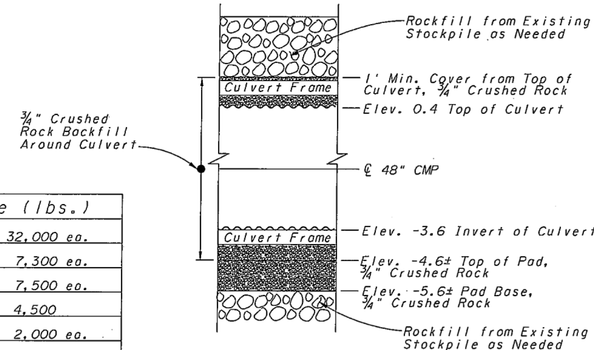
Graphics...00135.10 Permits TBP (11-2011) JD

Figure 4a
Old River Near Tracy Barrier
Plan

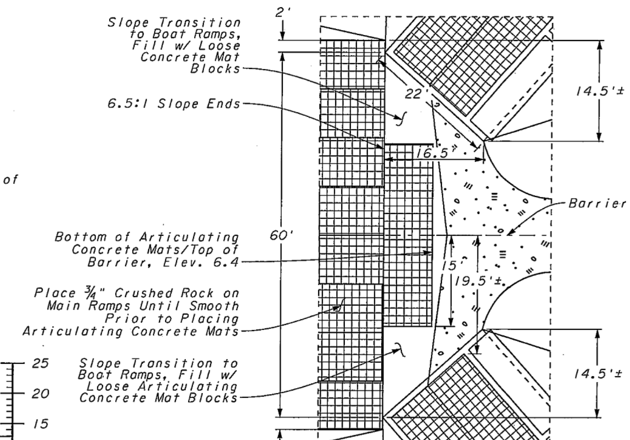


SECTION A-A
Scale: 1"=5'
Dwg. C4-1

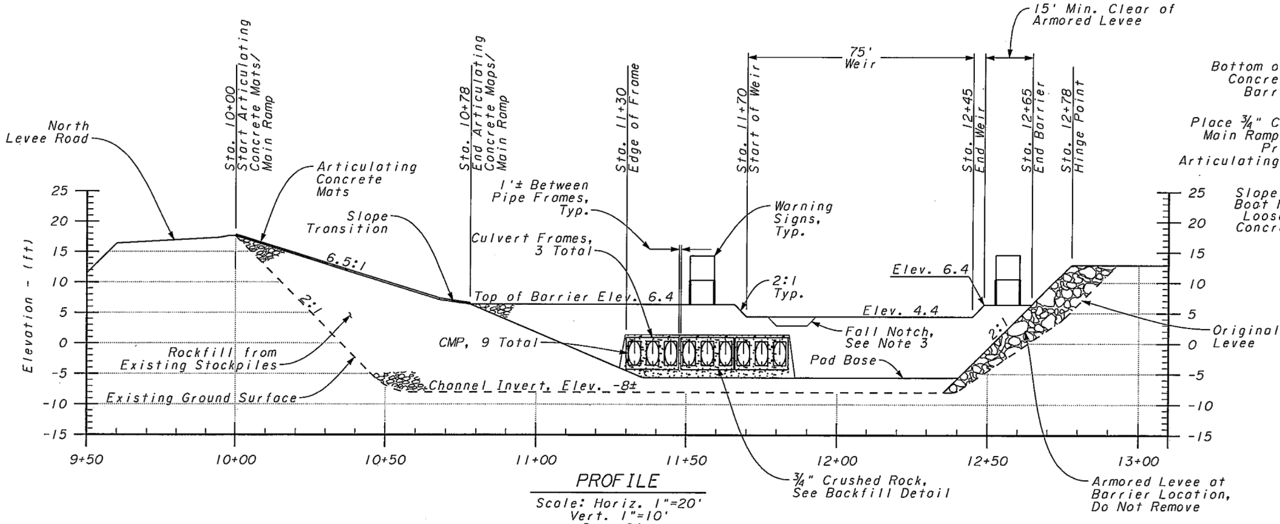
Weight Table (lbs.)	
Culvert Frame	32,000 ea.
Catwalk	7,300 ea.
Articulating Mats	7,500 ea.
Mat Spreader Bar	4,500
Docks	2,000 ea.
Dock Anchors	900 ea.



BACKFILL DETAIL
Not to Scale



RAMP DETAIL B
Scale: 1"=10'
Dwg. C4-1



PROFILE
Scale: Horiz. 1"=20'
Vert. 1"=10'
Dwg. C4-1

NOTES

1. All elevations are in feet and refer to NAVD88.
2. Abbreviations:
   M.H.H.W. - Mean High High Water
   M.L.L.W - Mean Low Low Water.
3. Fall Notch 10' wide, Elev. 2.9', Install as directed.
4. ¾" crushed rock pad to be leveled and tamped with an excavator bucket.

Scale of Feet
1"=20' 0' 10' 20' 40'
1"=5' 0' 5' 10'

Graphics...00135.10 Permits TBP (11-2011) JD

Figure 4b
Old River Near Tracy Barrier
Profile, Section and Details

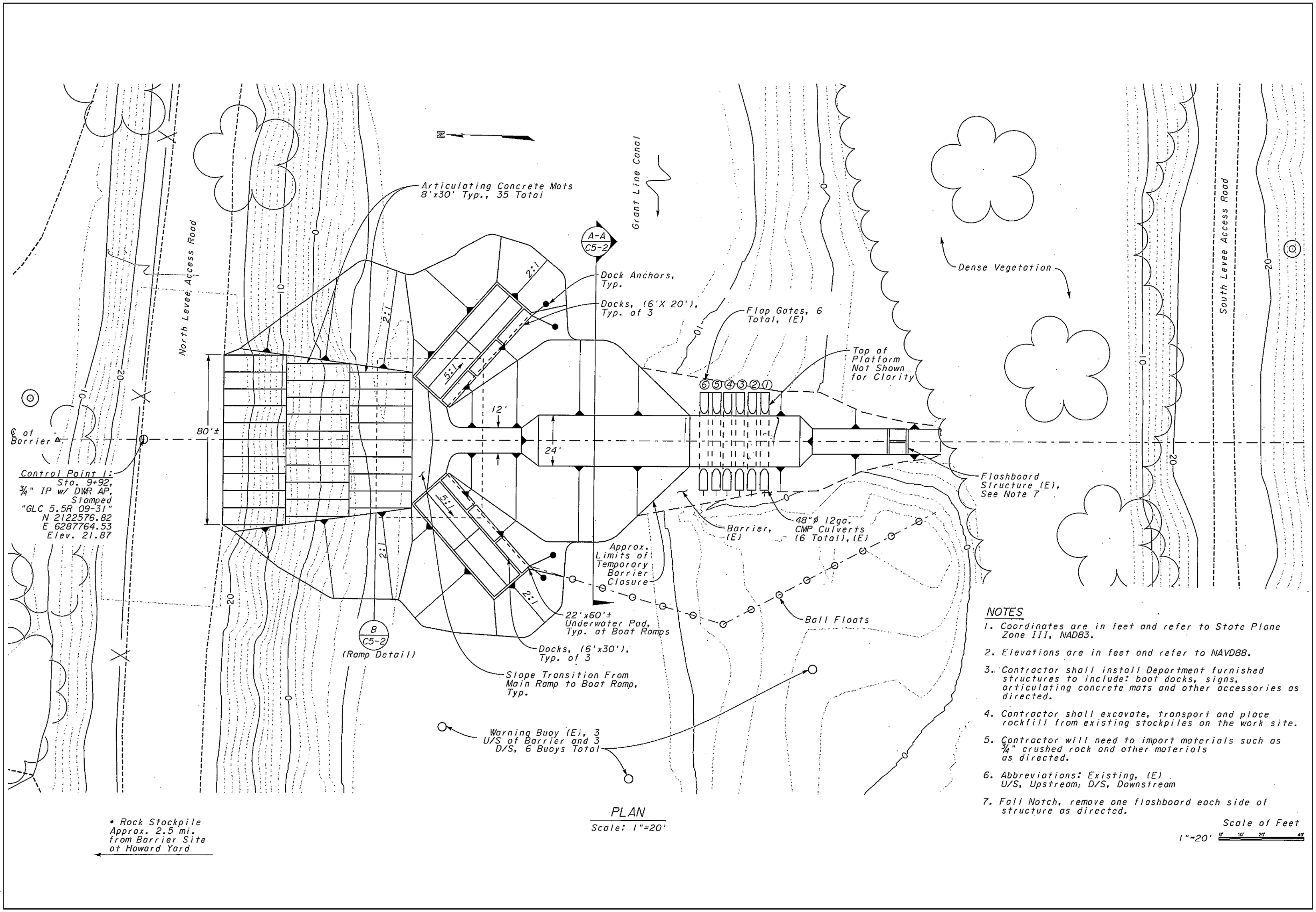
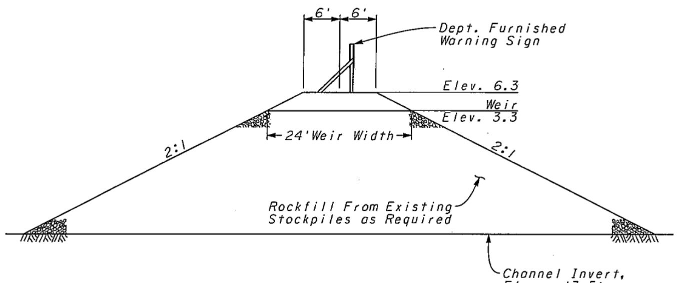
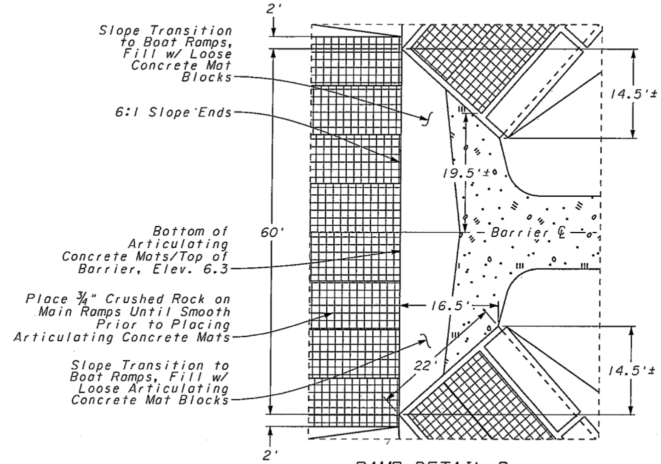


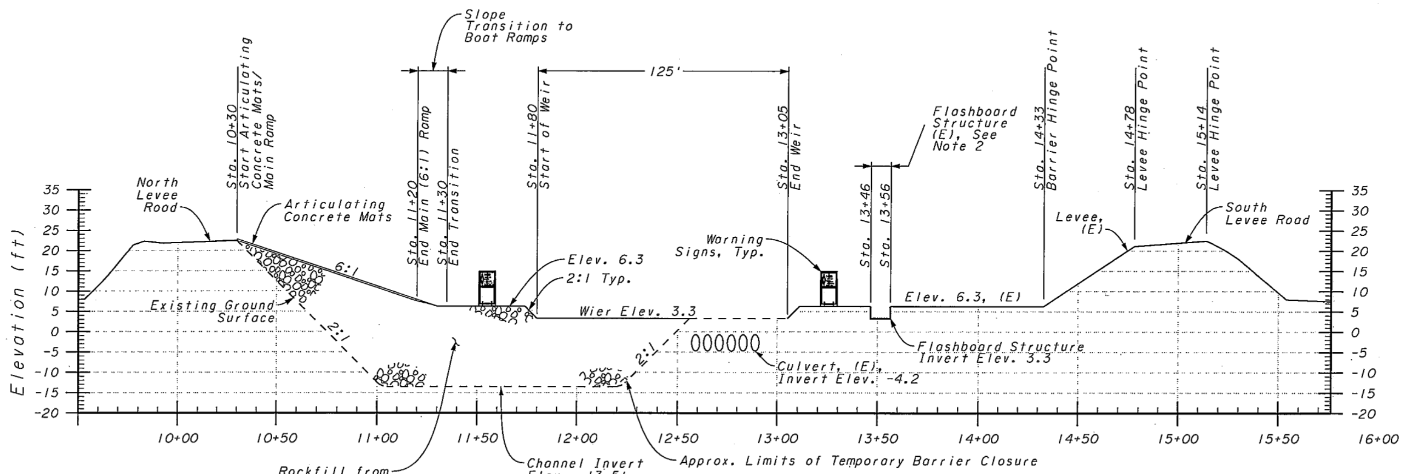
Figure 5a
Grant Line Canal Barrier
Plan



SECTION A-A
Scale: 1"=10'
Dwg. C5-1



RAMP DETAIL B
Scale: 1"=10'
Dwg. C5-1



PROFILE
Scale: Horiz. 1"=30'
Vert. 1"=15'
Dwg. C5-1

NOTES

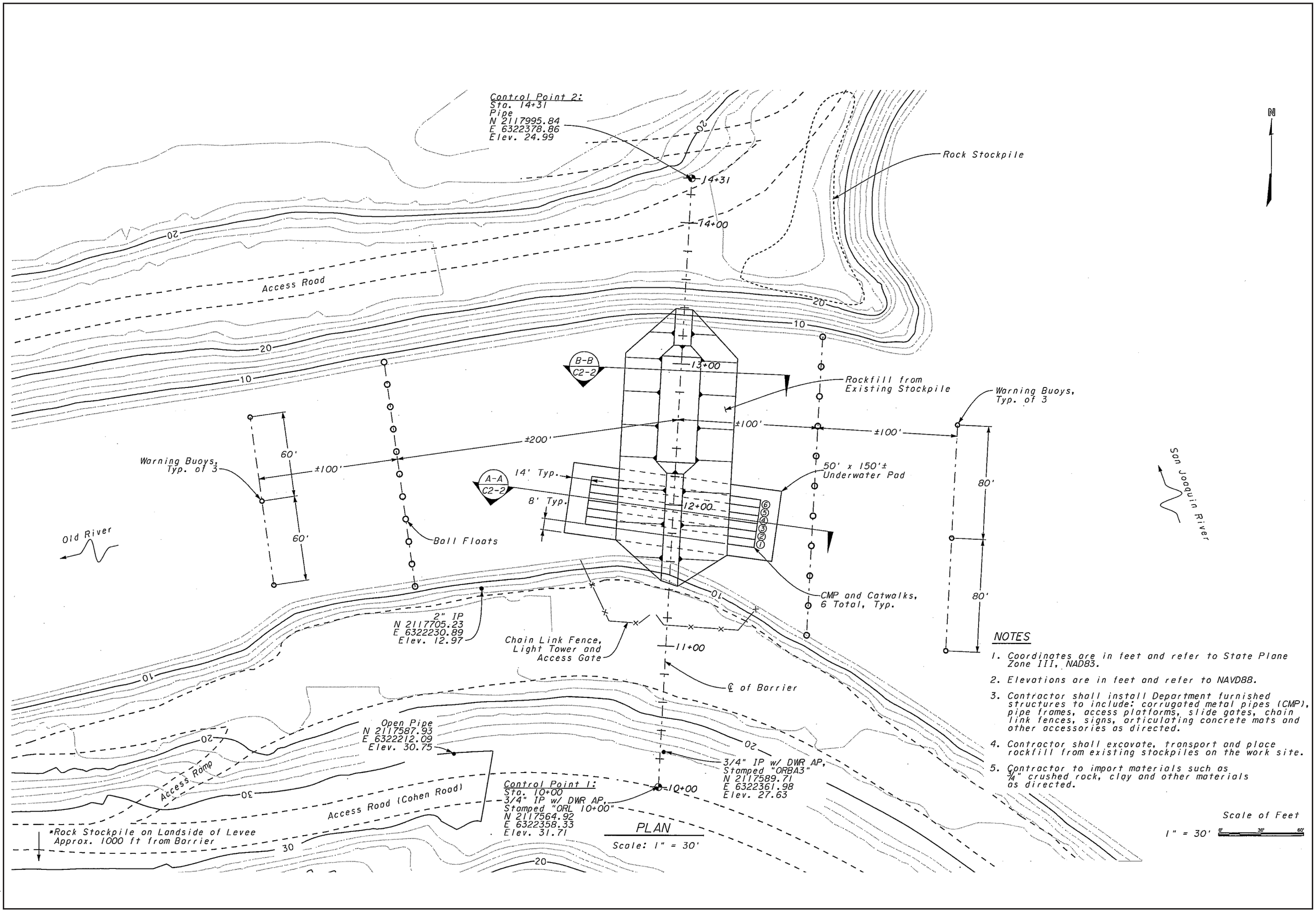
1. All elevations are in feet and refer to NAVD88.
2. Fall Notch, remove one flashboard each side, as directed.

