APPENDIX A

Technical Working Group Meeting Notes

OCAP Action IV.1.3
Technical Working Group Meeting Summary
07/07/2011

Meeting Date/Time: 07/07/2011, 2:00pm – 4:00pm (PST)

Participants:

Mark Holderman, DWR	Daniel Kratzville, CDFG (phone)
Jacob McQuirk, DWR	Maral Kasparian, USFWS (phone)
Josh Israel, USBR	Khalid Ameri, DWR
Ryan Reeves, DWR	Jeff Stuart, NMFS
George Heise, CDFG	Bill McLaughlin, DWR
Bob Pedlar, DWR	Josh Brown, DWR

Meeting Summary:

1. Purpose of Call

The primary purpose of the meeting was to discuss the draft table of contents for the report that Josh provided and to discuss/brainstorm options to be considered for all sites to further reduce diversion of emigrating juvenile salmonids. Also, to discuss performance objectives of the options that will be considered.

2. Discussion on the draft table to contents

BM: Introduced meeting topics, June 16th TWG meeting summary, and overall intent of the meeting.

JM: Suggested adding a flow/hydraulics section.

There were no major comments on the outline at this moment. However, detailed comments will be provided to Josh prior to the next TWG meeting. Josh discussed the ELAM model used on the Columbia River (provided documents through e-mail). He added that this model will be beneficial in validating fish behavior. Also, there was concern whether there is enough hydrodynamic data to run the ELAM model.

3. Option Brainstorming

A floating buoy fish barrier was introduced which is currently used at the Bonneville Dam on the Columbia River to direct migrating salmon away from the intakes. It's was noted that this type of structure might only work effectively in low flow environment. George will provide us with more detailed information regarding this type of barrier.

GH: Suggested to consider partially blocking the channel. For example Head of Old River; instead of having a 50/50 split we could reduce the split to 80/20. By achieving this we will be able to keep fish in the main channel. However, this option might work only at the HOR and not at other locations.

BM: Talked about the DSM2 hydrodynamic data analysis at a few of the project sites, since there is insufficient observed historical data available. Preliminary DSM2 hydraulic data analysis results will be available to the group prior to the next TWG meeting.

JS: Suggested consideration of behavioral-systems in combination with physical barrier. Also mentioned that NMFS Seattle office as having some experience with tidally influenced estuaries.

JI: Suggested to consider independent science review panel members involvement earlier in the study.

GH: Discussed the electric fish ladder technology used in the Merced River. However, he was concerned that this technology might not be feasible for juvenile entrainment.

JI: Introduced an option to transport fish by using a barge to a desired location downstream. This method is used in the Columbia River to increase returns of fish to the hatchery. In order for this option to work effectively we need to determine when the majority of fish will be present at a specific location. All agreed that a most common downside to this option would be increased predation and capturing different type of fish species simultaneously. Jeff was concerned that the life history of fish is an important part to fish behavior, so we need to have some type of criteria in place to determine when to use this option.

JI: Discussed the benefits of randomly releasing fish rather than at specific release points.

A permanent operable gate option was also discussed.

Flow vanes/louvers should be considered.

MH: Proposed to consider flow when operations of an option are needed.

JM: Indicated that no matter what option we select, we need a lead time to properly execute that particular option. BM pointed out that having a permanent permitting option in place to execute a preferred option instead of having to go through annual permitting would have its advantages.

MK: Proposed to consider the effects on Delta smelt as one of the criteria. She also added that other species such as longfin smelt might also be listed as an endangered species by the time we are done with the study and should also be considered. The timing of barrier operations effects on Delta smelt should be considered.

4. Action Items and Next Steps

- Next TWG Meeting scheduled for 07/28/11 at 1:00pm – 3:00pm (PST)
- Provide comments on the report outline to Josh (all)
- Look into science panel involvement (Stuart)
- Provide DSM2 hydraulic data analysis at each site (McLaughlin/Ameri)
- Update list of options and criteria (McLaughlin)
- Prepare site maps for each location (McLaughlin/Brown)
- Look into available bathymetry data (McLaughlin)
- Ftp site access information (Ameri)
- Talk with Steve/Rick about draft objectives criteria (Stuart)
- Look into EPRI, contact Ned Taft (McLaughlin)

OCAP Action IV.1.3
Technical Working Group Meeting Summary
08/25/2011

Meeting Date/Time: 08/25/2011, 10:00pm – 12:00pm

Participants:

George Heise, CDFG
Maral Kasparian, USFWS
Steve Thomas, NMFS
Jeff Stuart, NMFS
Mark Holderman, DWR
Jacob McQuirk, DWR
Bill McLaughlin, DWR
Bob Pedlar, DWR

Meeting Summary:

Franks Tract Project

The group discussed the Franks Tract Project at Three Mile Slough presented by Teresa Geimer to the group at the last meeting. Maral added that the existing project utilizing a gate could have nutrient flow concerns and possible predator concerns. It was suggested to include the additional site within the upcoming report in a narrative format.

Jeff added that NMFS is not limiting which channels are considered.

Discussion on the draft table of contents/maps

The latest draft of the table of contents sent out August 4^{th} was discussed with no additions suggested. DWR staff will write a majority of the report with the assistance of pertinent information provided from various agencies. Draft sections of the report will be sent out beginning in September for the group to begin review.

Project Sites

DWR staff discussed a tour of the Turner and Columbia Cuts sites that were toured by DWR staff the week before. If members of the group are interested, a tour of the sites can be arranged.

Bathymetric surveys of Turner and Columbia Cuts will be planned for use in further evaluation of options at the sites. The need for further fishery information was briefly discussed but additional research needs to be completed on existing documents.

Performance objectives/criteria

No additional objectives/criteria added.

Options

Maral commented that USFWS prefers flow friendly and submerged structures and that predatory behavior prevention is important.

No additional options added.

Independent Review Panel

DWR staff is still waiting to hear back from the Delta Stewardship Council (Sam Harader) to discuss forming an Independent Review Group in January 2012 to review the draft report.

Action Items and Next Steps

- Next TWG Meeting scheduled for September 15^{th} at 10:00am – 12:00pm
- Provide feedback on the Franks Tract project (all)
- Look into science panel involvement (Pedlar/McLaughlin)
- Provide feedback on options and criteria (All)

OCAP Action IV.1.3
Technical Working Group Meeting Summary

Meeting Date/Time: 10/06/2011, 10:00pm – 12:00pm

<u>Participants:</u>

George Heise, CDFG	Ben Geske, DWR
Maral Kasparian, USFWS(phone)	Jacob McQuirk, DWR
Steve Thomas, NMFS (phone)	Bill McLaughlin, DWR
Jeff Stuart, NMFS	Bob Pedlar, DWR
Khalid Ameri, DWR	Josh Israel, USBR
Josh Brown, DWR	Ryan Reeves, DWR

Meeting Summary:

Franks Tract Project/Other Projects

The group discussed the Franks Tract project at Three Mile Slough. Bill indicated that the Franks Tract project should be at least briefly discussed in the phase I report if not as an option.

Josh Israel added that the Yolo Bypass fish passage projects, BDCP, and other projects that may potentially have an effect on our study should also be discussed in the report. The various life cycle and passage models that are currently being developed will be extremely helpful in assisting with investigating engineering solutions under this particular OCAP action.

Discussion on the Report Write-Ups

Bill requested comments on the site description and species of interest write-ups form the group. A request for a San Joaquin River migration table and chart to be included in the species of interest section was made. DWR staff will write a majority of the report with the assistance of pertinent information provided from various agencies. The draft report will be completed by November 15^{th} for the group to review.

Science Panel Review

Bill added that after discussing with the Delta Stewardship Council, a science review panel will not be available to review the draft report in January 2012. A different independent science panel will need to be sought to review the report. The group will send contact information to Bill of possible candidates to structure a new Independent review panel. The goal is to have the panel review the report by January 2012.

Bathymetric Surveys/Other Data Source

Bill added that bathymetric surveys for use in further evaluation of options at Turner and Columbia Cuts will be completed sometime before the end of June 30, 2012.

There is a concern that there is limited fish survival or fish behavioral data available. Essential data that is being processed and analyzed from the VAMP and six year studies will be helpful. Additional information may be needed in the future.

Action Items and Next Steps

- Next TWG Meeting scheduled for November 10th at 10:00am – 12:00pm.
- Additional draft sections of the report will be sent out in the coming weeks.
- Provide feedback on developed sections of the report (all).
- Look into creating a new science review panel (all).

OCAP Action IV.1.3
Technical Working Group Meeting Summary

Meeting Date/Time: 11/10/2011, 10:00pm – 12:00pm

Participants:

George Heise, CDFG	Ben Geske, DWR
Maral Kasparian, USFWS	Jacob McQuirk, DWR
Steve Thomas, NMFS (phone)	Bill McLaughlin, DWR
Jeff Stuart, NMFS	Bob Pedlar, DWR
Khalid Ameri, DWR	Josh Israel, USBR (Phone)
Josh Brown, DWR	Ryan Reeves, DWR

Meeting Summary:

Discussion on the Phase I Draft Report

The group discussed the preliminary draft Phase I report and Bill requested comments on the report from the group. Jeff will provide the San Joaquin River migration table and the table will be added to the species of interest section of the report. The most complete draft report with TWG review will be completed by December 16th.

Science Panel Review

Independent science panel formation is still ongoing. Bill will screen possible candidates to structure the Independent review panel. The goal is to have the panel review the report by end of February 2012. Josh Israel proposed to have at least one fish Behaviorist on the panel. Bill proposed to form one Independent science panel to review both the Phase I draft report and the 2011 Georgiana Slough Non Physical Barrier study report.

Franks Tract Project/Other Projects

Bill showed concerns how the Franks Tract project should be discussed in the Phase I report. It was pointed out that to add the Franks Tract project in our report as an ongoing project that may potentially have an effect on the OCAP study.

Action Items and Next Steps

- Provide feedback and comments on the preliminary draft Phase I report (all).
- The most complete draft report will be sent out by December 16th, 2011.
- Look into creating a new science review panel.
- Next TWG Meeting will be scheduled in January, 2012 at the time the full draft is provided to the group in December.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 08/21/2012, 1:00pm – 3:00pm

Participants:

Chad Dibble, CDFG
Maral Kasparian, USFWS
Jason Roberts, CDFG
Jeff Stuart, NMFS
Bill McLaughlin, DWR
Khalid Ameri, DWR
Ben Geske, DWR
Jacob McQuirk, DWR
Bob Pedlar, DWR
Josh Israel, USBR
Michael Eakin, CDFG
Ryan Reeves, DWR
Mark Holderman, DWR
Josh Brown, DWR

Discussion on the Science Advisory Review of the Phase I Draft Report

Bill McLaughlin (BM) kicked-off the meeting and introduced meeting participants. BM stated that the purpose of the meeting was to discuss the phase I report Science Advisory Review panel comments and obtain input and comments from the Technical Working Group prior to finalizing the document.

Comment 4PS (pg 2) Discussion:
Jeff Stuart indicated that any action we take needs to work in harmony with other OACP actions. Jacob McQuirk added that due to limited available tools, it would be difficult if not impossible to achieve the system- wide analysis goal by the 2015 deadline. Josh Israel added that various life cycle and passage models, that are currently being developed, will be extremely helpful in assisting with investigating engineering solutions under this particular OCAP action at each location. BM showed concern that the deadline is fast approaching and it would not be possible to embrace system- wide analysis.

Jeff Stuart provided explanation of the intent of BO Action IV.1.3 language. It was confirmed that the action's intent is to perform engineering evaluation to identify technologies/alternatives at individual sites by 2015 deadline. Josh Israel pointed out that it's not clear whether we are going to adopt the CEQA/NEPA process during the 2nd phase of the report. It was agreed that the CEQA/NEPA process is not going to be achieved by the 2015 deadline; however, it will be acknowledged in the phase II report that the CEQA/NEPA process will occur after the phase II report is completed.

Maral Kasparian asked if the options we are considering will be supported by some type of data analyses. Bill added that some data analyses and conceptual designs will be part of the option screening in the phase II report and our main focus will be to determine fish deterrence ability, flow neutrality, upstream migration, and boat passage concerns for all options.

Comment 5P (pg 4) Discussion:
Josh Israel suggested that agencies should provide us with a number for determining what percentage for deterrence efficiency is expectable for a specific technology, and we need to have a clear objective that is quantifiable. Jeff Stuart acknowledged the need for a measurable deterrence goal for each junction and technology, and he affirmed that agencies will work on that. It was also agreed that the intent of this action is not to control predation, but we can't contribute to the existing predation issues at each site by considering any option.

Comment 22P (pg 9) Discussion:
Maral Kasparian suggested that if we decide to select habitat restoration for a specific site as an option, we need to know what impact it's going to have on other species habitat at each junction. It was also agreed upon to concentrate only on the single channels at Turner and Columbia Cuts.

Comment 12R (pg 16) Discussion:

BM asked if using hatchery fish for our study is going to be concern. Jeff Stuart indicated that this issue has been raised before and there is no plan B to consider, since it's not possible to tag wild fish.

Comment 3S (pg 12) Discussion:

BM asked if we need to look into different routes for fish migration even though it's clearly not part of the action. Jeff Stuart indicated that fish survivability is much higher in Steamboat and Sutter Sloughs; however, we are not asked to look into those junctions as part of this action.

Comment 4P (pg 4) Discussion:

It was agreed upon to add the detailed information about fish species in the appendix of the phase I report instead of having it in the main report.

Other Concerns

Maral Kasparian suggested updating some of the citations in the phase I report prior to finalizing the report, since some referenced material were already published or issued as we were preparing the draft report. She also requested that we include additional facts on the delta smelt in the report.

Chad Dibble suggested that we clearly state in the Phase I report when a particular discussion will be revisited in further detail in the Phase II report.

Action Items and Next Steps

- Provide feedback and comments on the Science Advisory Review of the Phase I Draft Report by COB August 24th, 2012 (all).
- Next TWG Meeting will be scheduled in September, 2012 at the time initial option screening process will be discussed.
- A copy of the WRAM, and Bob Pedlar's review/summary of the WRAM, will be emailed to the group for review. (Bill McLaughlin)

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 12/20/2012, 10:00am – 12:00pm

Participants:

Maral Kasparian, USFWS
Jeff Stuart, NMFS (phone)
Bill McLaughlin, DWR
Khalid Ameri, DWR
Ben Geske, DWR
Josh Israel, USBR (phone)
Michael Eakin, CDFG
Ryan Reeves, DWR
Mark Holderman, DWR
Josh Brown, DWR
George Heise, CDFG
Steve Thomas, NMFS (phone)
Teresa Geimer, DWR (phone)

Meeting Summary:

Bill McLaughlin kicked-off the meeting and introduced meeting participants. He stated that the purpose of the meeting was to discuss some of the engineering options that we are considering further and to see if we are able to eliminate some of the unrealistic options.

A PowerPoint presentation was given on the initial screening of the options. The group discussed some of the advantages and disadvantages associated with each option. Also some conceptual drawings of the considered options were shown.

Josh Israel commented on the non-physical options being flow neutral. He indicated that a non-physical barrier might be flow neutral regionally, but not locally. Josh would like to see the mechanics of fish behavior being considered with any of the options.

George Heise pointed out that having a full column fish screen might not be feasible due to adult fish migration. He suggested an alternative to consider is to have a partial column screen instead of having a full column screen which will allow passage for adult fish.

The group suggested considering the use of screen panels for the floating guidance walls instead of solid panels. One of the main issues with screening the panels is debris which will eventually clog the screens. Suspended louvers were brought up as an alternative to screen plates.

Bill asked the group if anyone felt strongly about eliminating any options from consideration. It was agreed among the group to eliminate the electric barrier option due to not being able to specifically target species of concern without affecting other fish species and public safety issues. Michael Eakin would like to see more information regarding the electrical barriers. Ben Geske will provide him with the research that has obtained.

A discussion was held regarding some details about the infrasound barrier. Topics covered include the zone of influence produced by the technology, description of the mechanism that produces the infrasound, the theory surrounding why and how the infrasound (particle acceleration) triggers a behavioral response in small fish, possible constraints for deployment at some or all of the sites, and specific questions to research further and report back to the group. It was decided that further research on topics raised would take place between now and the next meeting where Ben Geske will provide a presentation explaining the new findings and other additional details regarding the infrasound barrier technology.

Bill also asked the group if we needed to look into eliminating a new rock barrier as an option. It was pointed out that instead of having a rock barrier it would be better to have some type of engineered structure which could do the same job as a rock barrier. An engineered structure would be more cost effective and work in most of the flow conditions. The TWG was agreeable to dropping a rock barrier as an option.

The next TWG Meeting will be scheduled in mid February, 2013.

Action Items and Next Steps

- Develop the conceptual drawings further to show some of the hybrid options. (Bill McLaughlin)
- At the next TWG meeting we will discuss the Water Resources Assessment Methodology (WRAM) method used for scoring the options in the Phase II report. (All)
- A presentation covering more detailed information about the infrasound technology will be given at the next TWG meeting. (Ben Geske)

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 02/13/2013, 1:00pm – 3:00pm

Location: DWR HQ in Room 241 and (Conference Call)

Participants:

Ben Geske, DWR

Bill McLaughlin, DWR

Bob Pedlar, DWR

George Heise, CDFW

Jeff Stuart, NMFS (phone)

Josh Brown, DWR

Khalid Ameri, DWR

Krystal Acierto, CDFW

Maral Kasparian, USFWS

Mark Holderman, DWR

Ryan Reeves, DWR

Steve Thomas, NMFS (phone)

<u>Meeting Summary</u>:

Bill McLaughlin started the meeting with introductions and then briefly explained the agenda and intent of the meeting.

Ryan Reeves spoke about the possibilities of another study at Georgiana Slough in 2014. The idea of studying a floating fish guidance wall was discussed with the working group. Ryan mentioned that getting support from the TWG members was important and offered the opportunity for members to ask questions and voice their concerns. Jeff Stuart suggested an on/off, or in/out cycling of the technology similar to that of the BAFF study. George Heise brought up the idea of using some type of system to lift the walls, or move them out of the way instead of removing them from the water. This could improve the down time between on/off cycles. All of the meeting attendees were in support of the study idea/proposal. Ryan will deliver a more in depth study proposal at the next meeting, and also update the TWG members on the 2011 and 2012 GSNPB study results. Maral Kasparian mentioned that getting the study plan proposal to her prior to this summer would be beneficial due to their heavy work load and other project commitments.

Ben Geske gave a presentation on the infrasound fish guidance system as a follow up to the last meeting. The presentation included information such as the background and history of infrasound as a fish deterrent, technical aspects of the infrasound generator, the theory behind the behavioral responses induced by the propagated signal, the relevant zones of the infrasound's influence, laboratory and field study results, and visual aids such as pictures, diagrams, and a video. Jeff was concerned whether or not this technology would adversely affect other species such as Green Sturgeon. It was agreed upon to look into the issue. George asked what the difference between particle acceleration and sound pressure was. (After the meeting, Ben was able to look over his research and give his response here in the meeting notes - *Sound in water is comprised of both particle acceleration and pressure variations. Responses due to particle acceleration are related to a direct interaction between the motion of the particle and the fish's inner ear/otolith. Sound pressure indirectly interacts with the inner ear via the swim bladder. It could also be pointed out that sound pressure is measured with a microphone/hydrophone, and particle acceleration is measured with an accelerometer*). The fact that there have not been any recent field studies in the US or applications with the NMFS BiOp RPA Action IV.1.3 specific challenges such as fish species, hydraulic condition, and specific site challenges was brought up. There was a discussion regarding the uncertainties of the relatively new deterrence option and the need to possibly field test the technology came up when questions of how to answer those uncertainties arose. Ben will organize the material used in his research of the technology and place it in a shared location for the group members.

Bob Pedlar gave a presentation on the Water Resources Assessment Method (WRAM), which was developed by the Army Corps for their use in evaluating water resource project alternatives. This method will be used in the evaluation of the potential engineering solutions in order to help the TWG members weigh and score each option in comparison to each other and the action specific criteria. It was agreed among the group to review the WRAM criteria importance survey form prior to the next meeting. This would give each member time to understand the methodology and start thinking about how they might score or weigh each of the options and criteria. A general overview of the WRAM method was also provided to the TWG members to review and become familiar with the method. It was discussed that the "Do Nothing" and "Transporting" options should not be included in the assessment since these are not "Engineering Options".

Hydrodynamic data collection and updates on conceptual designs that were in the agenda will be discussed in the upcoming TWG meeting due to time constraints.

The next TWG Meeting will be scheduled for the 2nd week of April, 2013.

Action Items and Next Steps

- Send reference and previous study materials on the infrasound technology to the group. (Bill McLaughlin)
- Look into affects on Green Sturgeon. (Ben Geske)
- At the next TWG meeting Ryan Reeves will present the 2011 and 2012 BAFF results and he will also provide more details about the potential Floating Fish Guidance Wall implementation at the Georgiana Slough project site. (Ryan Reeves)
- Send out website link(s) on floating barriers to the group. (Bill McLaughlin)
- Send the Water Resources Assessment Methodology (WRAM) method criteria importance survey form to the group. (Bill McLaughlin)
- Develop the conceptual drawings further to show the other options. (Khalid Ameri/Ben Geske)

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 04/11/2013, 1:00pm – 3:00pm

Location: DWR HQ in Room 210 and (Conference Call)

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Dave Huston, DWR

George Heise, CDFW

Jeff Stuart, NMFS

Jon Burau, USGS

Josh Brown, DWR

Kari Bianchini, DWR

Khalid Ameri, DWR

Krystal Acierto, CDFW

Maral Kasparian, USFWS

Mike Cane, DWR

Noah Adams, USGS

Russ Perry, USGS

Ryan Reeves, DWR

Steve Thomas, NMFS

Meeting Summary:

Bill McLaughlin started the meeting with introductions and then briefly explained the agenda and intent of the meeting.

Ryan Reeves spoke about the possibilities of a floating fish guidance wall study at Georgiana Slough in spring 2014.

Presentations:

“Collapsing flow field complexity in junctions: The Critical Streakline” (Jon Burau)

Jon gave a presentation on the hydrodynamics of the Sacramento River in the vicinity of Georgiana Slough. He shared an animation of hydrodynamic data collected at the junction and discussed directional flow patterns in the area. He concluded that high densities of fish are near the streakline and it may be possible to shift the fish distribution toward the Sacramento River side of the streakline in order to avoid entrainment into Georgian Slough. It was suggested that fish distribution and hydrodynamic information is critical for the placement of any type of barrier to be effective.

“Proof of Concept for Using Simple Guidance Structures to Alter Migration Routing at River Junctions” (Russ Perry)

Russ talked about fish distribution in the channel at the Georgiana Slough project site. He emphasized how much fish distribution will affect the entrainment probability.

“Overview of Fish Guidance Boom Technologies Utilized in the Pacific Northwest” (Noah Adams)

Noah gave a presentation on the floating fish guidance wall technology that was utilized in the Pacific Northwest. It was pointed out that there is limited information on how much the floating fish guidance wall will be effective in higher flows that occur in the Sacramento River. As of now this type of technology is only tested in much lower flows. Ryan purposed the idea of studying a floating fish guidance wall at the Georgian Slough in 2014. All of the meeting attendees were in support of the study idea/proposal.

Water Resources Assessment Method (WRAM) criteria ranking discussion

It was agreed among the group to review and take a first stab on the WRAM criteria ranking, and results will be discussed at the next meeting.

The next TWG Meeting will be scheduled for the end of May or the 1st week of June, 2013.

Action Items and Next Steps

- Rank the Water Resources Assessment Methodology (WRAM). (All)
- Develop the conceptual drawings further to show the other options. (Khalid Ameri/Ben Geske)

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 06/20/2013, 1:00pm – 3:00pm

Location: DWR HQ in Room 341 and (Conference Call)

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Bob Pedlar, DWR

Colin Purdy, CDFW

George Heise, CDFW

Jacob McQuirk, DWR

Jason Roberts, CDFW

Jeff Stuart, NMFS

Josh Brown, DWR

Khalid Ameri, DWR

Krystal Acierto, CDFW

Mark Holderman, DWR

Steve Thomas, NMFS (phone)

Teresa Geimer, DWR

Meeting Summary:

Bill McLaughlin started the meeting with introductions and then briefly explained the agenda and intent of the meeting.

Presentation:

Physical Gate Option Conceptual Designs

Ben and Khalid gave a presentation on the draft physical gate deterrence options for Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut. An overflow gate (weir gate) was presented at Georgiana Slough and Columbia Cut, and an underflow gate (radial arm gate) was presented at the Head of Old River and Turner Cut. They noted that the designs are in the preliminary stage, and changes to the design will be incorporated once comments and suggestions are received from the group. Ben and Khalid mentioned that the two different gate styles could be used at any of the sites. A decision has not yet been made about what style of gate would be best suited for each individual site. Gates were placed in the junctions for the purpose of starting a discussion about the physical deterrence options.

There was a concern expressed regarding not addressing sturgeon passage as part of the physical gate conceptual designs. It was suggested that a boat lock, or a partially open radial arm gate could be used to accommodate sturgeon passage. A suggestion was made to look into some past surgeon passage studies such as the UC Davis research on the sturgeon passage structures Steve and George suggested contacting Bob Gatton with CH2M Hill regarding a sturgeon passage ladder design at the Sack Dam on the San Joaquin River. Steve also suggested that if a similar ladder design is used, that steel removable baffles be incorporated to provide operation flexibility.

Water Resources Assessment Method (WRAM) criteria ranking discussion

There was a discussion among the group regarding the WRAM criteria ranking. No one submitted a copy of their Agency's ranking results and DFW and USFWS expressed concerns about publically submitting individually ranked criteria. The group talked about preparing the RIC collectively as a TWG rather than submitting individual RIC's from each agency. There was also a concern about whether the same Relative Importance Coefficient (RIC) should be used for all the sites. Some suggested that having a different RIC for each site would be more feasible since each site has different priorities. The TWG members were asked to email Bill with ideas about how the group should approach this step of the WRAM process in order to continue making progress with this task. The ideas and suggestions will be discussed among all of the TWG members in the coming weeks.

Action Items and Next Steps

- Provide suggestions to rank the criteria for the RIC portion of the Water Resources Assessment Methodology (WRAM). (All)
- Provide comments/suggestions on the gate conceptual drawings. (All)
- Make revisions to the gate conceptual drawings. (Khalid Ameri/Ben Geske)

The next TWG Meeting will be scheduled for the end of July, 2013.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 08/29/2013, 10:00am – 12:00pm

Location: DWR HQ in Room 210 and (Conference Call)

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Colin Purdy, CDFW

George Heise, CDFW

Jacob McQuirk, DWR

Jason Roberts, CDFW (phone)

Jeff Stuart, NMFS

Krystal Acierto, CDFW

Subir Saha, DWR

Ryan Reeves, DWR

Kim Squires, BDFWO

Meeting Summary:

Bill McLaughlin started the meeting with introductions and then briefly explained the agenda and intent of the meeting. The group discussed how to best move forward with the WRAM process. A decision was made on how to come up with a relative importance coefficient for the entire group. A presentation was given by Ben Geske explaining the results from some modeling runs that included various physical gate operational scenarios.

Water Resources Assessment Method (WRAM) criteria ranking discussion

There was a discussion among the group regarding the WRAM criteria ranking. The goal for this meeting was to come up with an agreement on the best way to complete the relative importance criteria (RIC) portion of the WRAM. Many different suggestions were discussed. Three of the five agencies agreed that each agency should choose how they wanted to create their own set of RIC numbers. Bill McLaughlin will follow-up with USFWS and USBR (not in attendance during this conversation) to see if they agree with the idea as well. Each set of RIC numbers will remain anonymous, and will be averaged or blended to create one single set of RIC numbers that will represent the TWG group as a whole. The RIC numbers are to be completed within the next two weeks.

Presentation:

Physical Gate Modeling Results

Ben Geske gave a presentation that explained the results from various modeling scenarios. Bill explained some background as to why the modeling was requested, and what type of information that we were trying to gain through the modeling. Ben and Subir explained how the model was set up, and how the three scenarios differed from each other. The results were presented through graphs, open discussion, and questioning from meeting attendees. The group was asked to review the results and contact Ben with any follow-up questions, suggestions for improvement, and/or suggestions for additional modeling in the future.

Action Items and Next Steps

- Provide RIC numbers to Bill McLaughlin within two weeks in order to continue to make progress with the Water Resources Assessment Methodology (WRAM). (All)
- Provide comments/suggestions on additional modeling scenarios and what results folks would like to see from the modeling that has occurred. (All)

The next TWG Meeting will be scheduled for the middle of October, 2013.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 10/30/2013, 1:00am – 3:00pm

Location: DWR HQ in Room 335 and (Conference Call)

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Colin Purdy, CDFW

Jacob McQuirk, DWR

Josh Israel, USBR (phone)

Jeff Stuart, NMFS

Josh Brown, DWR

Khalid Ameri, DWR

Ryan Reeves, DWR

Meeting Summary:

Bill McLaughlin started the meeting with introductions and then briefly explained the agenda and intent of the meeting. The group was not able to discuss the Water Resources Assessment Methodology (WRAM) due to missing TWG members at the meeting. NMFS, DFW, and DWR have contributed a completed RIC document at this time. USFWS and Reclamation have yet to contribute their RIC documents. Ryan Reeves briefly talked about the upcoming 2014 Floating Fish Guidance Structure (FFGS) experiment at the Georgina Slough project site. A presentation was given by Ben Geske and Khalid Ameri explaining the FFGS conceptual designs at Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut.

Presentation:

FFGS Conceptual Designs

Ben and Khalid gave a presentation on the FFGS. They shared FFGS conceptual designs for Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut sites. Bill and Ryan gave some background as to why the FFGS has been considered as an engineering option. Ben and Khalid explained how the FFGS locations and alignments were determined at each individual site. It was concluded that the conceptual designs are based on the current available information and the design at Georgiana Slough might be altered after the 2014 FFGS Georgiana Slough study is completed. The Turner Cut and Columbia Cut conceptual designs will be altered once hydrodynamic data collected at those sites can be used to assist in locating the FFGS.

Action Items and Next Steps

- Follow up with USFWS and Reclamation to try and obtain their RICs. (Bill)
- Develop conceptual designs for other options. (Khalid Ameri/Ben Geske)
- Look into Marin Greenwood (ICF) presenting information on the Head of Old River synthesis report.
- Look into USGS presenting 2008 North of the Delta fish distribution data.

The next TWG meeting will be scheduled for the first or second week of December, 2013.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 12/10/2013, 1:00 pm – 3:00 pm

Location: DWR HQ in Room 210 and (Conference Call)

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Bob Pedlar, DWR

Dave Huston, DWR (phone)

George Heise, CDFW

Jacob McQuirk, DWR

Steve Thomas, NMFS (phone)

Jeff Stuart, NMFS

Josh Brown, DWR

Khalid Ameri, DWR

Krystal Acierto, CDFW

Marin Greenwood, ICF

Ryan Reeves, DWR

Meeting Summary:

Bill McLaughlin started the meeting with introductions and then briefly explained the agenda and intent of the meeting. Bill briefly talked about the Water Resources Assessment Methodology (WRAM). It was mentioned that a follow up meeting with Reclamation is scheduled to obtain the only missing RIC numbers in order to go forward with the WRAM process. Ryan Reeves talked about the 2012 draft Georgiana Slough Non-Physical Barrier Report. He indicated that the 2012 report is ready to be reviewed by the group. He asked the group to provide their comments no later than January 13th.

A presentation was given by Marin Greenwood explaining juvenile salmonid routing, barrier effectiveness, predation, and predatory fishes at the Head of Old River. The second presentation was given by Ben Geske and Khalid Ameri explaining the Infrasound Fish Fence (IFF) conceptual designs at Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut.

Presentations:

Head of Old River Synthesis Report

Marin gave a presentation summarizing the synthesis report by describing studies and results that took place at the Head of Old River between 2009 and 2012. The studies were conducted to investigate two types of fish barriers. One was the BAFF and the other was the Rock Barrier. The studies were designed to investigate juvenile salmonid routing, predation on juvenile salmonids, barrier effects, and density changes in predatory fish. He shared some interesting results and recommendations with the group.

- 2010-2011 through-Delta survival results suggest the SJR route is no longer safer (SJRGA 2011, 2013)—survival is v. low by any route
- Although BAFF does deter fish, it gave only a modest improvement in protection efficiency
- BAFF effects undone by predation
- Rock barrier had greatest overall efficiency, but estimated predation was high (~40%)
- There is uncertainty in fate classification, but main conclusion (BAFF should not be used at this location) is robust

The draft report will be available to the group around the middle of January 2014.

IFF conceptual designs

Ben and Khalid gave a presentation on the IFF. Ben gave a brief background as to why the IFF has been considered as an engineering option because the technology was introduced to the group at a previous TWG meeting. Conceptual designs were shared for Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut sites. Ben and Khalid explained how the IFF locations and alignments were determined at each individual site. It was pointed out that this technology uses particle acceleration rather than sound pressure. Khalid mentioned that this technology is not feasible to consider at the Head of Old River site due to the shallow water depth. He indicated that the zones of influence will be in contact with the channel bottom and water surface throughout the barrier alignment. As a result, this will lead to abnormal local environment effects at that site.

Action Items and Next Steps

- Follow up with Reclamation to obtain their RICs. (Bill)
- Compile and send additional IFF information with references to the group. (Ben)
- Review and provide comments on the 2012 Draft Georgian Slough Non-Physical Barrier Report by January 13th. (All)

The next TWG meeting will be scheduled for the last week of January or first week of February 2014.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 01/28/2014, 1:00 pm – 3:00 pm

Location: DWR HQ in Room 210 and (Conference Call)

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Bob Pedlar, DWR

Colin Purdy, CDFW

George Heise, CDFW

Jacob McQuirk, DWR

Jeff Stuart, NMFS

Khalid Ameri, DWR

Mark Holderman, DWR

Mike Cane, DWR

Ryan Reeves, DWR

Steve Thomas, NMFS (phone)

Meeting Summary:

Bill started the meeting with introductions and then briefly explained the agenda and intent of the meeting. Bill briefly gave an overview of the Franks Tract project on Threemile Slough. He mentioned that Reclamation staff was not able to attend the meeting and hopefully a presentation on the Franks Tract project will be given at the next TWG meeting.

A brief discussion was held regarding the 2012 draft Georgiana Slough Non-Physical Barrier Report comments. Colin indicated that he will send his comments to Bill this week. Jeff also indicated he will provide comments in the near future.

A presentation was given by DWR staff regarding design information for fish screens at Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut.

Presentations:

Fish Screen conceptual designs

Bill gave a background as to why fish screens have been considered as an engineering option. Ben shared design information for the Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut sites. The information included tabulated data showing how the design criteria inputs and outputs change according to the dynamic environment specific to each site. He also showed some preliminary calculations based on historical hydrodynamic data, channel geometry, and fish screening criteria. The objective of the presentation was to share BDO's preliminary calculations with regards to NMFS and DFW's fish screening criteria, and how they applied to each specific site. Concerns about failing to meet the criteria using site specific design flows and geometric layouts were also discussed.

Designing fish screens for the maximum diversion versus using average flows was discussed with the group. Maximum flows are extensively used in fish screen designs. The main concerns for designing fish screens at Georgian Slough and Head Old River were the size of the screens and being able to meet the approach velocity criteria of 0.2 fps (Delta Smelt) or 0.33 fps (Juvenile Salmonids) at all times. It was shown that in order to meet agencies design criteria, the size of the screens would be too large and not feasible to place in the junctions. However, for the Turner and Columbia Cut sites, the size of the screen was not a major concern. The main concerns for those two sites were the perpendicular flows and reverse flows which will cause fish to become impinged on the screen face and approach velocities not being met at all times. It was indicated that reverse flows occur about 50% of the time at Turner Cut and Columbia Cut which further complicates operation of a fish screen.

A discussion was had regarding the possibility for using partial column screens instead of full column screens. George indicated that this type of technology would still need to adhere to the current fish screening criteria, and that it seems to have similar issues to the full screen option. It was suggested to look into other technologies that might be more feasible than the fish screen such as the Floating Fish Guidance Structure that will be field tested this spring at Georgiana Slough.

In summary, the TWG members present (NMFS, DFW, and DWR) were agreeable to dropping a fish screen as an option. However, fish screening technologies may be combined with other engineering options in order to maximize fish deterrence if appropriate. USFWS and Reclamation staff not present at the meeting will be briefed on the meeting and asked if they formally concur with the other TWG members to drop the fish screen option.

Action Items and Next Steps

- Follow up with Reclamation and USFWS to obtain feedback and concurrence on dropping the fish screen technology from further consideration. (Bill)
- Coordinate with Reclamation to give a presentation on the Franks Tract project at the junction of the Sacramento River and Threemile Slough. (Bill)
- Develop conceptual designs for the Threemile Slough site. (Khalid/Ben)
- Provide comments on the 2012 Draft Georgiana Slough Non-Physical Barrier Report. (All)

The next TWG meeting will be scheduled for the second week of March 2014.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 04/30/2014, 10:30 am – 12:30 pm

Location: DWR HQ in Room 210

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Dave Huston, DWR (phone)

George Heise, CDFW

Jacob McQuirk, DWR

Jeff Stuart, NMFS (phone)

Josh Israel, USBR (phone)

Khalid Ameri, DWR

Mike Cane, DWR

Roy Leidy, AECOM

Ryan Reeves, DWR

Meeting Summary:

Bill opened the meeting by introducing the participants both on the phone and in the room. He described the agenda for the meeting and then started the presentation of the engineering solutions design packet.

A presentation was given by Ben and Khalid showing the latest set of conceptual designs for Georgiana Slough, Threemile Slough, Head of Old River, Turner Cut, and Columbia Cut. Ben and Khalid went through each drawing, for each individual site, and explained changes that were made due to new information or comments from previous TWG meetings. Questions and comments about the design, and how it addresses the ranking criteria, were encouraged by staff. Ryan suggested that we extend the upstream end of the Georgiana Slough FFGS further upstream, and closer to the river's edge. This could possibly improve deterrence by minimizing the number of fish going behind the barrier.

Josh discussed how additional water along with an engineering option for deterrence would be beneficial to the downstream migrants. The gate designs could accomplish this but to the detriment of the interior Delta based on modeling runs made on the impacts of decreased flows in Georgiana Slough, Head of Old River, Turner Cut, and Columbia Cut.

Bill asked the group to review the conceptual design package and provide comments. He concluded that the changes to the designs will be incorporated once all comments/suggestions are received from the group. Bill indicated that this process will help us with ranking each engineering option during the next step in the WRAM process.

Action Items and Next Steps

- Provide comments on the engineering options conceptual design package. (All)
- Make changes to drawings due to comments and suggestions from this meeting. (Geske/Ameri)
- Start working on the final report write-ups. (DWR)

The next TWG meeting will be scheduled for mid-June 2014.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 06/17/2014, 1:00 pm – 3:00 pm

Location: DWR HQ in Room 210

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Bob Pedlar, DWR

George Heise, CDFW

Jacob McQuirk, DWR

Jeff Stuart, NMFS (phone)

Khalid Ameri, DWR

Michael Eakin, CDFW

Roy Leidy, AECOM

Meeting Summary:

Bill opened the meeting with introductions and described the agenda for the meeting. He then discussed the write-ups that support the conceptual designs and their significance during the OCC portion of the WRAM evaluation. The group discussed how to best move forward with the 2nd phase of the WRAM process which is to evaluate different engineering options at the individual sites. The draft Georgiana Slough FFGS write-up was discussed. Bill mentioned that staff is in the process of producing write-ups for all four options at each of the five sites (20 total write-ups).