Weight Table (lbs.)	
Articulating Mats	7,500 ea.
Mat Spreader Bar	4,500
Dock Sections	2,000 ea.
Dock Anchors	900 ea.

Scale of Feet
1"=10' 0' 10' 20'
1"=30' 0' 30' 60'

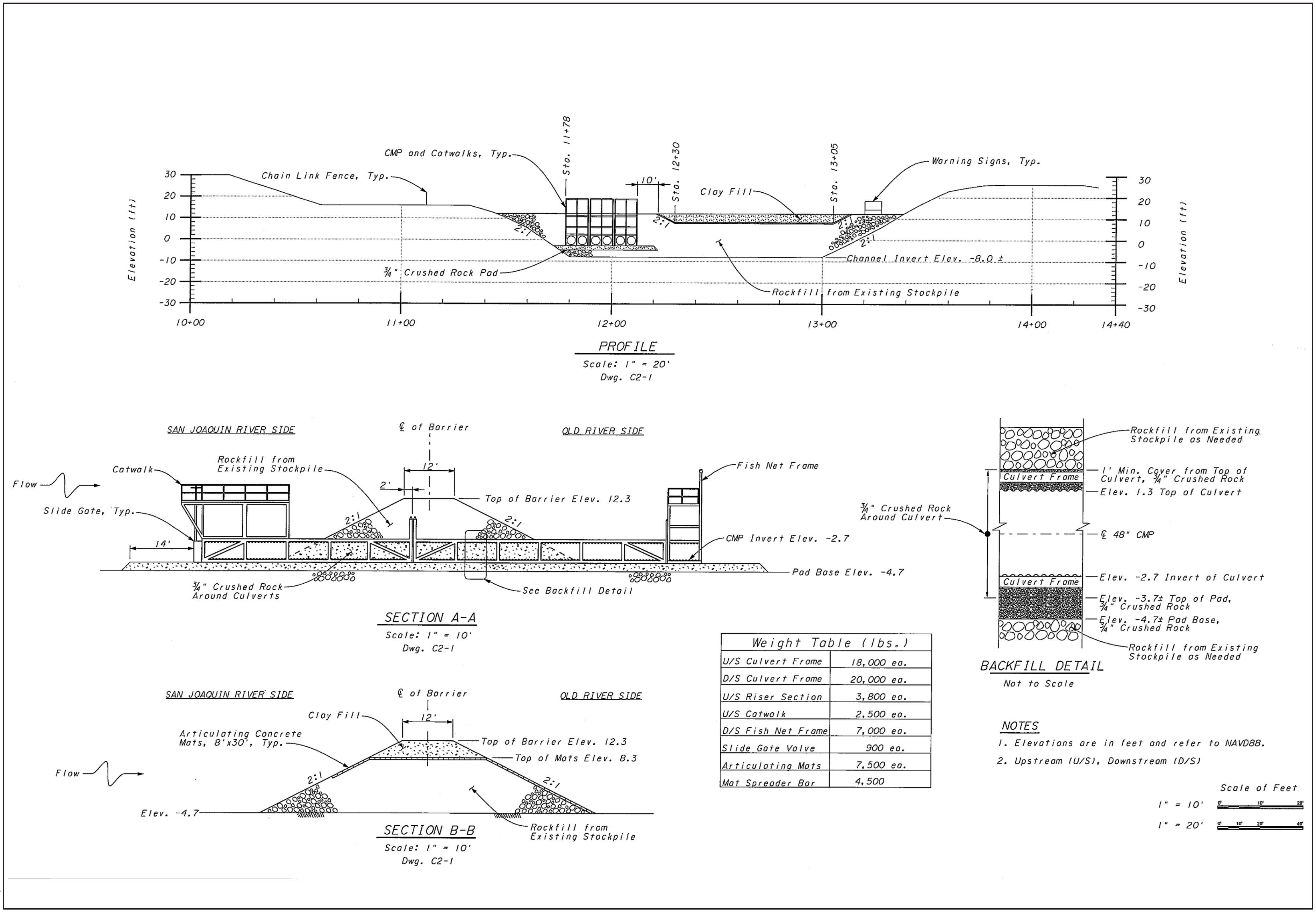
Graphics...00135.10 Permits TBP (11-2011) JD

Figure 5b
Grant Line Canal Barrier
Profile, Section and Details



Graphics... 00135.10 Permits TBP (11-2011) JD

Figure 6a
Head of Old River Barrier (Spring)
Plan



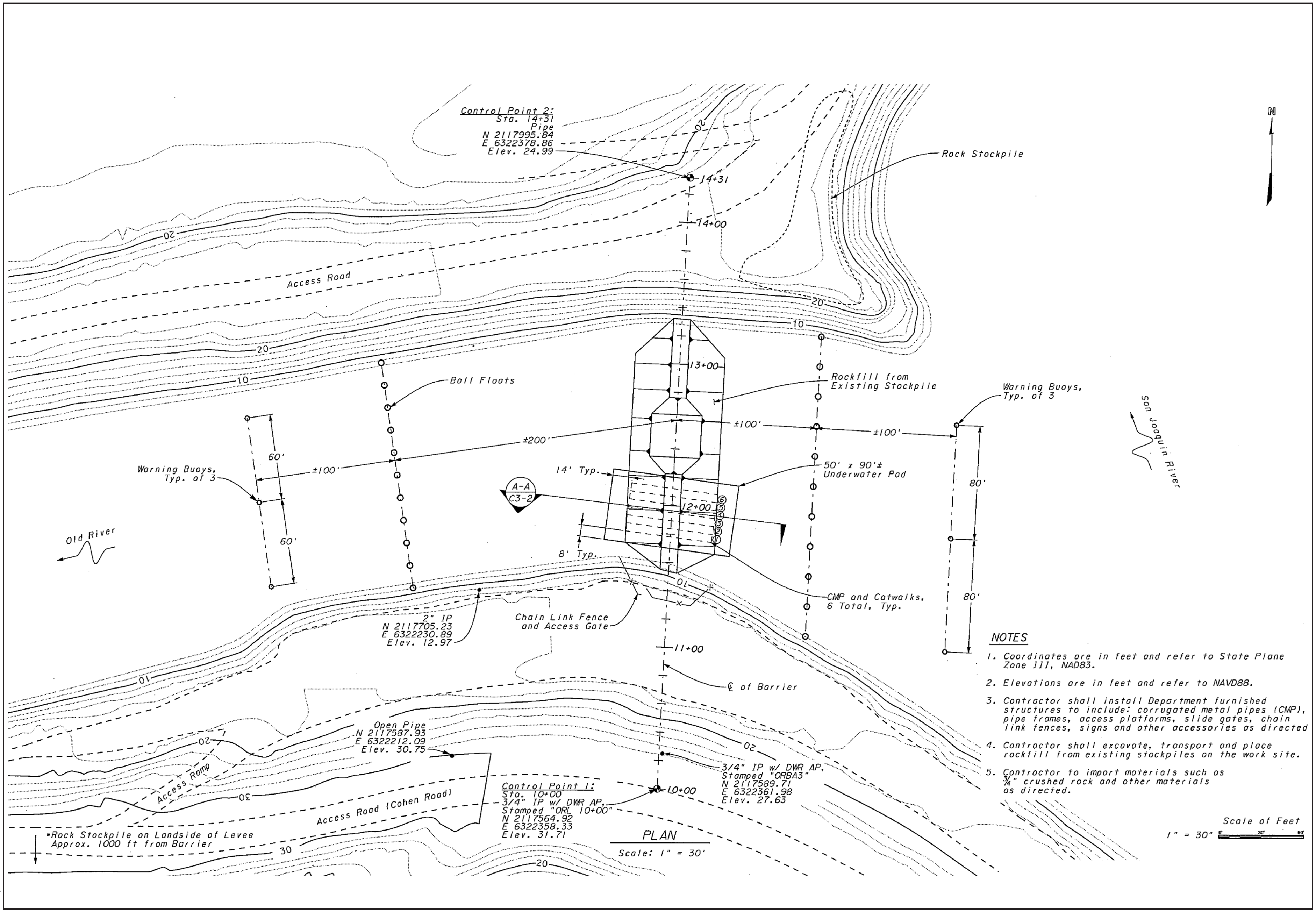
Weight Table (lbs.)	
U/S Culvert Frame	18,000 ea.
D/S Culvert Frame	20,000 ea.
U/S Riser Section	3,800 ea.
U/S Catwalk	2,500 ea.
D/S Fish Net Frame	7,000 ea.
Slide Gate Valve	900 ea.
Articulating Mats	7,500 ea.
Mat Spreader Bar	4,500

NOTES

1. Elevations are in feet and refer to NAVD88.
2. Upstream (U/S), Downstream (D/S)

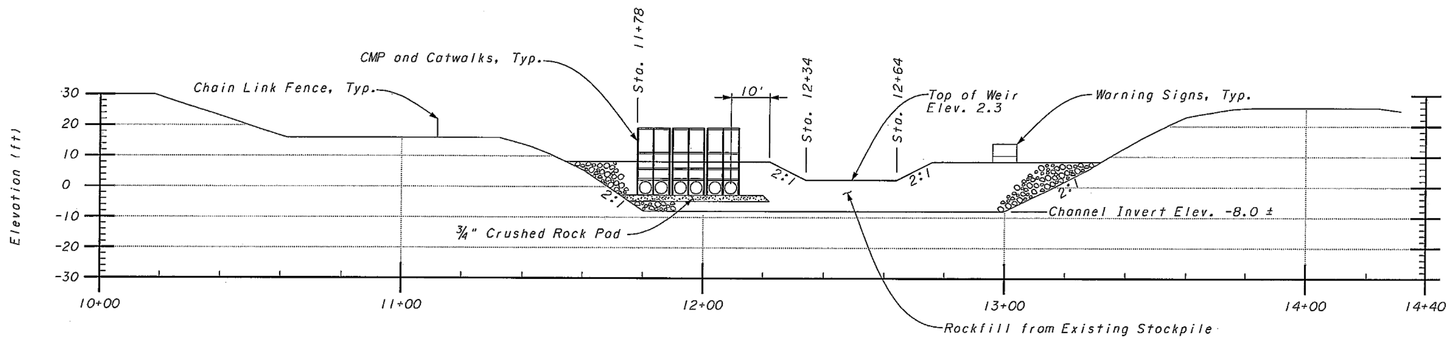
Figure 6b
Head of Old River (Spring)
Profile, Section and Details

Graphics... 00135.10 Permits TBP (11-2011) JD

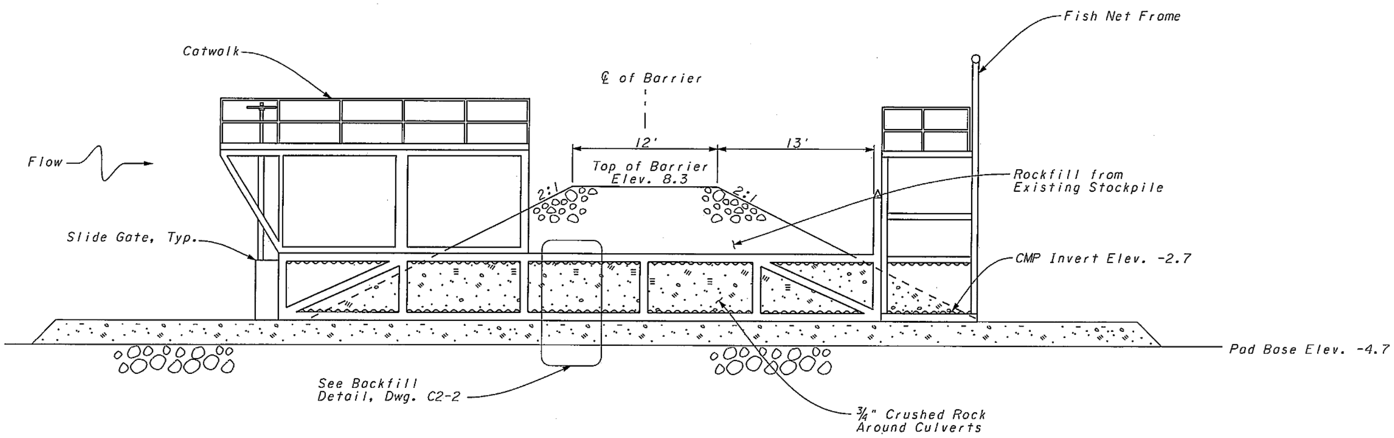


Graphics... 00135.10 Permits TBP (11-2011) JD

Figure 7a
Head of Old River Barrier (Fall)
Plan



PROFILE
Scale: 1" = 20'
Dwg. C3-1



SECTION A-A
Scale: 1" = 5'
Dwg. C3-1

SAN JOAQUIN RIVER SIDE

OLD RIVER SIDE

Weight Table (lbs.)	
U/S Culvert Frame	18,000 ea.
U/S Riser Section	3,800 ea.
U/S Catwalk	2,500 ea.
D/S Fish Net Frame	7,000 ea.
Slide Gate Valve	900 ea.
Articulating Mats	7,500 ea.
Mat Spreader Bar	4,500

NOTES

1. Elevations are in feet and refer to NAVD88.
2. Upstream (U/S), Downstream (D/S)

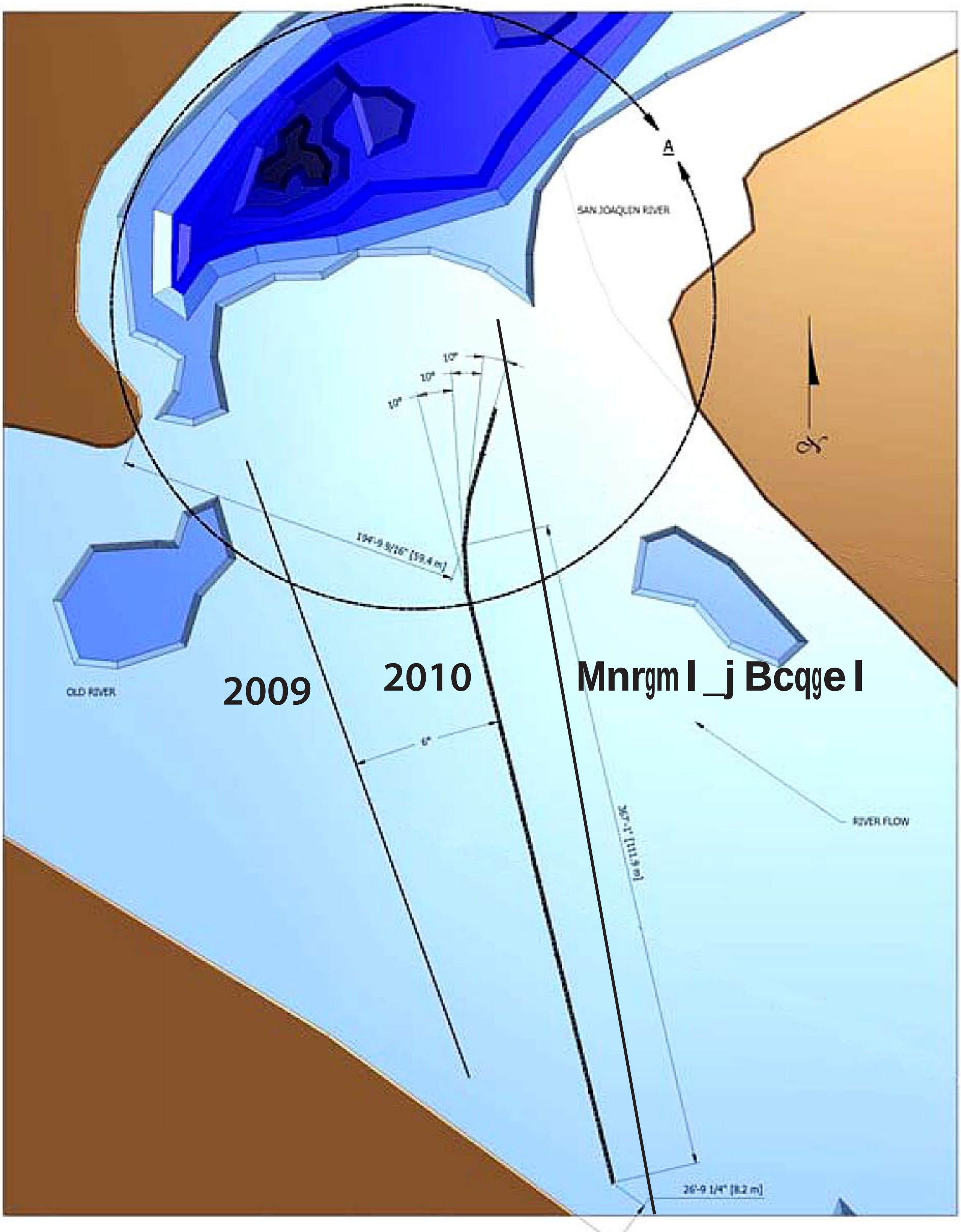
Scale of Feet

1" = 5'