The group discussed how to evaluate the predation effects for each option when there is no baseline densities of predators that exist at any of the junctions. Bill indicated that it would be difficult to determine whether a specific engineering option would contribute to predation rates of Juvenile salmonids in the absence of a baseline study. Roy Leidy pointed out that AECOM is currently working on the Synthesis report to examine the BAFF and Rock Barrier at the Head of Old River for predation impacts. This would be accomplished by investigating the predator density, predator behavior, and predation rates that occurred in the vicinity of the HOR during the studies.

There was a discussion about the deterrence effectiveness of the options that are currently on the table. Infrasound is one of the options which we are currently considering, but has not been tested in an environment such as the Sacramento River or San Joaquin River. Michael Eakin inquired about the possibility of the IFF units harming Delta Smelt larva due to the intense vibrations close to the units. Ben answered by saying that the IFF manufacturer (Profish - Sonny Damien) does not believe that the vibrations would harm very small fish, but also said that there hasn't been any tests to prove that yet. Jacob followed up with the idea that we (TWG group) would suggest that there be further laboratory and field testing conducted prior to permanent installation to answer the question. George and Roy both mentioned that it was important for all of the TWG members to have a consistent definition for all of the criteria while evaluating the options. A document containing the criteria definitions and "questions to ask yourself" during the grading process was sent to all the TWG members to review it in order keep the TWG members on the same thought process through this evaluation.

The Group discussed in general the difficulty in comparing options based on limited studies not reflecting variable conditions (i.e, flow) and in many cases no studies. (e.g., flow conditions during the Georgiana Slough BAFF tests varied but only low flow conditions occurred during the 2014 FFGS study. Jeff mentioned that he recalls a temporal flow period greater than 25,000 cfs. George suggested that we focus on dry and average water year types while evaluating the options. This was agreed upon by all meeting attendees. This should capture the periods when fish protection is most necessary.

The Group discussed potential sediment accumulation issues associated with options at some sites, primarily the Head of Old River shallower water depths. These potential issues should be considered and how they may affect O&M and performance.

Jacob mentioned that tidal excursion changes resulting from proposed plans to open up Liberty Island to tidal flows and other BDCP actions may influence the option evaluations. These potential changes should be considered. This is just one of many elements of the BDCP project that may influence option evaluations.

Bill asked the group to review the Georgiana slough FFGS draft write-up and provide comments. He concluded that the final write-up format will be used as a basis to provide consistent information to the group for all option write-ups.

Action Items and Next Steps

- Provide comments on the Georgiana Slough FFGS write-up. (All)
- Send out the final RIC values. (McLaughlin)
- Start working on the other engineering options write-ups. (Geske/Ameri)
- Post Georgiana Slough and HOR BAFF study reports on DWR Portal (McLaughlin)

The next TWG meeting will be scheduled for end of July or beginning of August 2014.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 08/06/2014, 1:00 pm – 3:00 pm

Location: DWR HQ in Room 210

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Bob Pedlar, DWR

George Heise, CDFW

Jacob McQuirk, DWR

Jeff Stuart, NMFS (phone)

Khalid Ameri, DWR

Michael Eakin, CDFW

Roy Leidy, AECOM

Steve Thomas, NMFS (phone)

Meeting Summary:

Bill opened the meeting with introductions and described the agenda for the meeting. He briefly discussed the conceptual design write-ups that support the OCC portion of the WRAM evaluation. Bill mentioned that staff is in the process of producing additional write-ups for the group to review. He asked the group to review the draft write-ups and provide comments. Jeff suggested addressing potential issues with boat navigation during extreme dry (drought) and high water conditions in the write-ups, especially for the BAFF at the Head of Old Rive option.

An Excel spreadsheet containing the OCC portion of the WRAM evaluation was discussed to keep the TWG members on the same thought process through this evaluation. Bill shared the combined averaged RIC values with the group. Bill added that he will send out the spreadsheet to the group for ranking around the end of August.

A draft outline for the Phase II report was discussed among the TWG members. Bill asked the group to review the outline and provide comments no later than August 14th. Bill indicated that the First Draft of the Phase II report would be completed by October 1st and the TWG members would potentiality have a month to review and provide comments.

Action Items and Next Steps

- Provide comments on the conceptual design write-ups. (All)
- Provide comments on the Final Draft Report Outline no later than August 14th. (All)
- Send out the OCC portion of the WRAM evaluation Excel sheet to the TWG members. (McLaughlin)
- Continue work on the engineering options write-ups. (Geske/Ameri)

The next TWG meeting will be scheduled for the middle of September 2014.

OCAP Action IV.1.3

Technical Working Group Meeting Summary

Meeting Date/Time: 12/16/2014, 10:00 am – 12:00 pm

Location: DWR HQ in Room 210

Participants

Ben Geske, DWR

Bill McLaughlin, DWR

Bob Pedlar, DWR

George Heise, CDFW

Jacob McQuirk, DWR

Jeff Stuart, NMFS (phone)

Khalid Ameri, DWR

Michael Eakin, CDFW

Roy Leidy, AECOM

Ryan Reeves, DWR

Meeting Summary:

Bill described the agenda for the meeting. The draft Phase II report was discussed. Bill asked the group to review the report and provide comments no later than January 12^{th}, 2015. Bill stated that as planned the draft does not include completed chapters 5 (WRAM Assessments) or 6 (Recommendations). Bill indicated that a revised Phase II draft report would then be distributed to the TWG members on February 9, 2015 with comments due no later than February 23, 2015. He discussed the costs associated with the conceptual designs. He indicated that he will send updated cost information which will include O&M and present worth costs for each option within a week.

Bill requested the TWG members provide recommendations to be included in the report. The current draft does not include recommendations (Chapter 6). It would be helpful to have TWG members provide input. Potential recommendations include: reviewing the 2014 FFGS report once it is finalized (data processing on-going), review other in-progress studies (6-year study, ELAM modeling, etc….), additional evaluations of technologies, and additional modeling (junction and operations). Re-assessing the options should also be considered as additional information is obtained.

Bill also discussed the OCC portion of the WRAM evaluation. An Excel spreadsheet containing the OCC portion of the WRAM evaluation was presented along with directions for completing it. Bill added that each agency would come up with one set of OCC numbers. Bill also suggested that as was done for the RIC numbers, averaging the OCC numbers from the five agencies seems to be the best strategy versus trying to have a consensus among everyone. Bill will follow-up with USFWS and USBR to let them know about the OCC process since they were not in attendance during this meeting. Bill indicated that the due date to submit the OCC numbers is also January 12^{th}.

Action Items and Next Steps

- Provide comments on the Phase II draft report no later than January 12^{th}, 2015. (All)
- Provide recommendations to be included in Chapter 6 no later than January 12^{th}, 2015. (All)

- Provide OCC numbers for the WRAM evaluation no later than January 12th, 2015. (All)
- Provide updated cost information for the conceptual designs to the TWG members within a week. (McLaughlin)

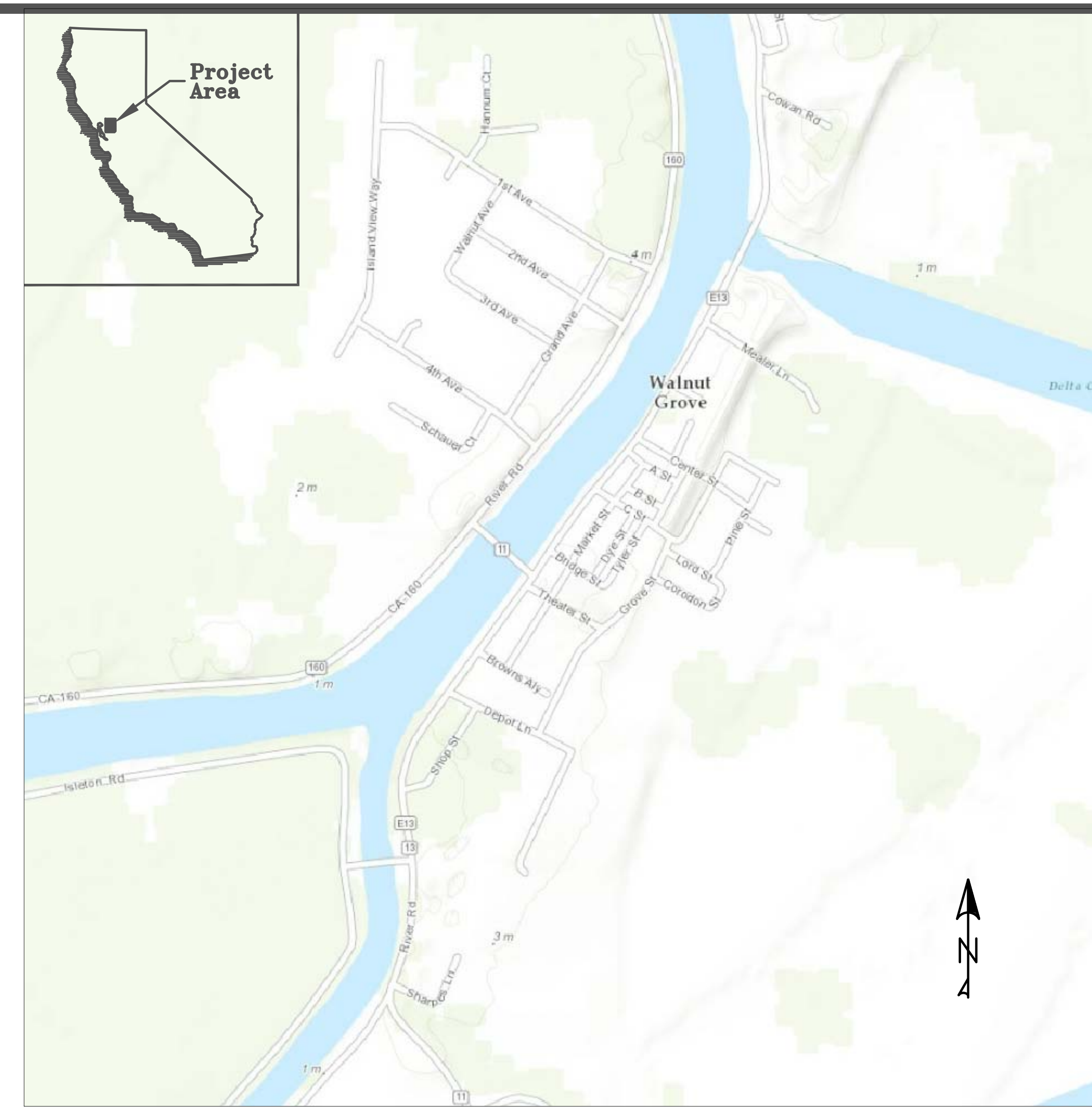
APPENDIX B

Conceptual Engineering Design Details

CONCEPTUAL ENGINEERING DRAWINGS FOR

GEORGIANA SLOUGH
NMFS BiOp RPA ACTION IV.1.3

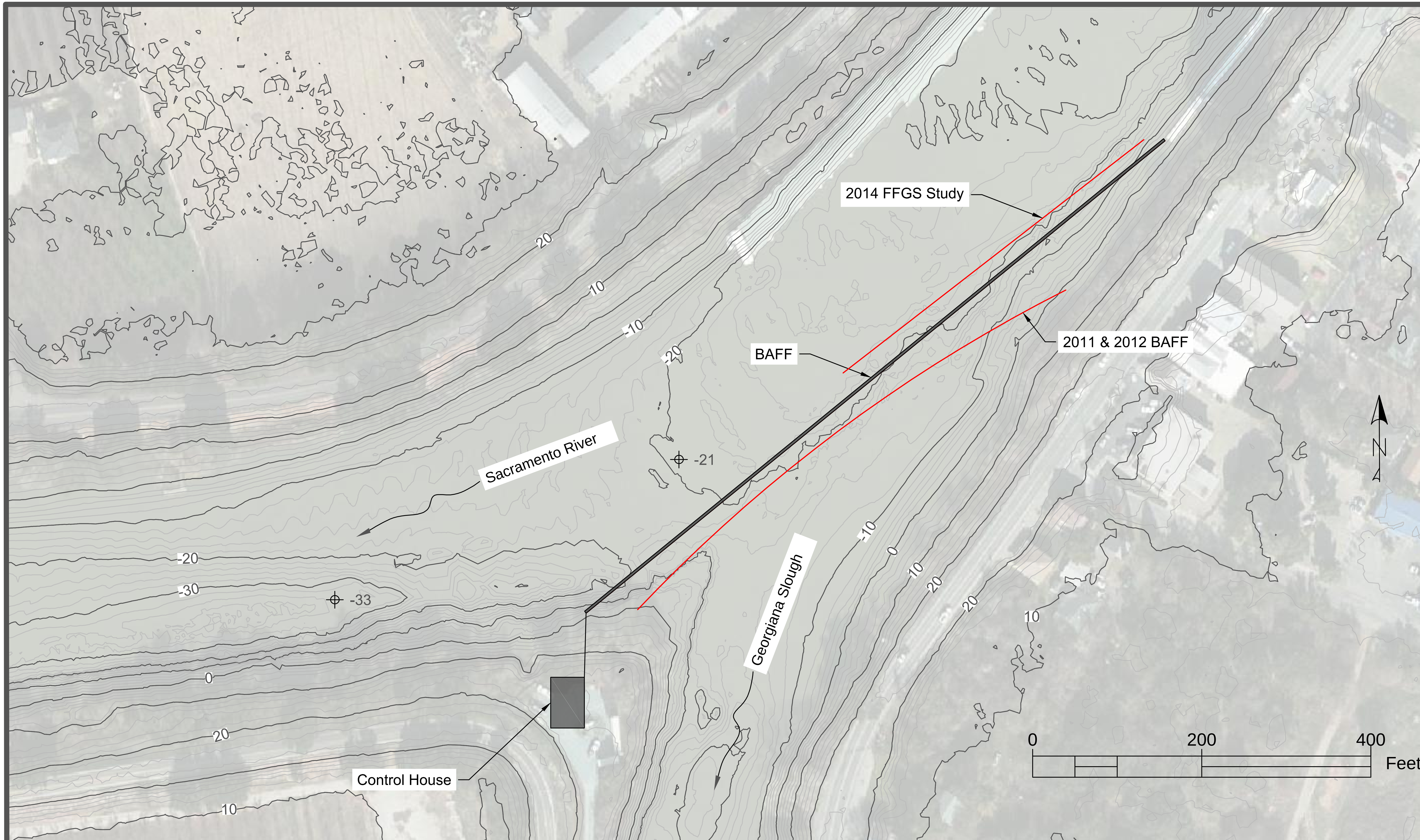
SACRAMENTO COUNTY, CALIFORNIA



INDEX OF SHEETS

PRELIMINARY
SUBJECT TO REVISION

Date Drawn: 10–7–2014 Drawn By: Ben Geske	Title Sheet and Area Map Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office	GS.dwg SHEET 1 OF 19



Date Drawn: 06–24–2014

Drawn By: Ben Geske

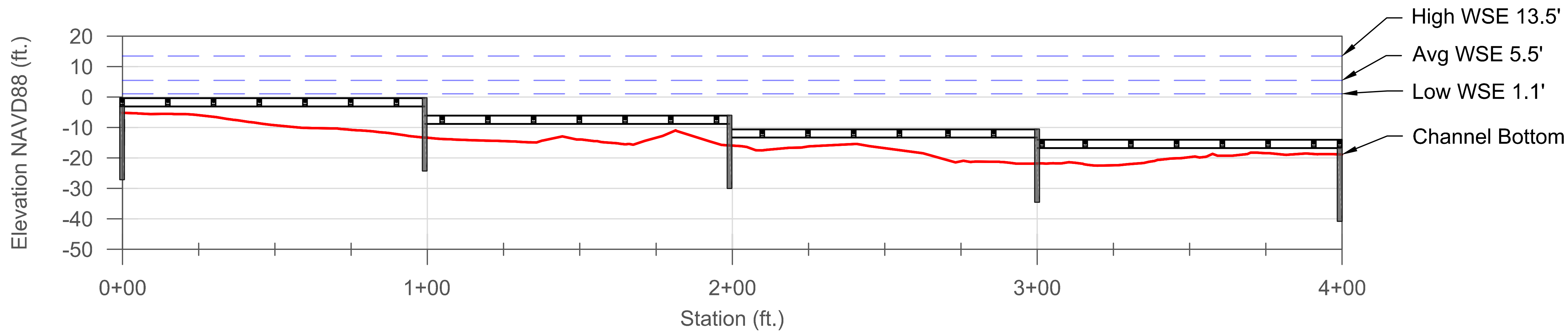
Plan: Bio–Acoustic Fish Fence

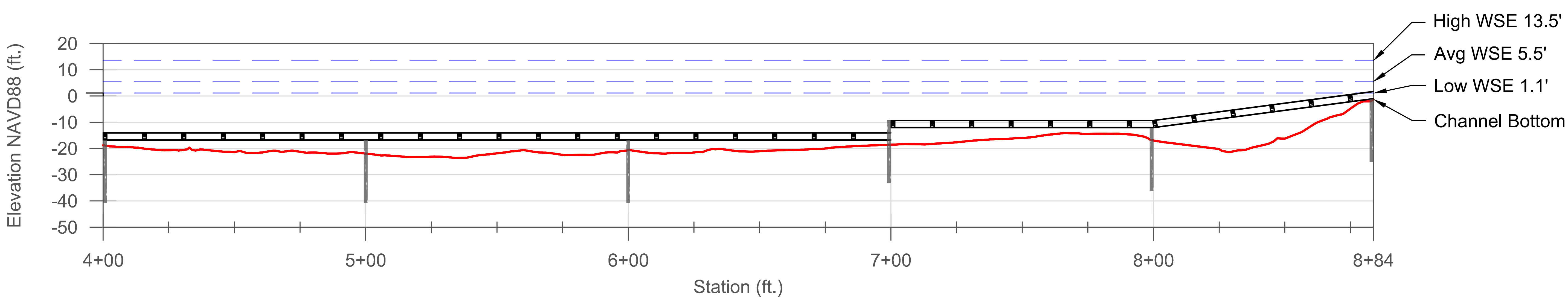
Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

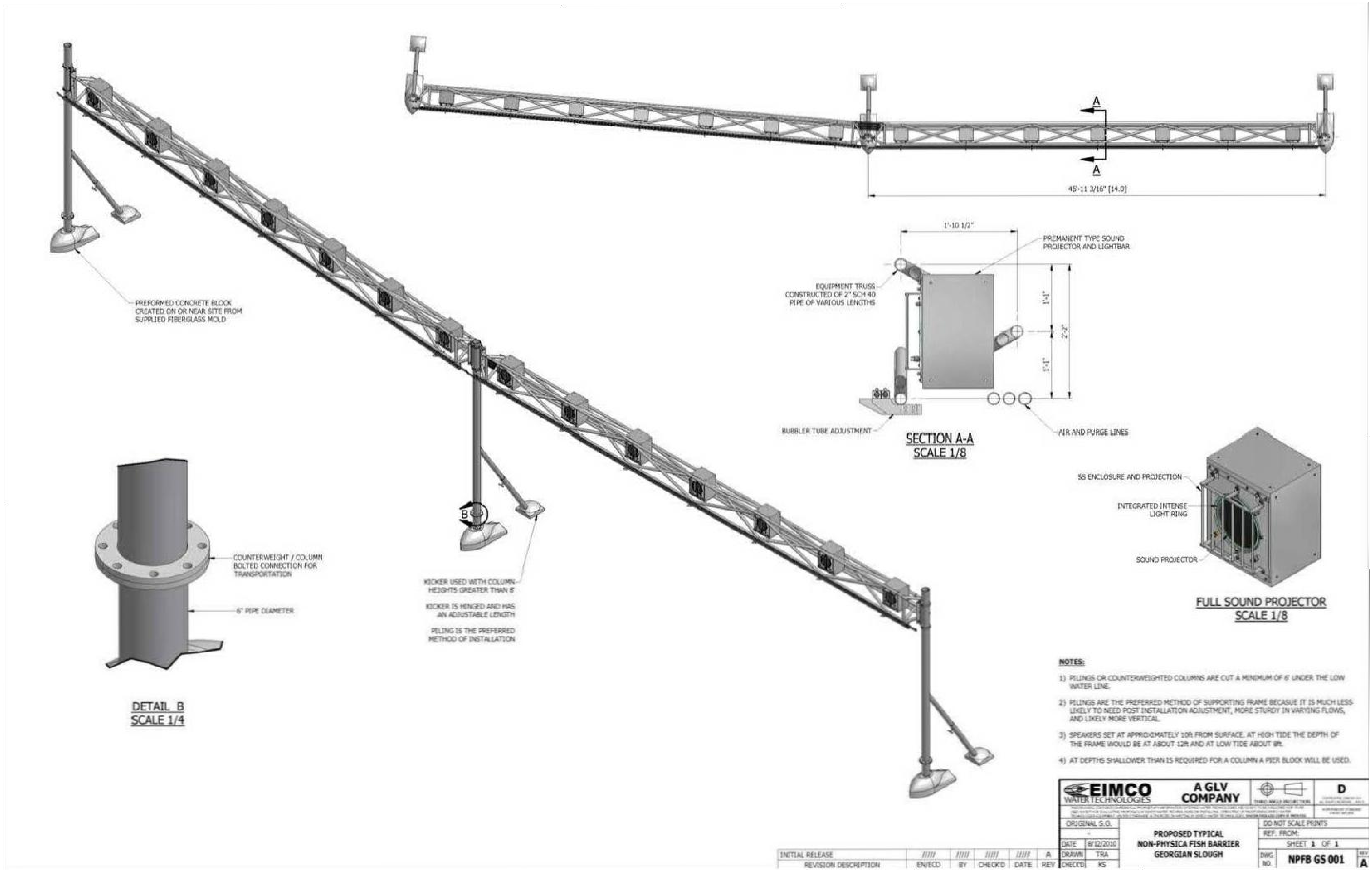
BAFFatGS.dwg

SHEET 2 OF 19

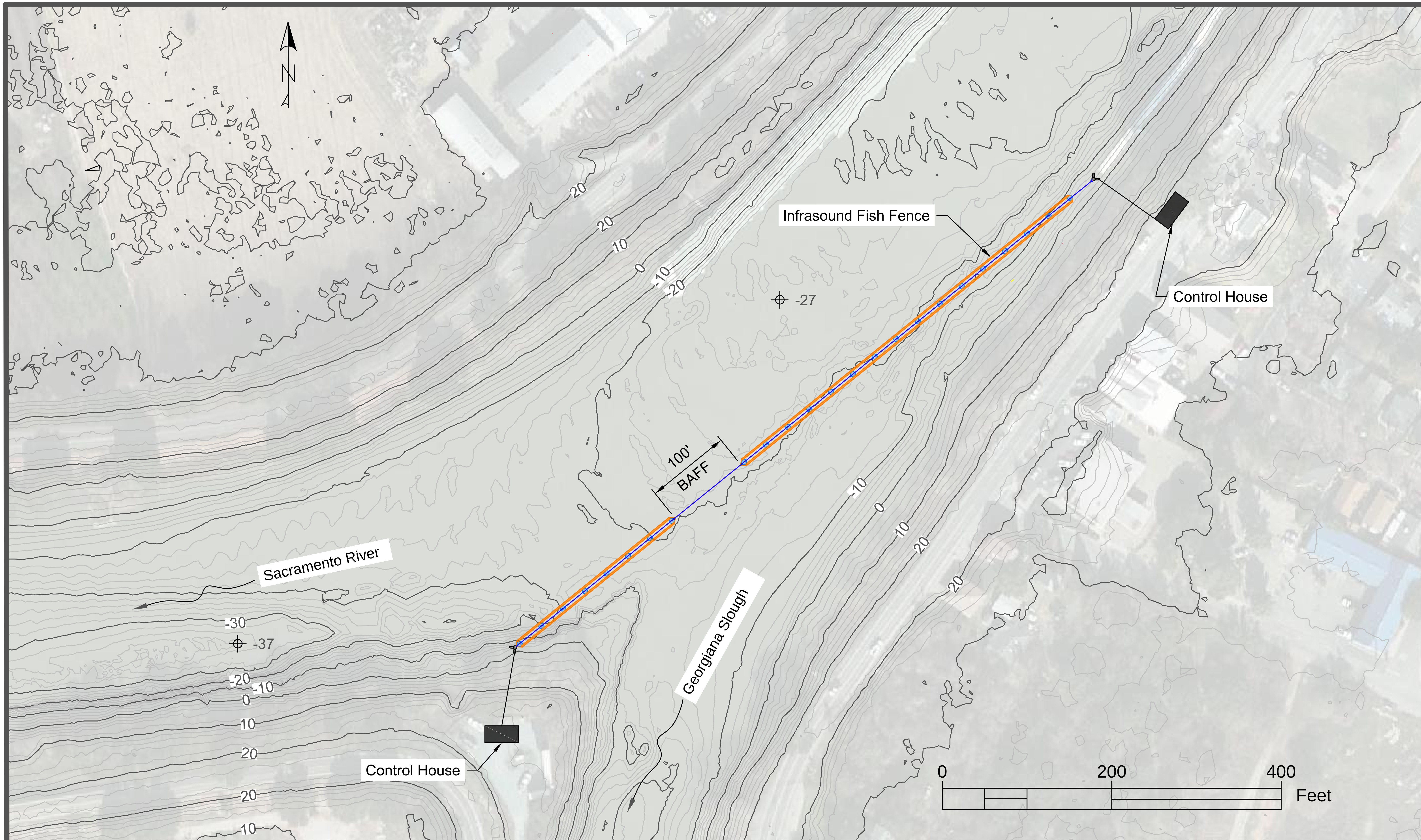




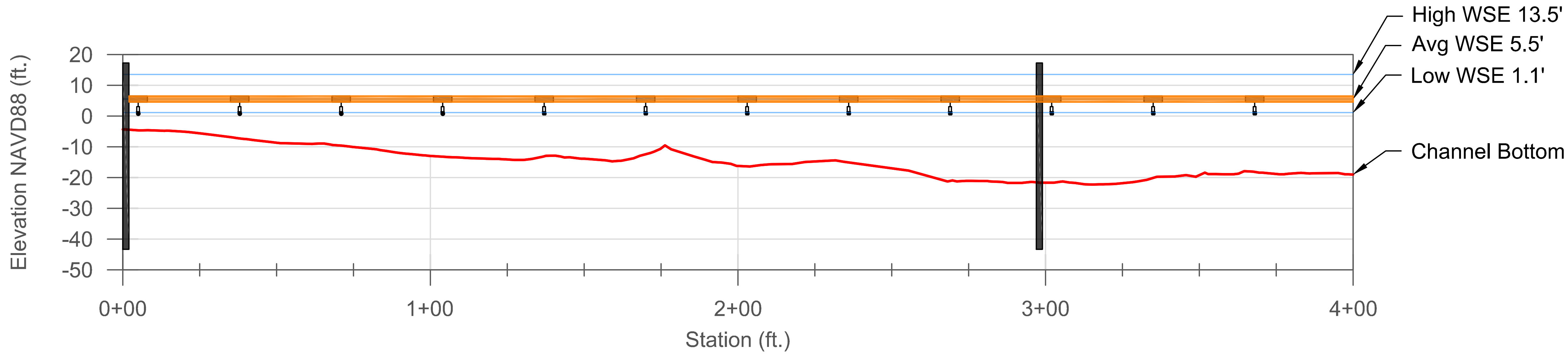
Date Drawn: 06-24-2014 Drawn By: Ben Geske	**Elevation: Bio-Acoustic Fish Fence** Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatGS.dwg SHEET 3 OF 19

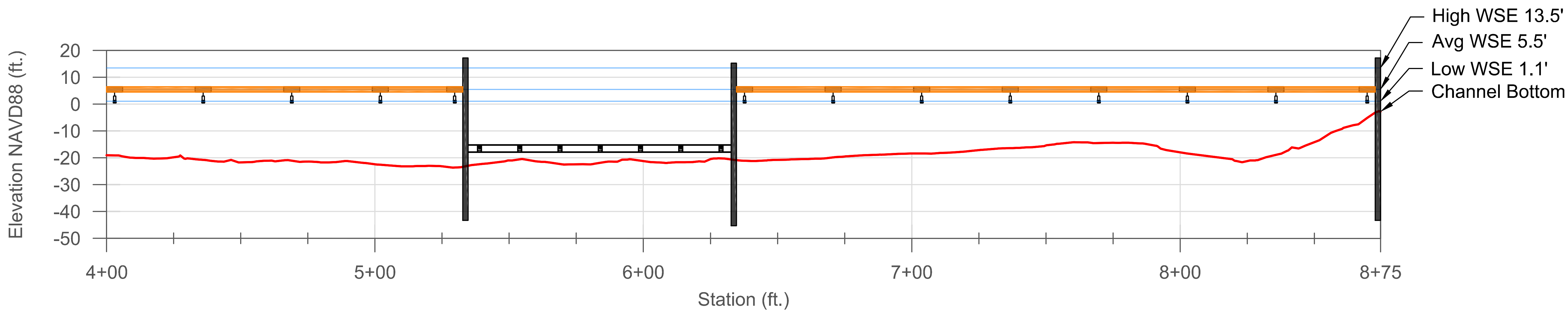


Date Drawn: 08-12-2010 Drawn By: EIMCO	**Detail: Bio-Acoustic Fish Fence** Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatGS.dwg SHEET 4 OF 19



Date Drawn: 06–24–2014 Drawn By: Ben Geske	Plan: Infrasound Fish Fence Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office	IFFatGS.dwg SHEET 5 OF 19





Date Drawn: 07–14–2014

Drawn By: Ben Geske

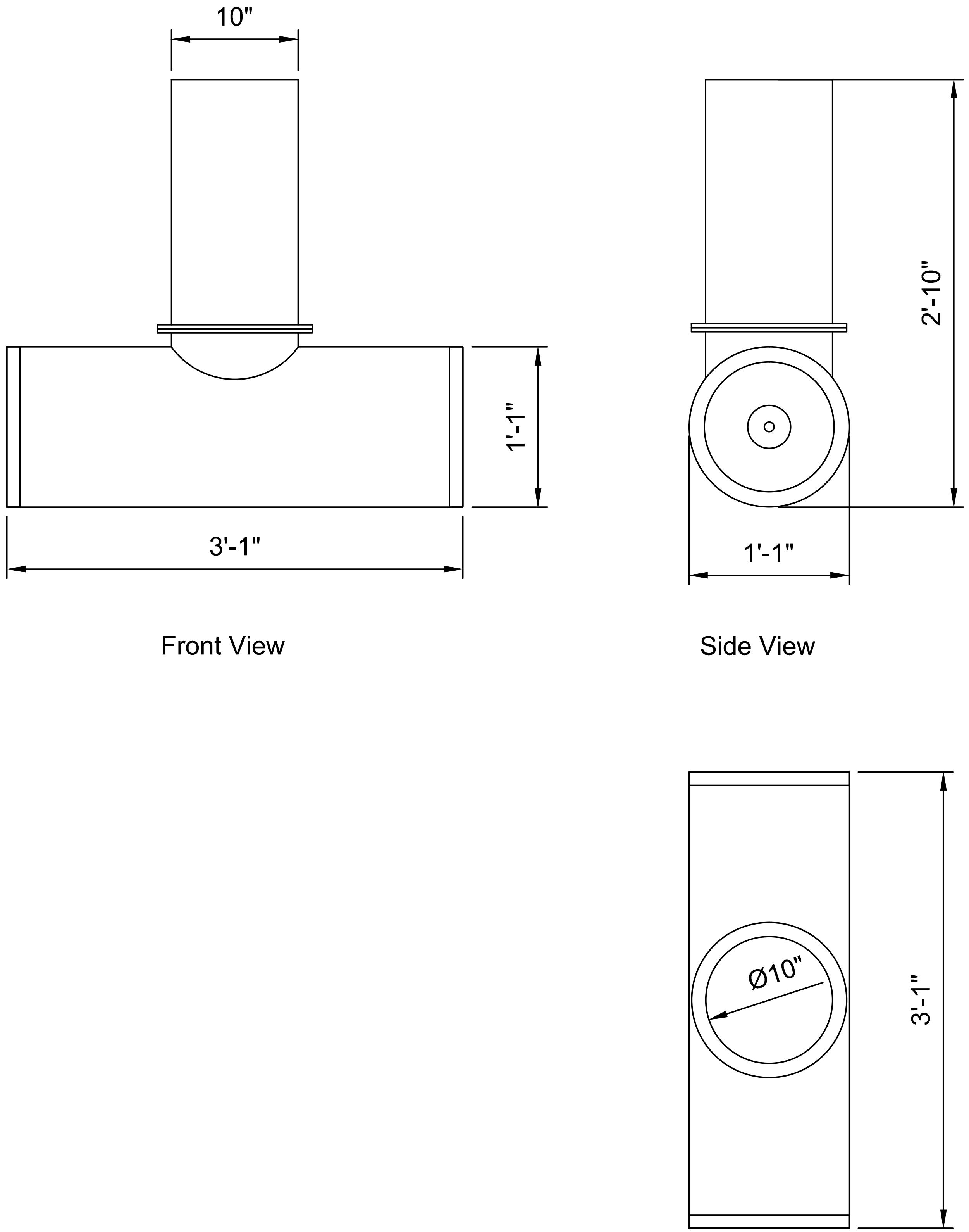
Elevation: Infrasound Fish Fence

Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

IFFatGS.dwg

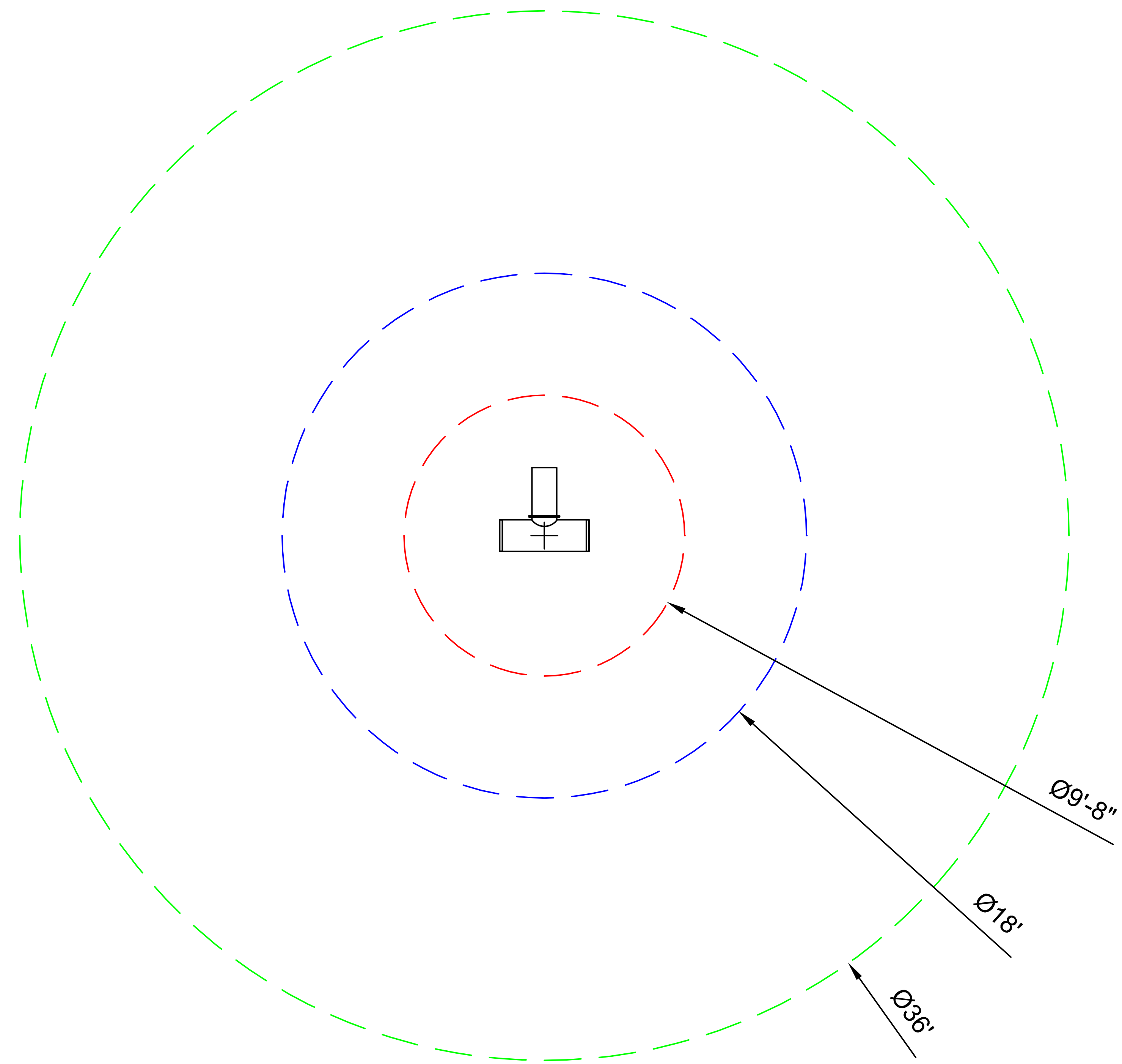
SHEET 6 OF 19



Front View

Side View

Top View

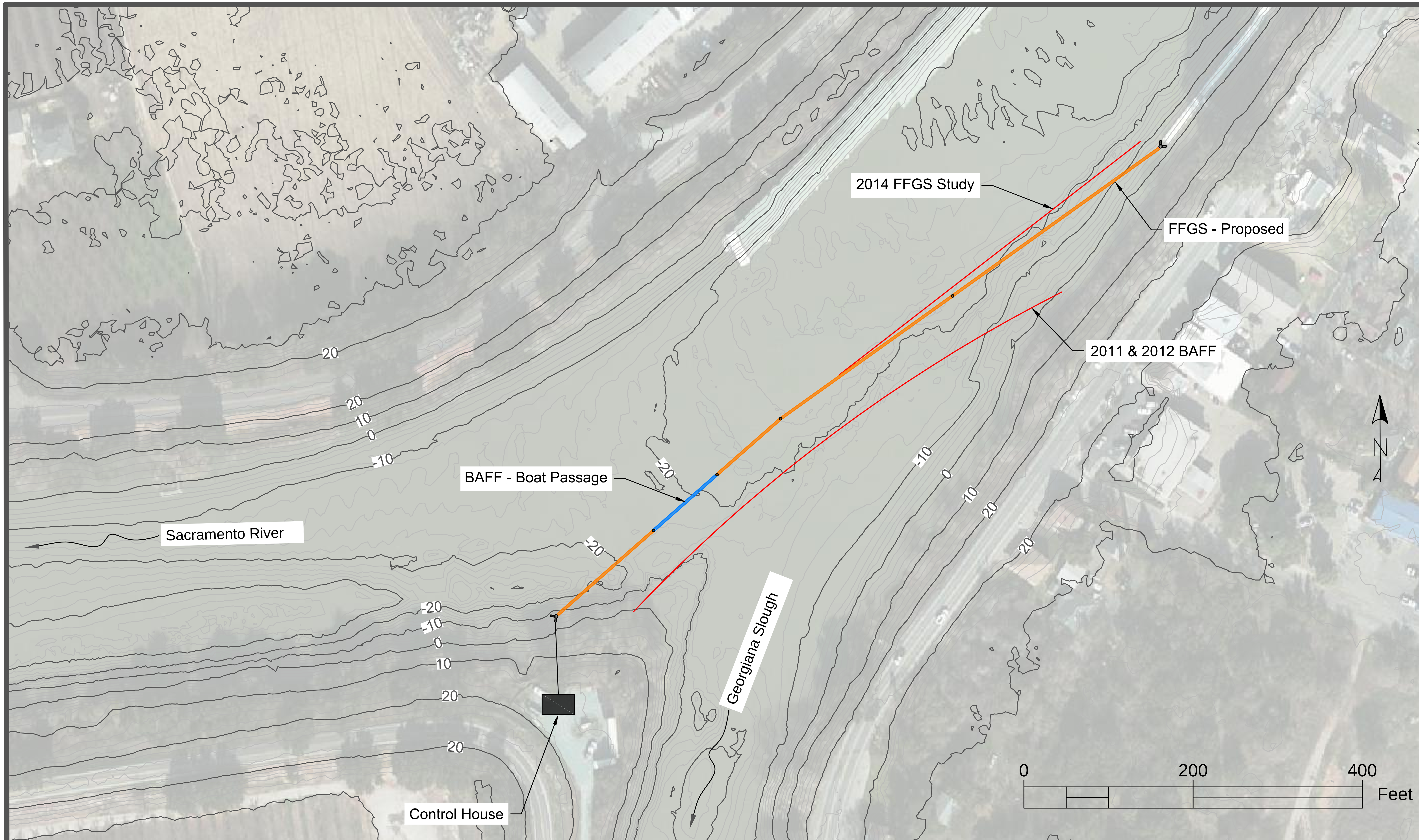


Red = Zone of exclusion from structural entities.

Blue = Fish dterrence zone.

Green = Boundary for measurable particle acceleration.

Date Drawn: 06–24–2014 Drawn By: Ben Geske	Detail: Infrasound Fish Fence Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office	IFFatGS.dwg SHEET 7 OF 19



Date Drawn: 06–24–2014

Drawn By: Ben Geske

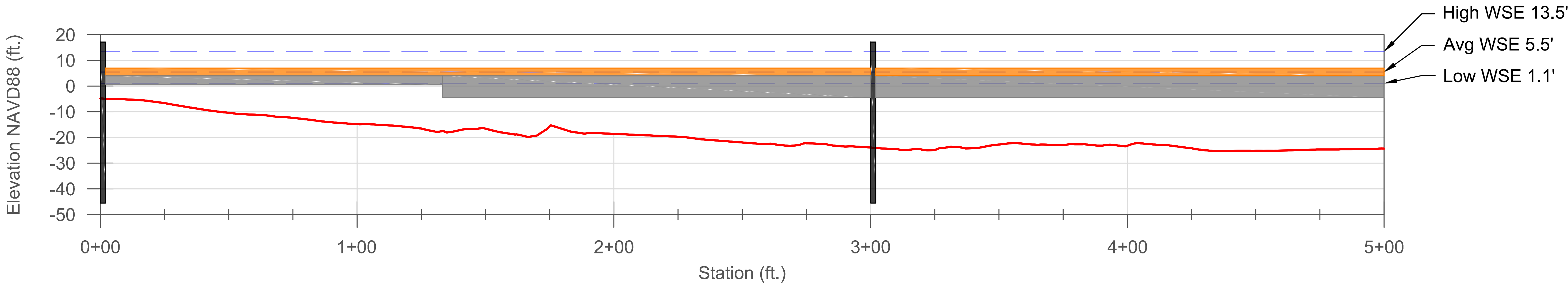
Plan: Floating Fish Guidance Structure

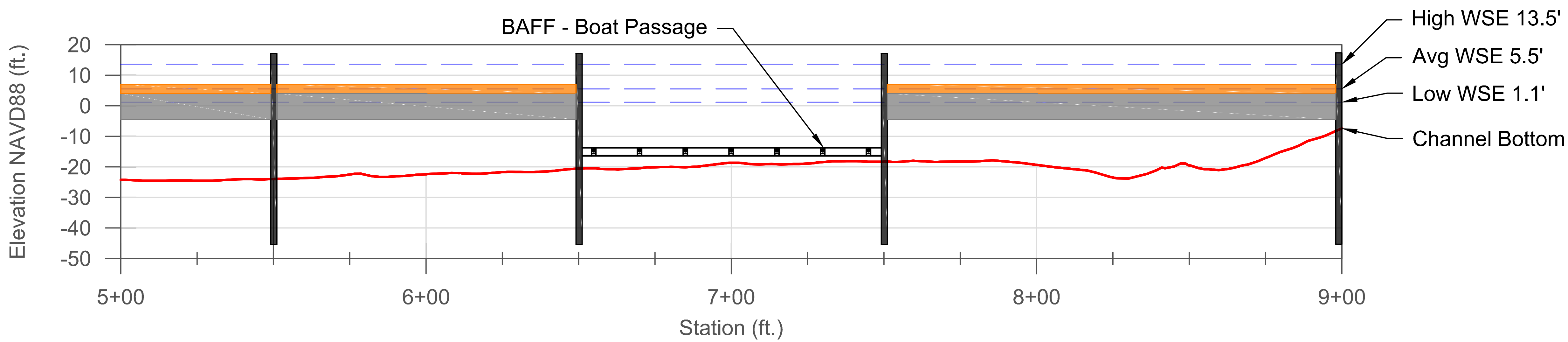
Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

FFGSatGS.dwg

SHEET 8 OF 19





Date Drawn: 06-24-2014

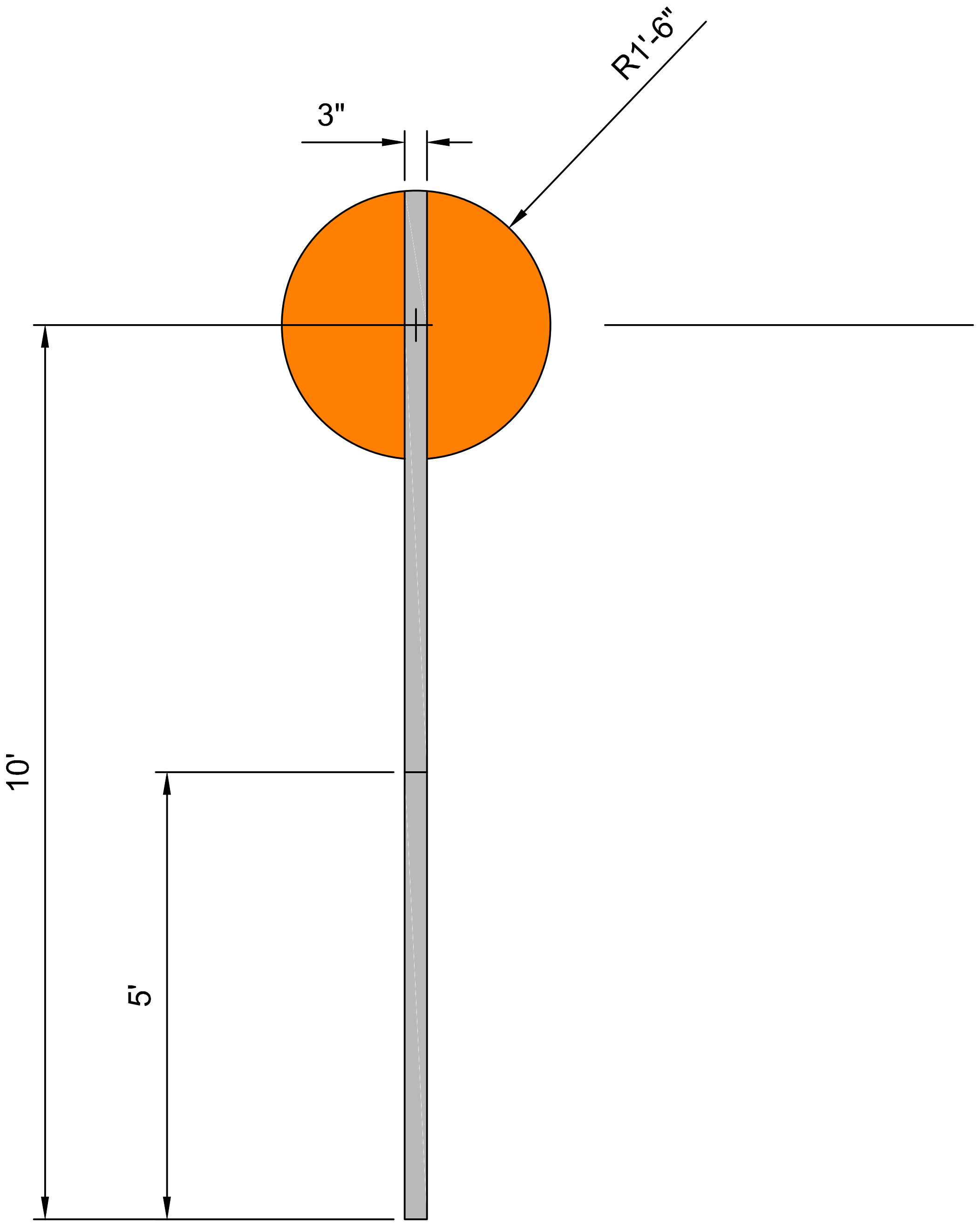
Drawn By: Ben Geske

Elevation: Floating Fish Guidance Structure

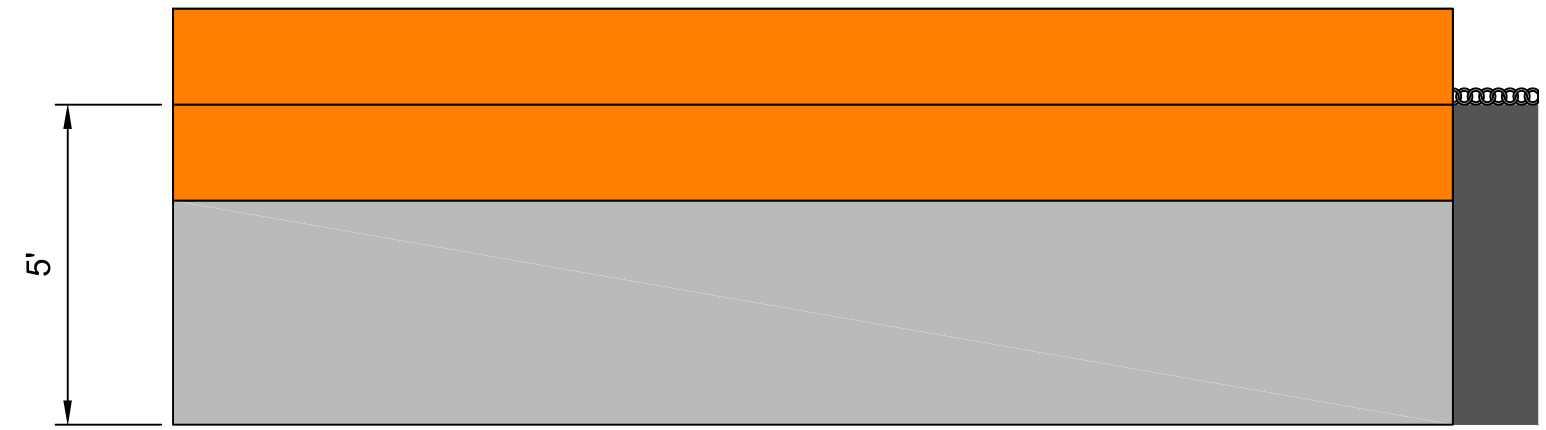
Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

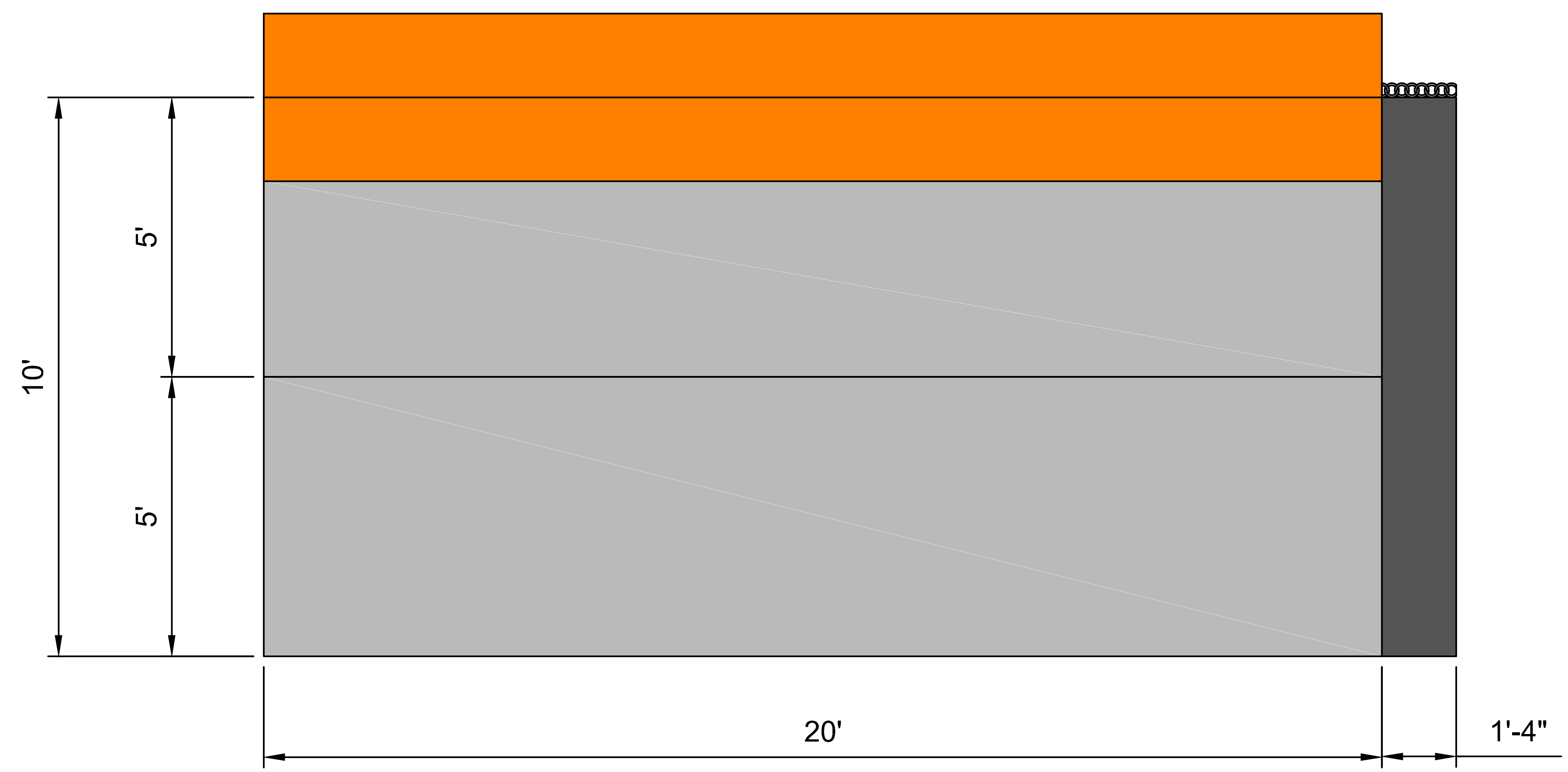
FFGSatGS.dwg



DETAIL: SINGLE FFGS SECTION - SIDE VIEW

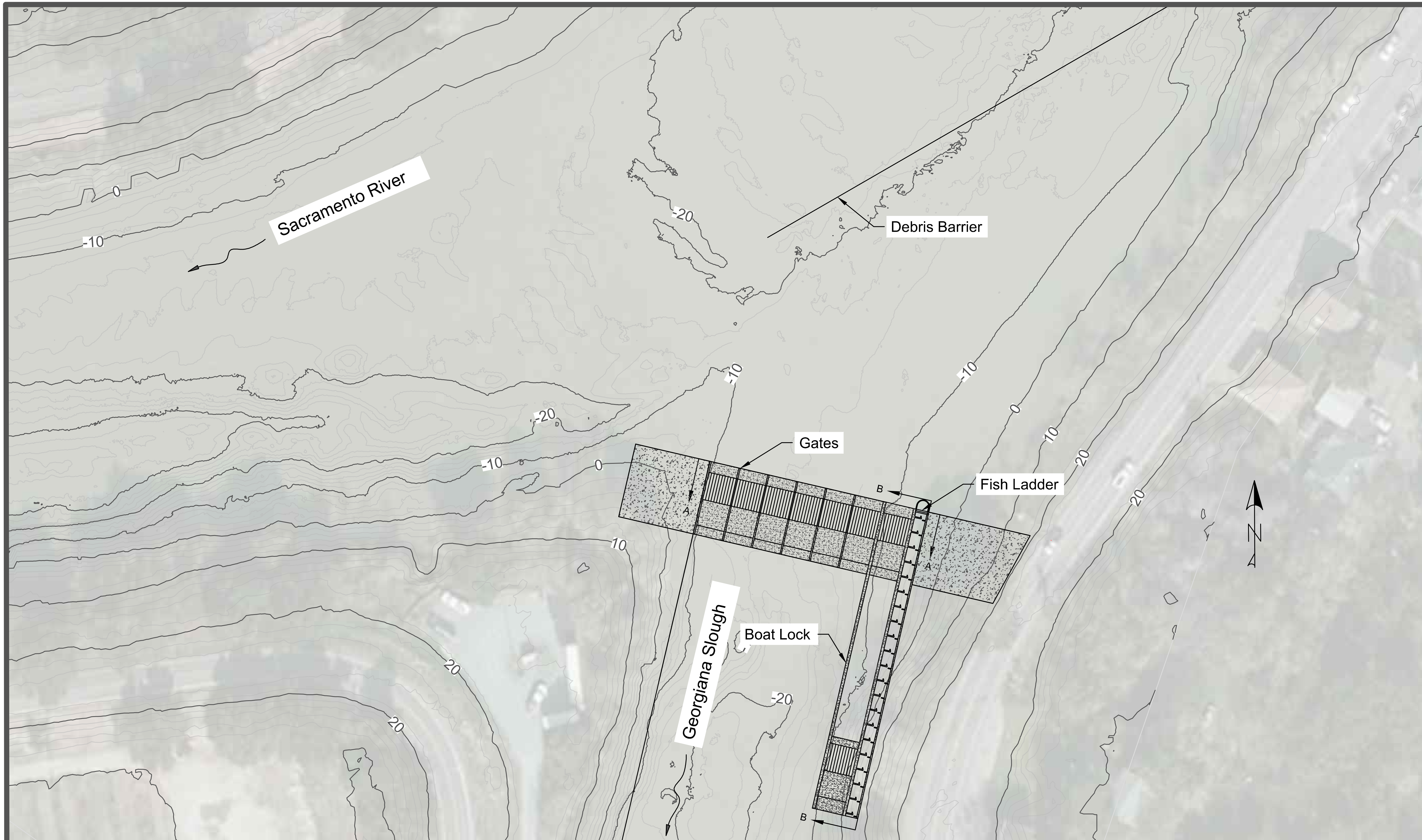


DETAIL: SINGLE 5' FFGS SECTION - FRONT/FACE



DETAIL: SINGLE 10' FFGS SECTION - FRONT/FACE

Date Drawn: 06-24-2014 Drawn By: Ben Geske	Detail: Floating Fish Guidance Structure Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		FFGSatGS.dwg SHEET 10 OF 19



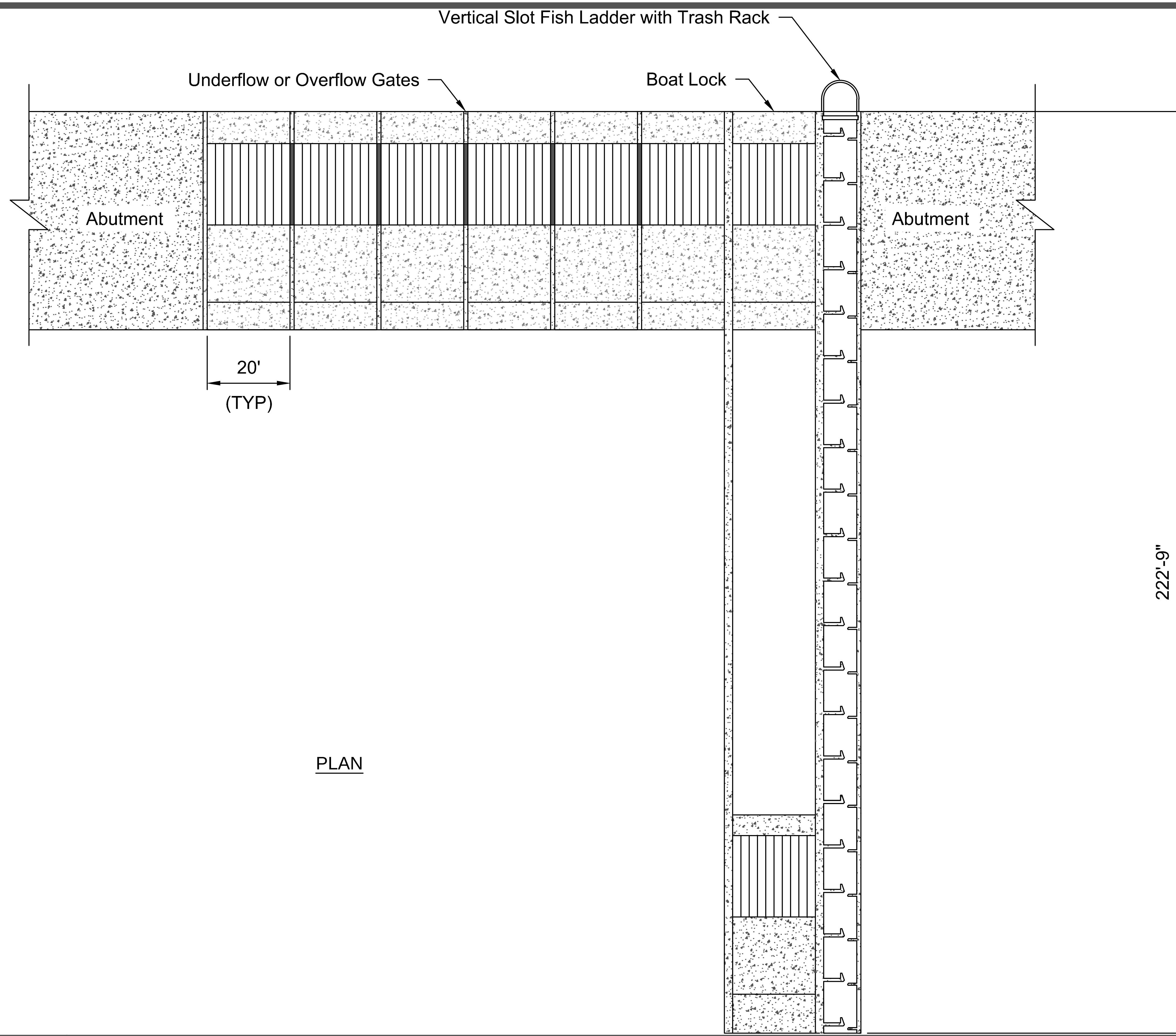
Date Drawn: 06-24-2014
Drawn By: Ben Geske

Plan: Gate, Boat Lock, and Fish Ladder

Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GateatGS.dwg



Date Drawn: 06-24-2014

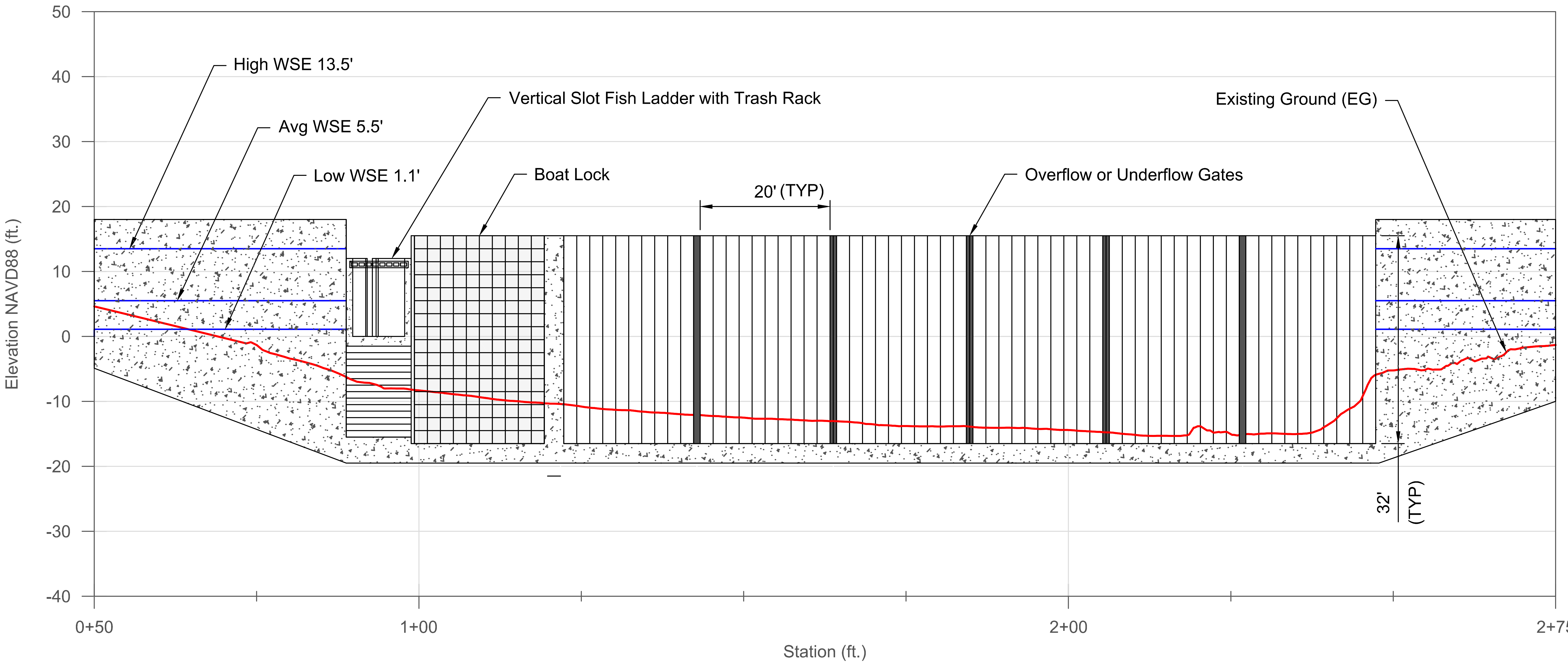
Drawn By: Ben Geske

Plan: Gate, Boat Lock, and Fish Ladder

Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GateatGS.dwg

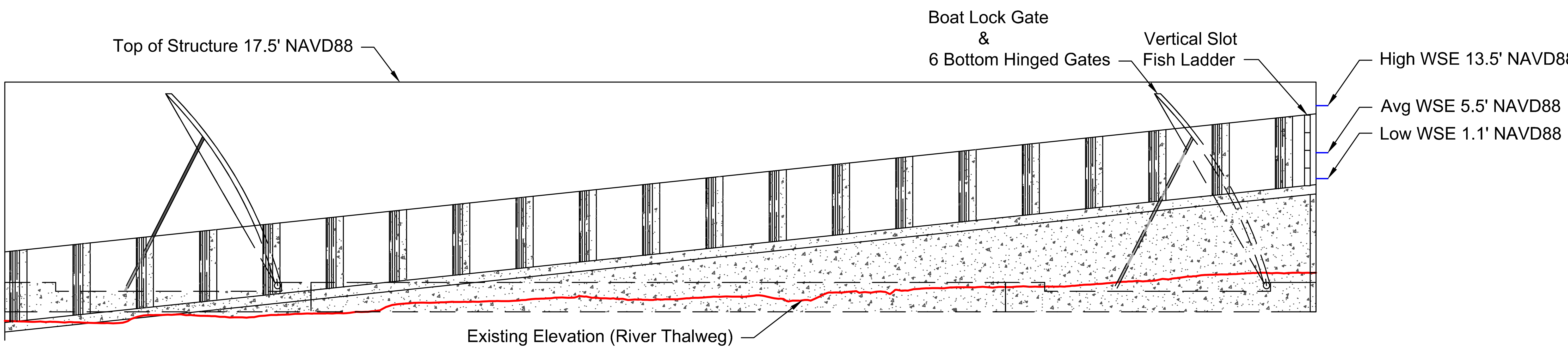


ELEVATION A - A

Looking Downstream

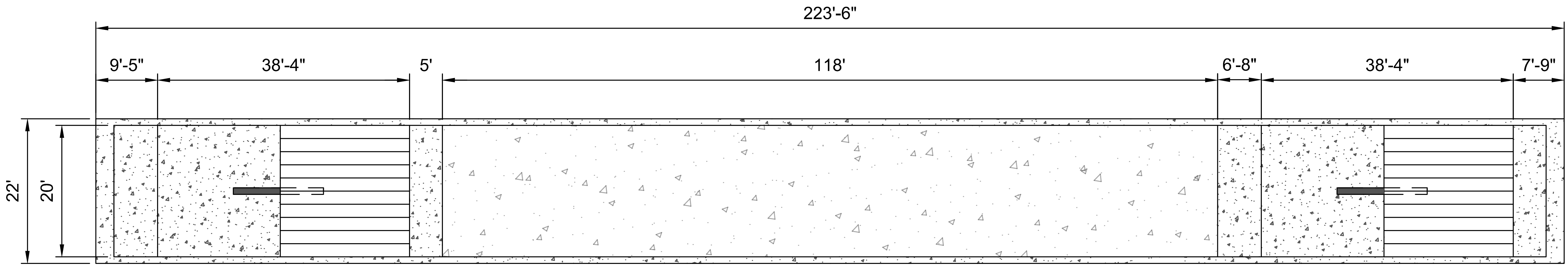
Date Drawn: 06-24-2014 Drawn By: Ben Geske	Elevation: Gate, Boat Lock, and Fish Ladder Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		GateatGS.dwg SHEET 13 OF 19

Gates with Boat Lock & Fish Ladder - Georgiana Slough

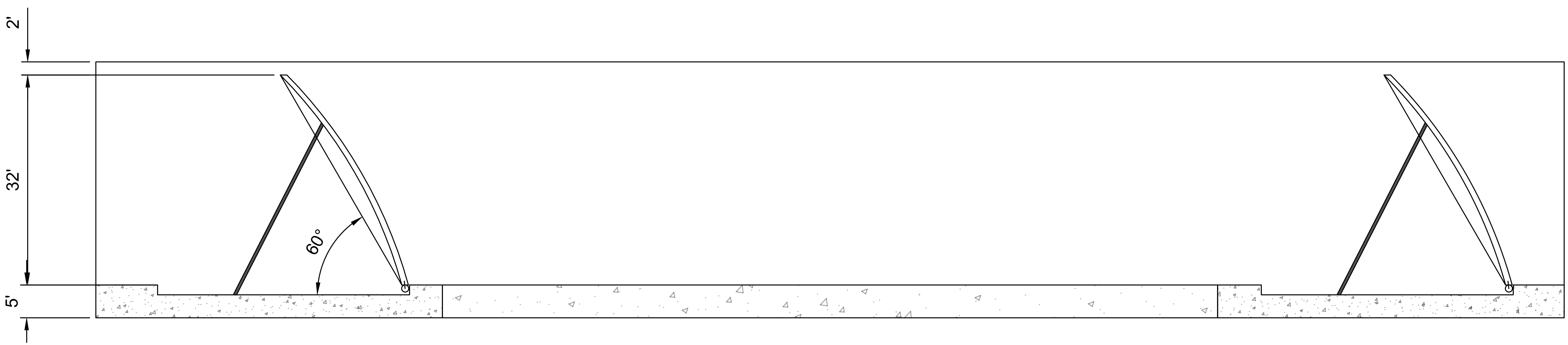


SECTION B - B

Date Drawn: 06-24-2014 Drawn By: Ben Geske	Section: Gate, Boat Lock, and Fish Ladder Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		GateatGS.dwg SHEET 14 OF 19



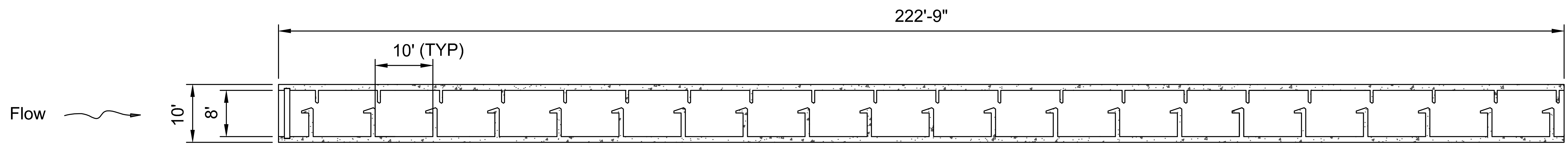
PLAN



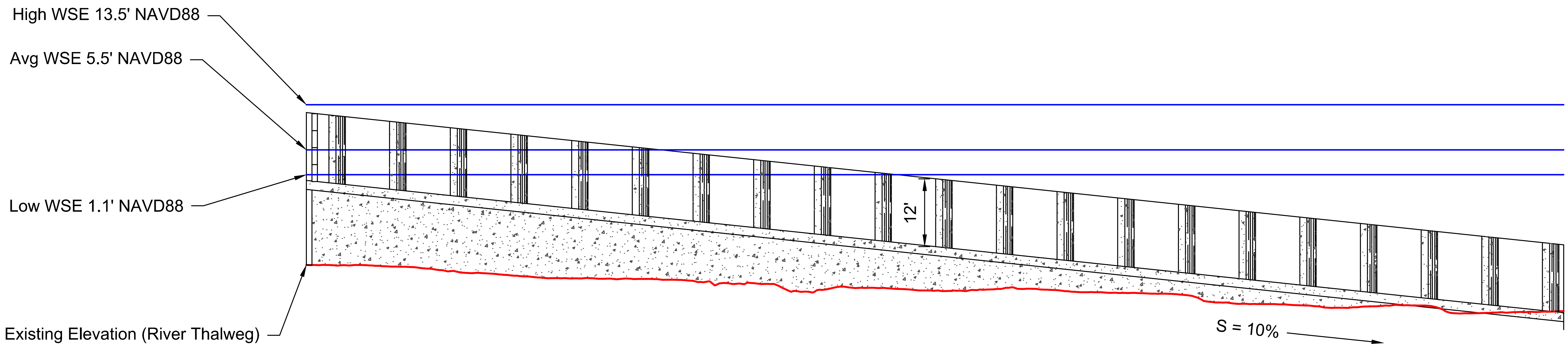
SECTION C-C

Date Drawn: 06-24-2014 Drawn By: Ben Geske	Plan & Section: Boat Lock Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	GateatGS.dwg SHEET 15 OF 19

20 Bay Vertical Slot Fish Ladder for Georgiana Slough

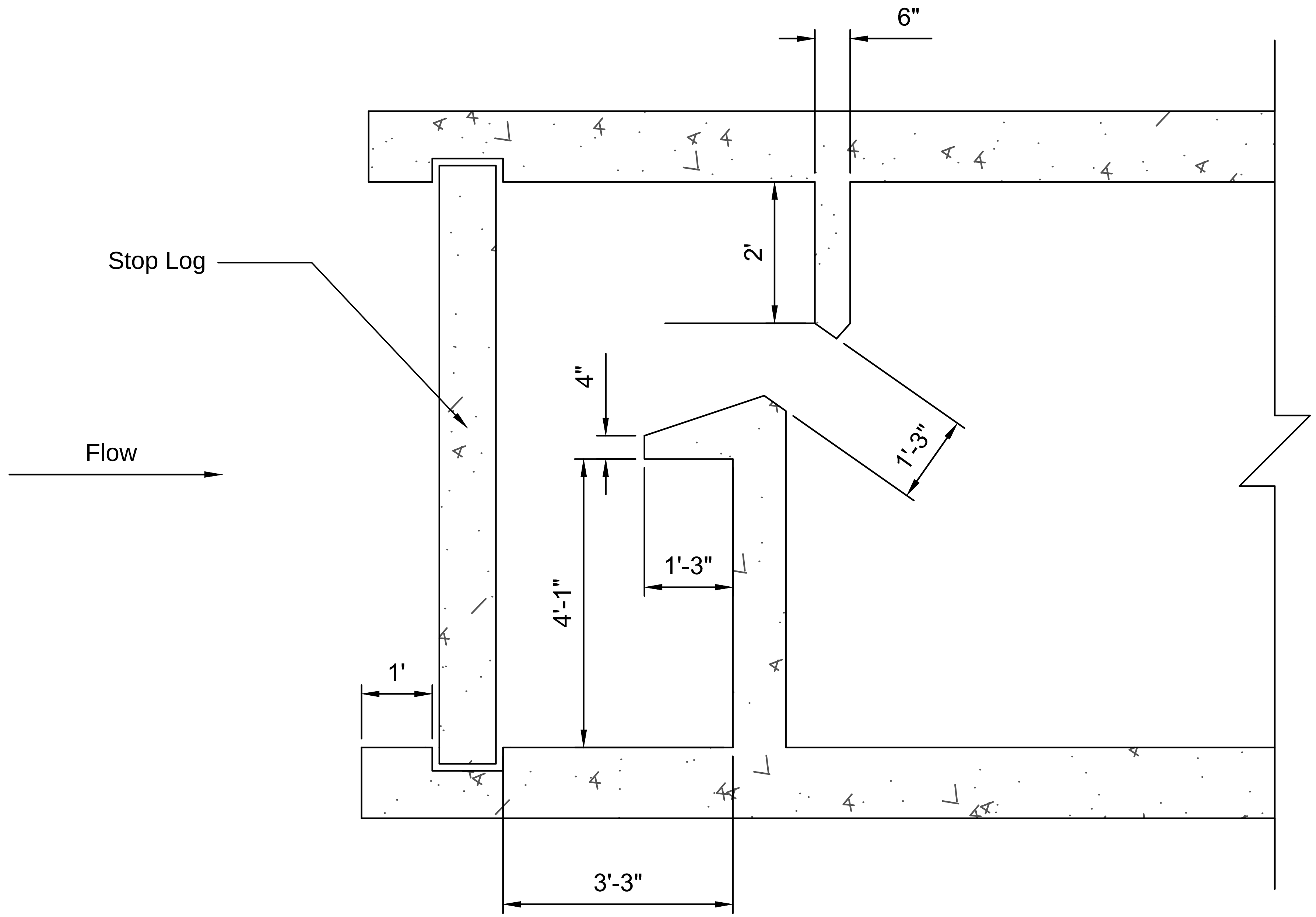


PLAN



SECTION

Date Drawn: 06-24-2014 Drawn By: Ben Geske	Plan & Section: Fish Ladder Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	GateatGS.dwg SHEET 16 OF 19