1" = 20'

Graphics... 00135.10 Permits TBP (11-2011) JD

Figure 7b
Head of Old River (Fall)
Profile and Section



Graphics/Projects/00135.10 Permitting TBP (11-11) JD

Figure 8
2009, 2010 and Mnrgml_j Barrier Comparison

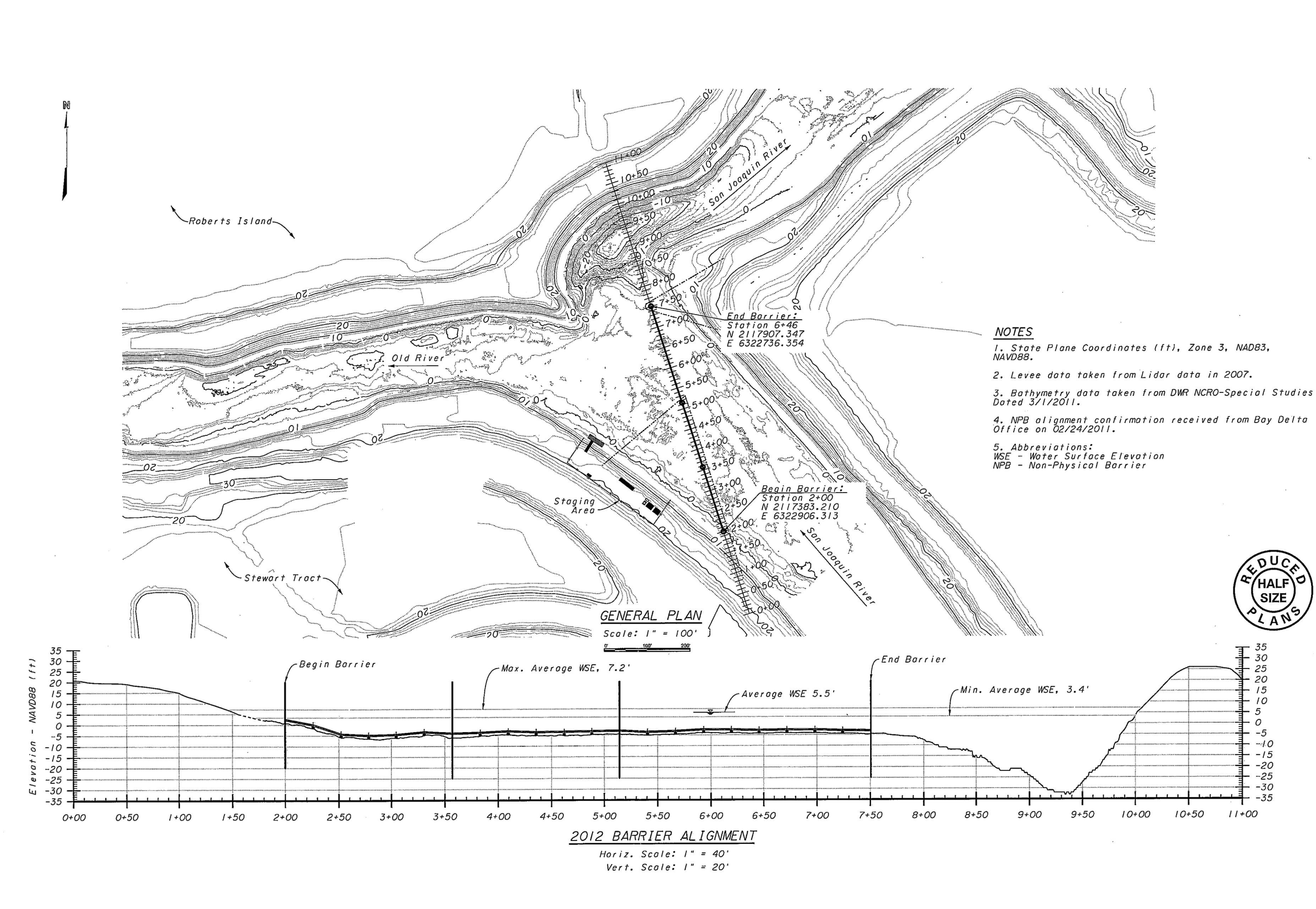
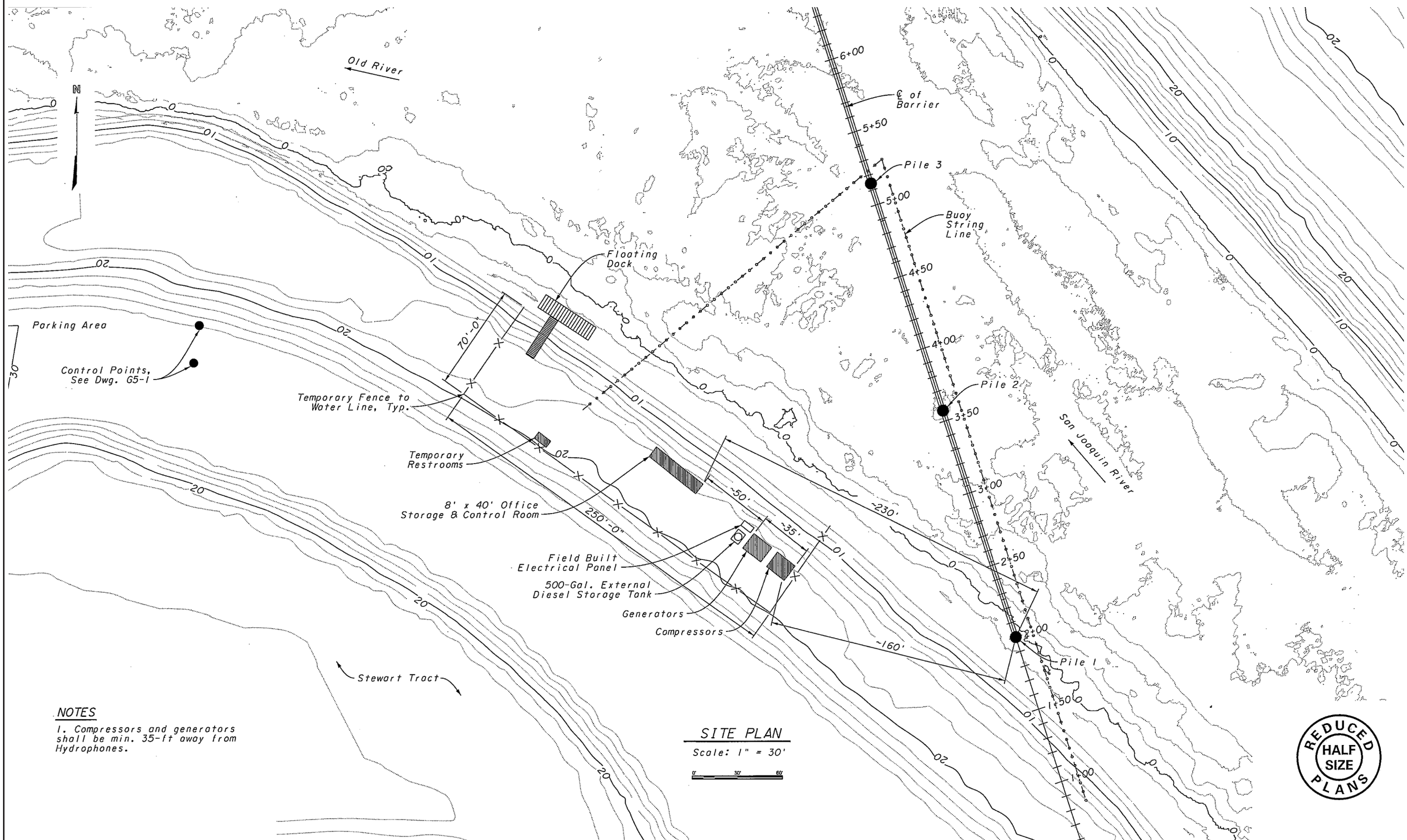
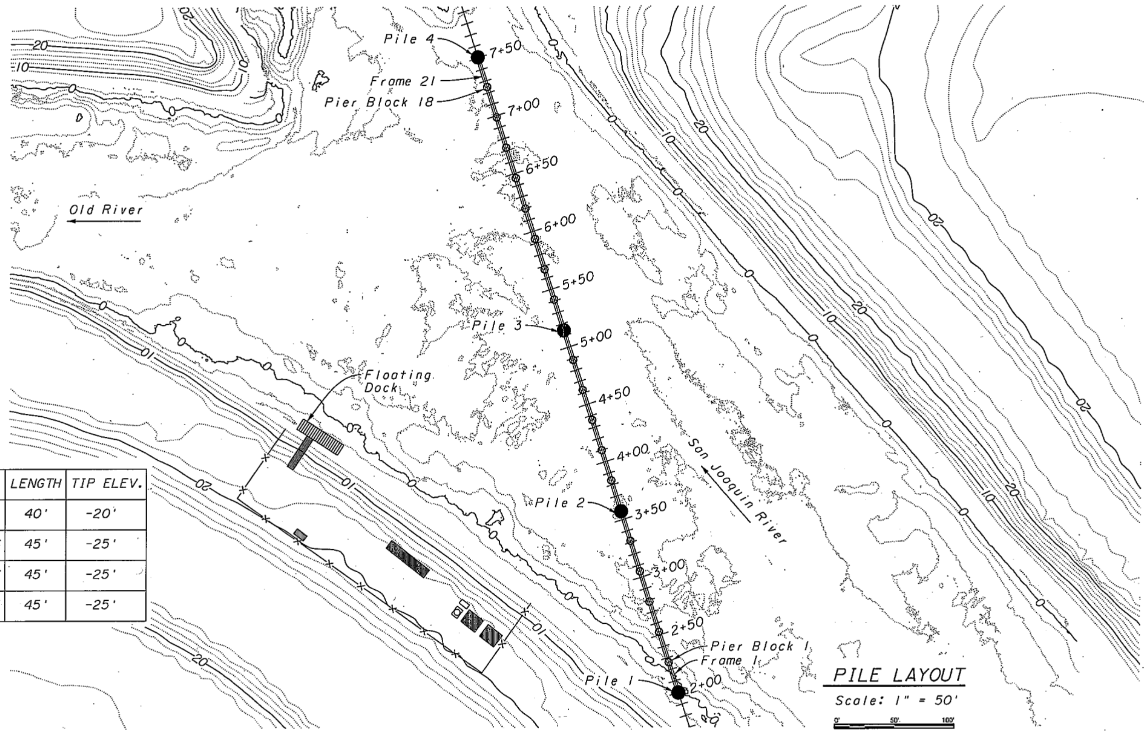


Figure 9a
Head of Old River Non-Physical Barrier
Plan and Profile



Graphics... 00135.10 Permits TPB (11-2011) JD

Figure 9b
Head of Old River Non-Physical Barrier
Staging Area - Plan



PILE No.	STATION	NORTHING	EASTING	LENGTH	TIP ELEV.
1	2+00.0	2117383.21	6322906.31	40'	-20'
2	3+57.0	2117532.50	6322857.86	45'	-25'
3	5+14.4	2117682.27	6322809.26	45'	-25'
4	7+50.6	2117906.92	6322736.35	45'	-25'

NOTES

1. State Plane Coordinates (ft), Zone 3, NAD83, NAVD88.

2. Pile Material Specifications:
Pipe 8 Std.: fy=35ksi; O.D. 8.625"; t=0.322; ASTM A53

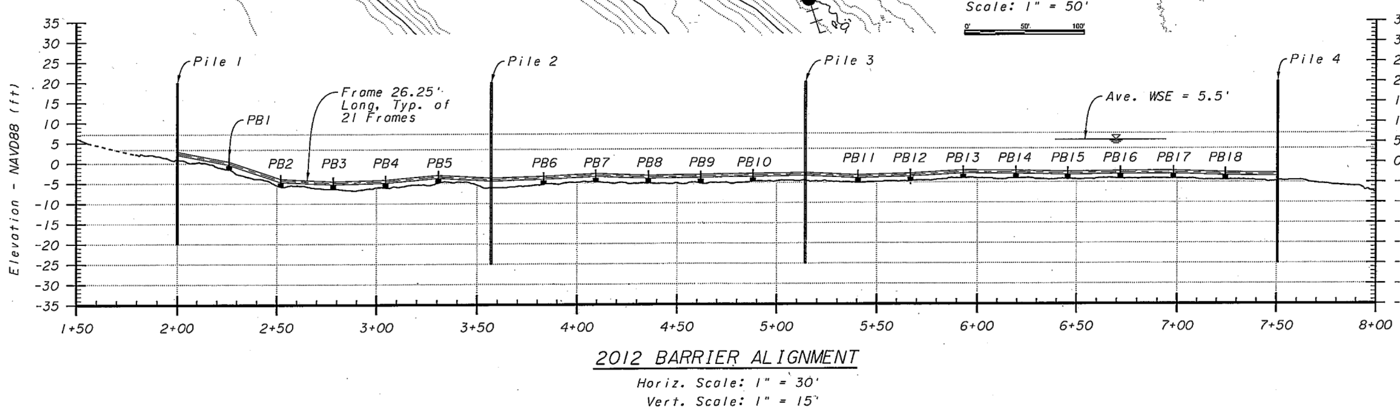
3. Pier blocks to be located between adjoining frames, except where pile is located.

4. Data collected from CDEC station "OHI" and analyzed from April-May of 2010:

Flow Range:
Minimum 1200 cfs
Maximum 3748 cfs

Stage Data:
Max WSE= 7.2'
Min WSE= 3.4'
Ave Max WSE= 5.9'
Ave Min WSE= 5.1'5.

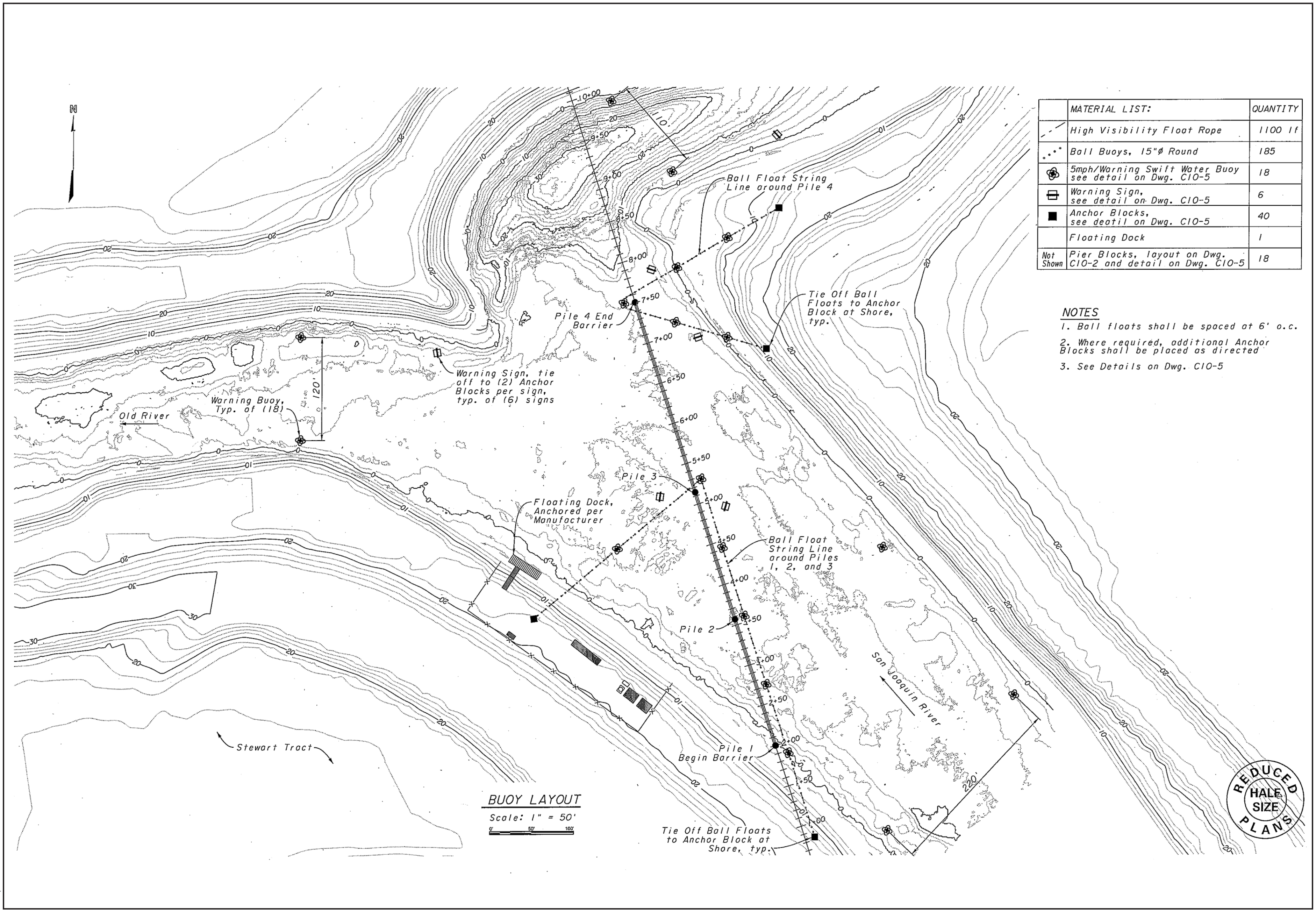
5. Abbreviations:
PB - Pier Block
ASTM - American Society for Testing & Materials
WSE - Water Surface Elevation
O.D. - Outside Diameter
t - Thickness