Date Drawn: 04–10–2014

Drawn By: Ben Geske

Detail: Vertical Slot Fish Ladder

Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GATEatGS.dwg

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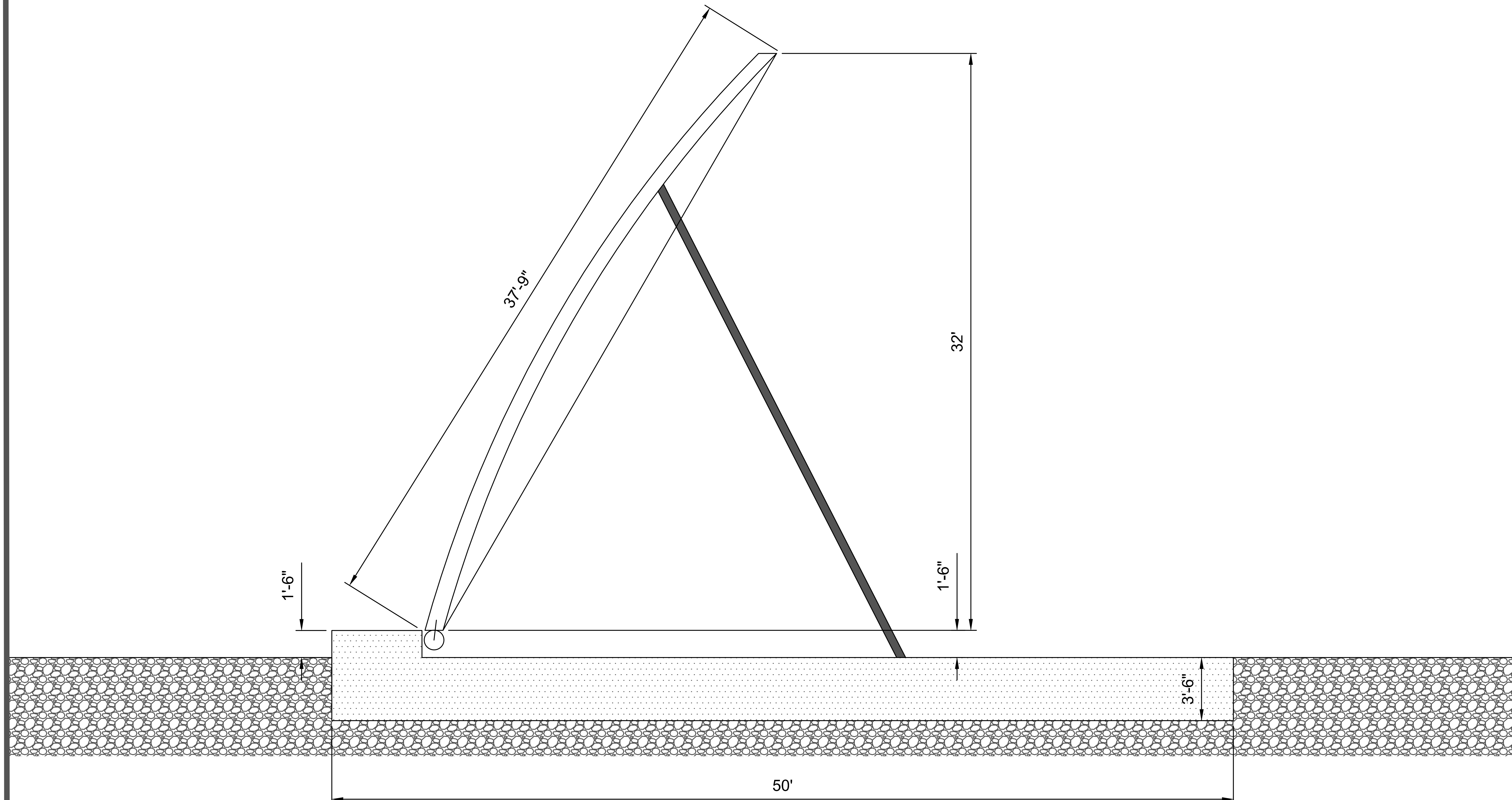

Date Drawn: 06-24-2014

Drawn By: Ben Geske

Detail: Overflow Gate

Location: Georgiana Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GateatGS.dwg

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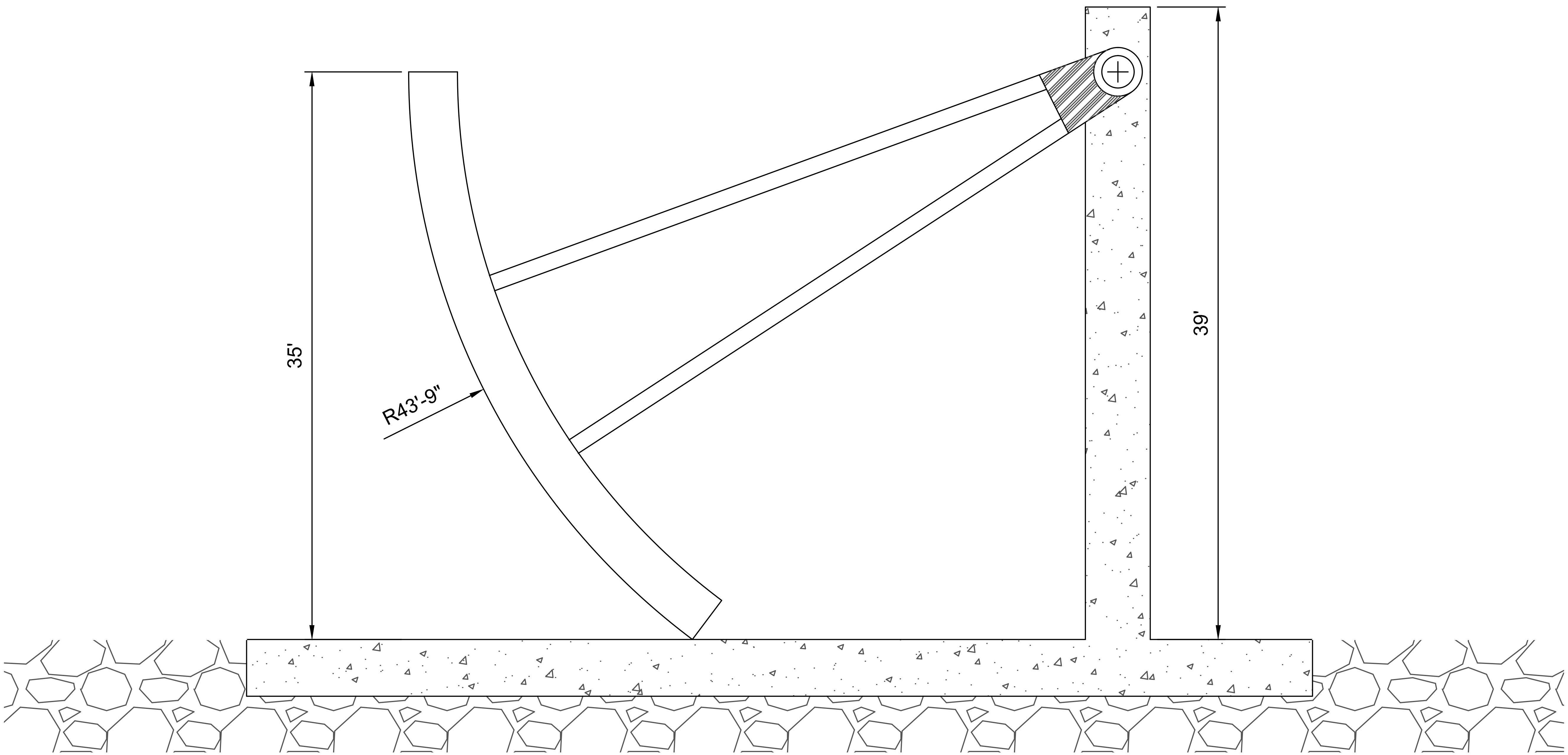
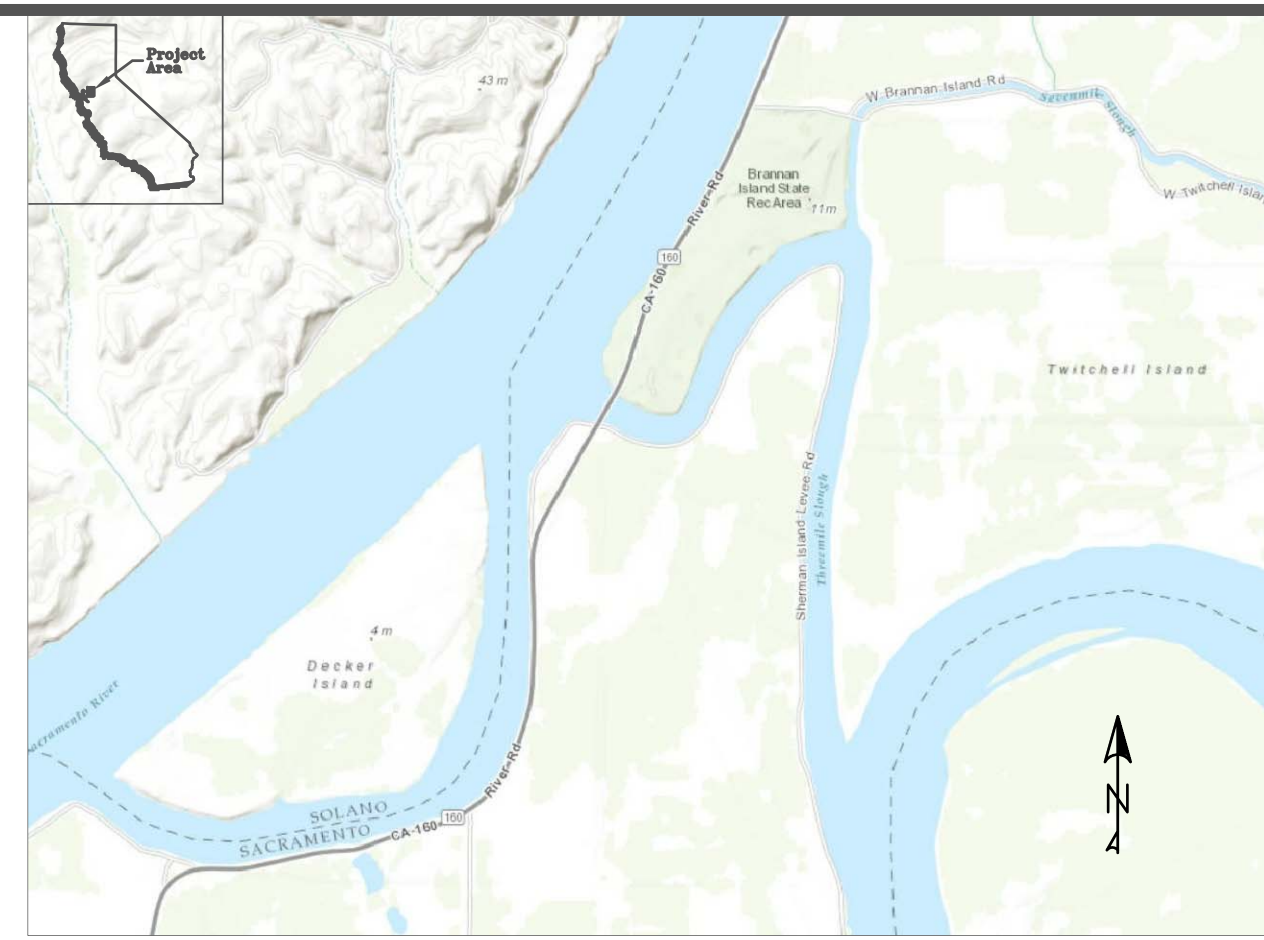


Date Drawn: 06-24-2014 Drawn By: Ben Geske	Detail: Underflow Gate Location: Georgiana Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	GateatGS.dwg SHEET 19 OF 19

CONCEPTUAL ENGINEERING DRAWINGS FOR

THREEMILE SLOUGH
NMFS BiOp RPA ACTION IV.1.3

SACRAMENTO COUNTY, CALIFORNIA



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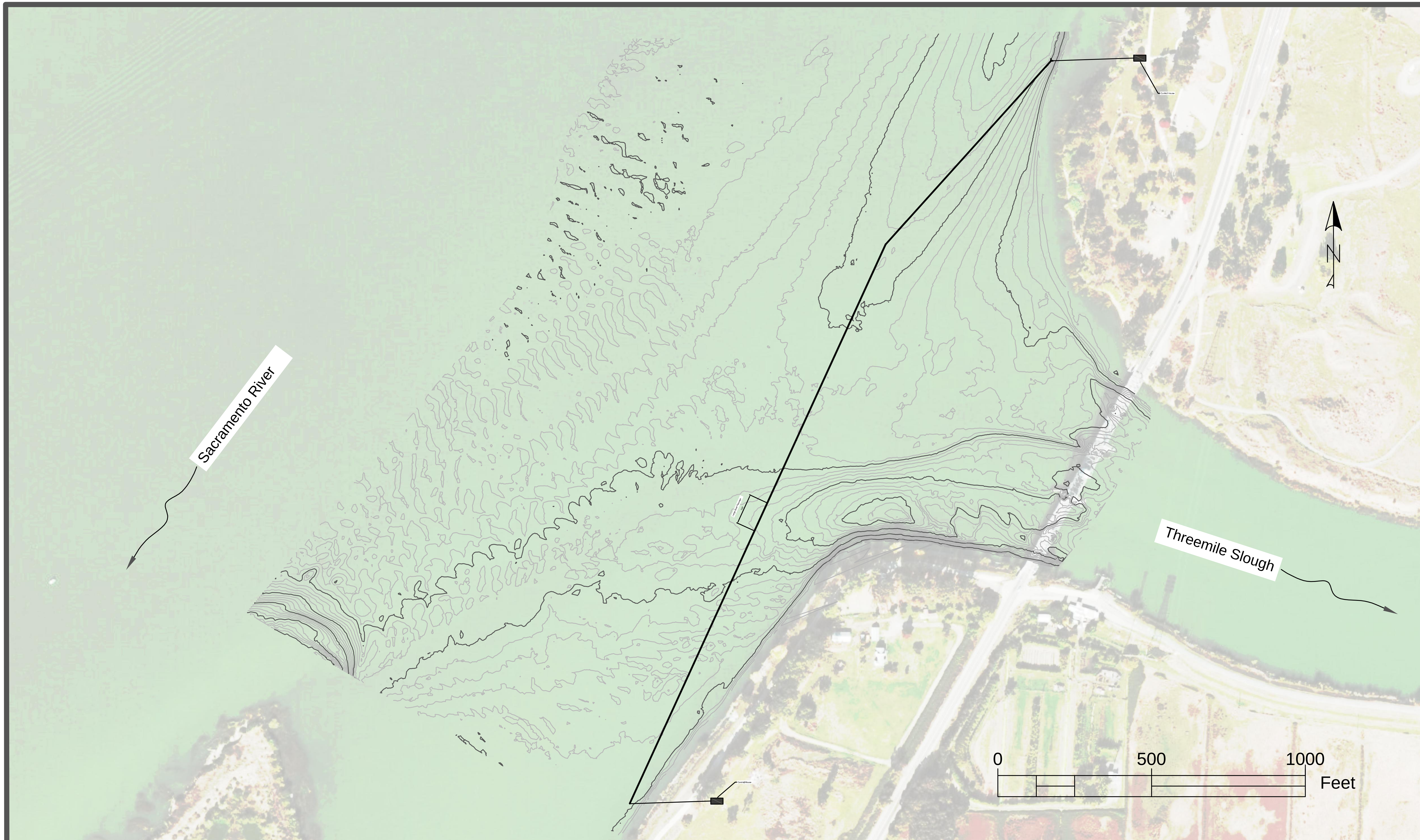
Date Drawn: 10–7–2014 Drawn By: Ben Geske Khalid Ameri	Title Sheet and Area Map Location: Threemile Slough	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office	TMS.dwg SHEET 1 OF 18



Date Drawn: 05-27-2014

Drawn By: Khalid Ameri

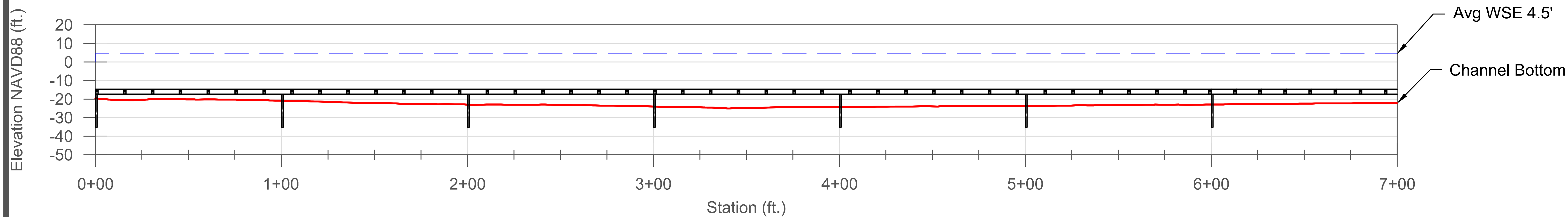
Plan: Bio-Acoustic Fish Fence

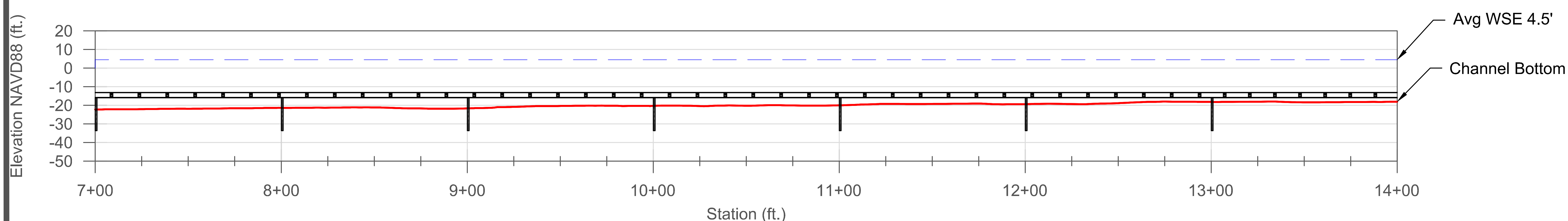
Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

BAFFatTMS.dwg

SHEET 2 OF 18





Date Drawn: 05-27-2014

Drawn By: Khalid Ameri

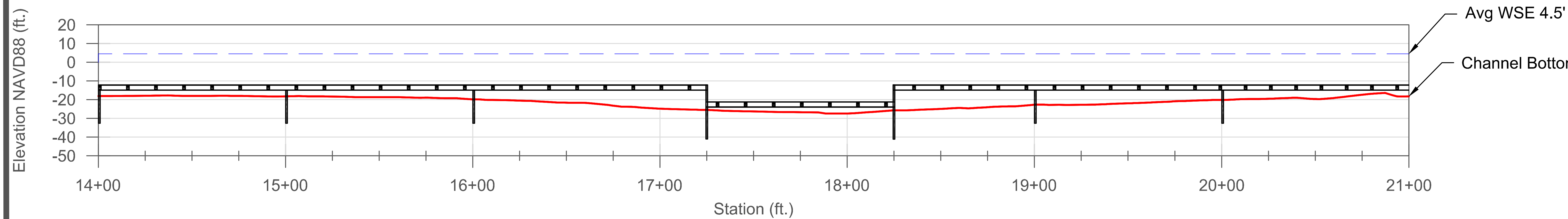
Elevation: Bio-Acoustic Fish Fence

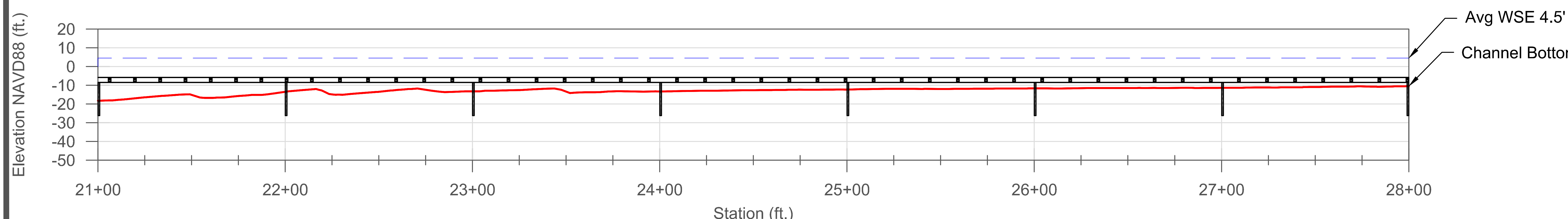
Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

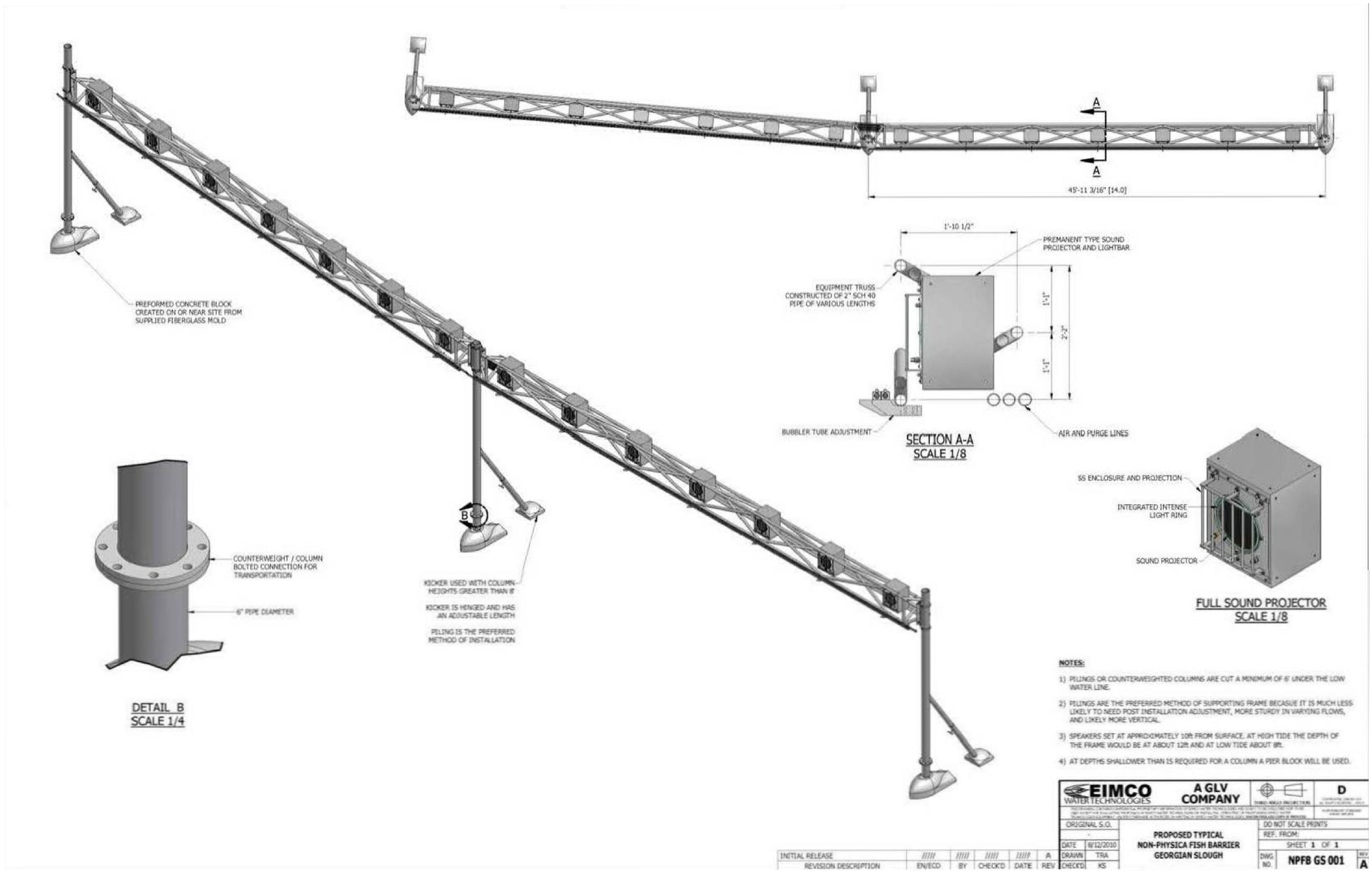
BAFFatTMS.dwg

SHEET 3 OF 18





Date Drawn: 05-27-2014 Drawn By: Khalid Ameri	Elevation: Bio-Acoustic Fish Fence Location: Threemile Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatTMS.dwg SHEET 4 OF 18



Date Drawn: 08-12-2010 Drawn By: EIMCO	**Detail: Bio-Acoustic Fish Fence** Location: Threemile Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatTMS.dwg SHEET 5 OF 18

Date Drawn: 06-10-2014

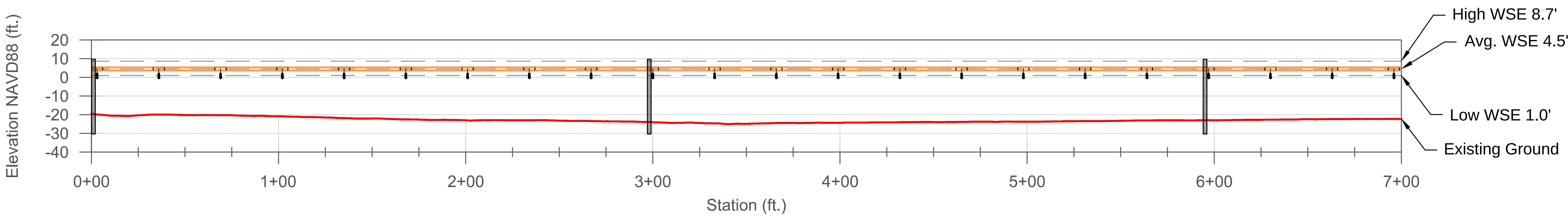
Drawn By: Khalid Ameri

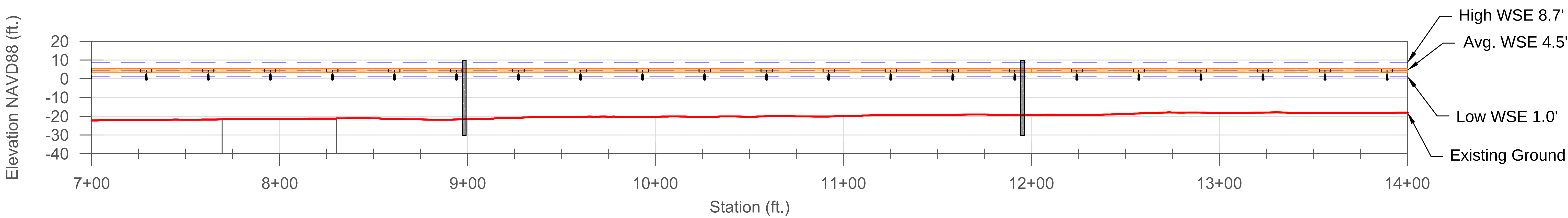
Plan: Infrasound Fish Fence

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

IFFatTMS.dwg





Date Drawn: 06-10-2014

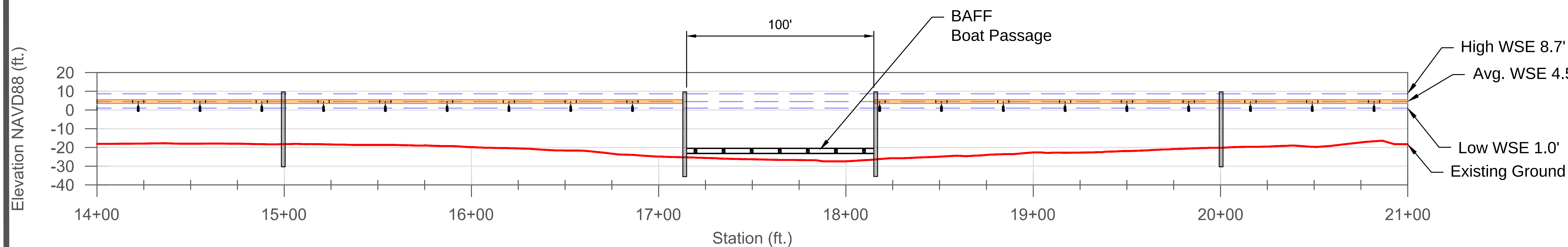
Drawn By: Khalid Ameri

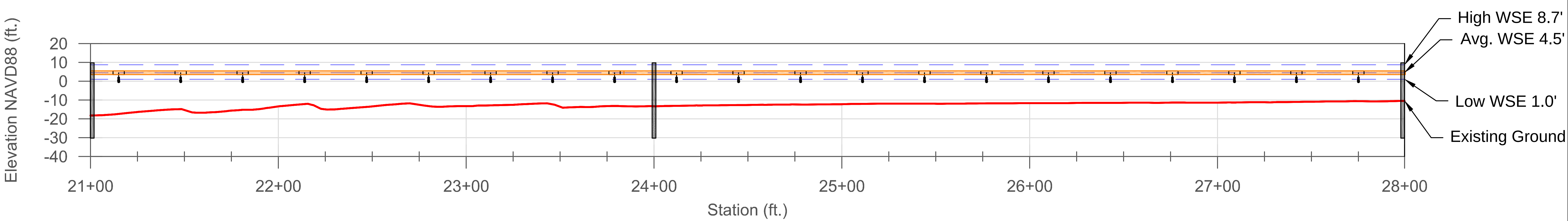
Elevation: Infrasound Fish Fence

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

IFFatTMS.dwg





Date Drawn: 06–10–2014

Drawn By: Khalid Ameri

Elevation: Infrasound Fish Fence

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

IFFatTMS.dwg

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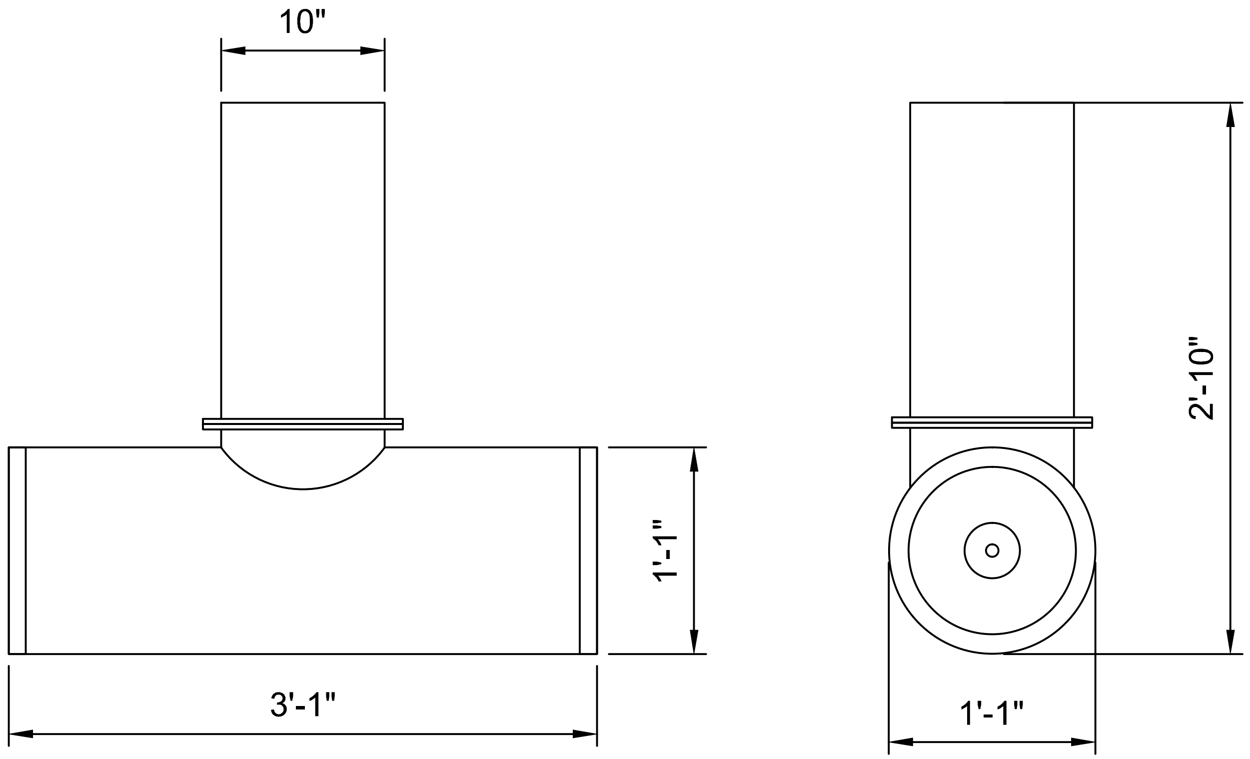
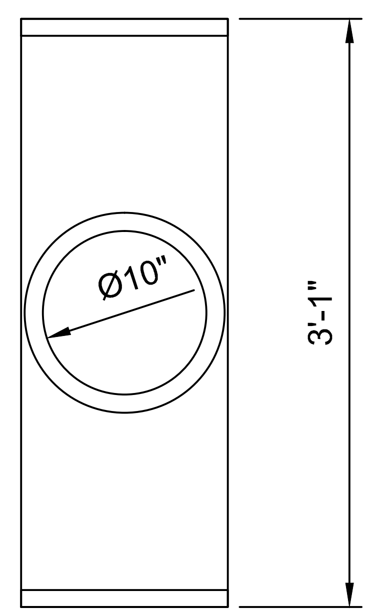
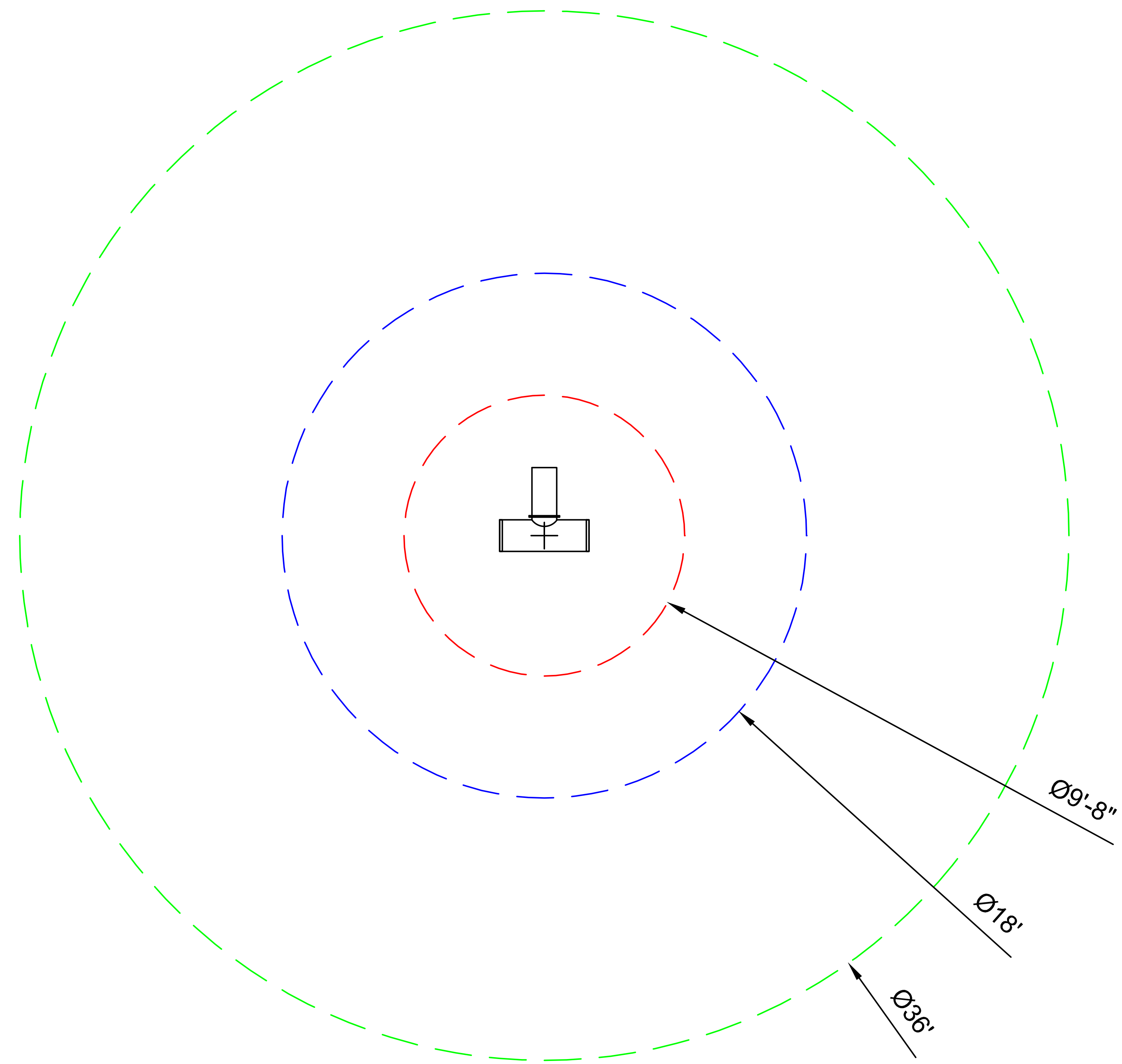


Front View

Side View



Top View



Red = Zone of exclusion from structural entities.

Blue = Fish dterrence zone.

Green = Boundary for measurable particle acceleration.

Date Drawn: 06–10–2014

Drawn By: Khalid Ameri

Detail: Infrasound Fish Fence

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

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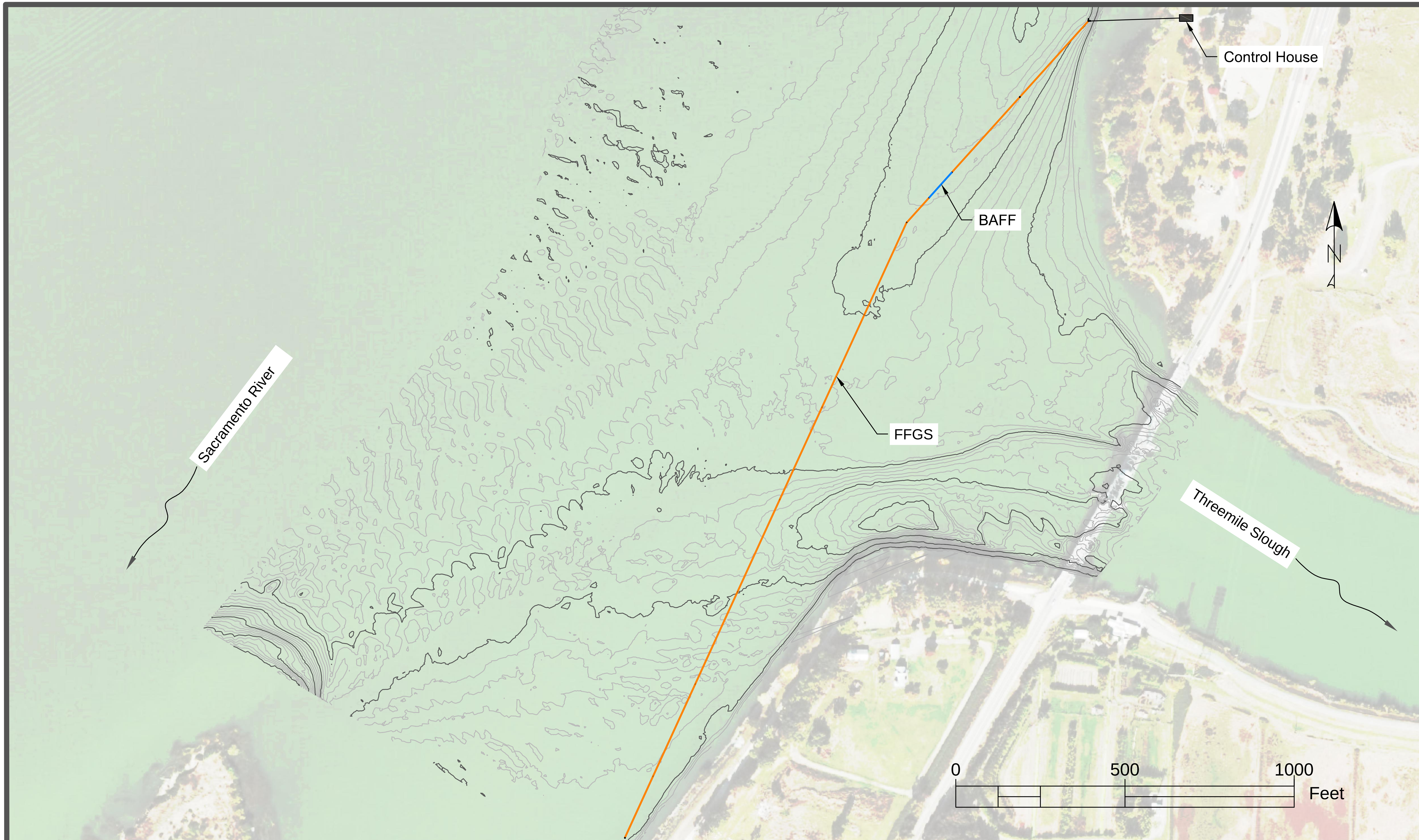

Date Drawn: 07-03-2014

Drawn By: Ben Geske

Plan: Floating Fish Guidance Structure

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

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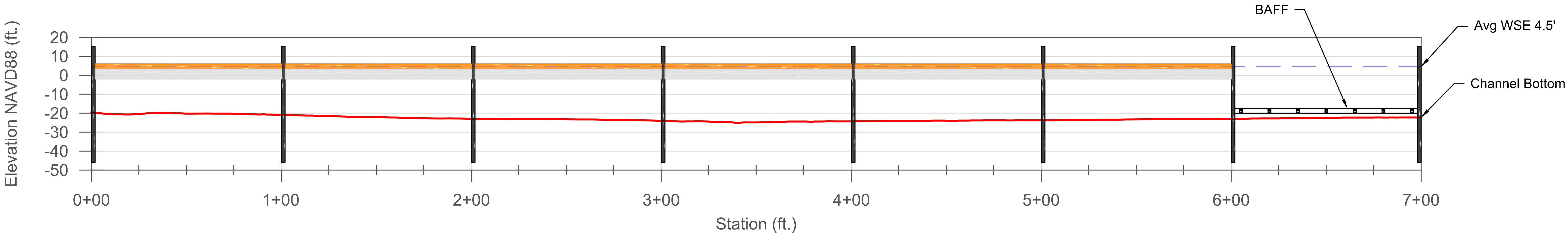
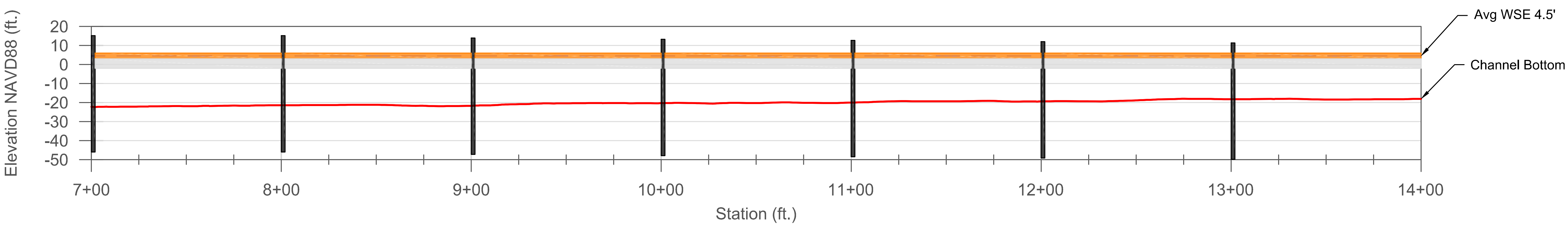
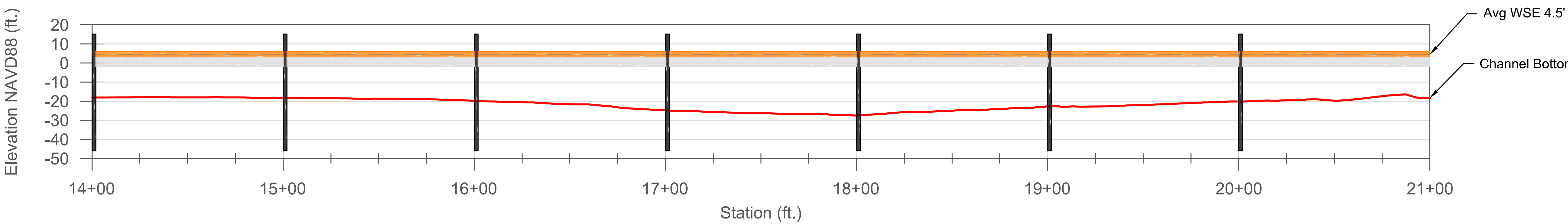
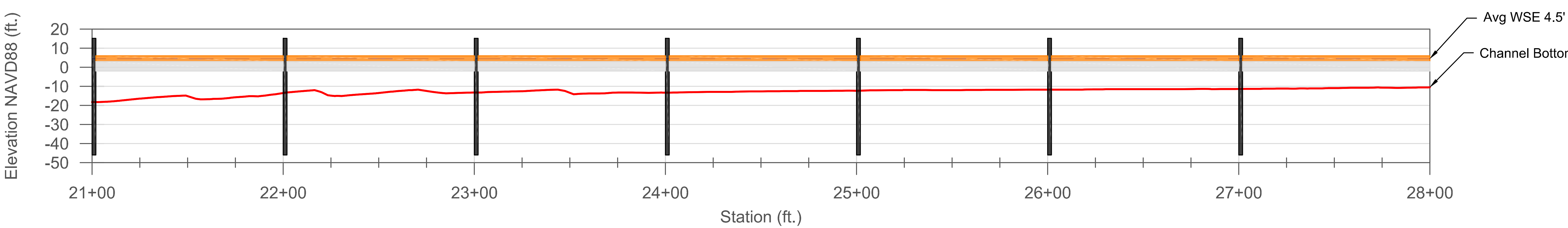




Date Drawn: 07-03-2014 Drawn By: Ben Geske	Elevation (North): Floating Fish Guidance Structure Location: Threemile Slough	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	FFGSatTMS.dwg SHEET 11 OF 18





Date Drawn: 07–03–2014

Drawn By: Ben Geske

Elevation (South): Floating Fish Guidance Structure

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

FFGSatTMS.dwg

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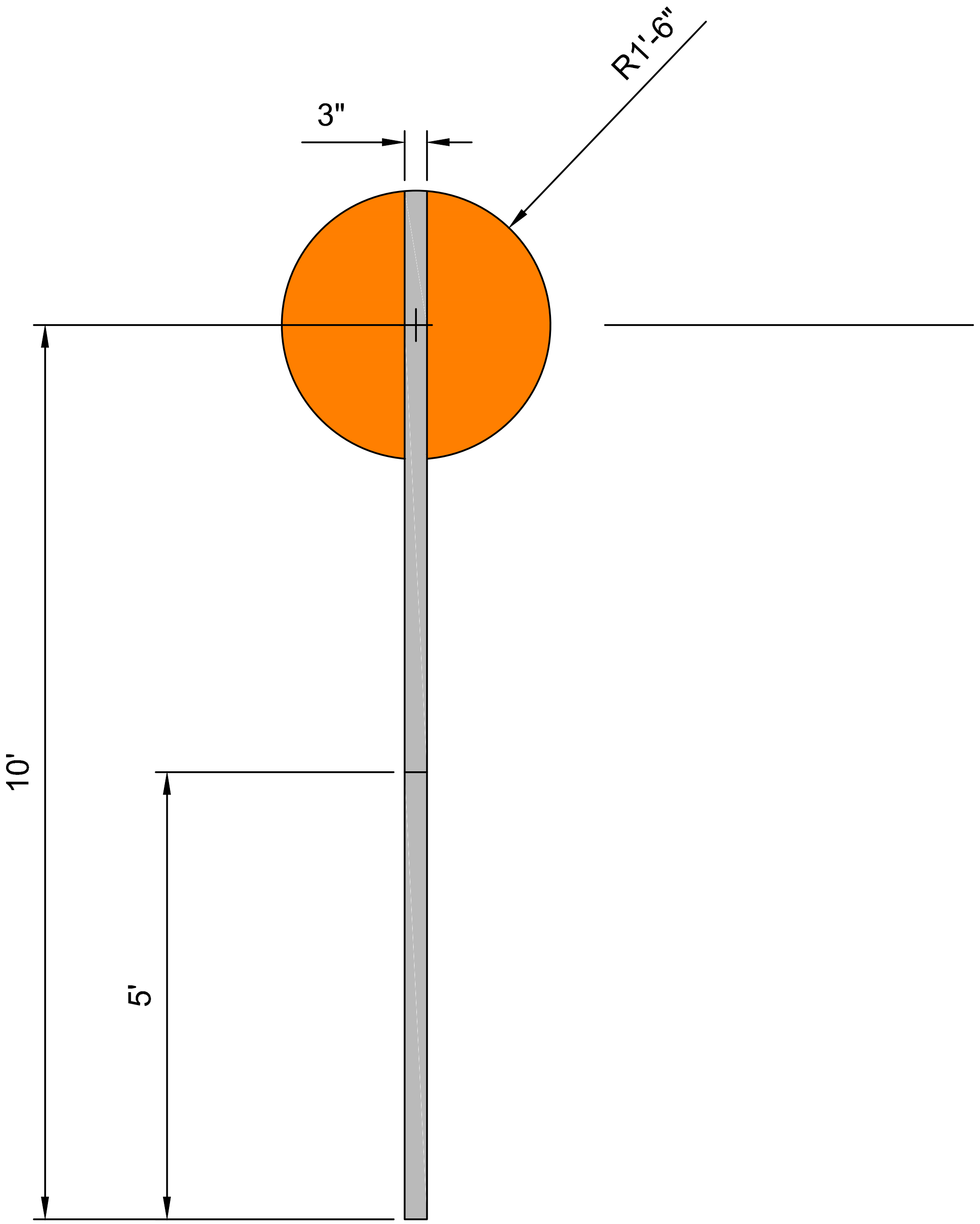
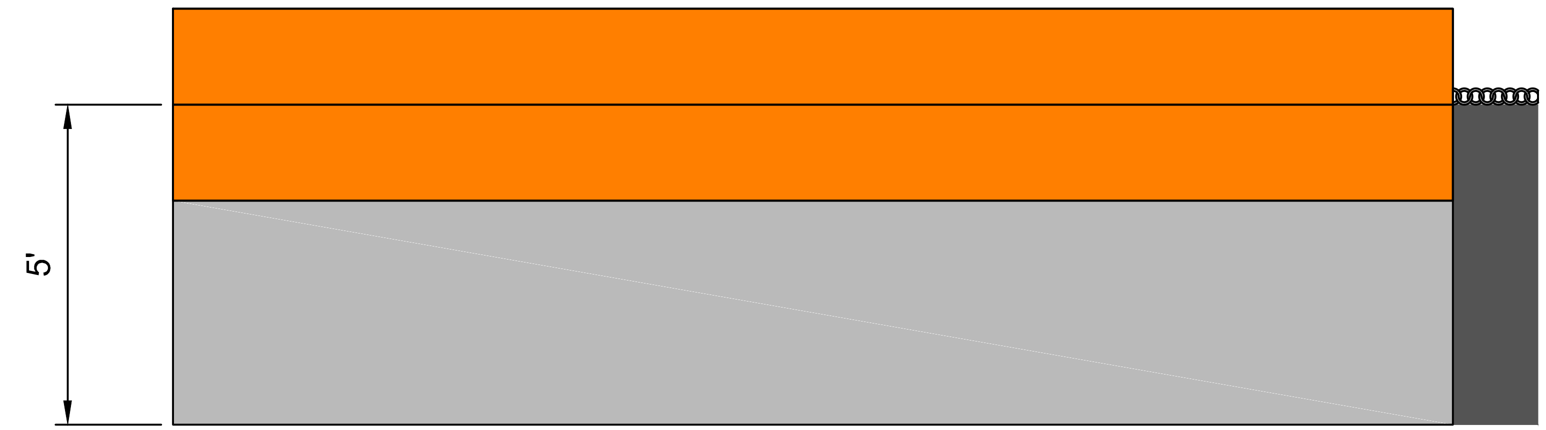
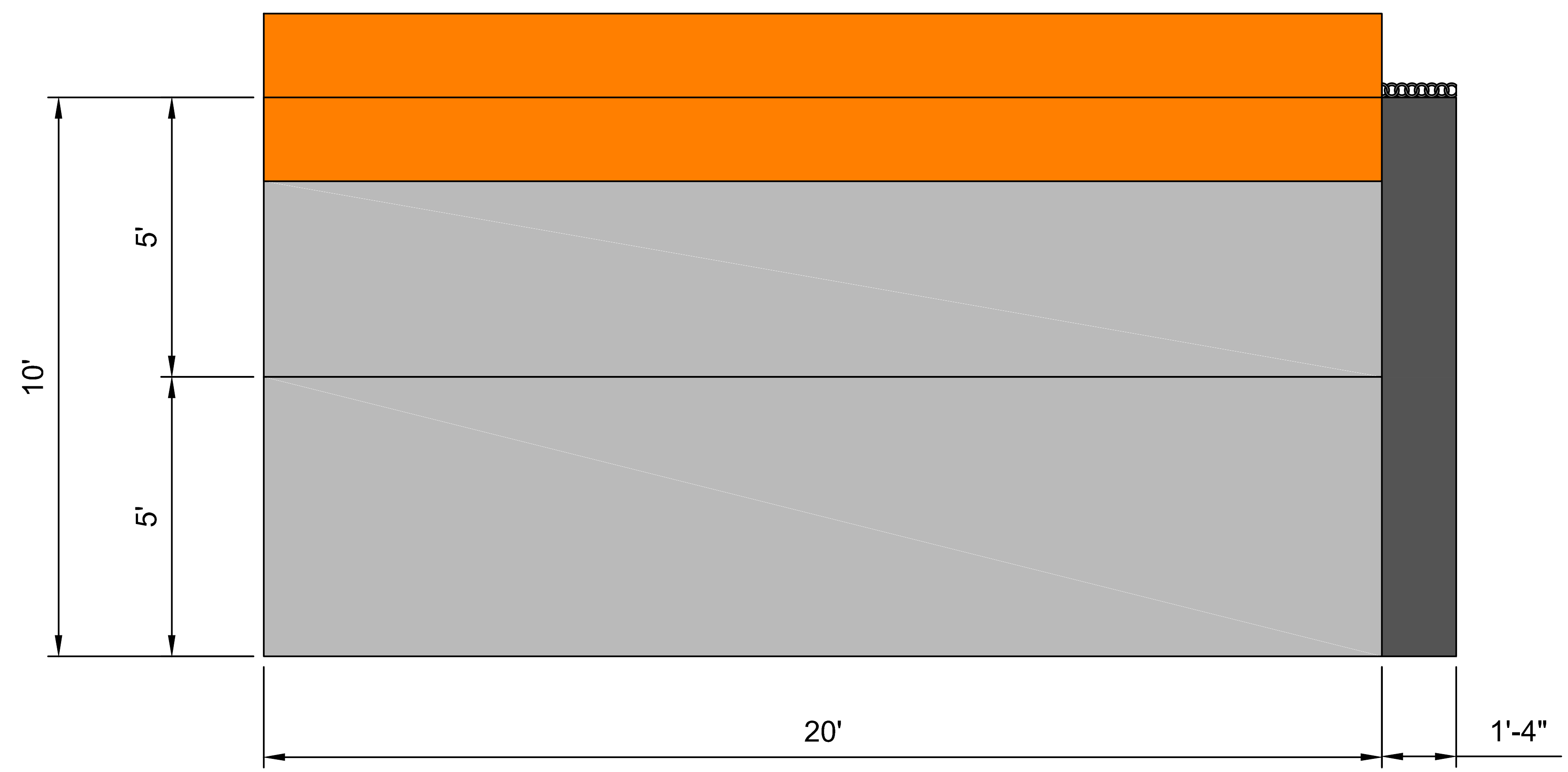


DETAIL: SINGLE FFGS SECTION - SIDE VIEW



DETAIL: SINGLE 5' FFGS SECTION - FRONT/FACE



DETAIL: SINGLE 10' FFGS SECTION - FRONT/FACE

Date Drawn: 06-24-2014

Drawn By: Ben Geske

Detail: Floating Fish Guidance Structure

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

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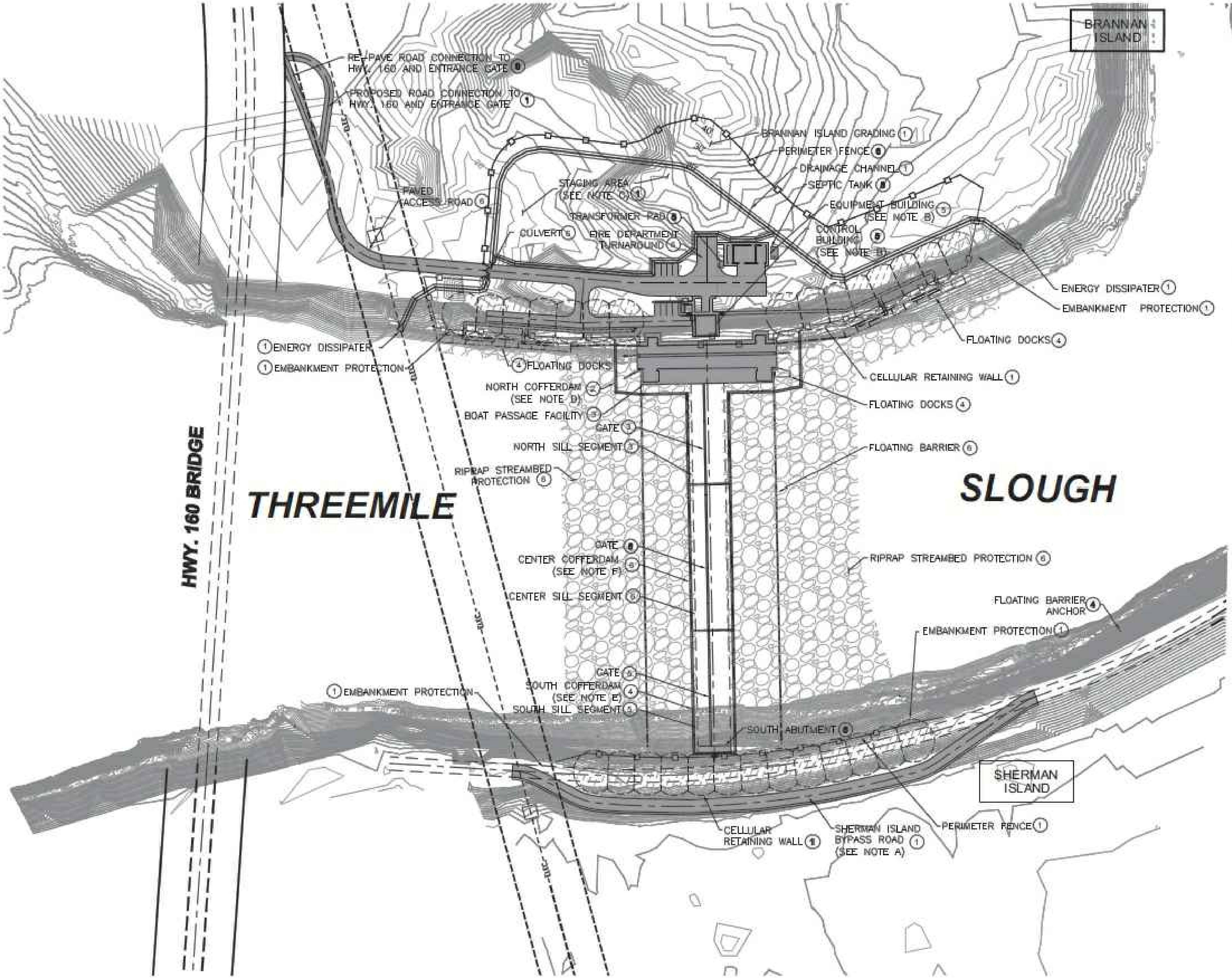


CONSTRUCTION PERIODS

1. DECEMBER 2011 – JULY 2012
2. AUGUST – NOVEMBER 2012 (FIRST RESTRICTED PERIOD)
3. DECEMBER 2012 – JULY 2013
4. AUGUST – NOVEMBER 2013 (SECOND RESTRICTED PERIOD)
5. DECEMBER 2013 – JULY 2014
6. AUGUST – NOVEMBER 2014 (THIRD RESTRICTED PERIOD)

NOTES

A. BYPASS ROAD TO BE REMOVED AFTER CONSTRUCTION OF CELLUAR RETAINING WALL

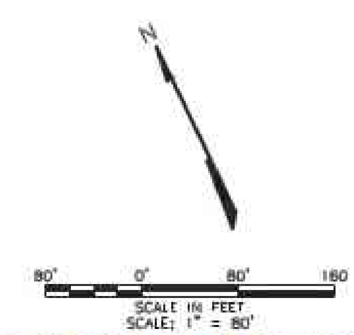
B. PILE DRIVING FOR EQUIPMENT BUILDING AND CONTROL BUILDING FOUNDATIONS SHALL BE DONE DURING THE THIRD CONSTRUCTION PERIOD

C. RESTORE STAGING AREA AT THE END OF CONSTRUCTION

D. NORTH COFFERDAM TO BE REMOVED IN THE FOURTH CONSTRUCTION PERIOD

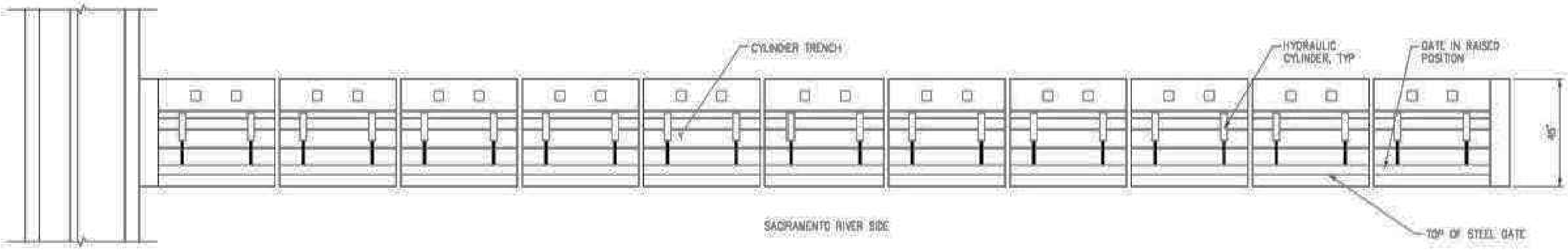
E. SOUTH COFFERDAM TO BE REMOVED IN THE SIXTH CONSTRUCTION PERIOD

F. CENTER COFFERDAM TO BE REMOVED IN THE SIXTH CONSTRUCTION PERIOD



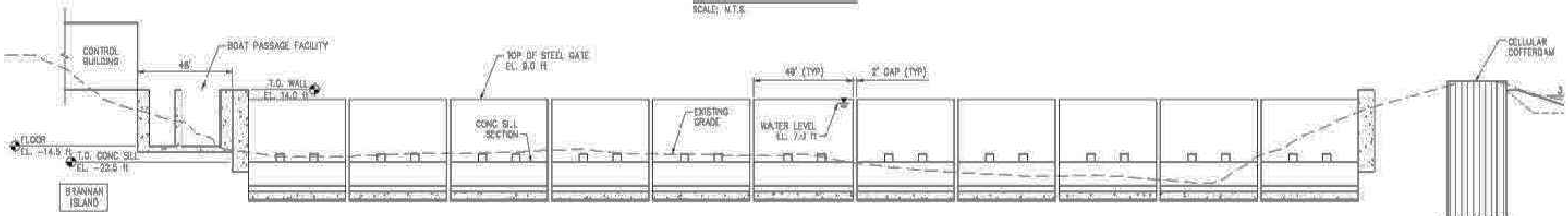
NOT FOR CONSTRUCTION

Date Drawn:	Plan: Franks Tract Project Gate	State of California	GateatGS.dwg
Drawn By:	Location: Threemile Slough	Natural Resources Agency Department of Water Resources Bay–Delta Office	SHEET 14 OF 18



PLAN

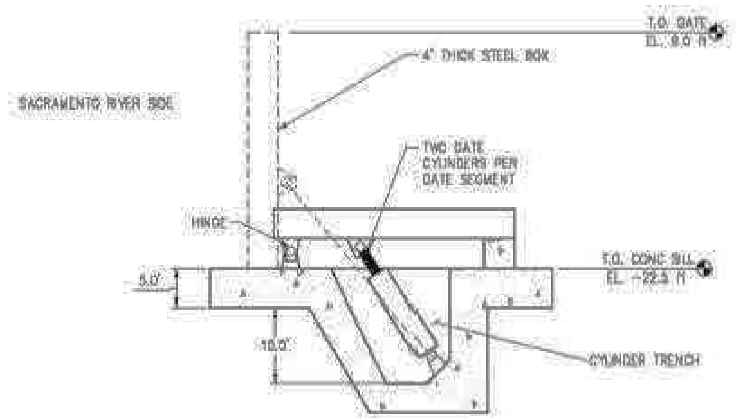
SCALE: N.T.S.



SECTION THROUGH TRENCH (HYDRAULIC CYLINDERS NOT SHOWN)

SCALE: N.T.S.

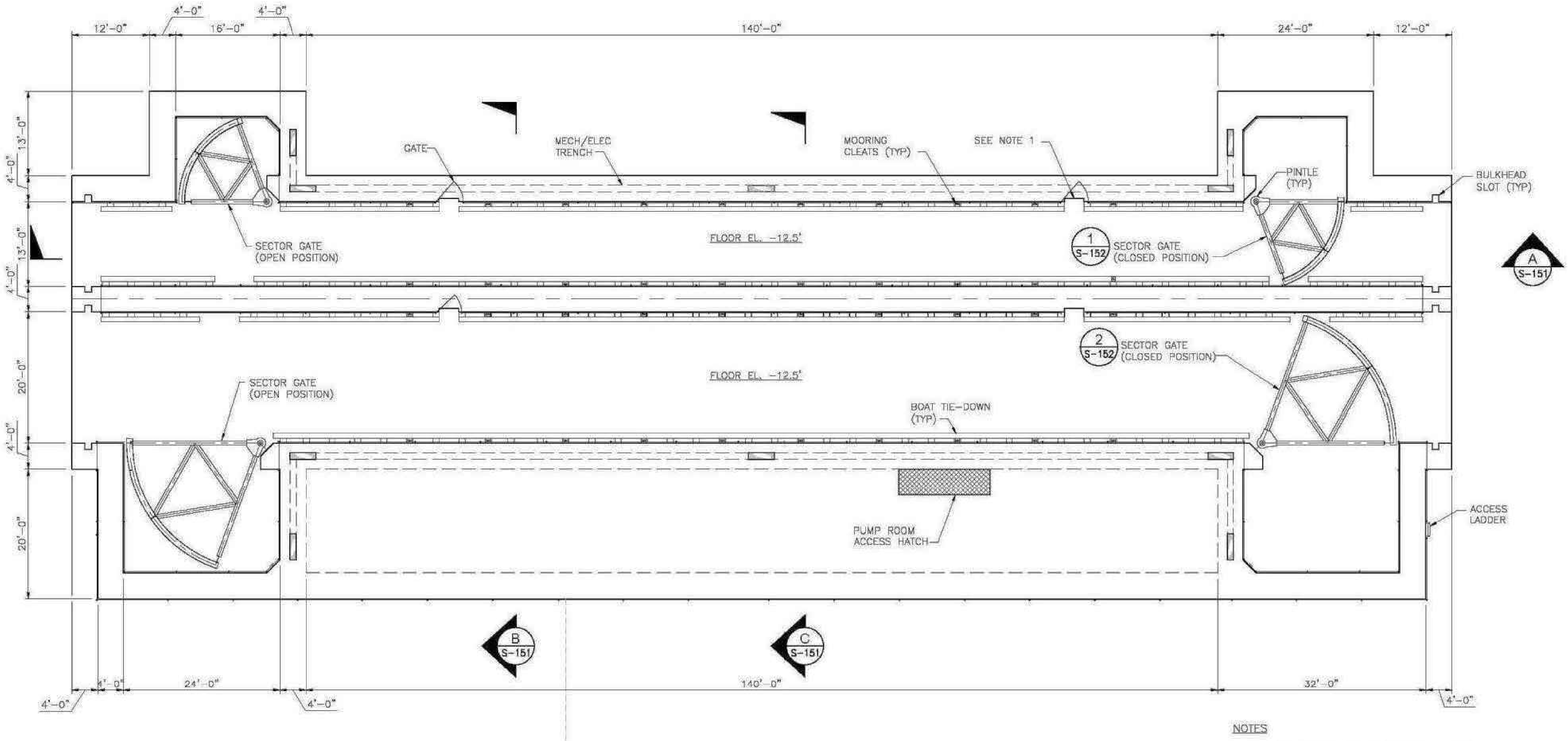
SHERMAN ISLAND



SECTION

SCALE: N.T.S.

Date Drawn: Drawn By:	Plan & Section: Franks Tract Project Gate Location: Threemile Slough	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office		GateatGS.dwg SHEET 15 OF 18



NOTES

1. ACCESS LADDERS NOT SHOWN FOR CLARITY.

PLAN AT EL. 14'
SCALE: 1/8"=1'-0"

Date Drawn:
Drawn By:

Plan: Boat Lock

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GateatTMS.dwg

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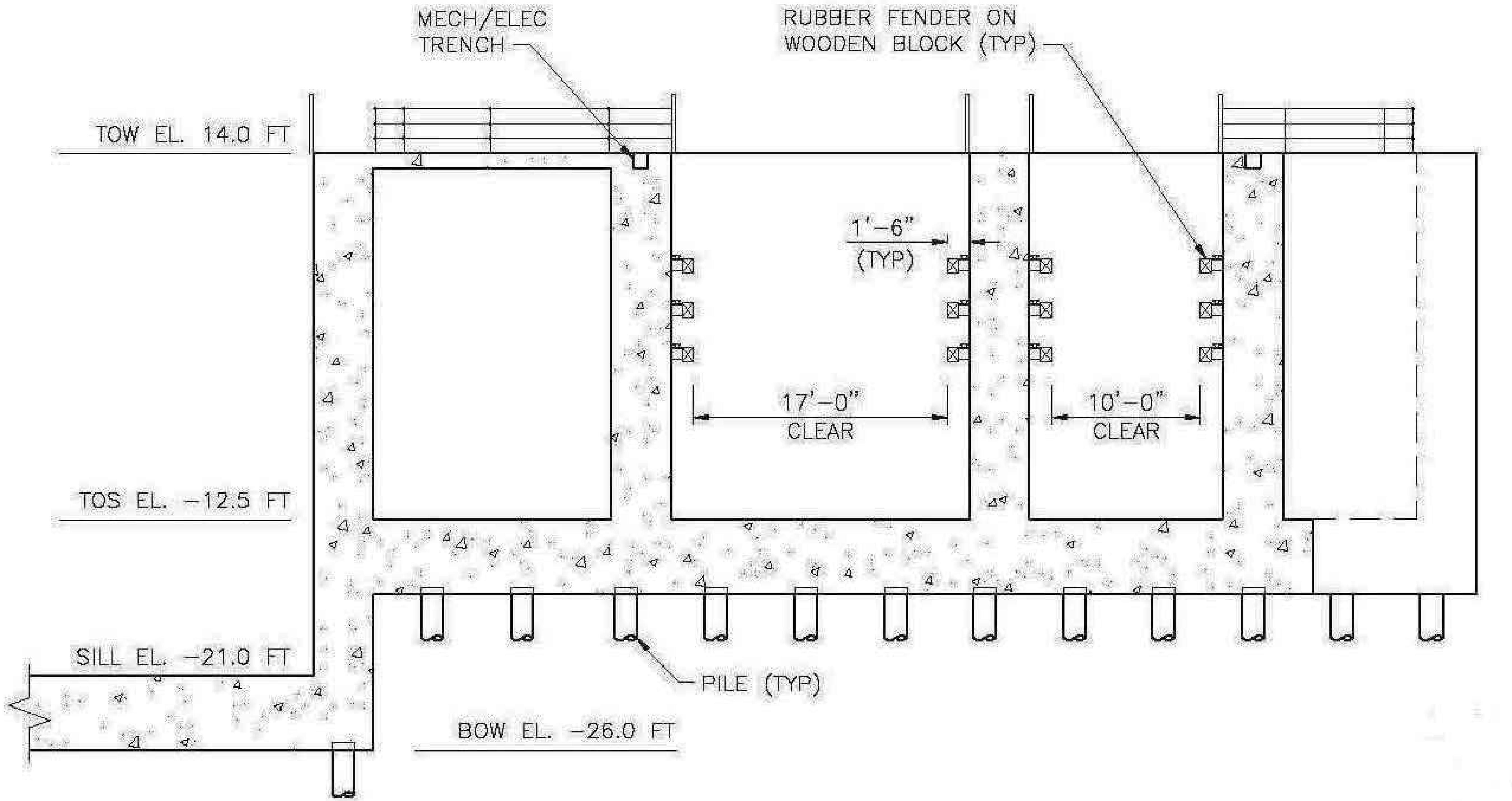

Date Drawn:

Drawn By:

Section: Boat Lock

Location: Threemile Slough

State of California
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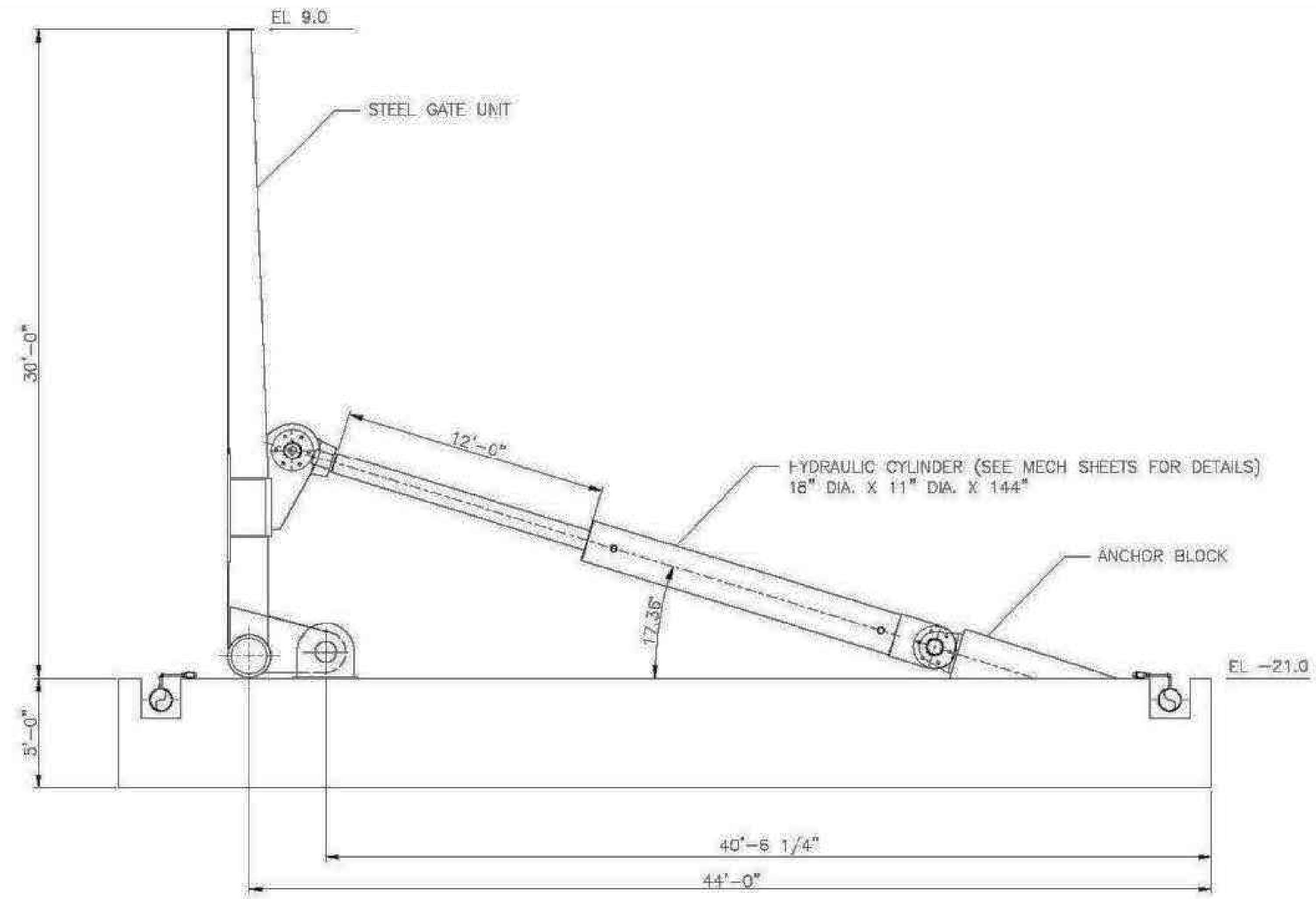
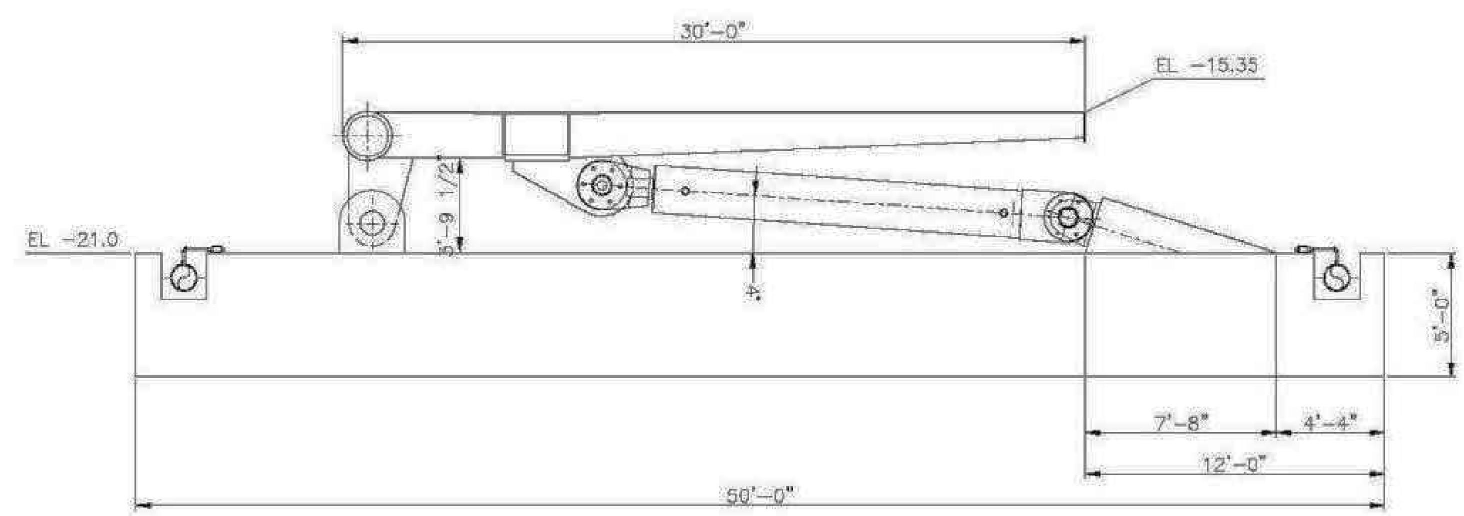