REDUCED PLANS HALF SIZE

Graphics... 00135.10 Permits TPB (11-2011) JD

Figure 9c
Head of Old River Non-Physical Barrier
Pile and Pier Block Layout - Plan and Profile



	MATERIAL LIST:	QUANTITY
	High Visibility Float Rope	1100 lf
	Ball Buoys, 15"Ø Round	185
	5mph/Warning Swift Water Buoy see detail on Dwg. C10-5	18
	Warning Sign, see detail on Dwg. C10-5	6
■	Anchor Blocks, see deatil on Dwg. C10-5	40
	Floating Dock	1
Not Shown	Pier Blocks, layout on Dwg. C10-2 and detail on Dwg. C10-5	18

NOTES
1. Ball floats shall be spaced at 6' o.c.
2. Where required, additional Anchor Blocks shall be placed as directed
3. See Details on Dwg. C10-5

Figure 9d
Head of Old River Non-Physical Barrier
Buoy Layout - Plan

Graphics... 00135.10 Permits TPB (11-2011) JD

Supplier	MATERIAL LIST:	QUANTITY
Cal-Neva	Sound Projector Cable 12GA / 3C	3135' (Total)
	Line 1, Frames 1-2	226'
	Line 2, Frames 3-4	223'
	Line 3, Frames 5-6	232'
	Line 4, Frames 7-8	178'
	Line 5, Frames 9-10	206'
	Line 6, Frames 11-12	263'
	Line 7, Frames 13-14	285'
	Line 8, Frames 15-16	310'
	Line 9, Frames 17-18	359'
	Line 10, Frames 19-20	413'
	Line 11, Frame 21	440'
Cal-Neva	Intense Light Power Cable 6GA / 3C	932' (Total)
	Line 1, Frames 1-6	156'
	Line 2, Frames 7-12	156'
	Line 3, Frames 13-18	235'
	Line 4, Frames 19-21	385'
OVIVO	Intense Light Signal Cable (no specification provided)	840' (Total)

CABLE NOTES

1. All cable lengths are measured as shown on the drawing from the barrier to the control room.

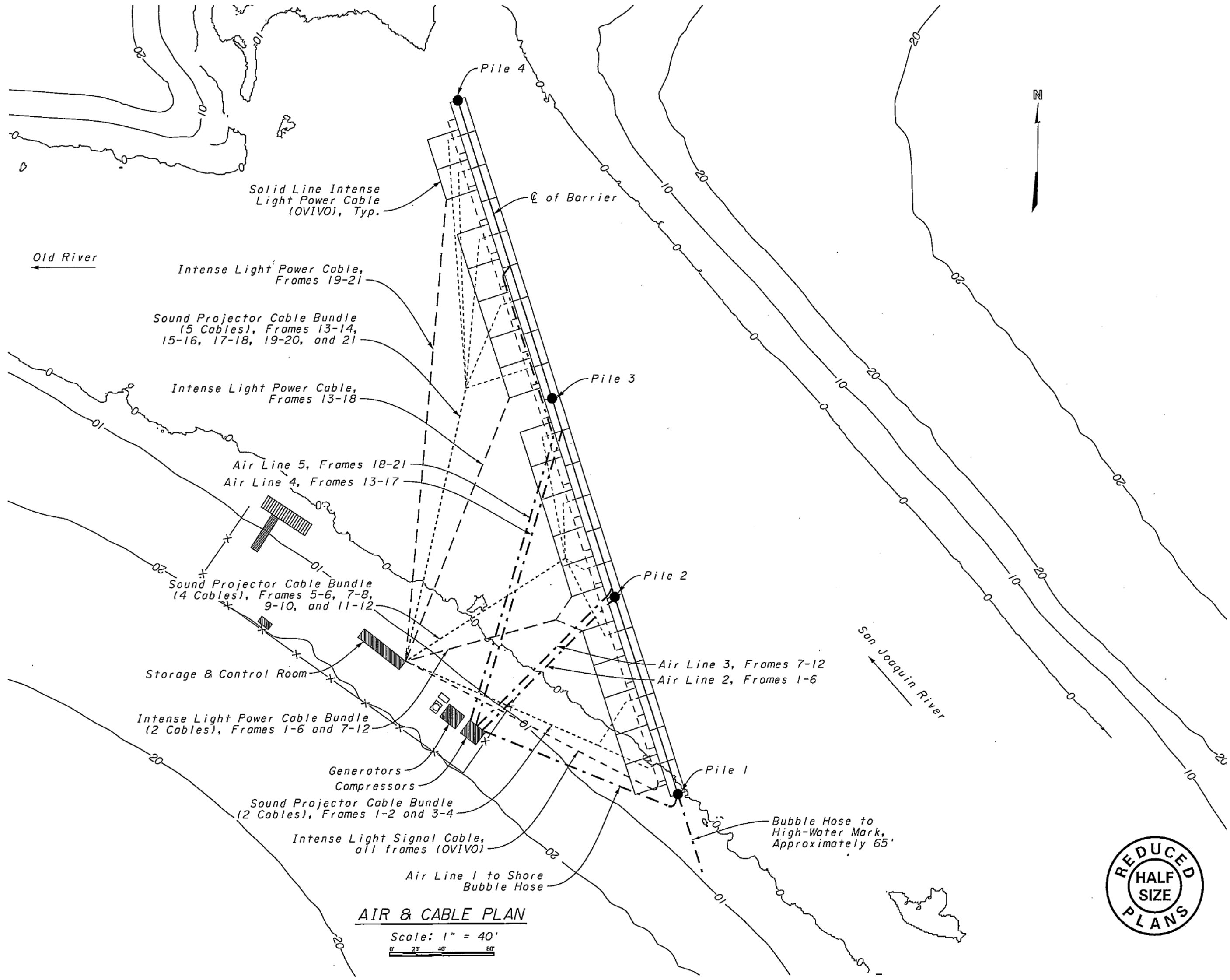
3. Approximate distance from control room to pile 1 is shown on Dwg. C10-1.

4. Intense Light Signal Cable is suppled by OVIVO Water. Intense Light Signal Cable Length from Control Room to Start of barrier is Approximately 220' as shown.

Supplier	MATERIAL LIST:	QUANTITY
Cal-Neva	2" PVC, Schedule 40	1159' (Total)
	Line 1, Pile 1 to shore	185'
	Line 2, Frames 1-6	161'
	Line 3, Frames 7-12	163'
	Line 4, Frames 13-17	255'
	Line 5, Frames 18-21	395'

PVC NOTES

1. All PVC lengths are measured as shown on the drawing from the barrier to the compressor.



Graphics... 00135.10 Permits TPB (11-2011) JD

Figure 9e
Head of Old River Non-Physical Barrier
Air and Cable Schematic - Plan

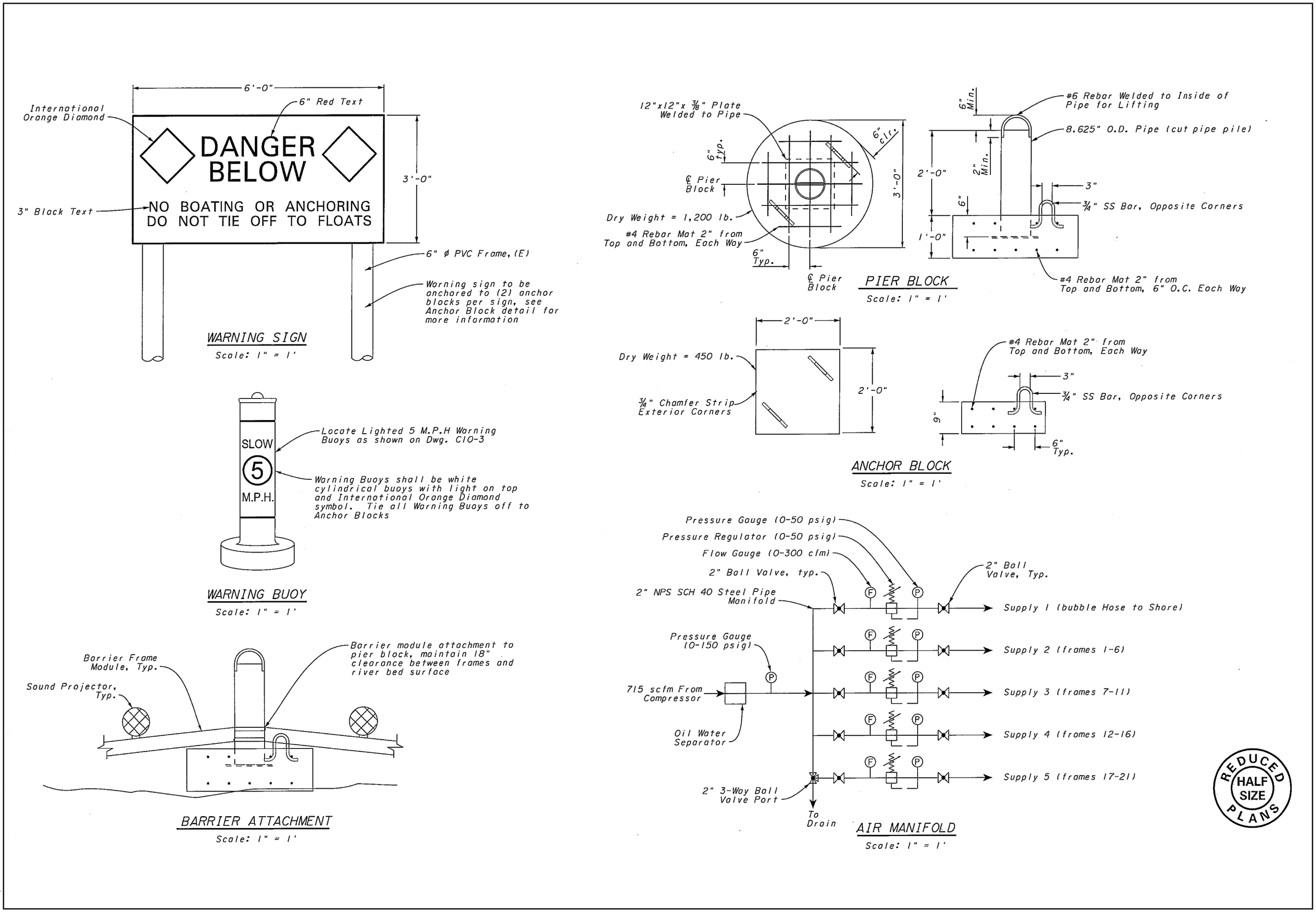


Figure 9f
Head of Old River Non-Physical Barrier
Pier and Anchor Blocks, Signs, and Buoy - Detail

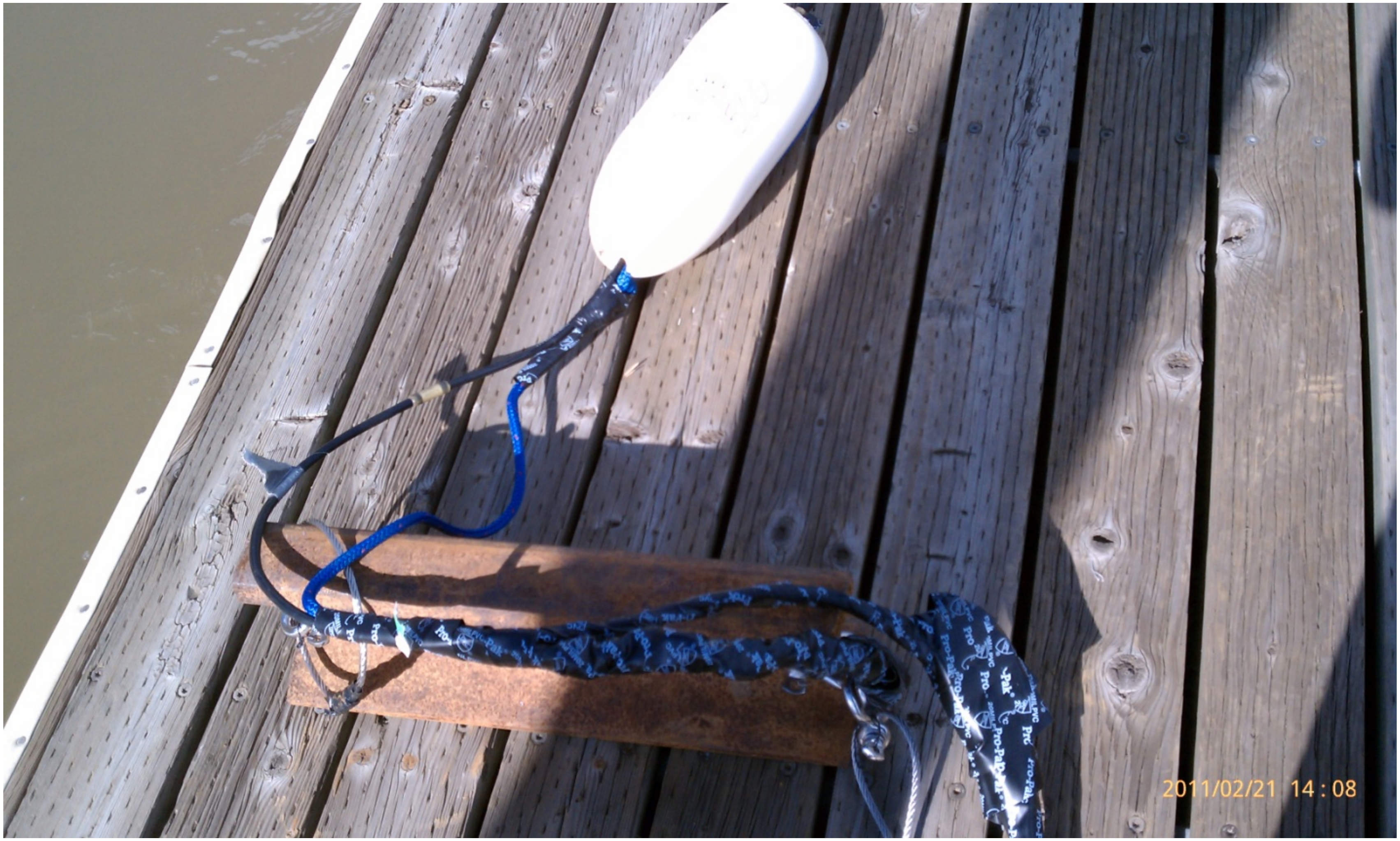


Figure 10: Photo of a railroad track anchor, line and buoy setup used to deploy a hydrophone.

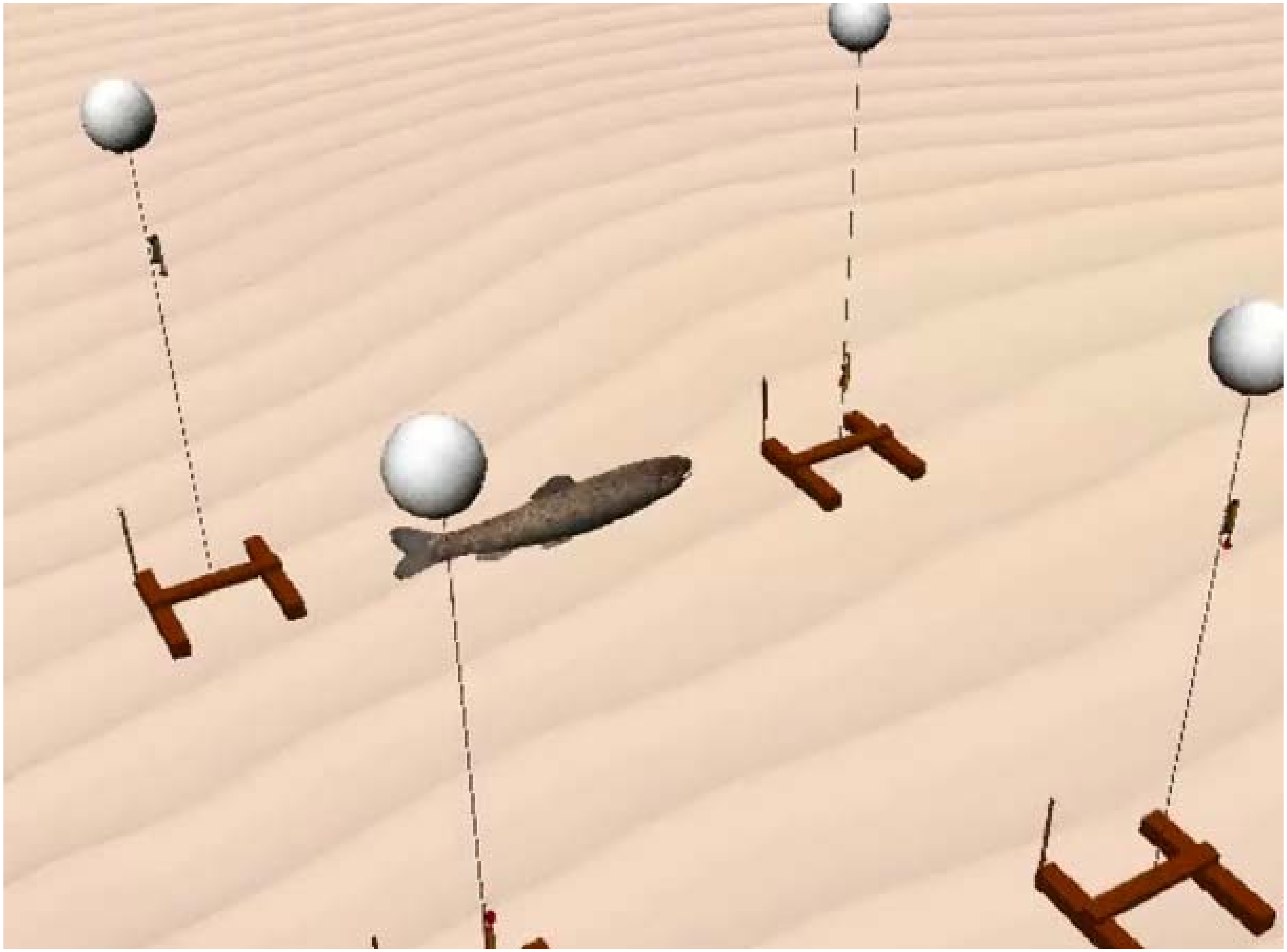


Figure 11: Example of hydrophone bottom mounts with tensioned lines used for the 2-D hydroacoustic study and the HOR.

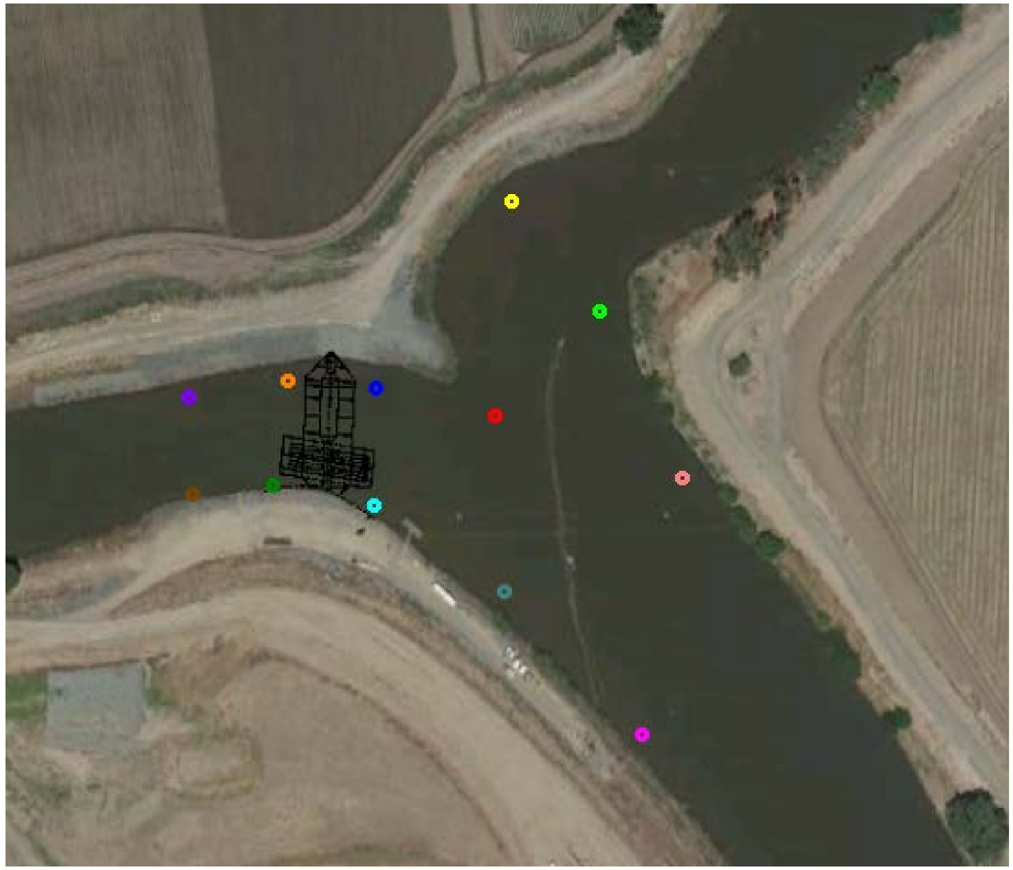


Figure 12: Example of hydrophone layout for a 2-D array around the HOR barrier.

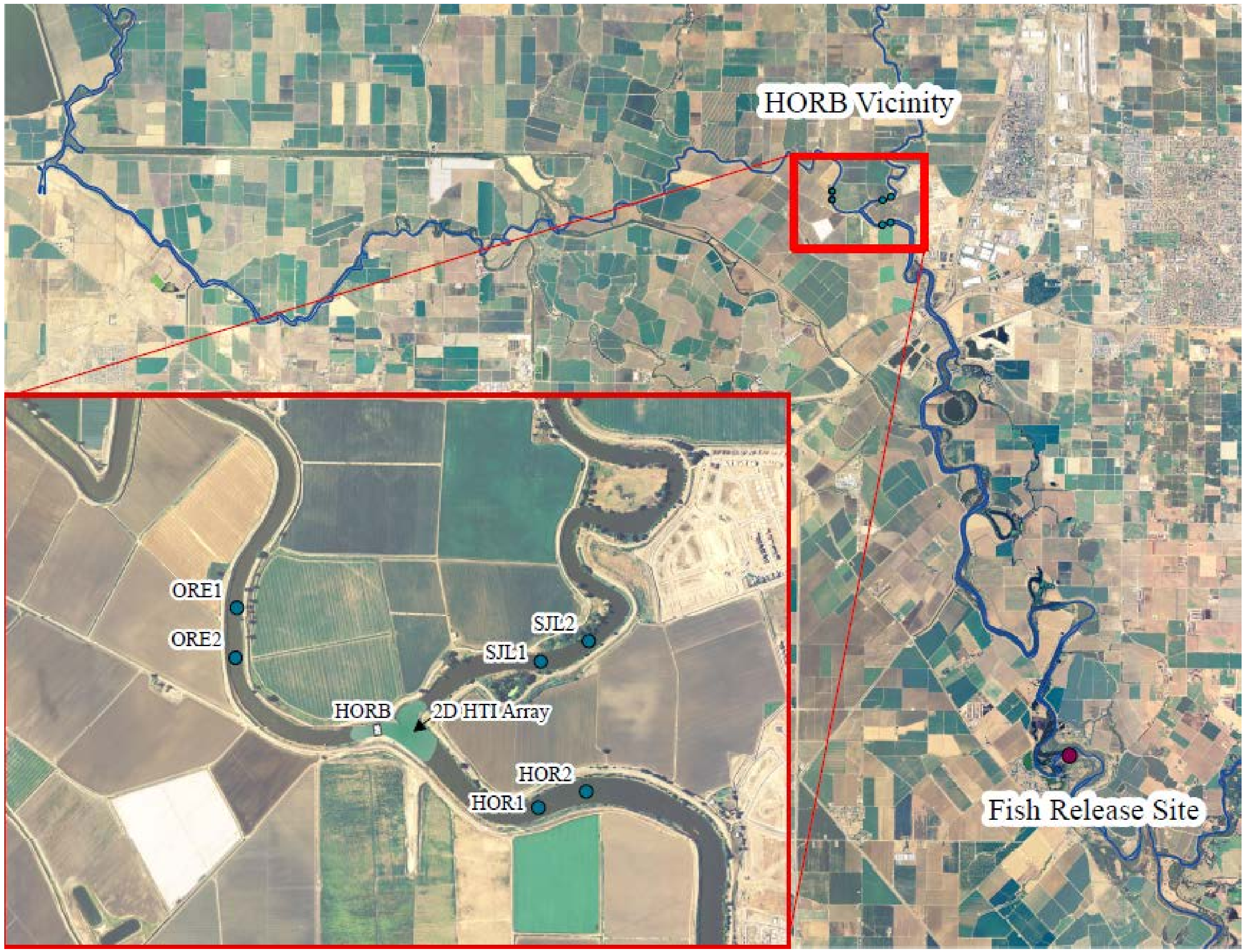


Figure 13: Example of peripheral node placement around the HORB showing a potential upstream tagged salmonid smolt release site.

APPENDIX B: HISTORICAL TBP SCHEDULE DATA

Year	Old River near Tracy (ORT)						
	Installation			Notched	Removal		
	Started	Closed	Completed		Started	Breached	Completed
1987							
1988							
1989							
1990							
1991	14-Aug		30-Aug		28-Sep		13-Oct (i)
1992	15-Apr boat port on		01-May 09-May boat port on		30-Sep		09-Oct (ii)
1993	12-May		1-Jun		27-Sep		6-Oct
1994	22-Apr boat port on All culverts tied open (5/18-6/1)		April-24 May-01		26-Sep		10-Oct
1995	3-Aug		8-Aug		27-Sep		6-Oct
1996	12-May		10-Jun (iii)		29-Sep		16-Oct
1997	8-Apr		17-Apr		30-Sep		7-Oct
1998	(vii)						
1999	15-May		28-May		28-Sep		8-Oct
2000	4-Apr		16-Apr		1-Oct		7-Oct
2001	23-Apr		26-Apr		13-Nov	14-Nov	26-Nov
2002	1-Apr		18-Apr		16-Nov	16-Nov	29-Nov
2003	1-Apr	14-Apr	22-Apr	17-Sep	13-Nov	15-Nov	25-Nov
2004	1-Apr	15-Apr	20-Apr	10-Sep	8-Nov	8-Nov	1-Dec
2005	9-May	31-May	6-Jun	15-Sep	8-Nov	10-Nov	30-Nov
2006	7-Jul	17-Jul	31-Jul	1-Oct	13-Nov	16-Nov	8-Dec
2007	2-Apr	18-Apr	23-Apr	21-Sep	5-Nov	7-Nov	18-Nov
2008	12-May	4-Jun	19-Jun	10-Sep	3-Nov	4-Nov	25-Nov
2009	18-May	23-Jun	3-Jul	12-Sep	2-Nov	4-Nov	19-Nov
2010	10-May	3-Jun	8-Jun	15-Sep	19-Oct	20-Oct	4-Nov
2011	27-May	10-Jun	15-Jun	15-Sep	10-Oct	11-Oct	31-Oct
2012	15-Mar	31-Mar	6-Apr				

Year	Spring Head of Old River					
	Installation			Removal		
	Started	Closed	Completed	Started	Breached	Completed
1987						
1988						
1989						
1990						
1991						
1992	15-April boat port on		23-April @ 4 ft 26-April @ 6 ft 01-May	02-Jun		08-Jun
1993						
1994	21-April boat port on		23-April @ 10 ft 01-May	18-May		20-May
1995			(vii)			
1996	6-May		11-May	16-May		03-Sep (iv)
1997	9-Apr		16-Apr	15-May		19-May
1998	(vii)					
1999	(vii)					
2000	5-Apr		16-Apr	19-May		2-Jun
2001	17-Apr		6-Apr	23-May		30-May
2002	2-Apr		18-Apr	22-May	24-May	7-Jun
2003	1-Apr	15-Apr	21-Apr	16-May	18-May	3-Jun
2004	1-Apr	15-Apr	21-Apr	19-May	24-May	10-Jun
2005	(xi)	(xi)	(xi)	(xi)	(xi)	(xi)
2006	(xi)	(xi)	(xi)	(xi)	(xi)	(xi)
2007	11- Apr	20- Apr	26- Apr	19- May	22- May	6- Jun
2008	(xiv)	(xiv)	(xiv)	(xiv)	(xiv)	(xiv)
2009	(xv)	(xv)	(xv)	(xv)	(xv)	(xv)
2010	5-Apr (xv)	(xv)	16-Apr (xv)	(xv)	(xv)	(xv)
2011	(xvii)	(xvii)	(xvii)	(xvii)	(xvii)	(xvii)
2012	15-Mar	1-Apr	11-Apr	-	-	-

Year	Fall Head of Old River (v)						
	Installation			Notched	Removal		
	Started	Closed	Completed		Started	Breached	Completed
1968(ix)	30-Sep		3-Oct		15-Nov		21-Nov
1969							
1970	1-Oct		6-Oct		13-Nov		14-Nov
1971	24-Sep		1-Oct		8-Nov		12-Nov
1972	25-Sep		29-Sep		7-Nov		10-Nov
1973	1-Oct		5-Oct		14-Nov		15-Nov
1974	12-Sep		18-Sep		1-Nov		9-Nov
1975	17-Sep		26-Sep		1-Nov		4-Nov
1976	28-Oct		1-Nov		22-Nov		23-Nov
1977			27-Oct				5-Dec
1978							
1979			1-Oct				29-Nov
1980							
1981			15-Oct				25-Nov
1982							
1983							
1984	5-Sep		8-Sep				19-Oct
1985							
1986							
1987	9-Sep		11-Sep				28-Nov
1988	22-Sep		28-Sep				2-Dec
1989	27-Sep		28-Sep		27-Nov		30-Nov
1990	10-Sep		11-Sep				27-Nov
1991	9-Sep		13-Sep		22-Nov		27-Nov
1992	8-Sep		11-Sep		30-Nov		4-Dec
1993	08-Nov (vi)		11-Nov		3-Dec		7-Dec
1994	6-Sep		8-Sep		28-Nov		30-Nov
1995	(vii)						
1996	30-Sep		3-Oct		18-Nov		22-Nov
1997							
1998	(vii)						
1999	(viii)						
2000	27-Sep		7-Oct		27-Nov		8-Dec
2001	24-Sep		6-Oct		22-Nov	22-Nov	2-Dec
2002	24-Sep		4-Oct		11-Nov	12-Nov	21-Nov
2003	2-Sep	15-Sep	18-Sep	16-Sep	3-Nov	4-Nov	13-Nov
2004	7-Sep	27-Sep	29-Sep	28-Sep	1-Nov	2-Nov	12-Nov
2005	19-Sep	28-Sep	30-Sep	29-Sep	7-Nov	8-Nov	15-Nov
2006	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)
2007	5-Oct	17-Oct	18-Oct	18-Oct	9-Nov	10-Nov	29-Nov
2008	1-Oct	16-Oct	16-Oct	16-Oct	3-Nov	3-Nov	9-Nov
2009	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)
2010	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)
2011	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)	(xiii)
2012	-	-	-		-	-	-

Year	Middle River						
	Installation			Notched	Removal		
	Started	Closed	Completed		Started	Breached	Completed
1987			15-May		End of Sep		End of Sep
1988	26-May		28-May		23-Sep		23-Sep
1989			12-Apr		26-Sep		26-Sep
1990			16-Apr		29-Sep		29-Sep
1991	4-Apr		5-Apr		27-Sep		27-Sep
1992	8-Apr		10-Apr		28-Sep		29-Sep
1993	14-Jun		17-Jun		23-Sep		24-Sep
1994	23-Apr		25-Apr		29-Sep		5-Oct
1995	8-Aug		11-Aug		10-Oct		10-Oct
1996	18-May		20-May		29-Sep		29-Sep
1997	3-Apr		7-Apr		27-Sep		28-Sep
1998	(vii)						
1999	15-May		18-May		29-Sep		2-Oct
2000	4-Apr		6-Apr		1-Oct		7-Oct
2001	20-Apr		23-Apr		12-Nov	18-Nov	17-Nov
2002	10-Apr		15-Apr		20-Nov	20-Nov	23-Nov
2003	12-Apr	15-Apr	23-Apr	17-Sep	7-Nov	8-Nov	10-Nov
2004	9-Apr	12-Apr	13-Apr	23-Sep	9-Nov	10-Nov	12-Nov
2005	10-May	12-May	17-May	15-Sep	7-Nov	8-Nov	9-Nov
2006	5-Jul	7-Jul	8-Jul	1-Oct	17-Nov	18-Nov	20-Nov
2007	7-Apr	10-Apr	10-Apr	21-Sep	19-Nov	20-Nov	29-Nov
2008	19-May	21-May	23-May	10-Sep	5-Nov	5-Nov	9-Nov
2009	19-May	19-Jun	14-Jul	12-Sep	16-Nov	17-Nov	19-Nov
2010	18-May	24-May	24-May	15-Sep	28-Oct	28-Oct	2-Nov
2011	1-Jun	6-Jun	6-Jun	15-Sep	10-Oct	11-Oct	18-Oct
2012	12-Mar	16-Mar	17-Mar				