CREST GATE - CLOSED POSITION
SCALE: 1/4"=1'-0"



Date Drawn:

Drawn By:

Detail: Overflow Gate

Location: Threemile Slough

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

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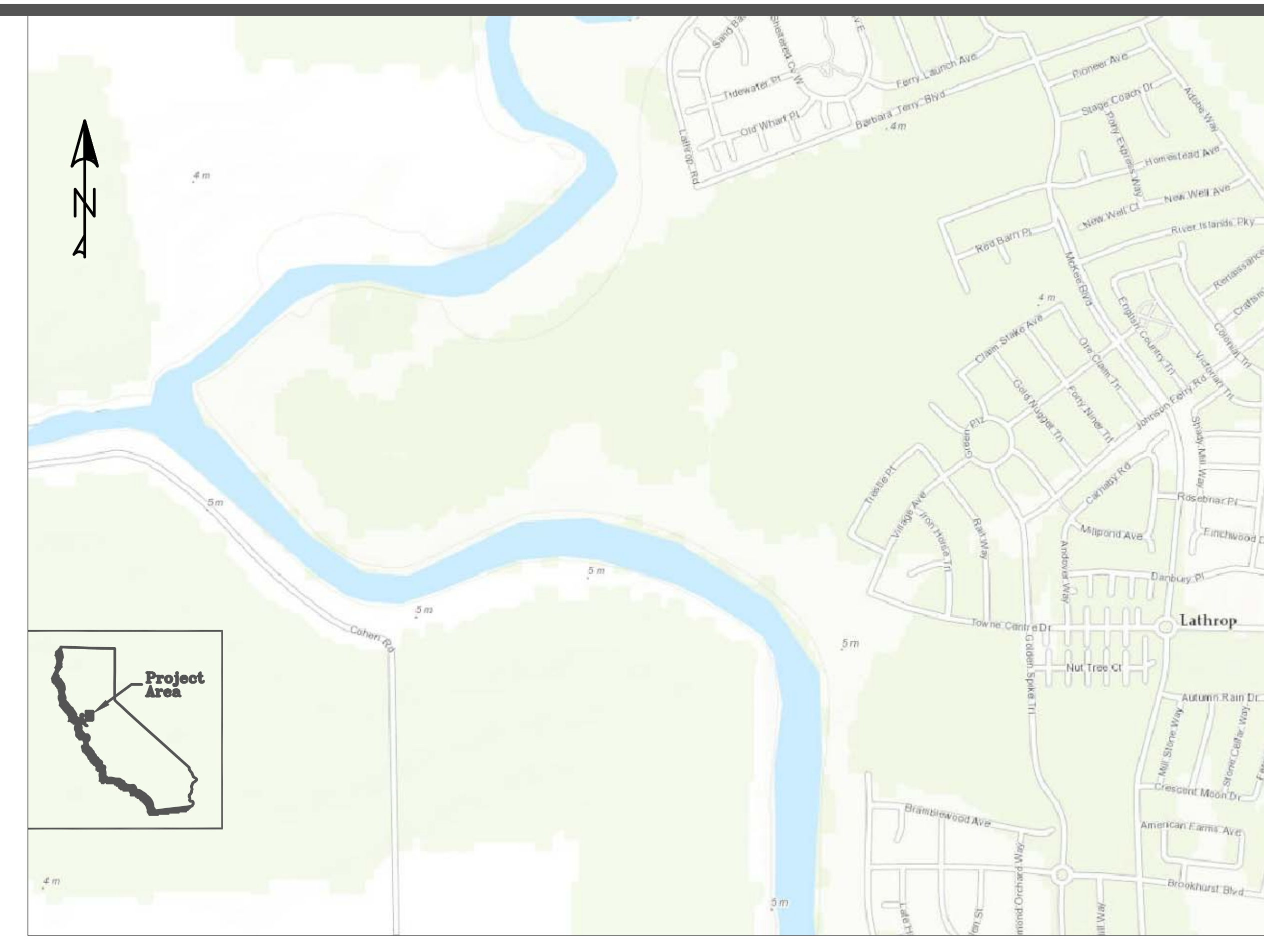
SHEET 18 OF 18

CONCEPTUAL ENGINEERING DRAWINGS FOR

HEAD OF OLD RIVER
NMFS BiOp RPA ACTION IV.1.3

SAN JOAQUIN COUNTY, CALIFORNIA



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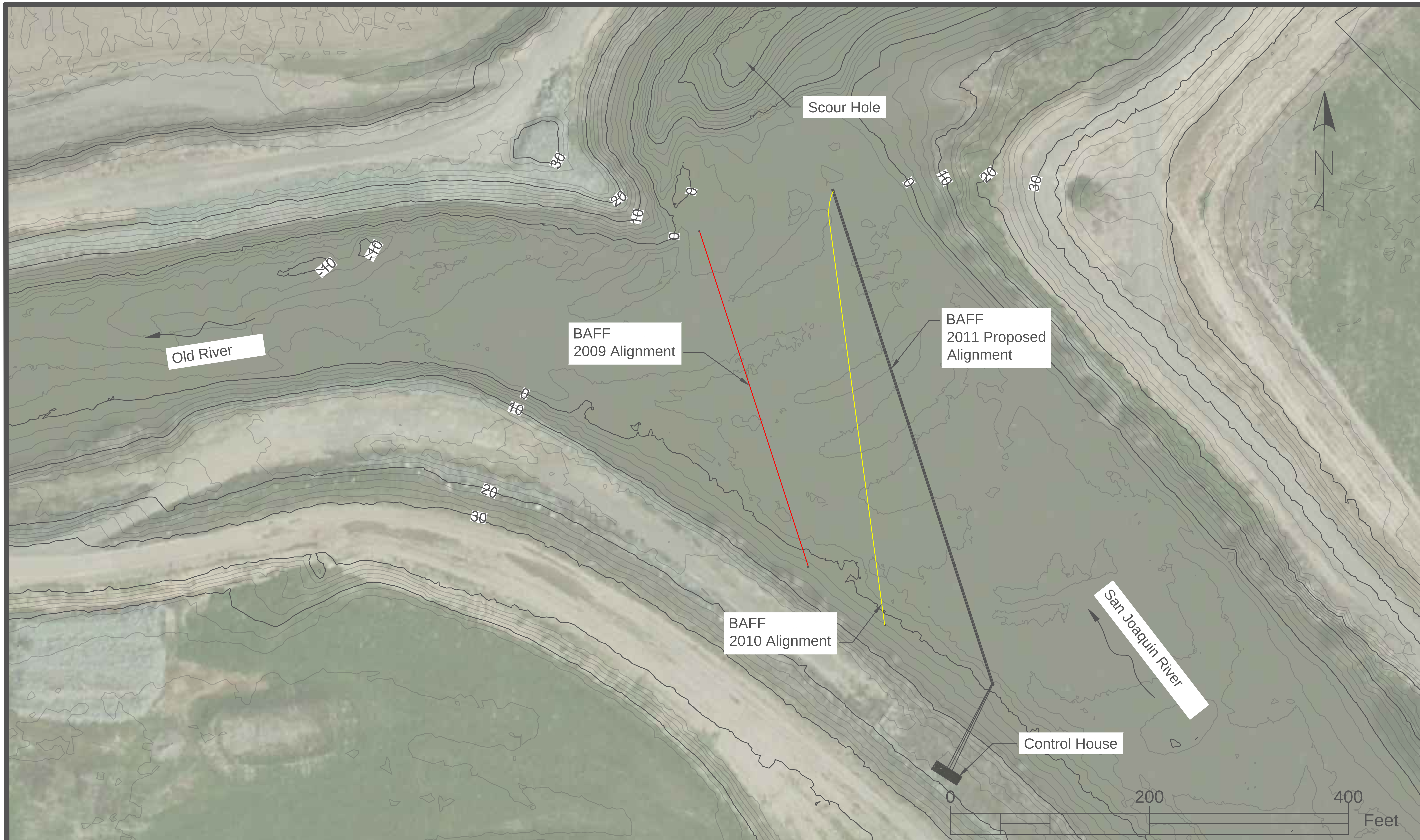


Date Drawn: 04-17-2014

Drawn By: Khalid Ameri

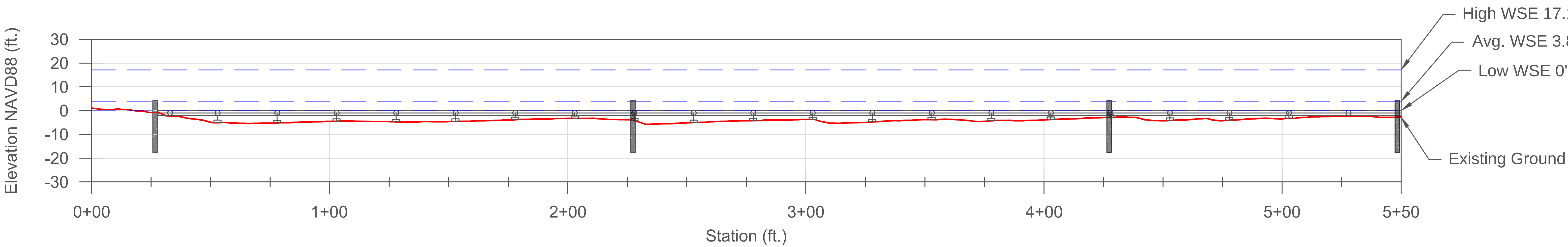
Plan: Bio-Acoustic Fish Fence

Location: Head of Old River

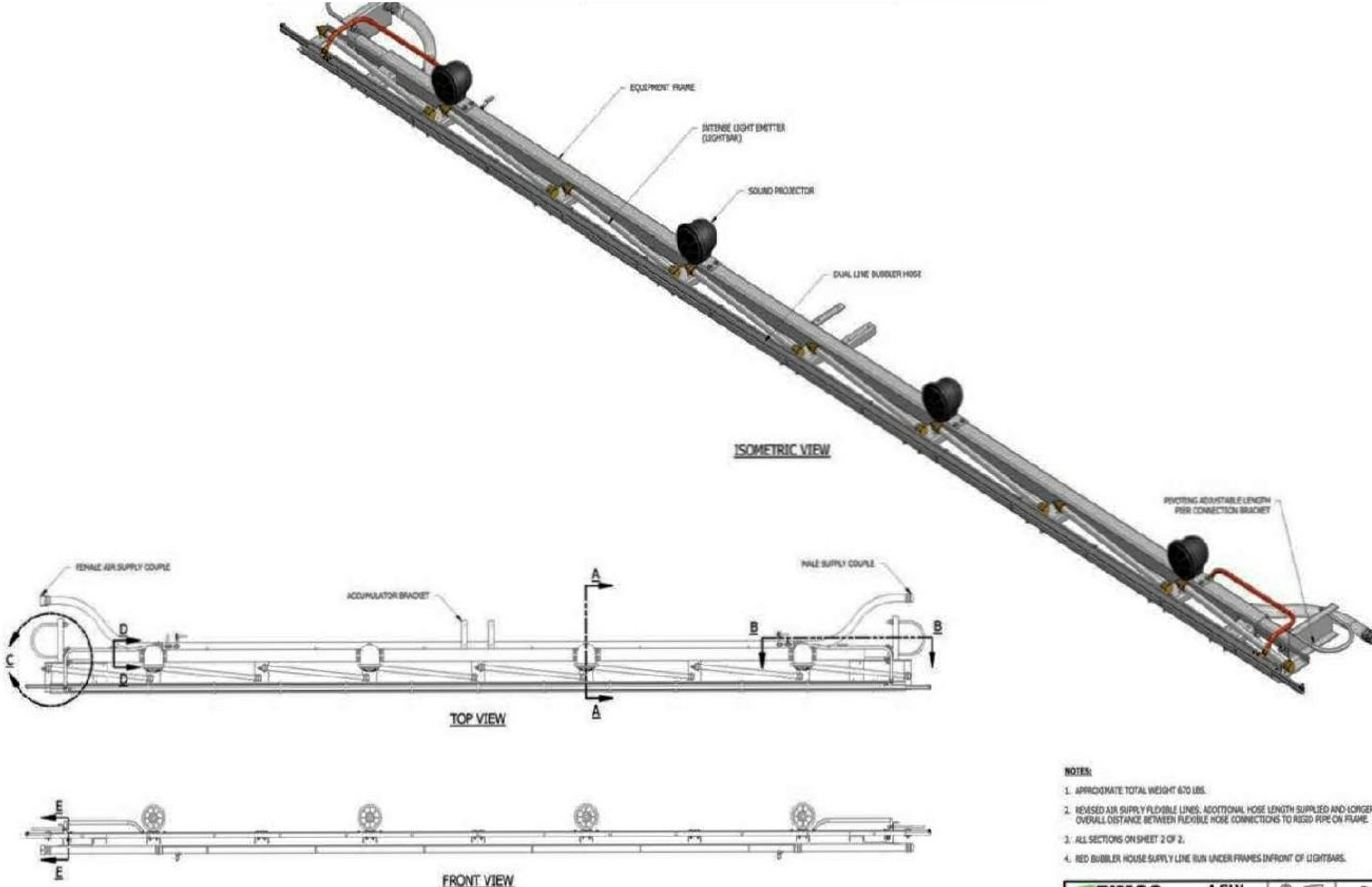
State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

BAFFatHOR.dwg

SHEET 2 OF 18



Date Drawn: 04-17-2014 Drawn By: Khalid Ameri	Elevation: Bio-Acoustic Fish Fence Location: Head of Old River	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatHOR.dwg SHEET 3 OF 18



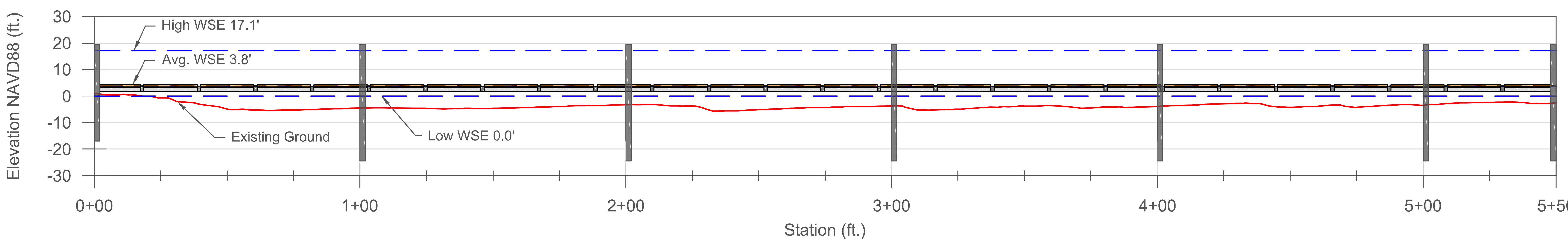
NOTES:

1. APPROXIMATE TOTAL WEIGHT 670 LBS.
2. REVISED AIR SUPPLY FLEXIBLE LINES. ADDITIONAL HOSE LENGTH SUPPLIED AND LONGER OVERALL DISTANCE BETWEEN FLEXIBLE HOSE CONNECTIONS TO RIGID PIPE ON FRAME.
3. ALL SECTIONS ON SHEET 2 OF 2.
4. RED BUBBLER HOUSE SUPPLY LINE RUN UNDER FRAMES INFRONT OF LIGHTBARS.

EIMCO TECHNOLOGIES — A GLV COMPANY | D
ORIGINAL E.O. | DO NOT SCALE PRINTS

Date Drawn: 2009 Drawn By: EIMCO	Detail: Bio–Acoustic Fish Fence Location: Head of Old River	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office	BAFFatHOR.dwg SHEET 4 OF 18

Date Drawn: 04–24–2014 Drawn By: Khalid Ameri	Plan: Floating Fish Guidance Structure Location: Head of Old River	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office		FFGSatHOR.dwg SHEET 5 OF 18



Date Drawn: 04–24–2014

Drawn By: Khalid Ameri

Elevation: Floating Fish Guidance Structure

Location: Head of Old River

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

FFGSatHOR.dwg

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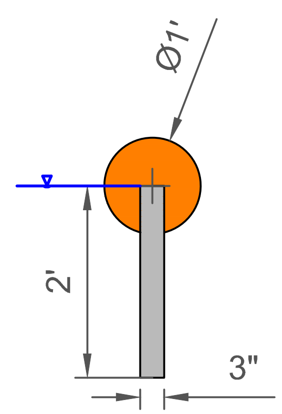
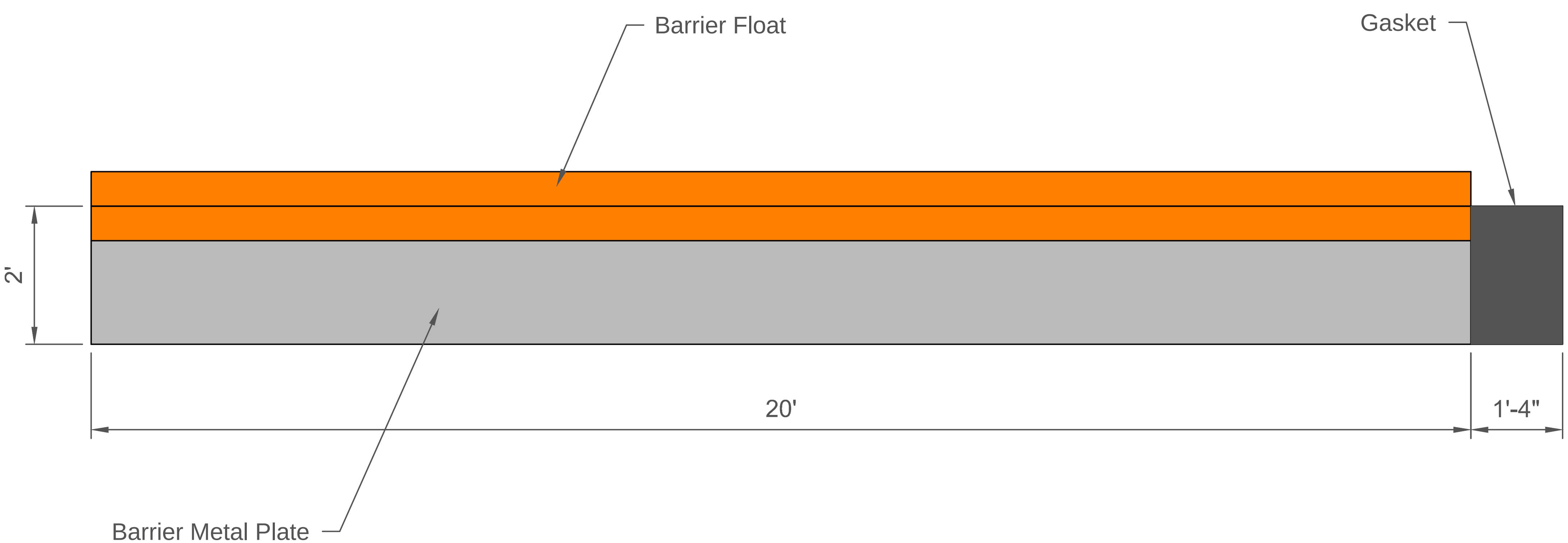


SINGLE FFGS SECTION - SIDE VIEW



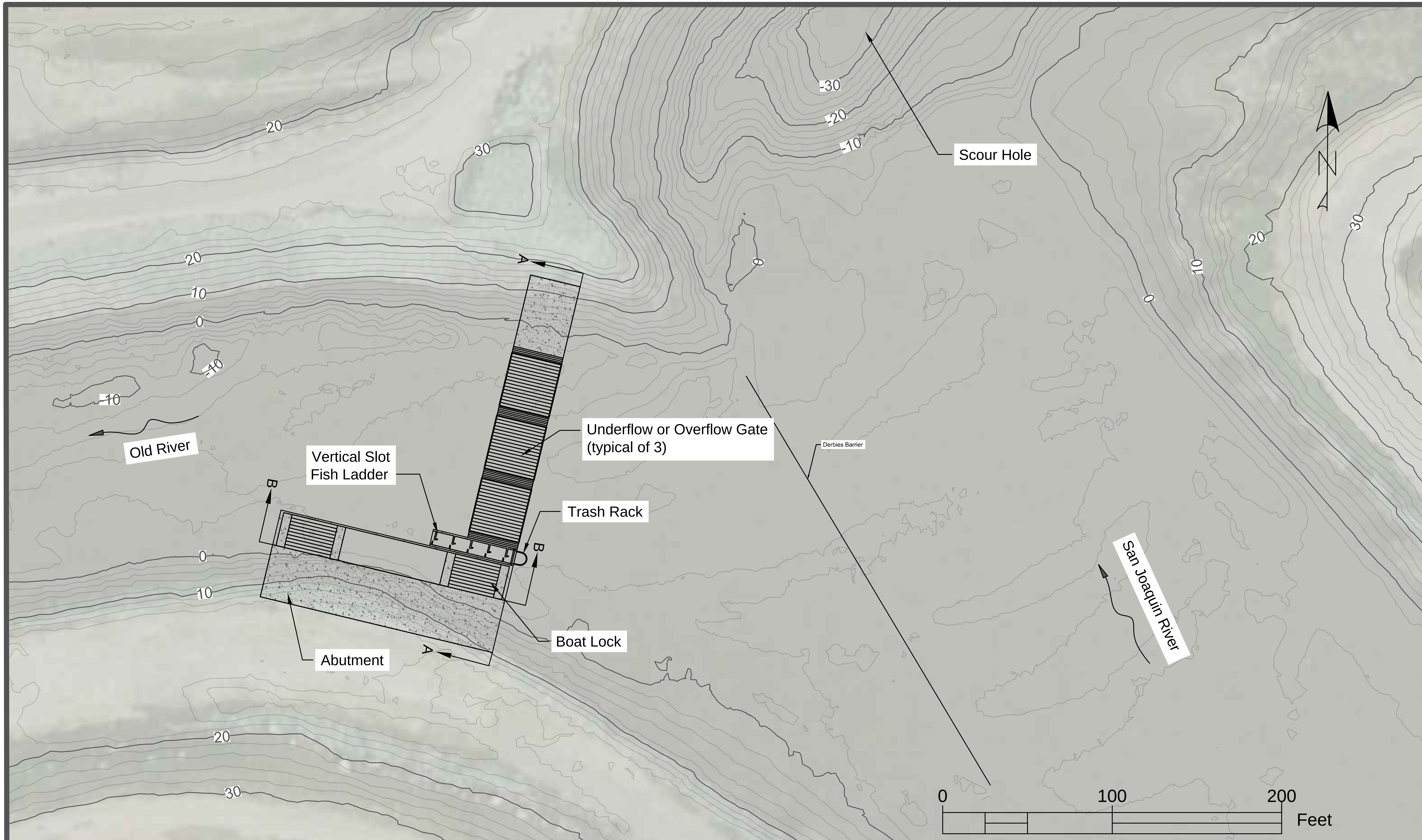
SINGLE FFGS SECTION - FRONT/FACE

Date Drawn: 04-24-2014
Drawn By: Khalid Ameri

Detail: Floating Fish Guidance Structure
Location: Head of Old River

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

FFGSatHOR.dwg



Date Drawn: 04–10–2014

Drawn By: Khalid Ameri

Plan: Gates with Boat Lock & Fish Ladder

Location: Head of Old River

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GATEatHOR.dwg

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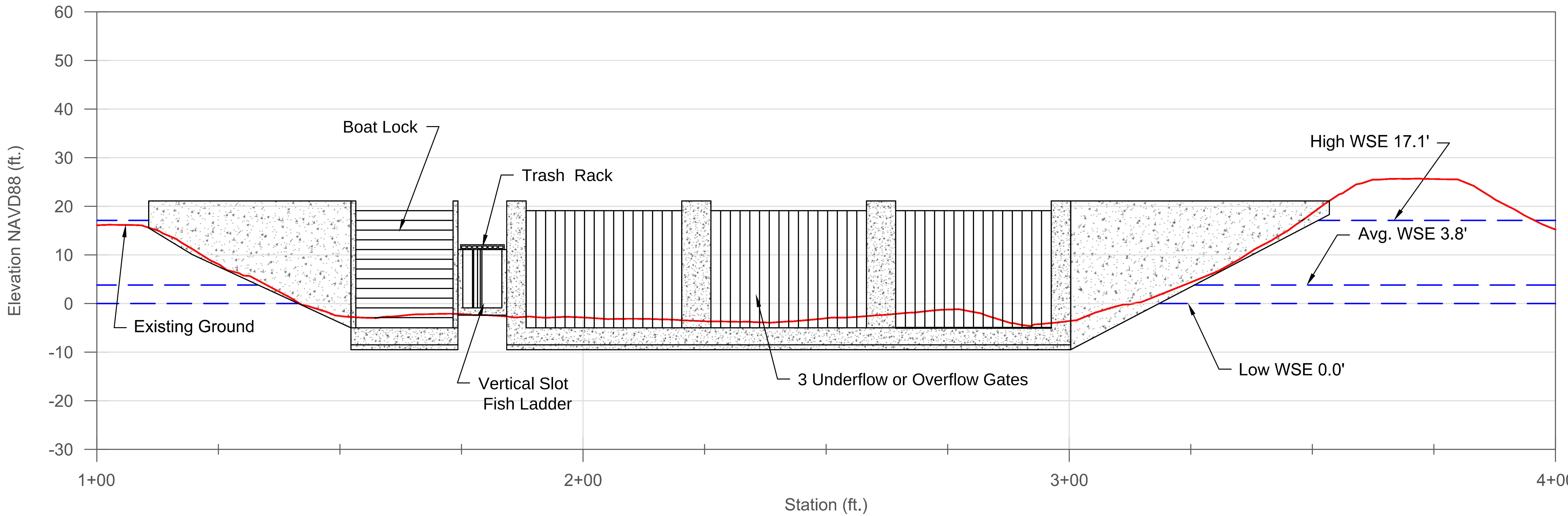
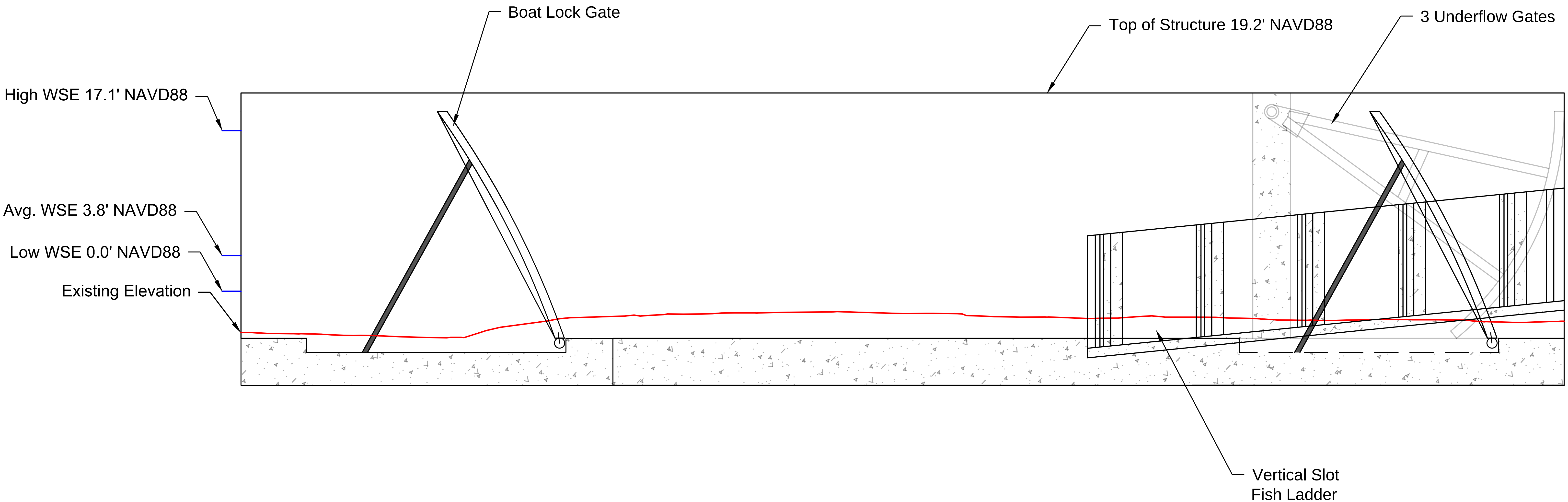


Date Drawn: 04-10-2014 Drawn By: Khalid Ameri	Elevation A-A: Gates with Boat Lock & Fish Ladder Location: Head of Old River	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		GATEatHOR.dwg SHEET 9 OF 18



Date Drawn: 04–10–2014

Drawn By: Khalid Ameri

Section B–B: Underflow Gates with Boat Lock & Fish Ladder

Location: Head of Old River

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GATEatHOR.dwg

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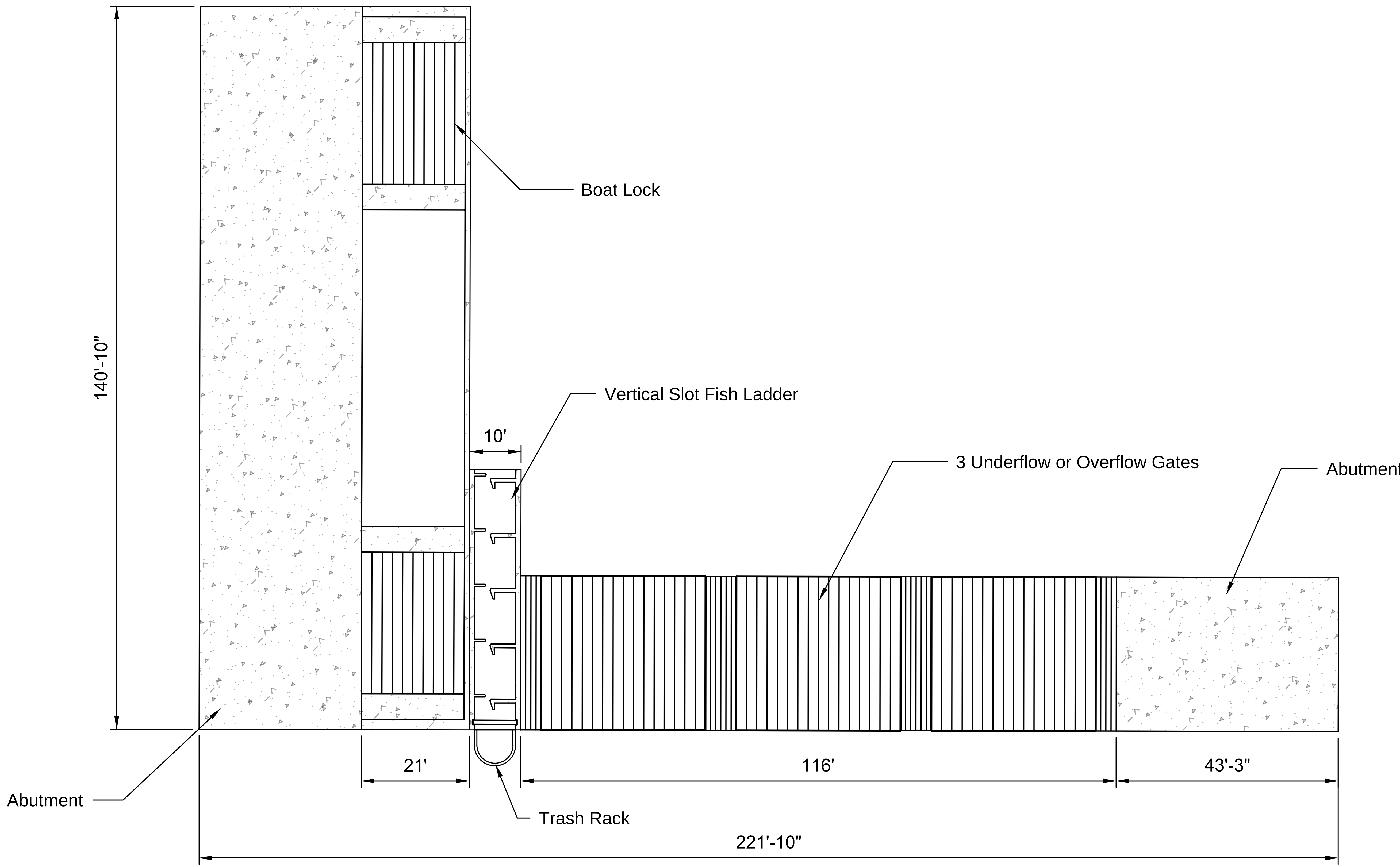


Date Drawn: 04–10–2014
Drawn By: Khalid Ameri

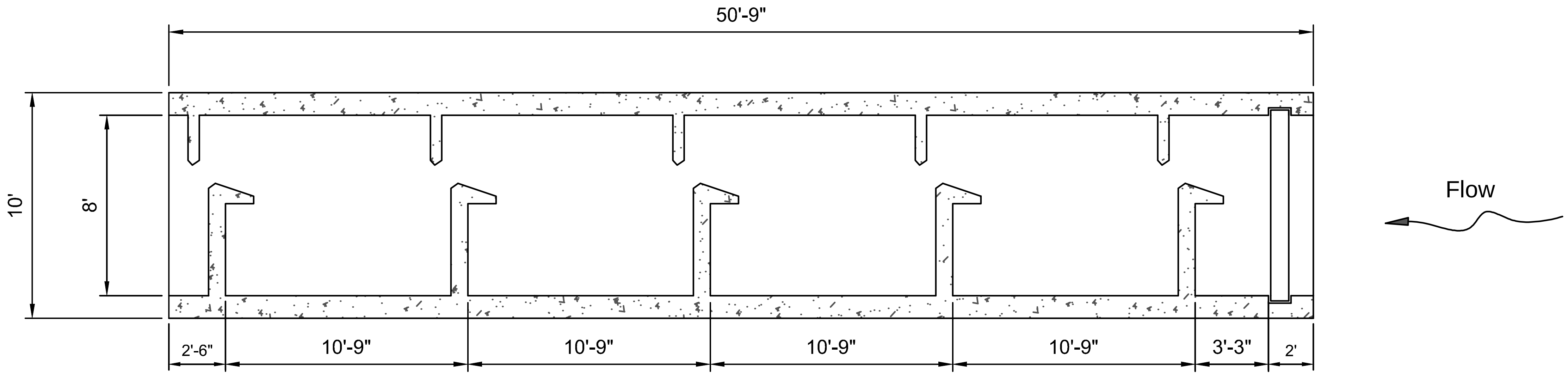
Detail: Gates with Boat Lock & Fish Ladder

Location: Head of Old River

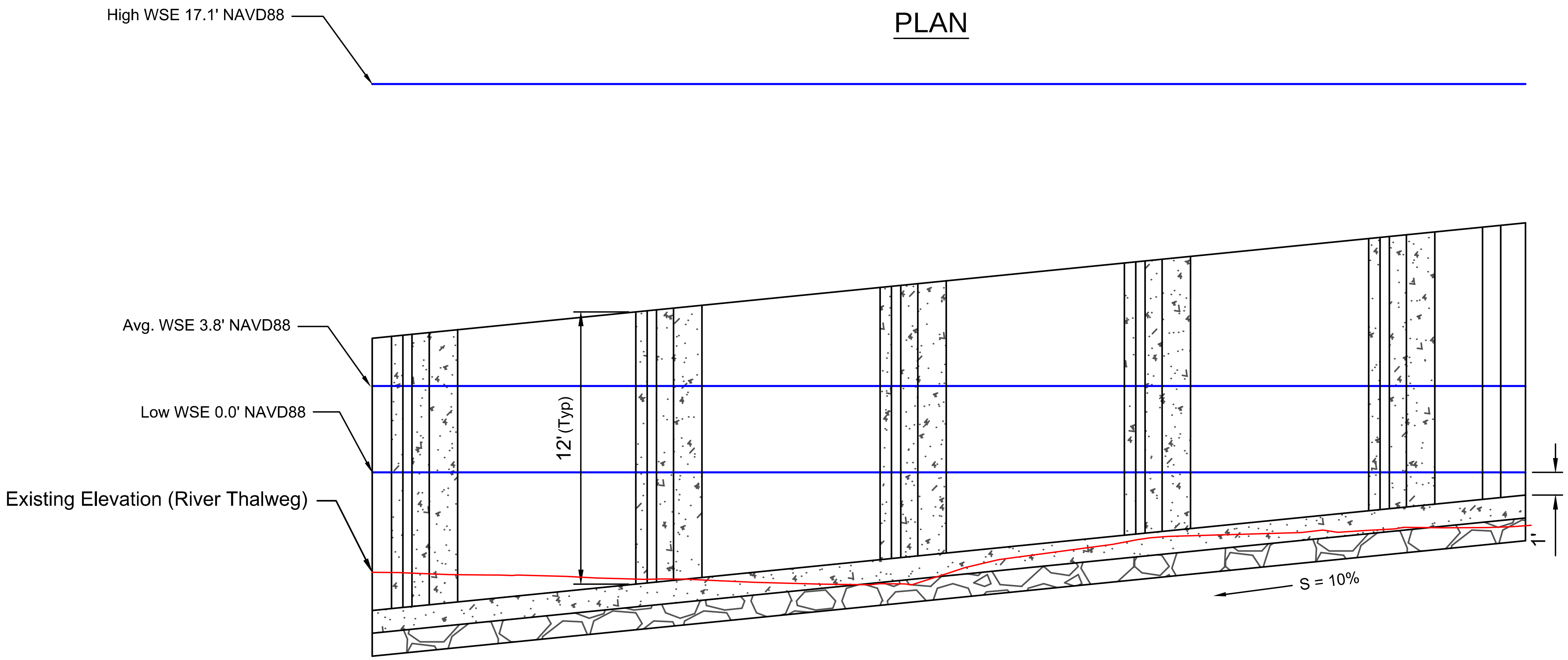
State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GATEatHOR.dwg