Year	Grant Line Canal							
	Installation			Removal				
	Started	Closed	Completed	Flashboards Adjusted (x)	Notched	Started	Breached	Completed
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996	17-Jun		10-Jul			2-Oct		15-Oct
1997	21-May		4-Jun			26-Sep		15-Oct
1998	(vii)							
1999	15-May		3-Jun			23-Sep		5-Oct
2000	19-May		1-Jun			1-Oct		7-Oct
2001	2-May		6-May			11-Nov	12-Nov	18-Nov
2002	1-Apr		12-Jun			14-Nov	16-Nov	25-Nov
2003	1-Apr (Partial) 9-Jun (Full)	11-Jun	23-Apr (Partial) 17-Jun (Full)	16-Sep		10-Nov	13-Nov	25-Nov
2004	1-Apr (Partial) 2-Jun (Full)	9-Apr (Partial) 5-Jun (Full)	28-Apr (Partial) 9-Jun (Full)	9-Sep		11-Nov	12-Nov	6-Dec
2005	2-May (xii)	14-Jul	18-Jul	14-Jul & 14-Sep		7-Nov	15-Nov	30-Nov
2006	7-Jul (xii)	20-Jul	26-Jul	20-Jul & 1-Oct		14-Nov	21-Nov	6-Dec
2007	9-Apr (Partial) 27-Apr (Full)	17-Apr (Partial) 10-May (Full)	17-Apr (Partial) 11-May (Full)	17-Apr (Partial) 10-May (Full)	21-Sep	6-Nov	8-Nov	29-Nov
2008	19-May (Partial) 23-May (Full)	2-Jun (Partial) 26-Jun (Full)	2-Jun (Partial) 27-Jun (Full)	10-Sep	10-Sep	8-Nov	11-Nov	24-Nov
2009	29-May	24-Jun (Partial) 1-Jul (Full)	3-Jul	7-Jul	12-Sep	28-Oct	30-Oct	13-Nov
2010	16-May	7-Jul	9-Jul	7-Jul	15-Sep	11-Oct	14-Oct	19-Nov
2011	10-Jun (xviii)	14-July (xix)	2-Aug (xx)	(xxi)	(xxi)	17-Oct	19-Oct	4-Nov
2012	5-Apr	19-Apr (Partial) 5-May (Full)	7-May					

(i) Barrier notched on Sept. 28, 1991. Construction resumed on Oct. 10 and finished on Oct. 13.

(ii) Barrier notched on Sept. 30, 1992. Construction resumed on Oct. 2 and finished on Oct. 9.

(iii) Construction was delayed on 5/17 and resumed on 6/5 due to high flows.

(iv) Barrier was breached on 5/ 16 on an emergency basis, but complete removal wasn't done until 9/3, after Corps demanded permit compliance of complete removal.

(v) Barrier was installed in previous years.

(vi) Installation delayed due to high flows.

(vii) Not intalled due to high San Joaquin River flows.

(viii) Not installed upon DFG's request.

(ix) In 1963 and 1964 an old rock barge was intentionally flooded and sunk at the head of Old River in an experiment to see if it could serve as a temporary barrier. Results were not promising and rock was placed directly for the 1968 barrier. No barriers were in place in 1965, 1966 or 1967.

(x) Flashboards adjusted to allow minimum 6-inches flow for fish passage.

(xi) Spring Head of Old River not installed due to high flows in the San Joaquin River.

(xii) Only above water portion of boat ramps constructed due to hgh flows. North abutment not installed until full closure of barrier. No "partial" barrier configuration for 2005.

(xiii) Fall Head of Old River not installed because existing flows and dissolved oxygen levels in the San Joaquin River were sufficient for Chinook Salmon.

(xiv) Not installed in accordance with Wanger decision to protect Delta Smelt.
(xv) Non Physical "Bubble Barrier" installed as a pilot test to prevent salmon from entering Old River.

(xvi) Includes installation of new culverts in the Middle River barrier north and south abutments.

(xvii) The Non-Physical Barrier was planned but could not be installed due to high velocity currents in the San Joaquin River that posed excessively dangerous conditions for divers and ruled out the possibility of installing the necessary equipment on the channel bottom.

(xviii) Started Grantline Canal barrier south abutment construction to replace culverts, using barge and crane from shoreline.

(xix) Due to high flows the Grantline Canal barrier fish flashboard structure washed out and will be re-constructed at a later date. The weir section elevation had to be reduced to accommodate the high flow. All 6 culverts were in tidal position (closed).

(xx) The Grantline Canal barrier weir section was completed back to its designed weir elevation (1.0 ft NGVD) and all 6 culvert flap-gates were tied open.

(xxi) The Grantline Canal flashboard structure was washed out earlier in the year and the California Department of Fish and Game did not require a notch this year due to high flows.

APPENDIX C: 2012 TBP AND GS SOUND MONITORING MEMO'S

Memo

To:	Jacob McQuirk (DWR)		
From:	Chris Shields	**Email:**	chris.shields@atkinsglobal.com
Phone:	916-325-1424	**Date:**	April 17, 2012
Ref:	100026852	**cc:**	Chris Fitzer (AECOM)
Subject:	Underwater Noise Monitoring Results During Vibratory Pile Installation of the Georgiana Slough Non-Physical Barrier		

Introduction

This technical memorandum presents results of short-term underwater noise measurements conducted at the Georgiana Slough Non-Physical Barrier (GSNPB) construction site from February 15 through February 27, 2012. The purpose of the noise measurements was to monitor the underwater noise levels generated by vibratory pile-driving activities during the GSNPB construction as a condition of the Biological Opinion (BO) issued by the National Marine Fisheries Service (NMFS) on February 11, 2011 (NMFS 2011). The GSNPB site is located in the north Sacramento–San Joaquin Delta in unincorporated Sacramento County, at the divergence of the Sacramento River and Georgiana Slough, just downstream of Walnut Grove.

Construction involving vibratory pile driving is generally described as continuous operation of the hammer to seat the pile. To install the project piles, the pile would be hoisted into position with a crane and stabilized by a deck-mounted jig, or template, on the working barge. The vibratory hammer is mounted on the crane. The hammer would then attach to the pile. The pile would be driven for a short period until the pile sinks a couple of feet into the substrate, where it would no longer require the support of the jig. The hammer would pause for the jig to be removed and then operate continuously until the pile is driven down to the final depth. The final depth of some of the piles would be below the surface of the river, requiring an extension arm to be attached to the hammer. The underwater noise analysis discussed in the 2011 BO assumed that 20 piles would be installed in 2 days and that each pile would require up to 10 minutes to be installed. Assuming each second represents a single hammer strike, 6,000 strikes per day or 12,000 strikes for all piles to be installed would be required to complete the project. Under these assumptions, the NMFS Underwater Noise Calculation Spreadsheet modeled the daily accumulated sound exposure level ($SEL_{accumulated}$) to be 198 decibels (dB) at 10 meters (33 feet) for 10 piles using a reference peak sound pressure level of 171 dB at 10 meters for a 12-inch steel pile. The 2012 construction year includes additional piles for scientific purposes and a total pile count of 23.

MONITORING METHODOLOGY

The NMFS criteria for underwater noise levels were established specifically for impact pile driving and were not intended to be applied to vibratory driving. However, conservative thresholds for underwater noise levels for vibratory pile driving were established for the GSNPB project. The following thresholds were applied to the project's pile-driving activities at 10 meters:

- Peak sound pressure = 171 dB
- RMS (Root Mean Square)= 155 dB,
- SEL = 155 dB, and
- $SEL_{accumulated}$ = 198 dB.

Short-term underwater noise levels of vibratory pile-driving activities were measured from February 15 through February 27, 2012, by an Atkins acoustics specialist. Short-term underwater noise levels were measured using a Larson Davis Laboratories (LDL) Model 831 precision integrating sound level meter (SLM) with a Reson TC4013 omni-directional hydrophone. The SLM was calibrated before and after use with a G.R.A.S. Pistonphone Type 42AF to ensure that the measurements would be accurate. All underwater measurements were taken at 10 meters away from where the pile was installed and at varying depths based on the depth of the river channel at each pile location. The meter was programmed to collect peak sound pressure levels every 1 second. As stated in the BO, sound levels of less than 150 dB were not considered to contribute to the accumulated SEL for the purposes of assessing injury; therefore, strikes that measured less than 150 dB were not counted as strikes or included in accumulated SEL calculations. Using the varying 1 second peak sound pressure levels measured between strikes, peak sound-pressure levels were logarithmically averaged and the mean peak sound-pressure level was applied to the NMFS Underwater Noise Calculation Spreadsheet to determine the daily accumulated SEL.

RESULTS

A description of pile-driving activities is presented below and Table 1 presents noise monitoring results. The Attachment presents the NMFS Underwater Noise Calculation Spreadsheet for each day of monitoring.

Pile 22 was the first pile to be installed. The pile location is adjacent to River Road in Walnut Grove and upstream from the BAFF. The hydrophone was located 10 meters from the pile and measurements were taken from the CS Marine working barge. The pile came in contact with riprap, resulting in longer installation time. Pile 22 required 490 strikes to be seated.

Pile 15 was installed in 127 strikes with the vibratory hammer. The resulting peak sound pressure levels were relatively low, with an average 1-second peak sound pressure level of 158 dB. It should be noted that Pile 15 was installed much faster than in the previous year and the barrier mounting bracket was not attached for this pile or any others during the 2012 construction year because of the high peak sound pressure levels that were observed during the 2011 construction year.

Piles 12 through 14 and 21 required between 108 and 135 strikes to be seated. The average peak sound pressure levels ranged between 166 dB and 168 dB, and the peak sound pressure levels ranged between 174 dB and 183 dB for the highest peak sound pressure level measured while the piles were being installed.

Pile driving activities ceased after the sixth pile (Pile 21) was installed. As shown in Table 1 the $SEL_{Accumulated}$ resulted in 175 dB for stationary fish. The $SEL_{Accumulated}$ for moving fish did not result in a calculated number due to the low peak sound pressure levels measured throughout the day.

Piles 18 through 20 and 5 through 11 were installed on the second day of monitoring. Again, fish barrier mounting brackets were not preinstalled on these piles or the remaining piles for the fish barrier. Pile 20 required the most number of strikes (245) to be seated. The number of strikes to seat the piles decreased dramatically, allowing more piles to be installed for the day. Average peak sound pressure levels ranged from 158 dB to 177 dB with the highest peak sound pressure level measuring 187.2 dB.

Piles 1 through 4 and 17 were installed on the third day of monitoring, February 17, 2012. The highest peak sound pressure level measured during installation was 187.6 dB and the average peak sound pressure level was 174 dB, with 399 total strikes for the day of pile driving activities. As shown in Table 1 the $SEL_{Accumulated}$ resulted in 175 dB for stationary fish.

Memo

Pile 23 was installed on the last day of monitoring, February 27, 2012. A total of 317 strikes were required to seat this pile. Pile 23 is one of the new scientific piles for the 2012 study year. The average peak sound pressure level was 175 dB, as shown in Table 1 below. The highest peak sound pressure level measured was 187.6 dB.

CONSCLUSION

Daily underwater noise monitoring of pile driving activities associated with Georgiana Slough Non-Physical Barrier construction are shown in Table 1 below and demonstrate that the daily $SEL_{accumulated}$ threshold was not exceeded on any one full day of pile driving.

REFERENCE

National Marine Fisheries Service (NMFS). 2009. Pile driving calculation spreadsheet. Available at: http://www.wsdot.wa.gov/Environment/Bioloby/BA/BAguidance.thm. Accessed: November 4, 2008.

Table 1
Underwater Noise Level Measurements of Vibratory Hammer Pile Driving
(at 10 meters from pile)

Date	Time of Day		Pile	Depth (feet)[1]	Number of Strikes	Peak[2] (dB)	Average Peak[3] (dB)	Daily Number of Strikes	Daily Average Peak[3] (dB)	SELaccumulated (dB)	
	Start	End								Stationary Fish	Moving Fish
2-15-2012	10:02:42	10:20:36	22	5	490	184.8	172	1102	170	175	--
	11:55:00	11:58:11	15	5	127	155.1	158				
	13:20:15	13:23:38	14	5	130	183.3	168				
	14:07:03	14:12:52	13	8	135	175.5	168				
	14:47:08	14:51:44	12	8	110	175.3	169				
	15:34:04	15:51:20	21	10	108	174.2	166				
2-16-2012	09:52:34	10:03:13	20	10	245	170.9	158	1192	169	175	--
	10:37:30	10:39:51	11	10	137	183.6	167				
	11:06:47	11:10:10	10	10	102	181.3	166				
	11:36:35	11:37:32	9	10	57	179.3	173				
	12:42:19	12:44:23	8	10	65	178.1	171				
	13:19:17	13:30:37	19	10	166	179.7	168				
	13:57:41	14:01:54	7	10	133	182.3	177				
	14:38:56	14:42:26	18	10	85	181.3	167				
	15:23:54	15:27:22	6	10	124	175.9	164				
	16:00:40	16:01:46	5	10	66	187.2	164				
2-17-2012	09:20:15	09:21:15	4	8	61	172.5	160	399	174	175	--
	09:53:25	09:54:19	3	8	55	178.8	169				
	10:27:42	10:28:52	2	5	71	178.8	170				
	11:01:49	11:04:03	1	5	108	185.0	176				
	11:38:12	11:42:24	17	10	104	187.6	177				
2-27-2012	08:24:14	10:34:54	23	8	317	187.6	175	317	175	175	167

Notes: dB = decibel; SELaccumulated = daily accumulated sound exposure level.
[1] Depth of hydrophone in water body.
[2] Peak sound pressure refers to the highest absolute value of a measured waveform.
[3] Average of peak sound pressure levels measured during pile installation.
Source: Underwater measurements conducted by Atkins in 2012, National Marine Fisheries Service Underwater Noise Calculation Spreadsheet 2012.

Memo

To:	Jacob McQuirk-DWR		
From:	Chris Shields	**Email:**	Chris.Shields@atkinsglobal.com
Phone:	916-325-1424	**Date:**	11 May 2012
Ref:		**cc:**	Roy Leidy-AECOM
Subject:	2012 South Delta Temporary Barriers Project		

Introduction

The South Delta Temporary Barriers Project (TBP) is an ongoing project that calls for the seasonal construction of temporary rock barriers to ensure that local agricultural diverters within the South Delta Water Agency do not experience adverse water level and circulation impacts caused by the State Water Project (SWP) and the Central Valley Project (CVP). The temporary rock barriers are designed to function as flow control structures that trap tidal waters behind them during high tide, improving water levels and circulation for local south Delta farmers, as well as improve migration of Central Valley fall-run Chinook salmon originating in the San Joaquin River watershed by blocking movements into the Old River Channel from the mainstem San Joaquin River, reducing potential entrapment within the SWP and CVP pumps. Temporary rock barriers were installed at Middle River, Old River near Tracy and Head of Old River.

Adhering to the project description provided to the National Marine Fisheries Service (NMFS) for the purposes of Section 7 consultation, the amount of sound generated in the aquatic environment during construction of temporary rock barriers installed would be monitored. The ecological surrogate identified in the Biological Opinion for 2012 South Delta Temporary Barriers Project regarding underwater noise monitoring is as follows:

- Ecological Surrogates

  The analysis of the effects of the proposed TBP anticipates that the construction and removal of each barrier will result in acoustic noise generated in the aquatic environment that exceeds typical ambient background conditions for the action area. Based on the types of vehicles and equipment to be used, the methods described for construction and removal of the barriers, and the effects analysis conducted for this consultation, the amount of sound generated in the aquatic environment associated with the construction and removal of each barrier shall not exceed 150 dB at a distance of 100 meters from the source activity at any time.