SHEET 11 OF 18



PLAN



SECTION B-B

Date Drawn: 04-10-2014

Drawn By: Khalid Ameri

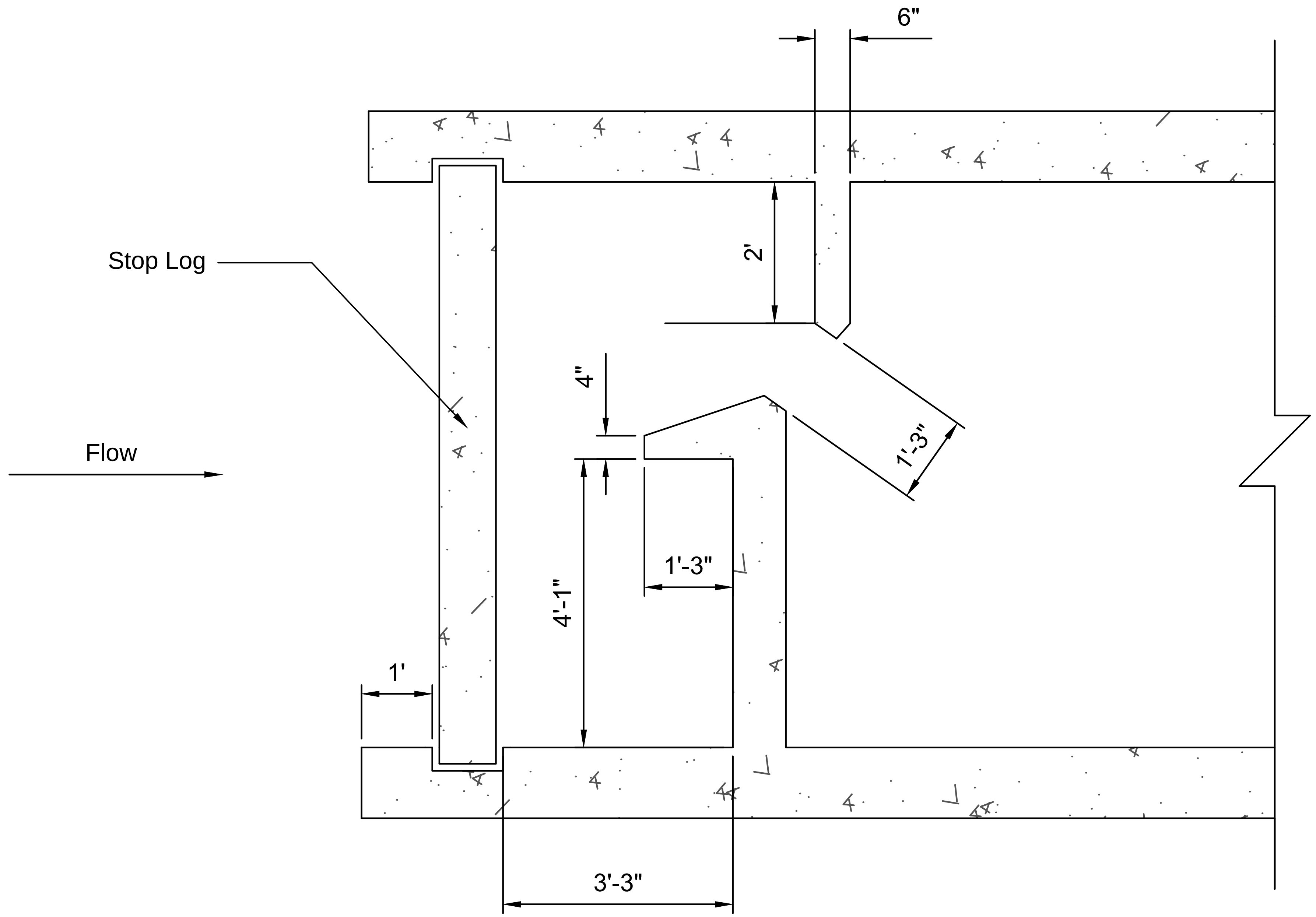
Detail: Vertical Slot Fish Ladder

Location: Head of Old River

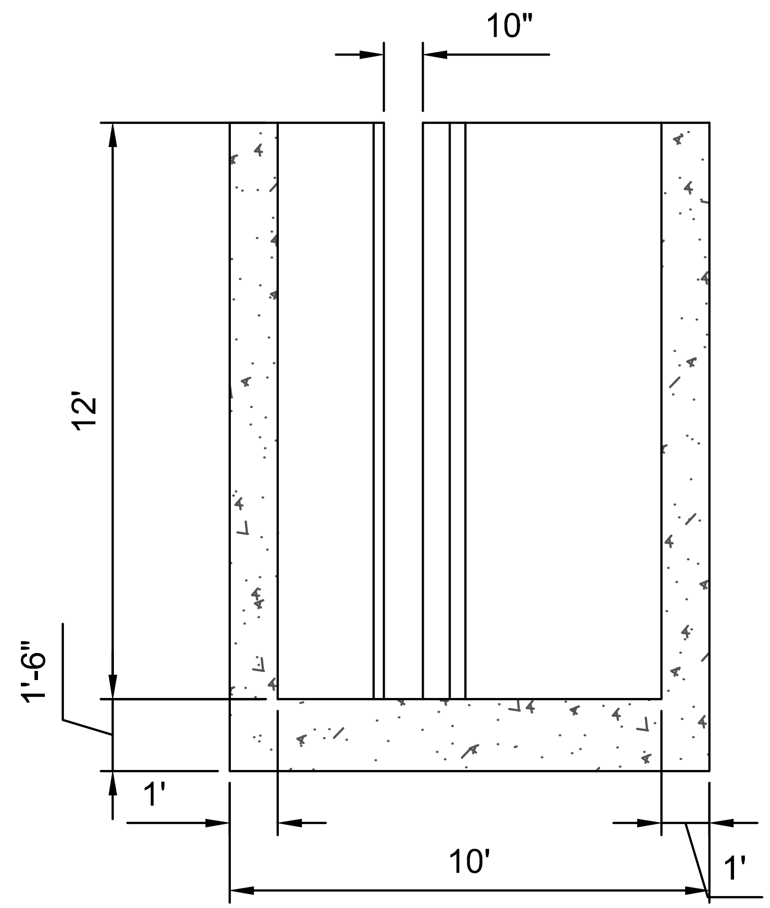
State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatHOR.dwg

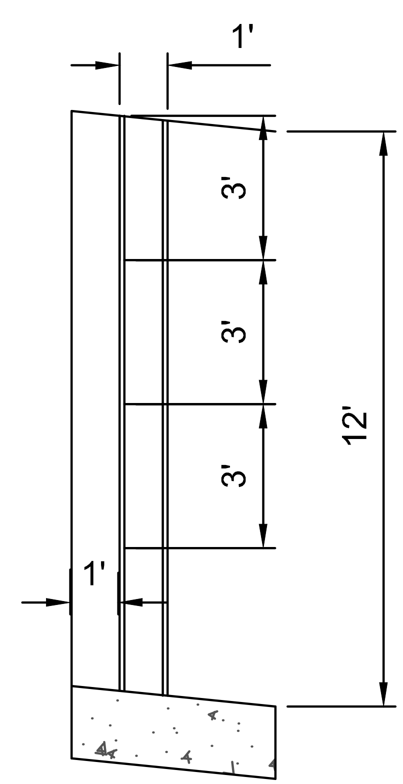
SHEET 12 OF 18



Date Drawn: 04-10-2014 Drawn By: Khalid Ameri	Detail: Vertical Slot Fish Ladder Location: Head of Old River	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	GATEatHOR.dwg SHEET 13 OF 18



SECTION A-A



Date Drawn: 04-10-2014

Drawn By: Khalid Ameri

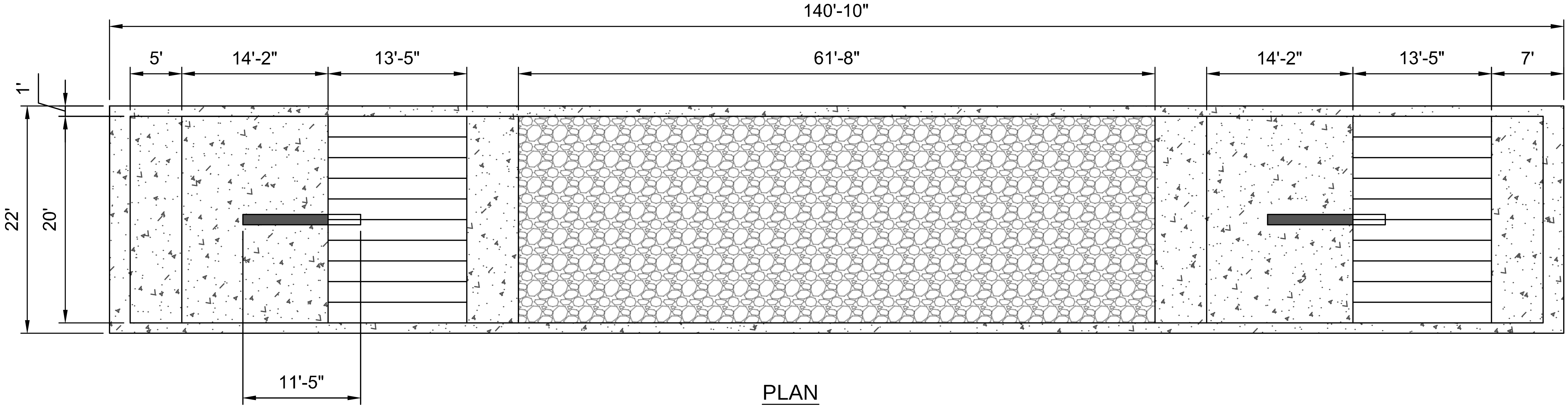
Detail: Vertical Slot Fish Ladder

Location: Head of Old River

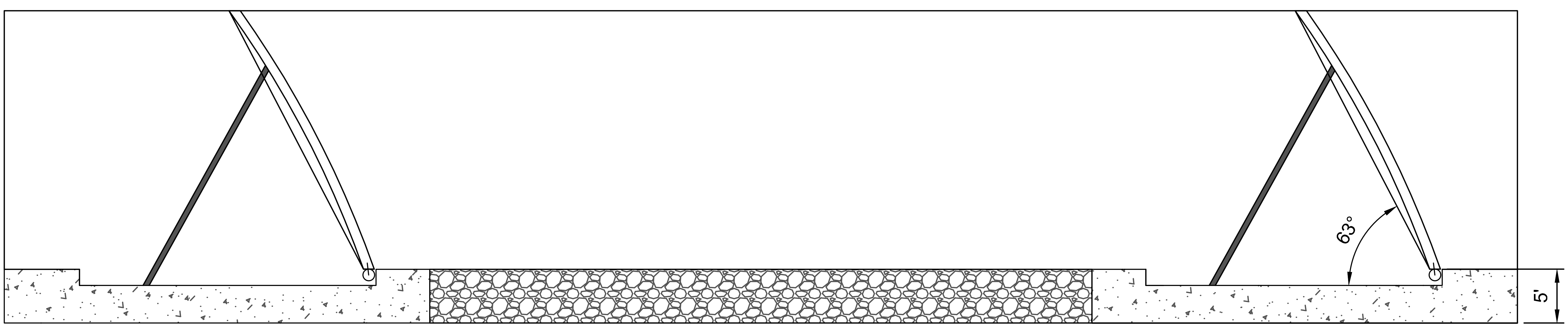
State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatHOR.dwg

SHEET 14 OF 18

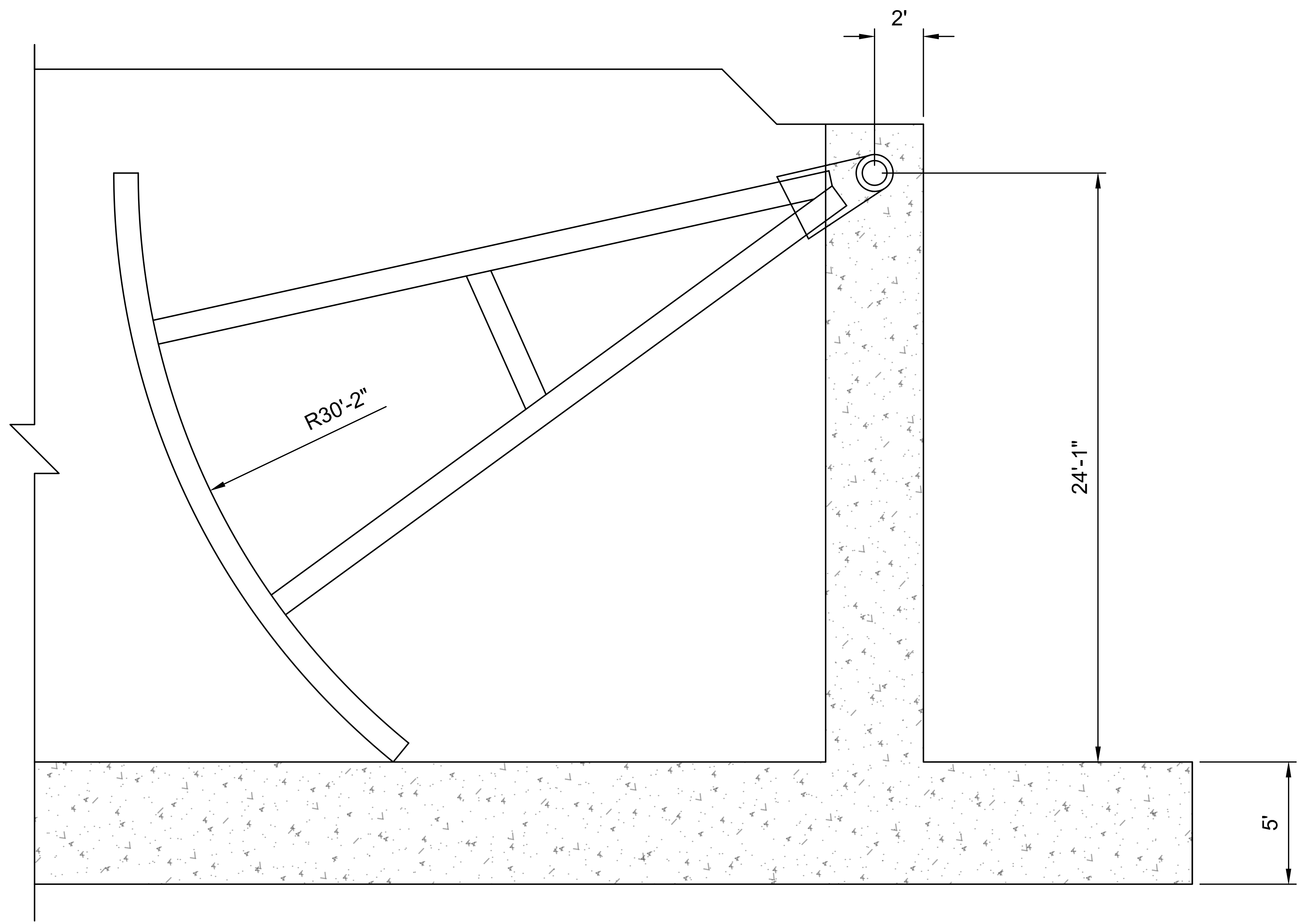


PLAN



SECTION B-B

Date Drawn: 04-10-2014 Drawn By: Khalid Ameri	**Detail: Boat Lock** Location: Head of Old River	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	GATEatHOR.dwg SHEET 15 OF 18



Date Drawn: 04–10–2014

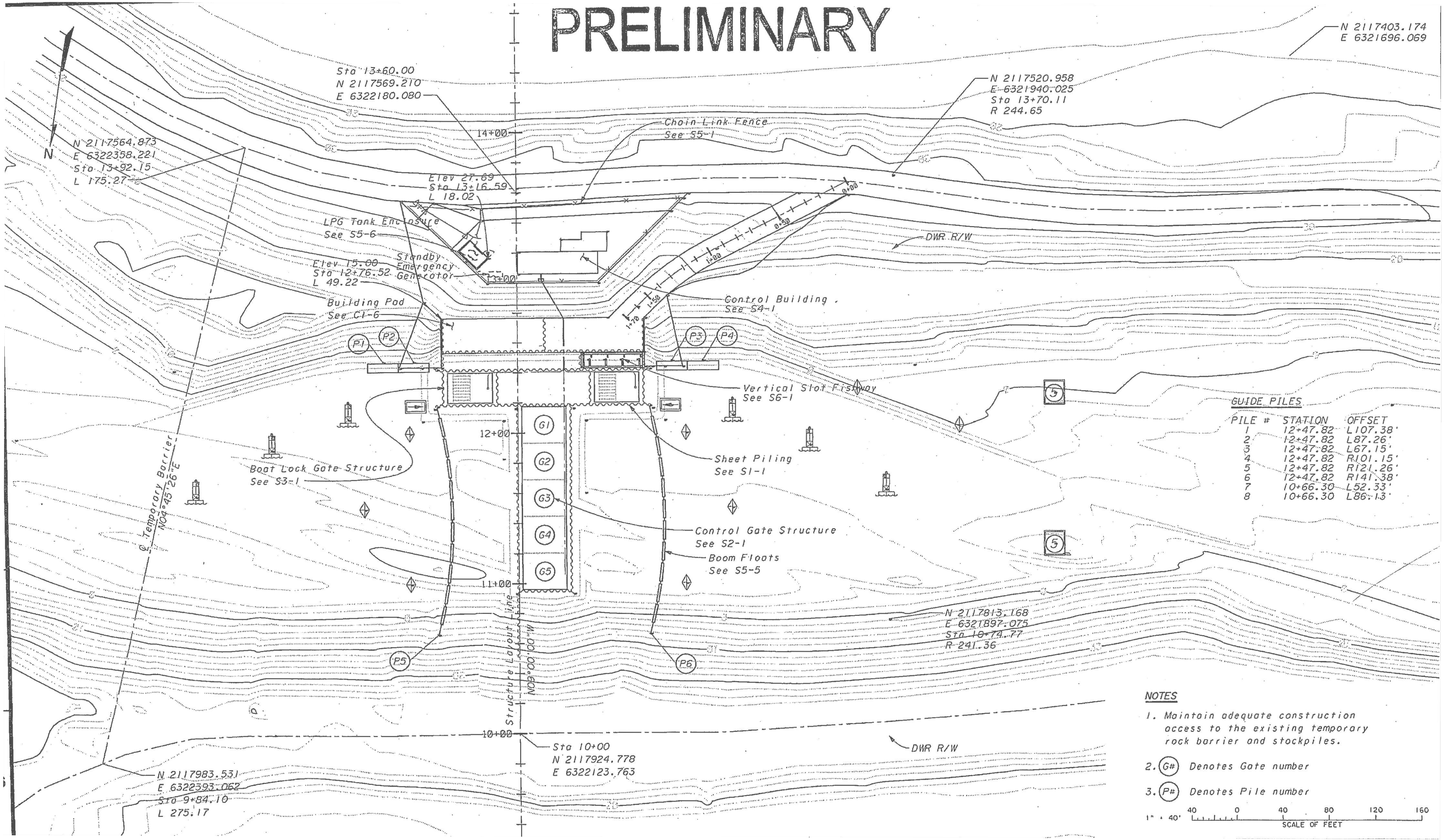
Drawn By: Khalid Ameri

Detail: Radial Arm Gate

Location: Head of Old River

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GATEatHOR.dwg



Date Drawn: 06-22-2007

Drawn By: DWR, Division of Engineering

Plan: SDIP – Old River Fish Control Structure

Location: Head of Old River

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

SDIP_GATEatHOR.dwg

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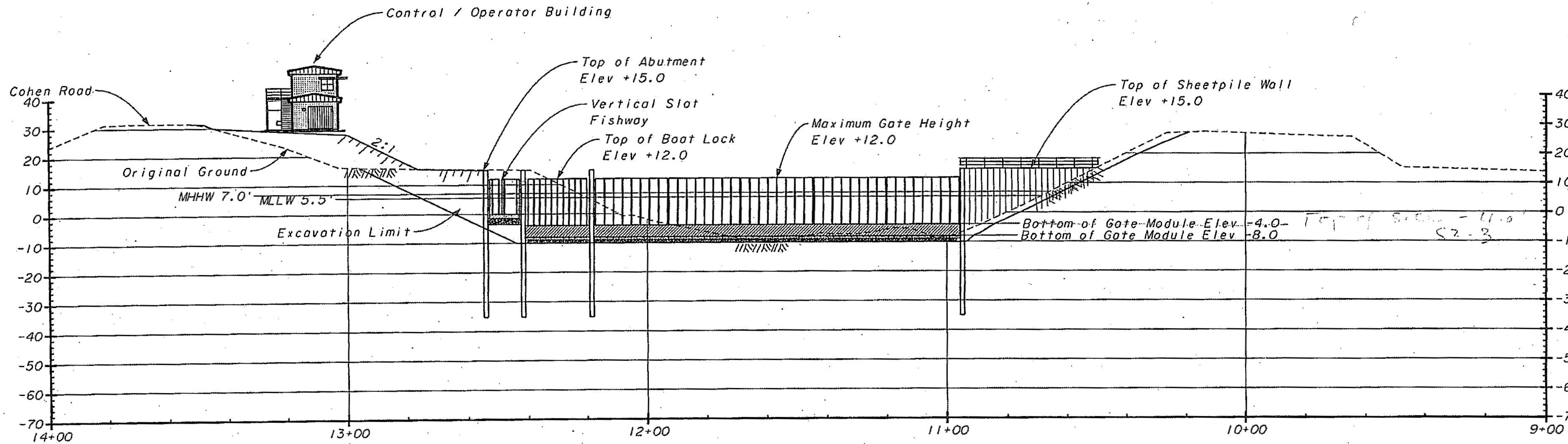


STRUCTURE PROFILE

Scale: 1'=20'

PRELIMINARY

NOTES

1. Vertical Datum - 1988 NAVD
2. Sheetpile not shown for clarity.

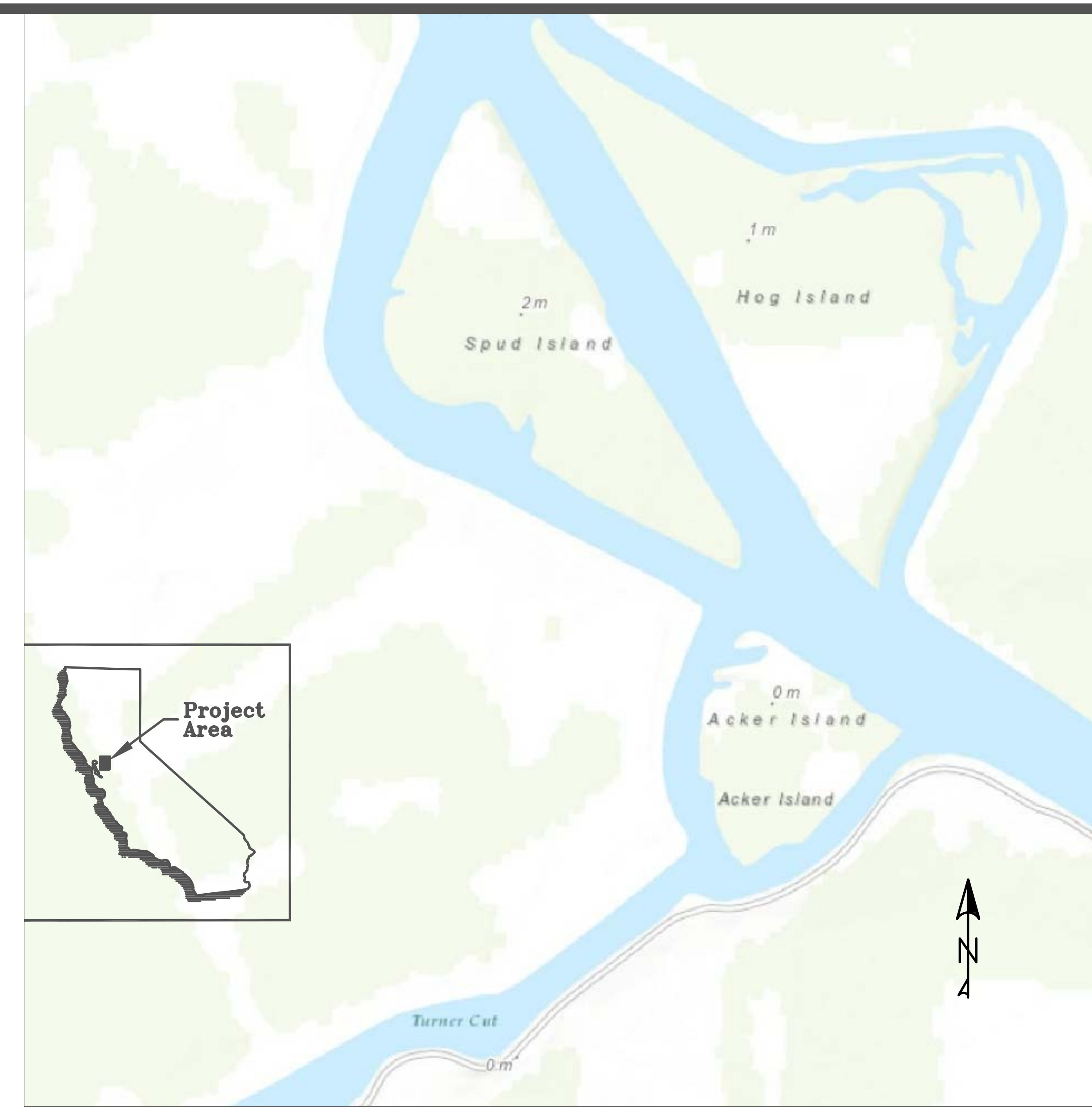
1" = 20' 20 0 20 40 60 80 SCALE OF FEET

Date Drawn: 06-22-2007 Drawn By: DWR, Division of Engineering	Elevation: SDIP - Old River Fish Control Structure Location: Head of Old River	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	SDIP_GATEatHOR.dwg SHEET 18 OF 18

CONCEPTUAL ENGINEERING DRAWINGS FOR

TURNER CUT
NMFS BiOp RPA ACTION IV.1.3

SAN JOAQUIN COUNTY, CALIFORNIA



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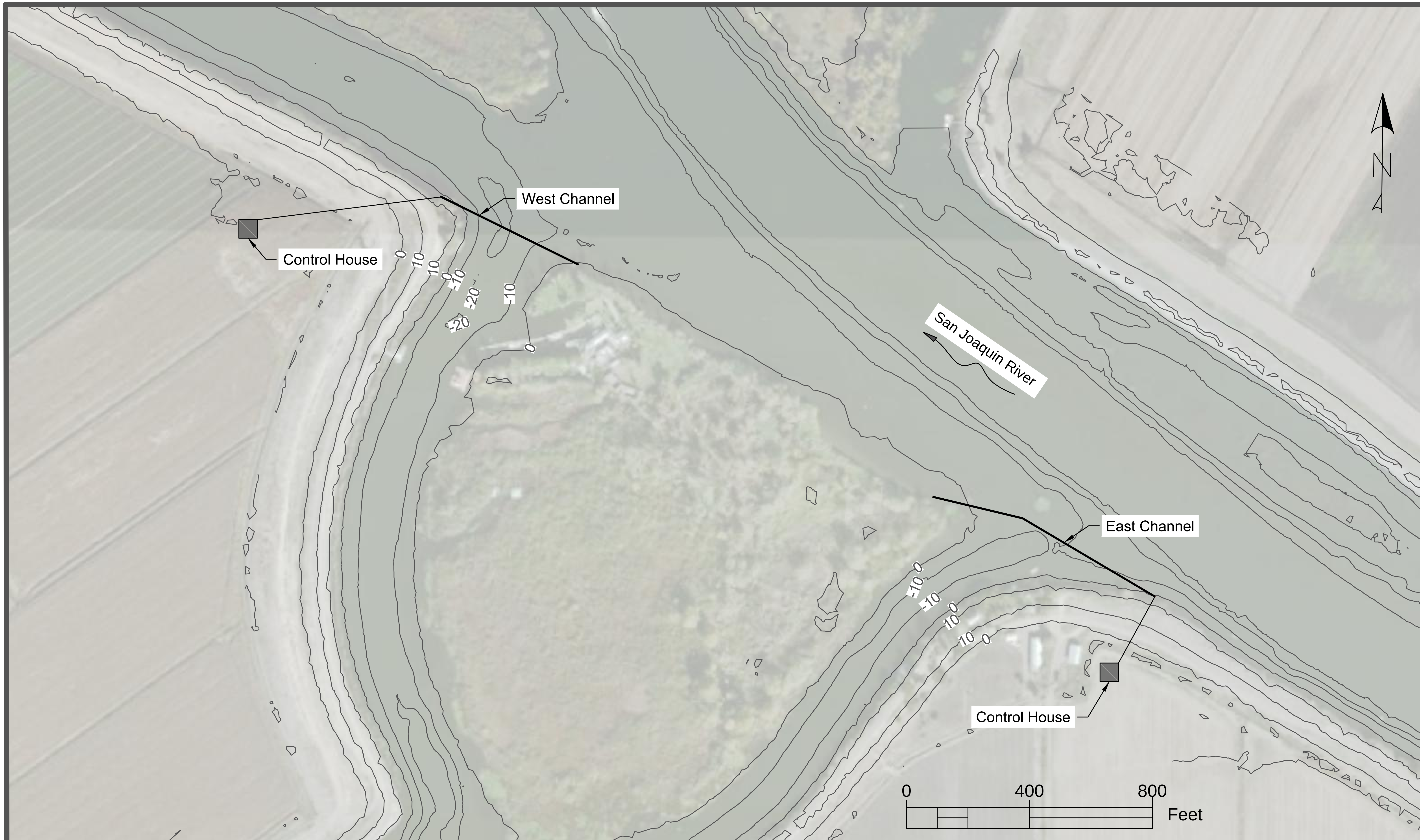
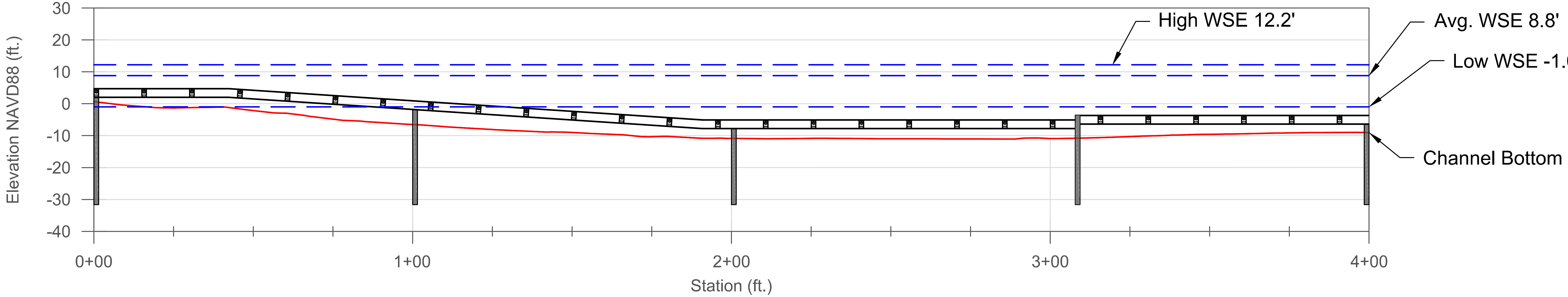
SUBJECT TO REVISION

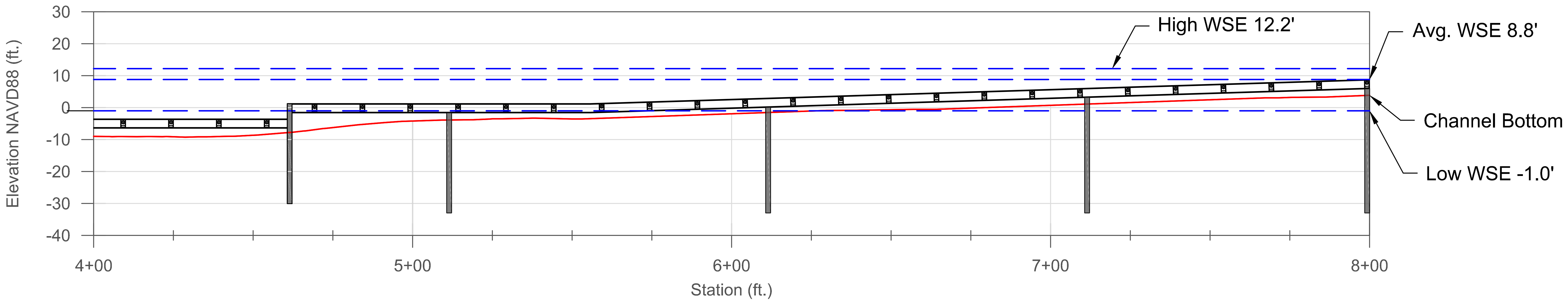
Date Drawn: 10–7–2014 Drawn By: Khalid Ameri	Title Sheet and Area Map Location: Turner Cut	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office	TC.dwg SHEET 1 OF 20



Date Drawn: 06-30-2014 Drawn By: Khalid Ameri	Plan: Bio-Acoustic Fish Fence Location: Turner Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatTC.dwg SHEET 2 OF 20

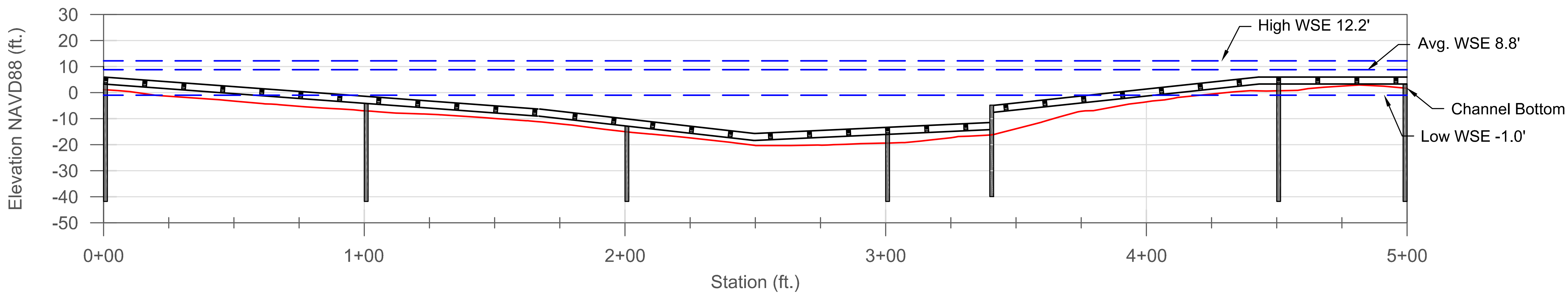
East Channel



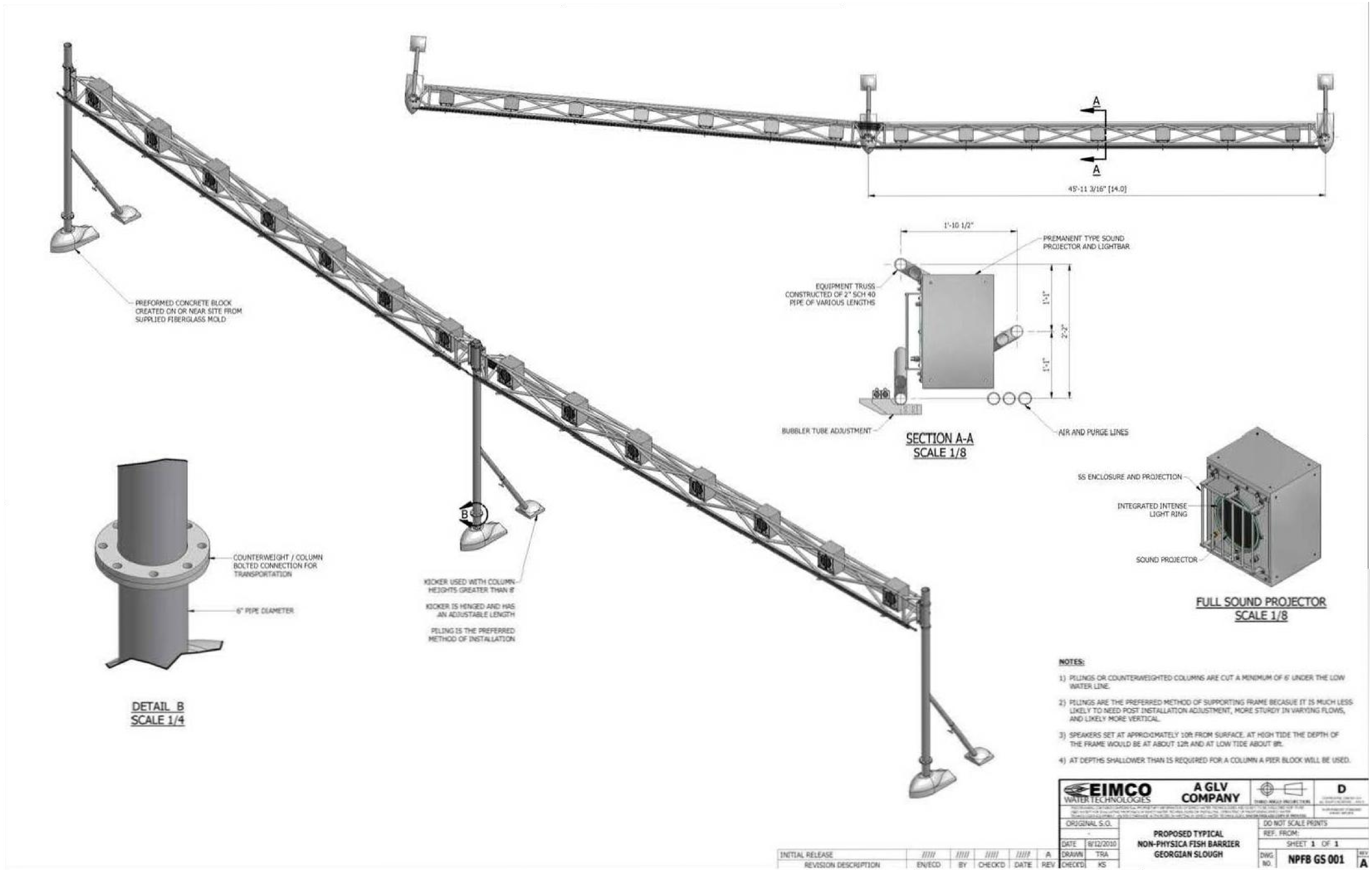


Date Drawn: 06-30-2014 Drawn By: Khalid Ameri	Plan: Bio-Acoustic Fish Fence Location: Turner Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatTC.dwg SHEET 3 OF 20