MONITORING METHODOLOGY

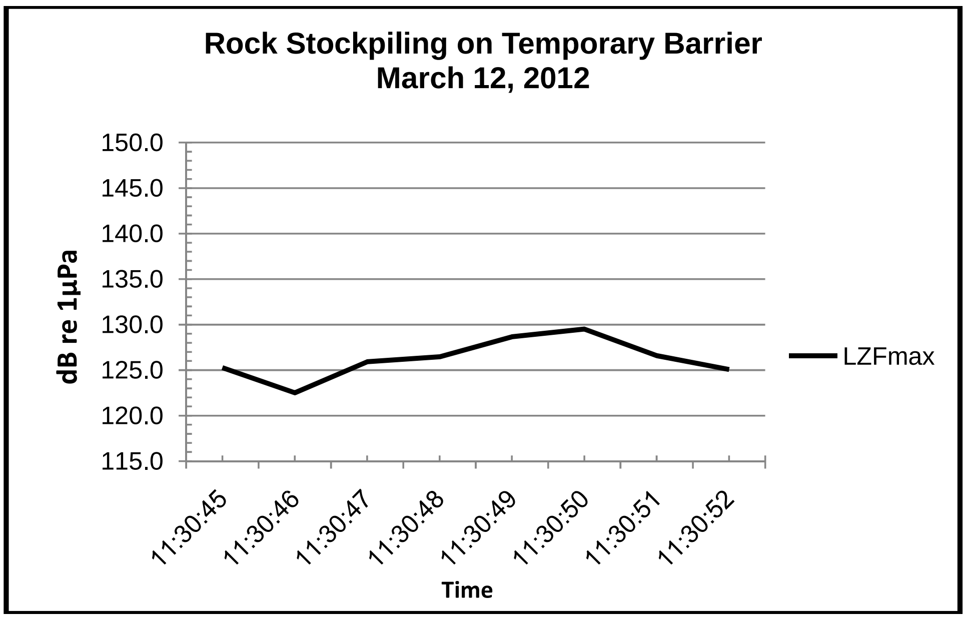
Underwater noise levels were measured using a Larson Davis Laboratories (LDL) Model 831 precision integrating sound level meter (SLM) with a Reson TC4013 omni-directional hydrophone. The SLM was calibrated with a G.R.A.S. Pistonphone Type 42AF to ensure that the measurements would be accurate. All underwater measurements were taken at a distance of 100 meters from in-stream temporary rock barrier construction locations. The SLM was manually operated. The SLM logged data every second of activation recording the date, time, and maximum underwater noise level. The SLM was activated during rock placement and piling on top of the temporary barrier, while rock piles were pushed into the river and in-stream rock placement by clam-bucket. The monitoring of underwater noise levels focused on the aquatic noise levels generated during rock placement, specifically, noise levels generated during rock placement within the water channel. Instantaneous maximum underwater noise levels are denoted as dB LZFmax in this memo and are relative to dB re 1µPa.

RESULTS

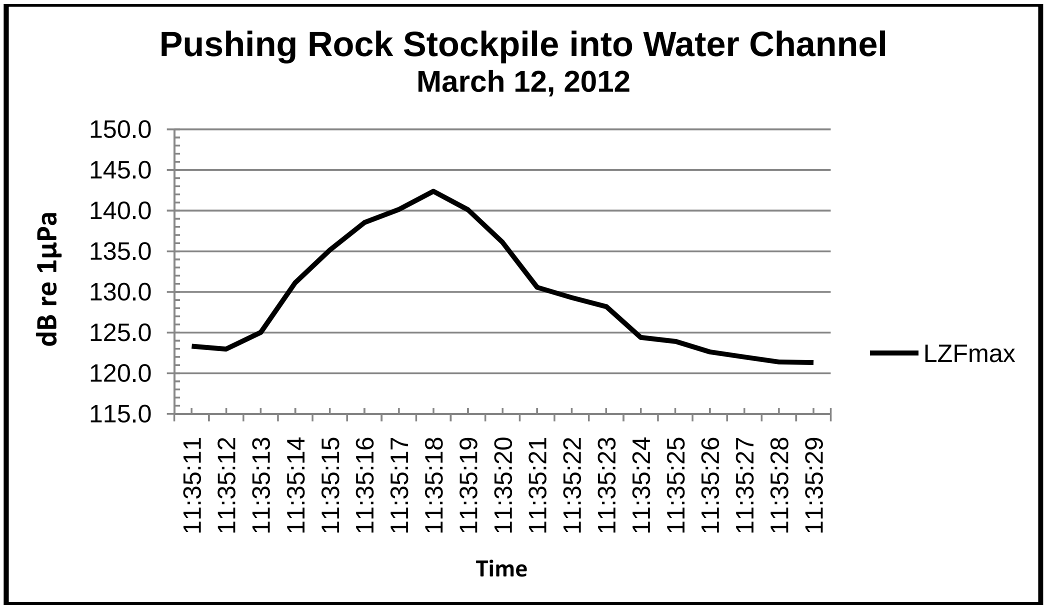
Middle River

Underwater noise levels attributable to the construction of the temporary rock barrier at Middle River were monitored on March 12 and 13, 2012. The Middle River temporary barrier was constructed utilizing one dozer, one excavator and several rock delivery trucks. Rock was stockpiled on the levee road adjacent to the temporary rock barrier construction site by trucks. The excavator would then re-position the rocks down the levee slope and at the levee toe so that the dozer could access the rock. The dozer would scoop rock into the bucket and transport the rock to the edge of the temporary rock barrier, originating from the levee toe and into the channel, for placement and stockpiling. Rock would be stockpiled at the end of the forming temporary rock barrier before being pushed into the channel. This method was repeated throughout the day as the temporary rock barrier construction continued into the water channel. The results are summarized below and complete data sheets are included in the Appendix A:

- Ambient noise level: 115-120 dB LZFmax
- Rock stockpiling: 119-143 dB LZFmax - A graphical representation of typical underwater noise levels due to rock stockpiling on the temporary rock barrier is shown below.



- Pushing rock stockpile into water channel: 130-148 dB LZFmax - A graphical representation of typical underwater noise levels due to pushing stockpiled rock on the temporary rock barrier into the water channel is shown below.

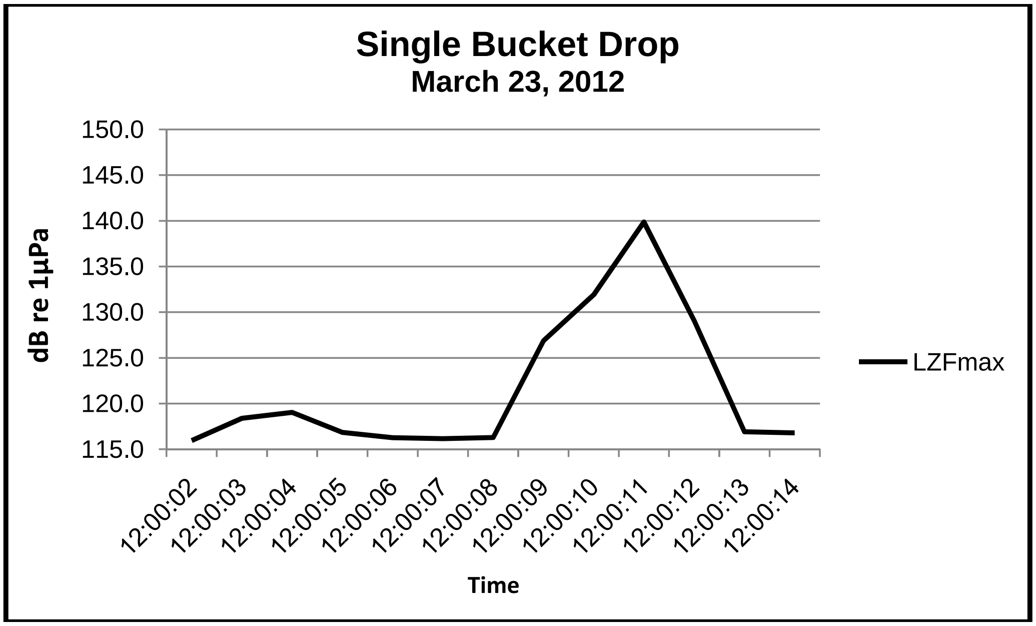


Head of Old River

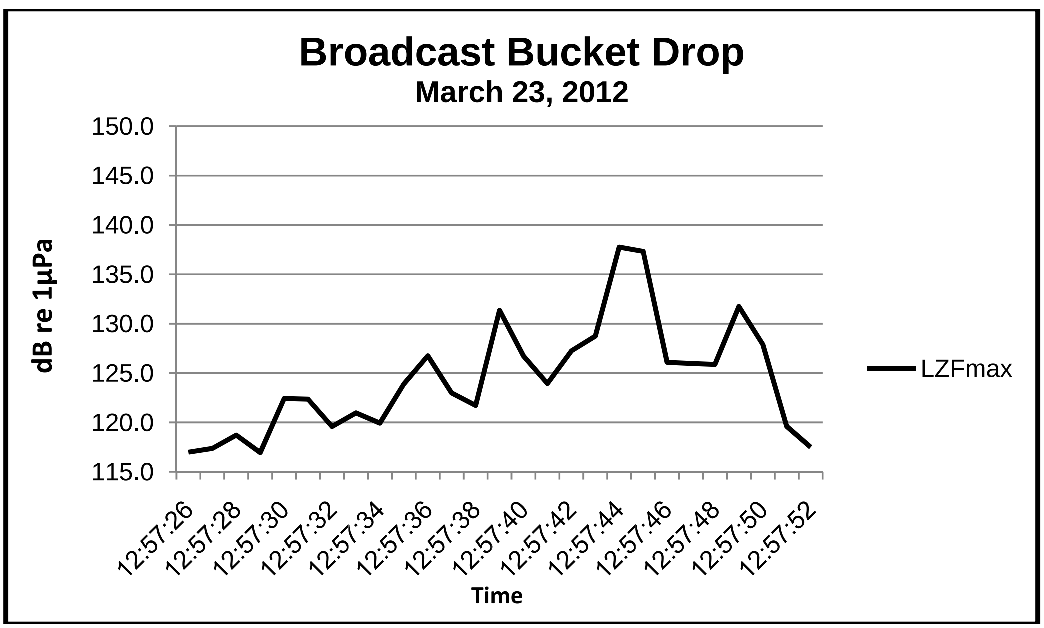
Underwater noise levels attributable to the construction of the temporary rock barrier at Head of Old River were monitored on March 22 and 23, 2012. The Head of Old River temporary barrier was constructed utilizing one dozer, one barge calm bucket and several rock delivery trucks. Rock was stockpiled on the water side of the levee along the river bank adjacent to the temporary rock barrier construction site by trucks. The dozer would then re-position the rocks at the edge of the river bank so that the barge excavator could access the rock. The barge excavator would scoop rock into the bucket and swing the rock over the temporary rock barrier for placement. Rock was deposited in a single bucket drop, spread over an area of the rock barrier in a broadcasting motion, or by a submerged bucket drop. The majority of rock deposits consisted of the bucket dropping in a freefall with a full load of rock onto the temporary barrier, and then the bucket would be dragged along the length of the submerged rock barrier. The bucket was dragged along the rock barrier to locate gaps or to evenly spread the rock along the barrier when the barrier was near the desired elevation. These events varied in duration. These methods were repeated throughout the day as the temporary rock barrier construction continued into the water channel. The results are summarized below and complete data sheets are included in the Appendix B:

- Ambient noise level: 115-121 dB LZFmax

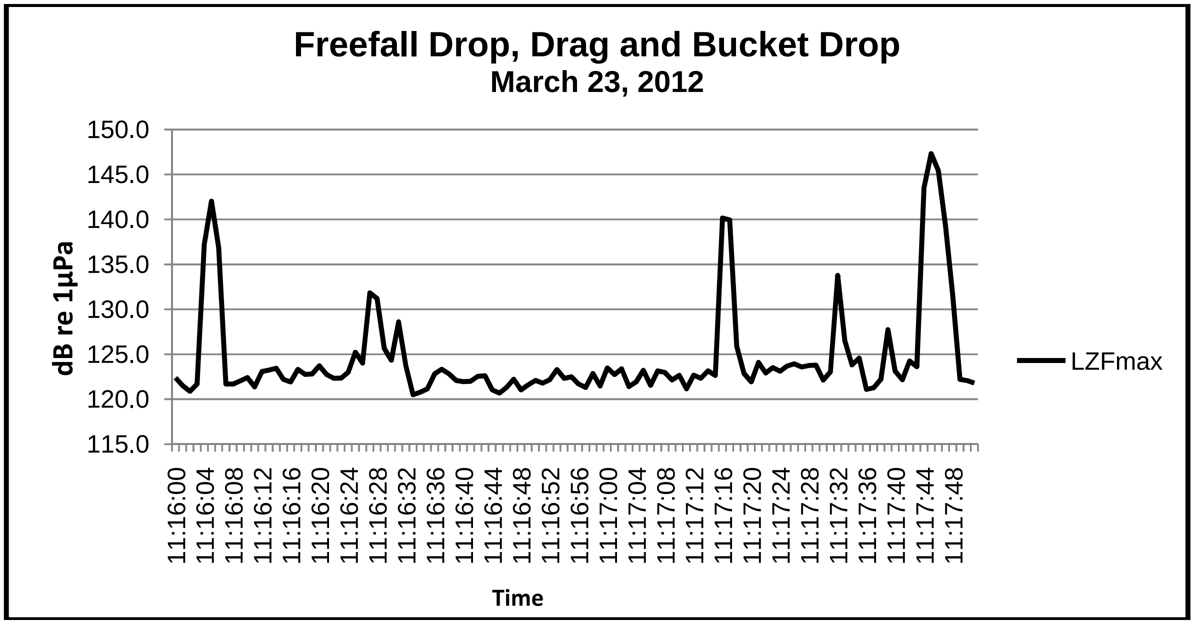
- Single bucket drop: 135-140 dB LZFmax - A graphical representation of typical underwater noise levels due to a single bucket drop on the temporary rock barrier is shown below.



- Broadcast bucket drop: 125-138 dB LZFmax - A graphical representation of typical underwater noise levels due to a broadcast bucket drop on the temporary rock barrier is shown below.



- Freefall drop, drag and bucket drop: 131-147 dB LZFmax - A graphical representation of typical underwater noise levels due to a freefall drop, drag and bucket drop on the temporary rock barrier is shown below.



Old River near Tracy

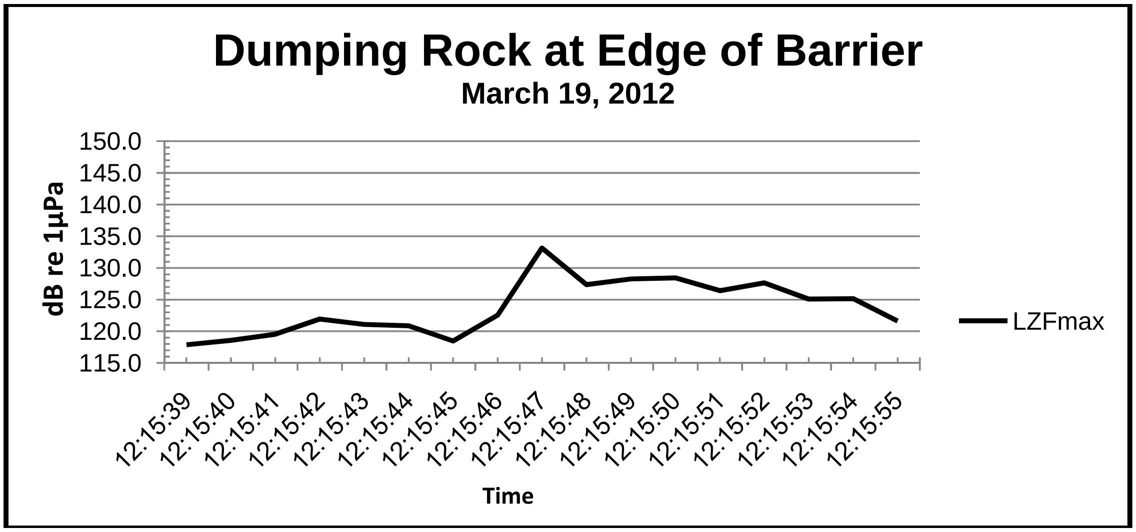
Underwater noise levels attributable to the construction of the temporary rock barrier at Old River near Tracy were monitored on March 19, 20 and 26, 2012. The Old River near Tracy temporary barrier was constructed utilizing one dozer, one excavator, one clam bucket and one rock delivery truck on March 19 and 20. Rock was stockpiled on agricultural property to the east of the temporary rock barrier construction site and loaded onto the truck using the excavator. Rock was transported to the site with the truck and dumped at the edge of the rock barrier adjacent to the levee, forming the boat launch pad. Rock was either stockpiled along the edge of the temporary barrier with some errant rocks entering the water or dumped directly into the water channel. After stockpiling a considerable amount of rock, the dozer would then push the stockpiled rock into the water channel. The dozer would make several short back and forth movements on the forming launch pad as it was pushing the rock into the water channel.

Construction practices changed on March 26, a clam bucket was used as the barrier moved further into the water channel from the formed boat launch pad. Rock was transported by truck and stockpiled on the boat launch pad. Clam bucket work activities were similar to the Head of Old River clam bucket activities described above. There were full bucket drops, broadcasting of full bucket drops, full bucket freefall drop followed by bucket drop broadcast over the barrier and full bucket freefall drop, broadcast, removal of some rock followed by another drop. These methods were repeated throughout each day as the temporary rock barrier construction continued into the water channel and varied in duration. The results are summarized below and complete data sheets are included in the Appendix C:

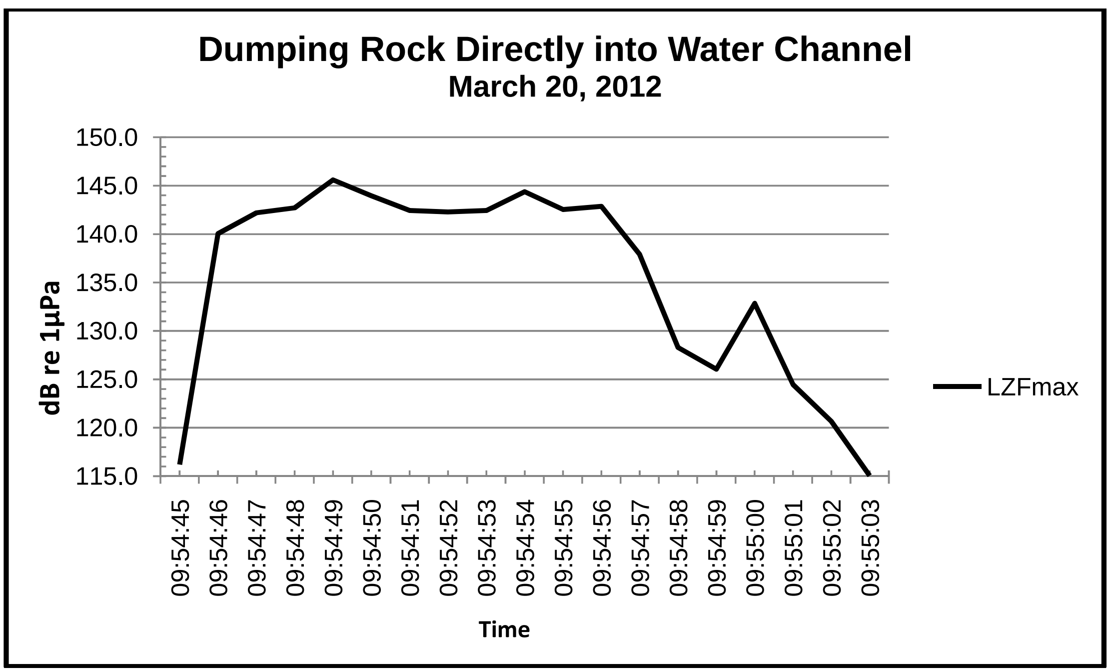
- Ambient noise level: 113-114 dB LZFmax

- Stockpiling rock, no rock entering the water: 115-119 dB LZFmax

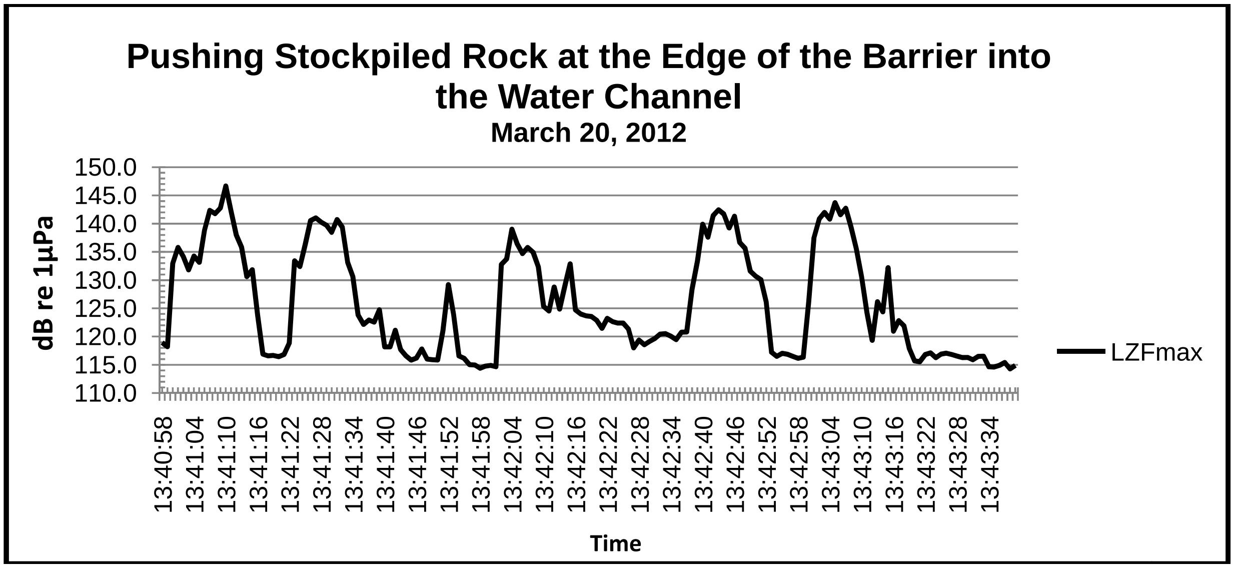
- Dumping rock at edge of barrier with some rocks entering water: 120-133 dB LZFmax- A graphical representation of typical underwater noise levels due to dumping rock at the edge of the temporary rock barrier is shown below.



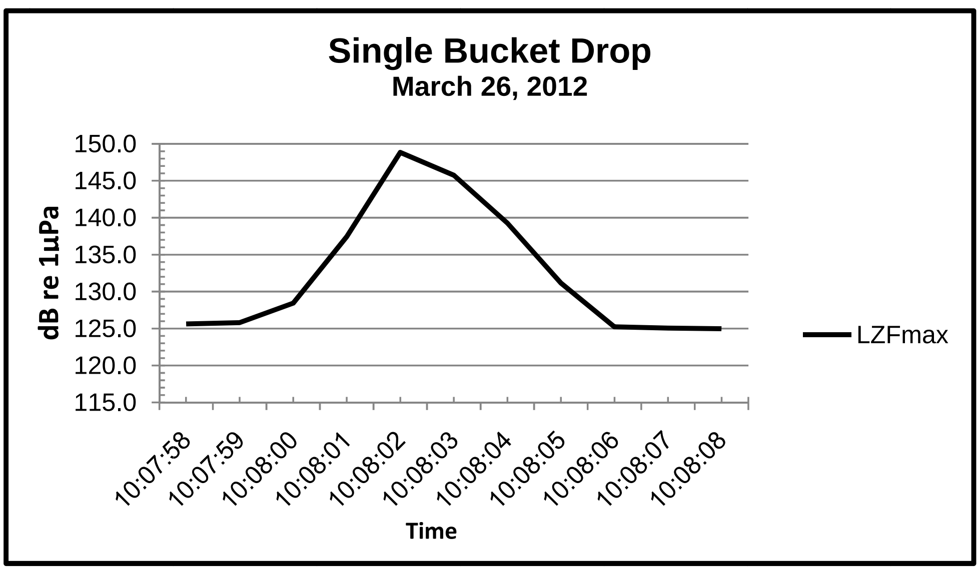
- Dumping rock directly into water channel: 125-147 dB LZFmax - A graphical representation of typical underwater noise levels due to dumping rock directly into the water channel is shown below.



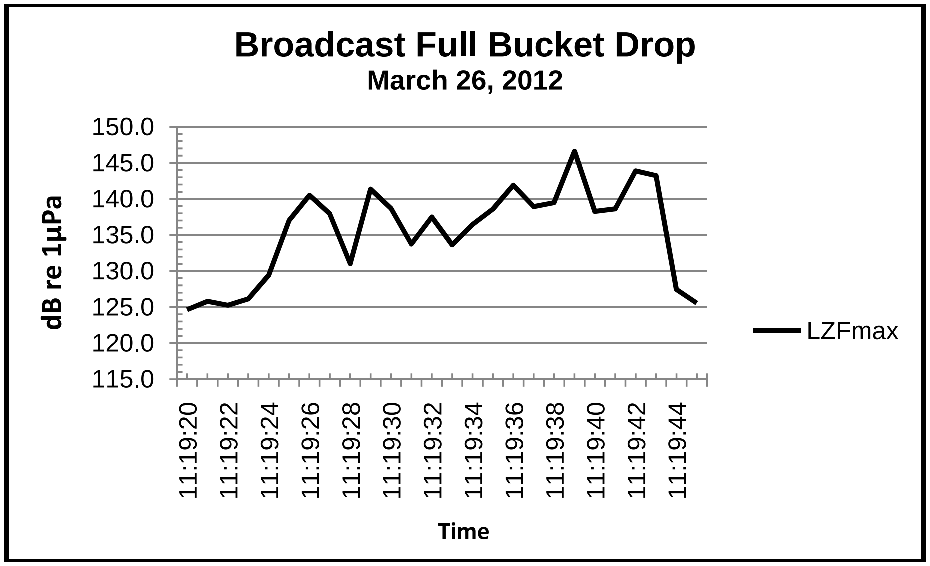
- Pushing stockpiled rock at edge of barrier into the water channel: 129-147 dB LZFmax - A graphical representation of typical underwater noise levels due to pushing stockpiled rock at the edge of the barrier into the water channel is shown below.



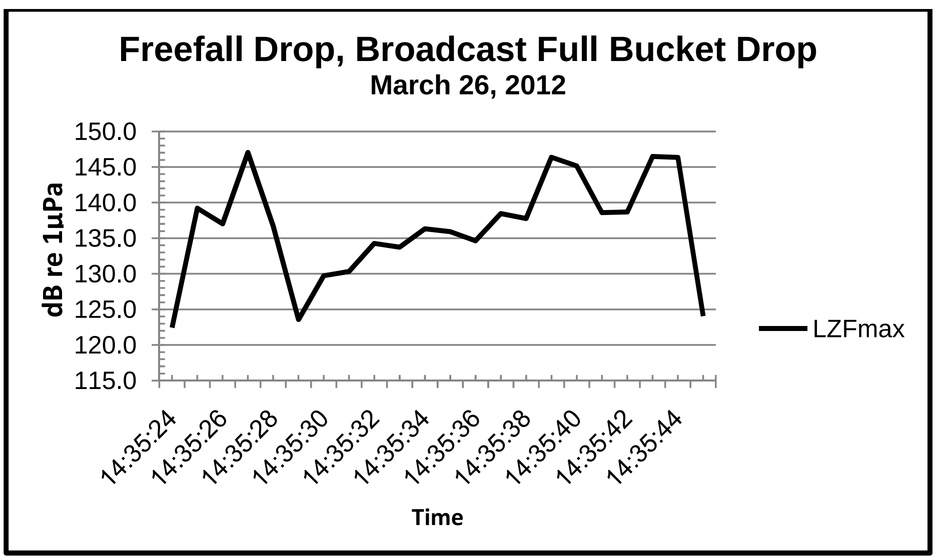
- Single bucket drop: 140-149 dB LZFmax - A graphical representation of typical underwater noise levels due to a single bucket drop on the temporary rock barrier is shown below.



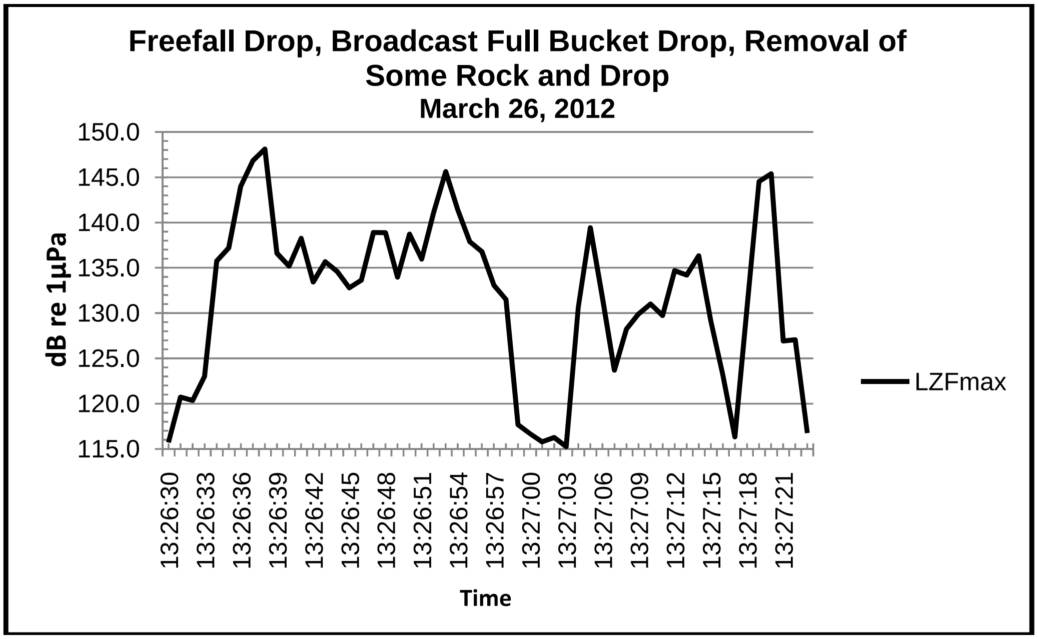
- Broadcast full bucket drop: 141-147 dB LZFmax - A graphical representation of typical underwater noise levels due to a broadcast bucket drop on the temporary rock barrier is shown below.



- Freefall drop, broadcast full bucket drop: 142-147 dB LZFmax - A graphical representation of typical underwater noise levels due to a freefall drop, broadcast full bucket drop on the temporary rock barrier is shown below.



- Freefall drop, broadcast full bucket drop, removal of some rock and drop: 138-147 dB LZFmax - A graphical representation of typical underwater noise levels due to a freefall drop, broadcast full bucket drop, removal of some rock and drop on the temporary rock barrier is shown below.



CONCLUSION

The monitoring conducted at Middle River, Head of Old, and Old River near Tracy properly characterizes the underwater noise level trends attributable to temporary rock barrier construction at each site. Based on the underwater noise levels measured and observed during the monitoring, the ecological surrogate threshold was not exceeded and it was determined that monitoring was no longer warranted.

APPENDIX D: ENVIRONMENTAL AWARENESS TRAINING INFORMATION

Worker Environmental Awareness Program

Training will be done by a qualified biologist for all workers at the job site.

Species List for WEAP Training – Handout attachment 1

Winter and Spring Run Chinook Salmon

Central Valley Steelhead

North American Green Sturgeon

Delta Smelt Longfin

Smelt Swainson's

Hawk Western Pond

Turtle

Best Management Practices

1. No pets, camping, firearms, or any other use of the right of way area will be allowed. The Contractor's employees will not be allowed at the work site during nonworking hours.
2. Any sightings, trappings, injuries, or fatalities to animals that occur as a result of project-related activities shall be reported immediately to the Engineer.
3. Food-related trash, such as wrappers, cans, bottles, scraps, shall be placed in closed containers and removed daily from work sites. Trash or garbage shall be removed to a county approved disposal site at least weekly by the Contractor. The right of way shall be policed daily by the Contractor's personnel.
4. Review of the potential penalties for taking a listed wildlife species will be described.
5. Protocol to follow if sensitive species are encountered, including appropriate contact points, such as the Engineer or designated representative, inspectors, and environmental personnel.
6. Fact sheets or cards will be available to the Contractor's employees.
7. Traffic shall be restricted to existing roads and flagged right of way or temporary construction easement.

Follow-up meetings to present additional topics pertaining to the above subjects as they occur or are brought to the attention of the Engineer or the Contractor during construction.

WEAP Handout

Temporary Barriers Project

Worker Environmental Awareness Training

Delta Smelt

Hypomesus transpacificus

Threatened – State and Federal

- Migrate from SF Bay to Delta
- Spawn from Jan. to Jul. mostly in the Delta.
- Eat microscopic crustaceans

Longfin Smelt

Spirinchus thaleichthys

Species of Concern

- Migrate from SF Bay through Delta
- Spawn in late winter to Spring in the Delta
- Eat microscopic crustaceans

Rainbow Trout (Steelhead)

Oncorhynchus gairdneri

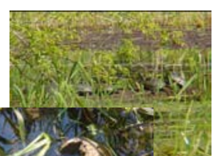
Endangered – Federal

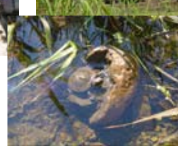
Migrate from fresh to salt water and back

Spawn in fresh water from Dec. to Apr.

Western Pond Turtle

State-Species of Concern





Nests Mar. to Aug. along waterways

Basks on logs and beaches

Chinook Salmon

Oncorhynchus tshawytscha

Federal

Spring = Threatened

Winter = Endangered

Migrate from fresh to salt water

Spawn in fresh water

Delta is a migratory path

Juveniles migrate through the Delta year round

Migration route affects survival

Green Sturgeon

Acipenser medirostris

Threatened - Federal

Long-lived, slow growing fish

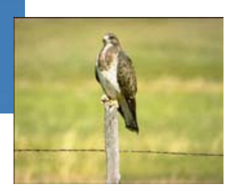
Adults are mostly marine

Spawn in fresh water

Young migrate to salt water

Swainson's Hawk

State-Threatened



Nest from Mar to May

Protected from construction impacts within a ¼ mile of nests