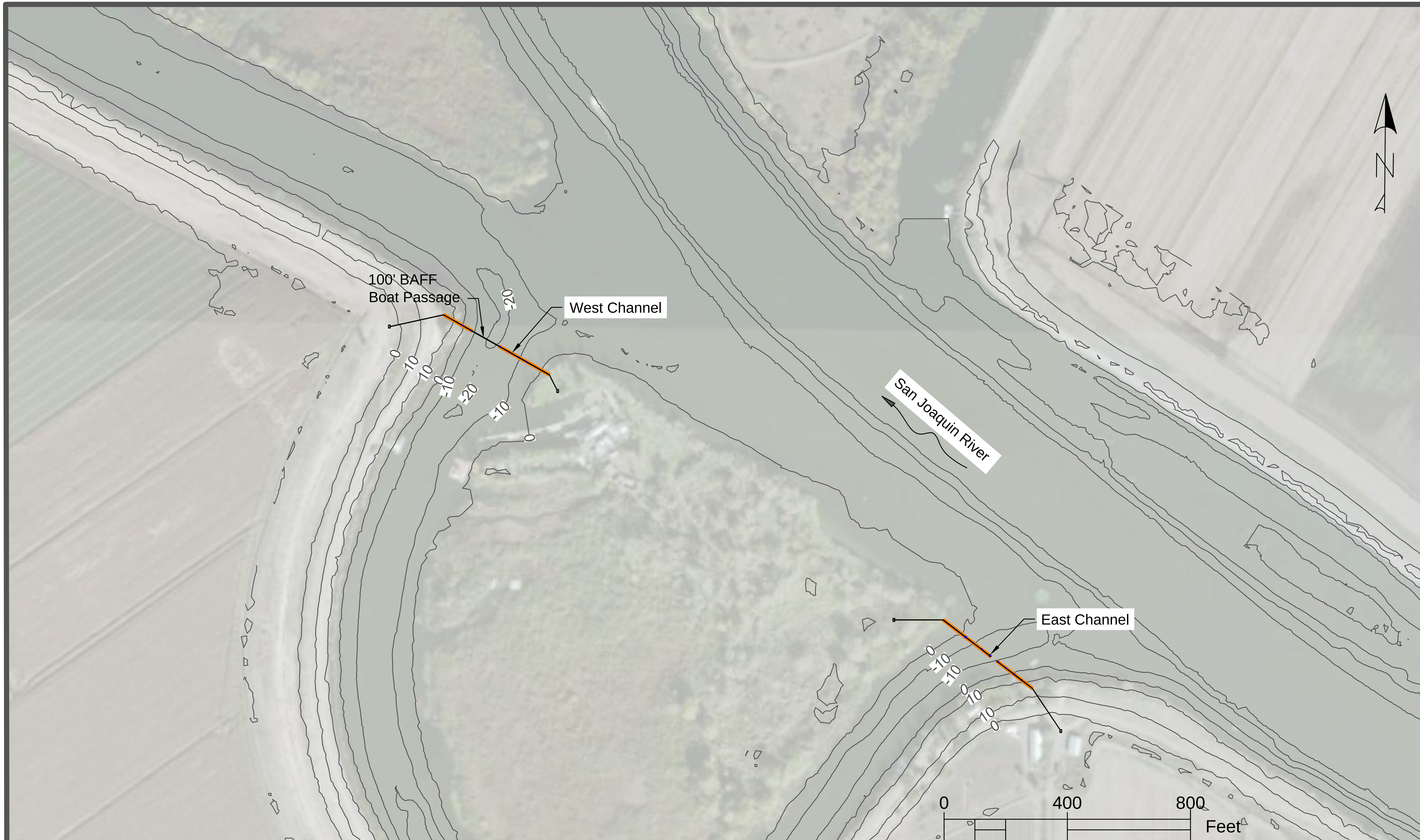
West Channel



Date Drawn: 06–30–2014 Drawn By: Khalid Ameri	Plan: Bio–Acoustic Fish Fence Location: Turner Cut	State of California Natural Resources Agency Department of Water Resources Bay–Delta Office		BAFFatTC.dwg SHEET 4 OF 20



Date Drawn: 08-12-2010 Drawn By: EIMCO	Detail: Bio-Acoustic Fish Fence Location: Turner Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatTC.dwg SHEET 5 OF 20



Date Drawn: 06–16–2014

Drawn By: Khalid Ameri

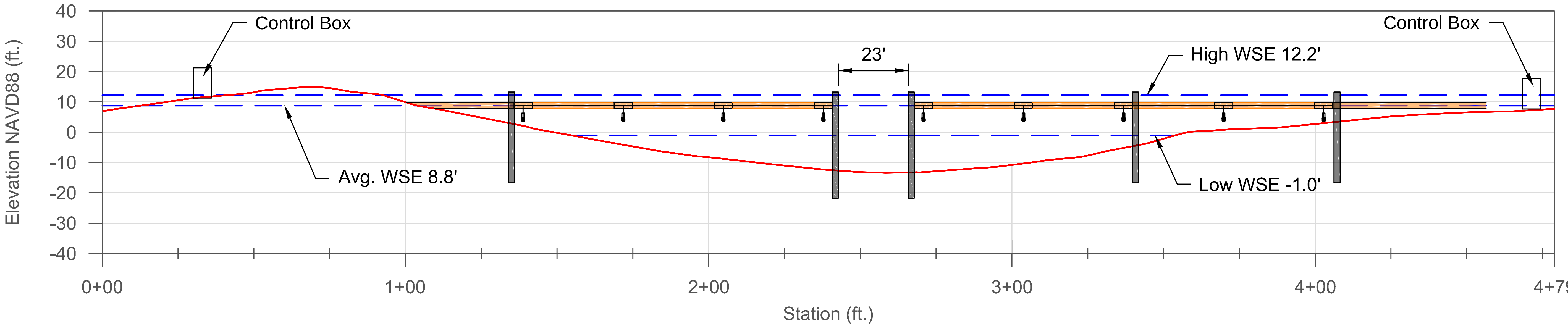
Plan: Infrasound Fish Fence

Location: Turner Cut

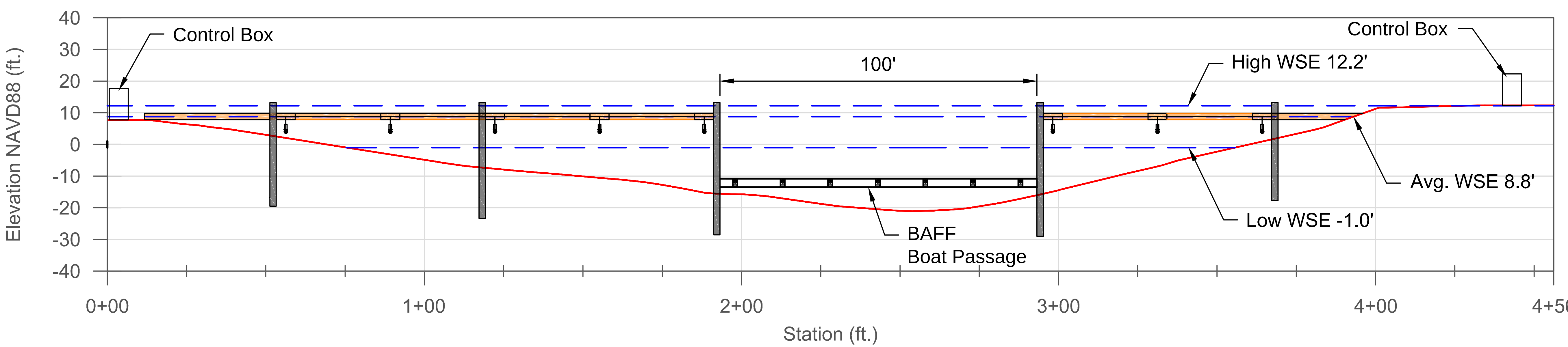
State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

IFFatTC.dwg

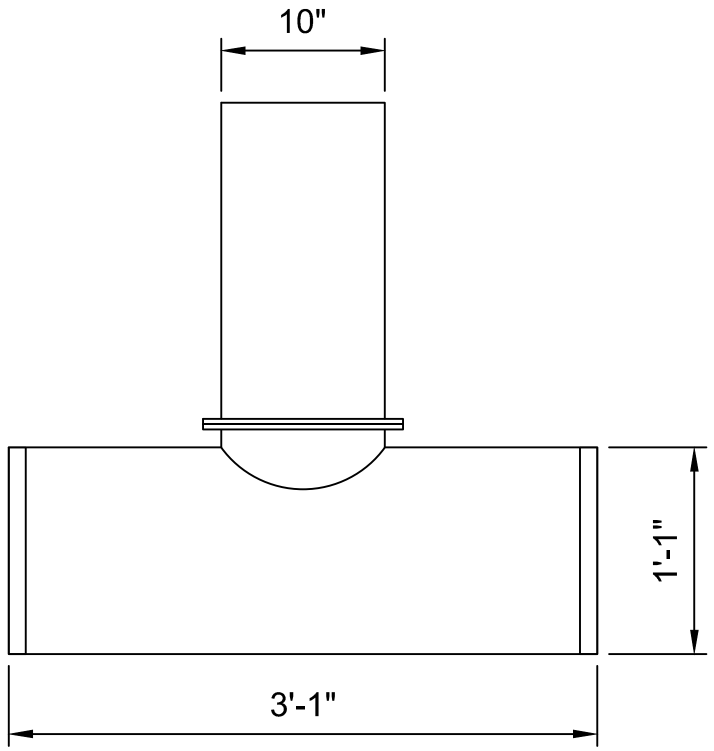
East Channel



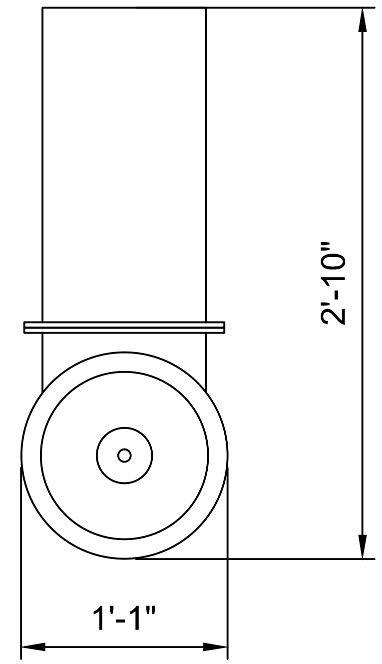
West Channel



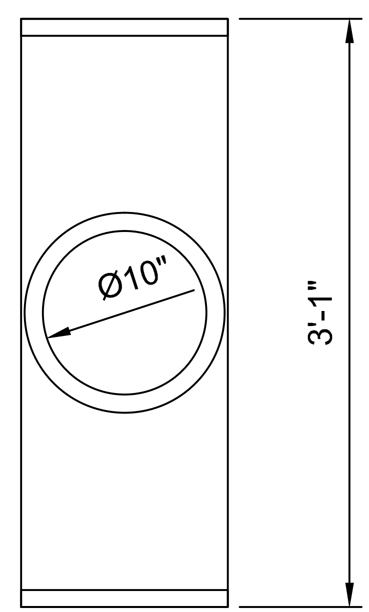
Date Drawn: 06-16-2014 *Drawn By: Khalid Ameri*	*Elevation: Infrasound Fish Fence* *Location: Turner Cut*	*State of California* *Natural Resources Agency* *Department of Water Resources* *Bay-Delta Office*		*IFFatTC.dwg* *SHEET 7 OF 20*



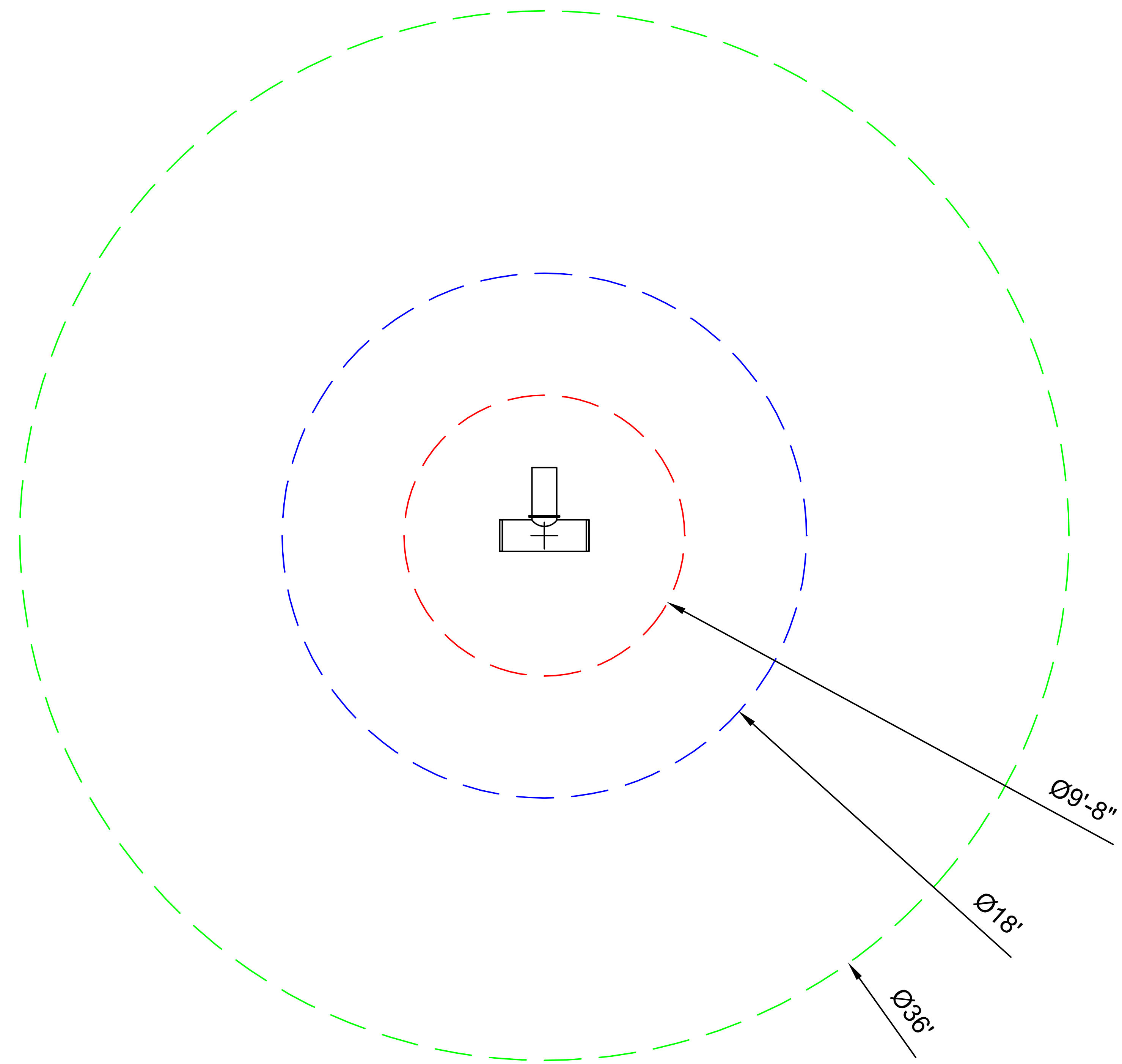
Front View



Side View



Top View



Red = Zone of exclusion from structural entities.

Blue = Fish dterrence zone.

Green = Boundary for measurable particle acceleration.

Date Drawn: 06–16–2014

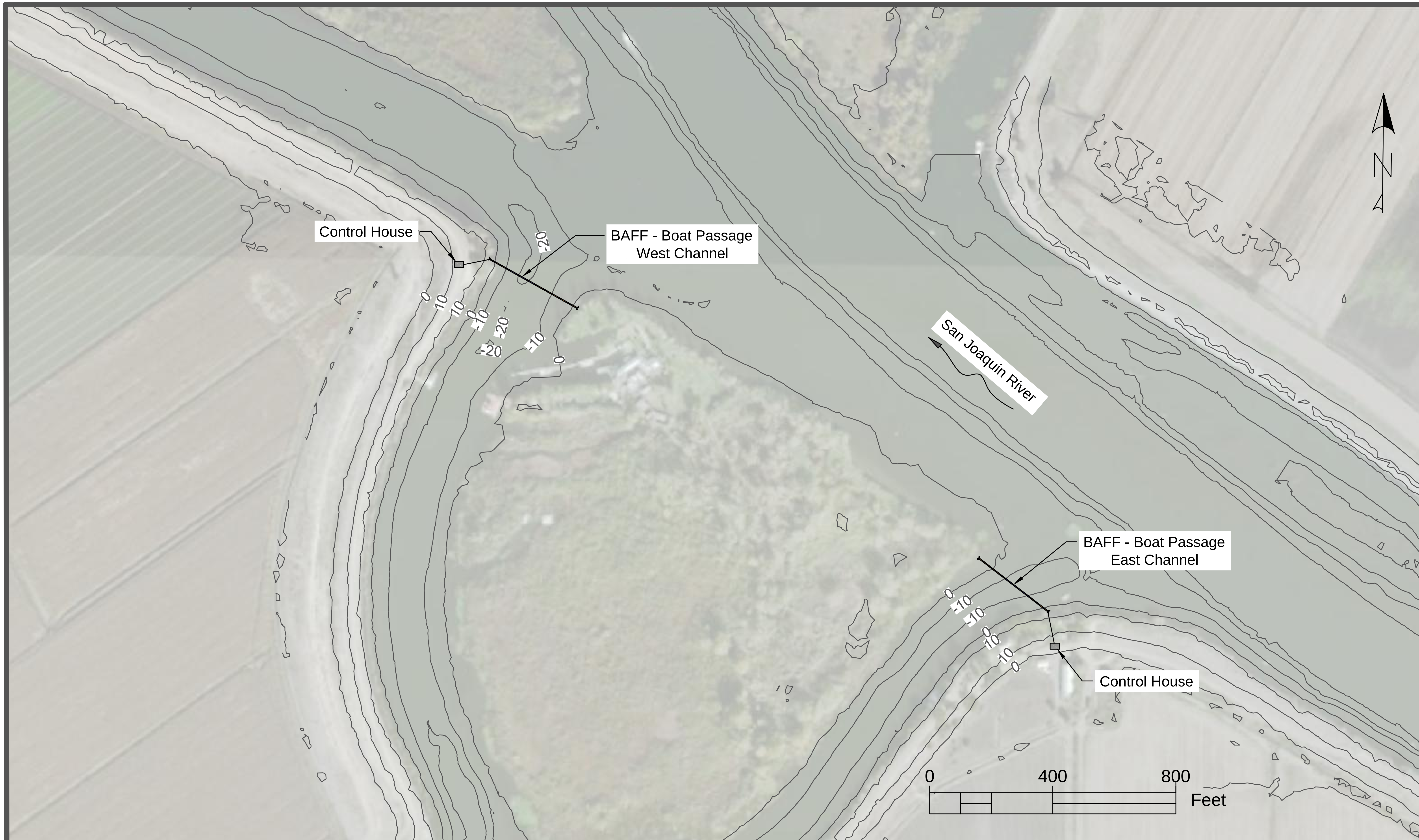
Drawn By: Khalid Ameri

Detail: Infrasound Fish Fence

Location: Turner Cut

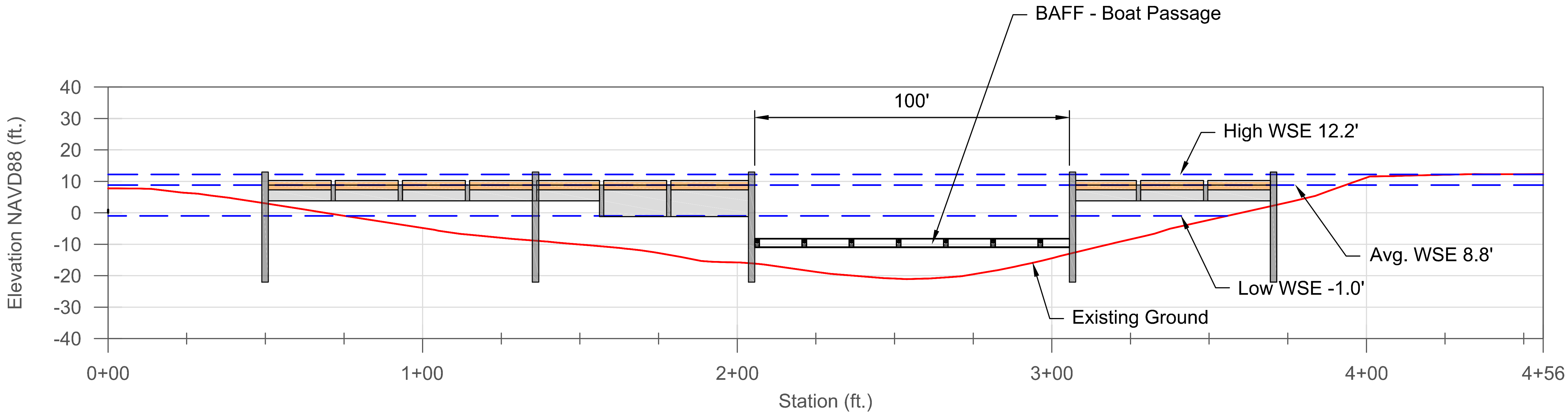
State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

IFFatTC.dwg

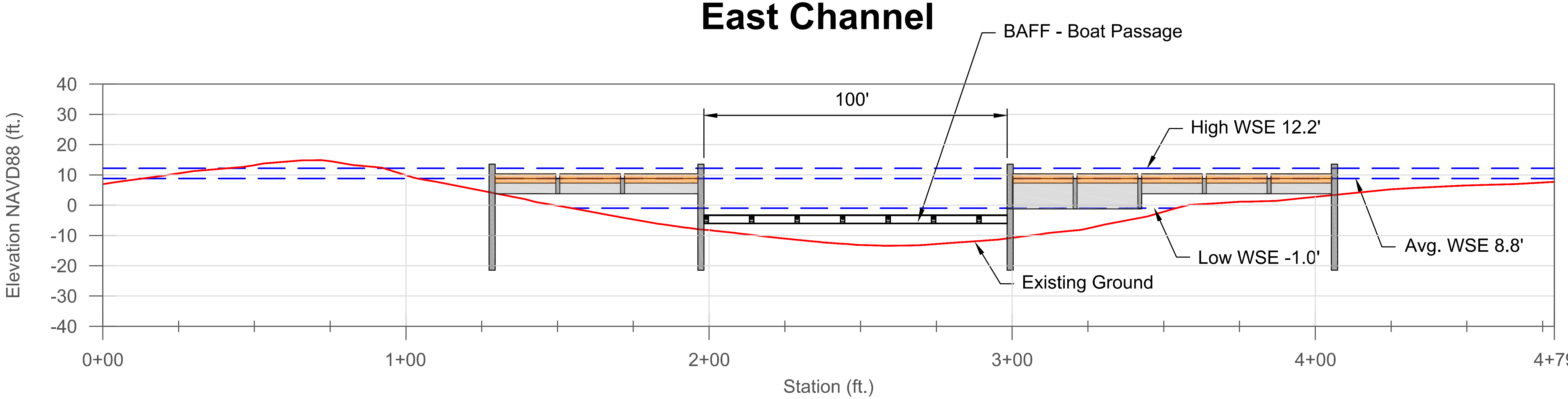


Date Drawn: 06-23-2014 Drawn By: Khalid Ameri	Plan: Floating Fish Guidance Structure Location: Turner Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	FFGSatTC.dwg SHEET 9 OF 20

West Channel



East Channel



Date Drawn: 06–23–2014

Drawn By: Khalid Ameri

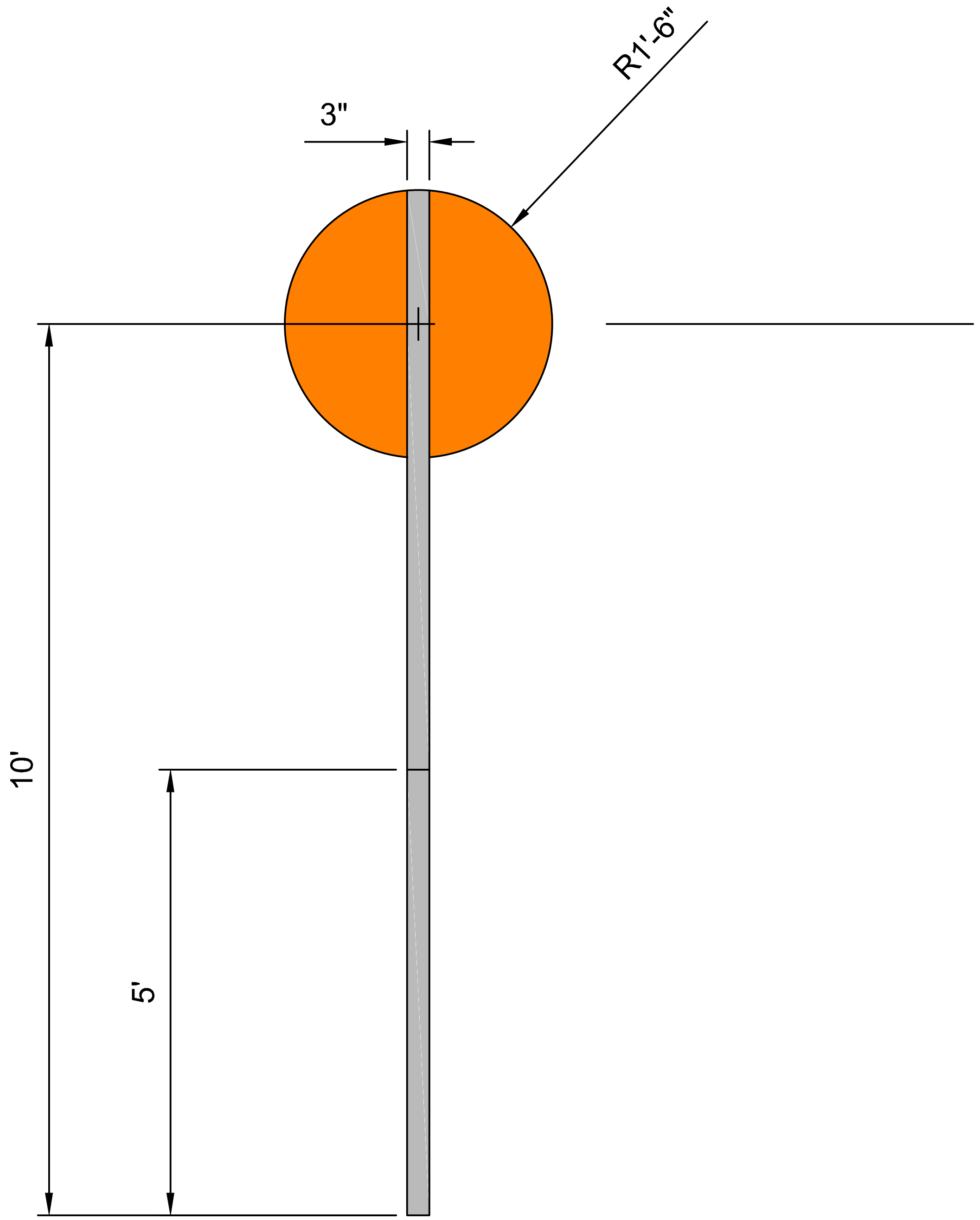
Elevation: Floating Fish Guidance Structure

Location: Turner Cut

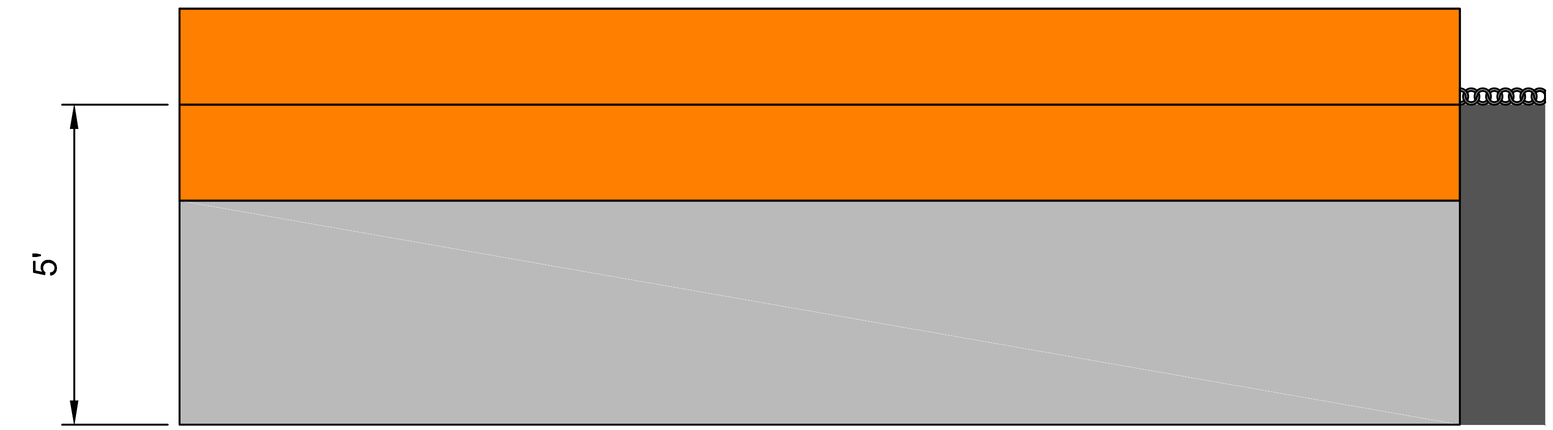
State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

FFGSatTC.dwg

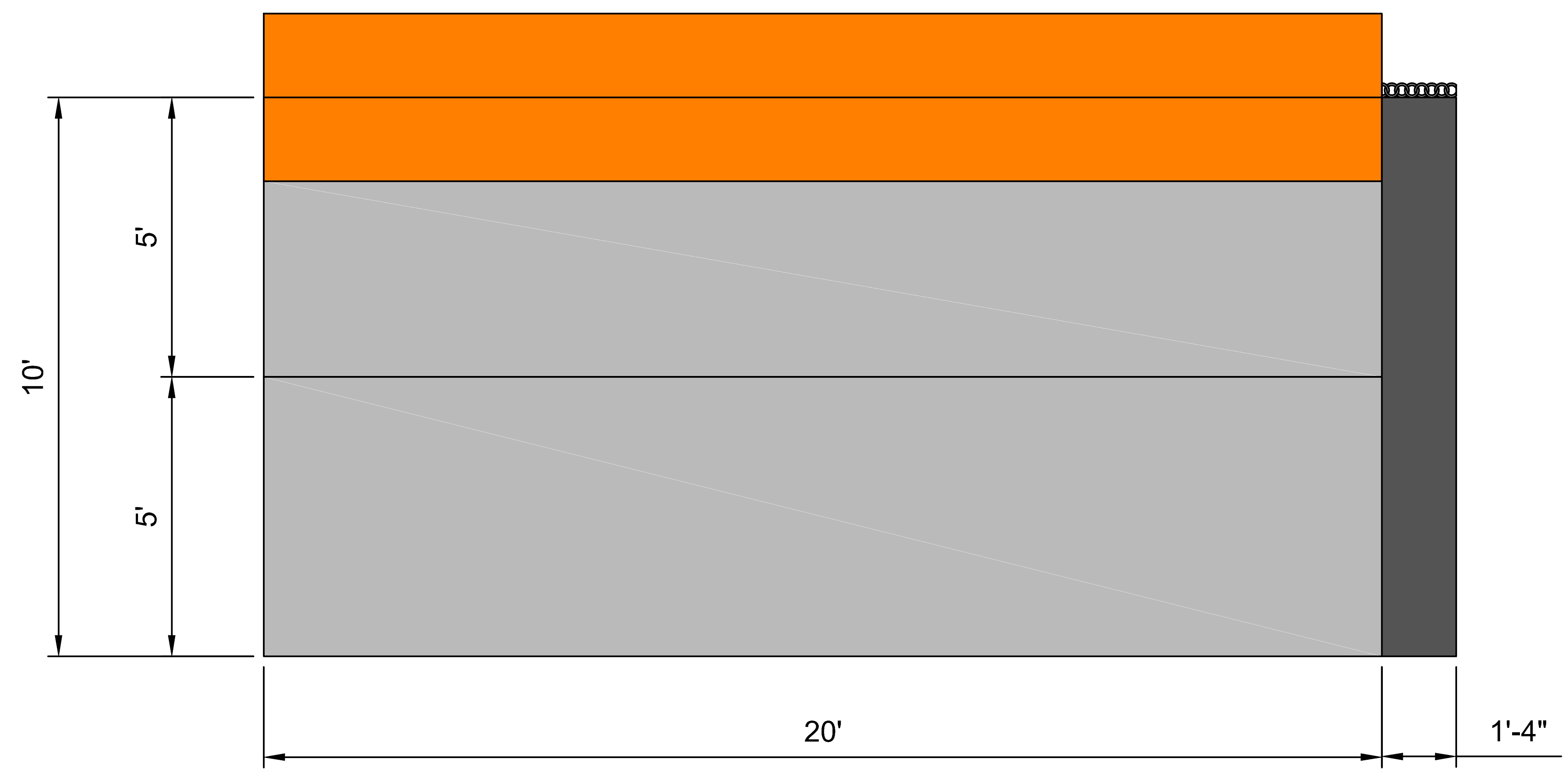
SHEET 10 OF 20



DETAIL: SINGLE FFGS SECTION - SIDE VIEW



DETAIL: SINGLE 5' FFGS SECTION - FRONT/FACE



DETAIL: SINGLE 10' FFGS SECTION - FRONT/FACE

Date Drawn: 06-23-2014

Drawn By: Khalid Ameri

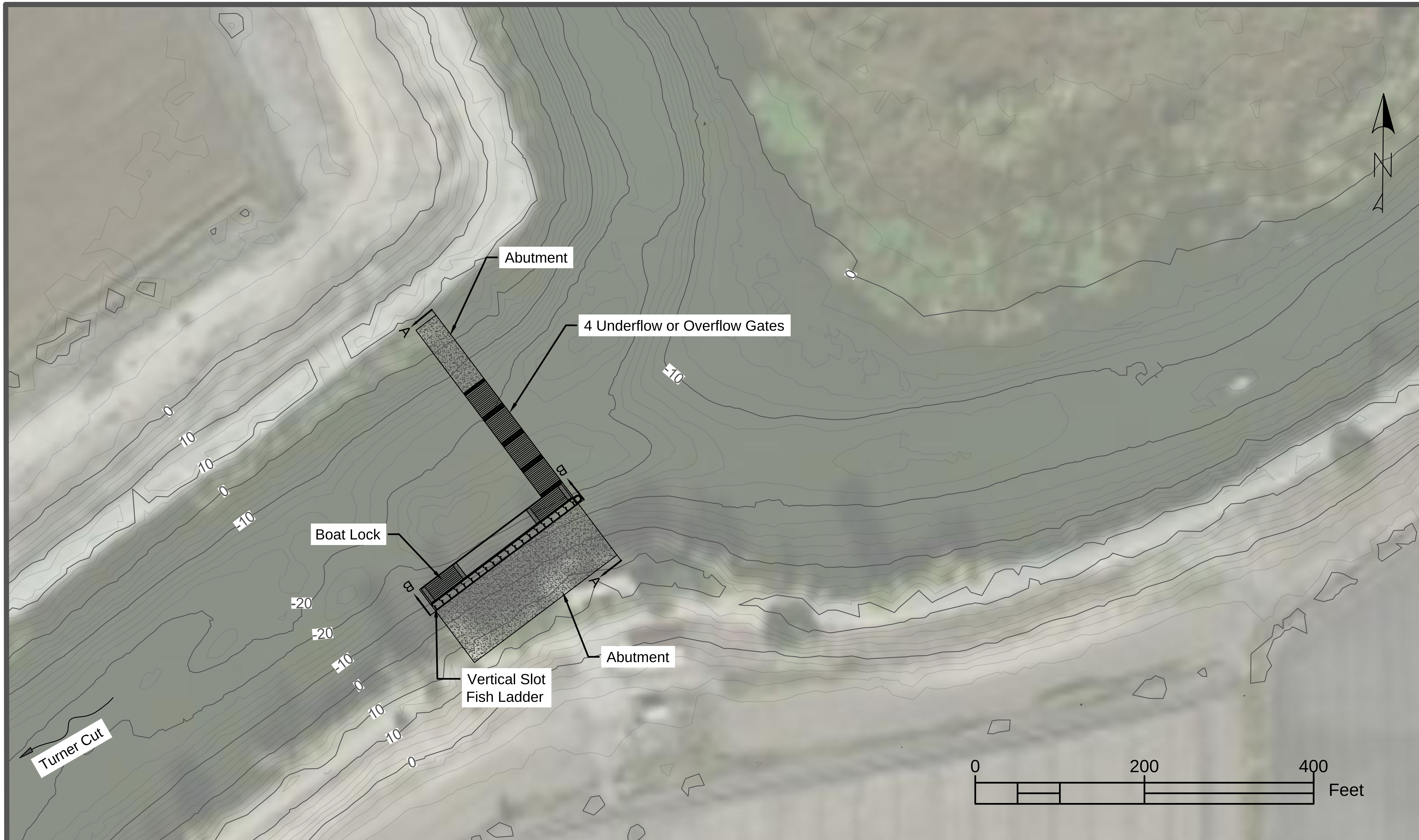
Detail: Floating Fish Guidance Structure

Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

FFGSatTC.dwg

SHEET 11 OF 20



Date Drawn: 05-06-2014

Drawn By: Khalid Ameri

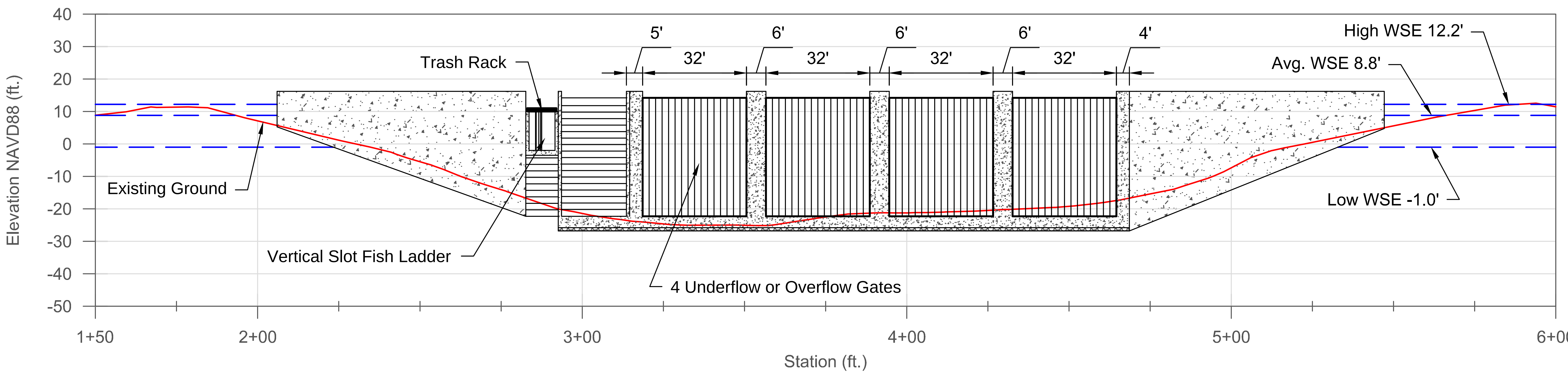
Plan: Gates with Boat Lock & Fish Ladder

Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatTC.dwg

SHEET 12 OF 20



Date Drawn: 05–06–2014

Drawn By: Khalid Ameri

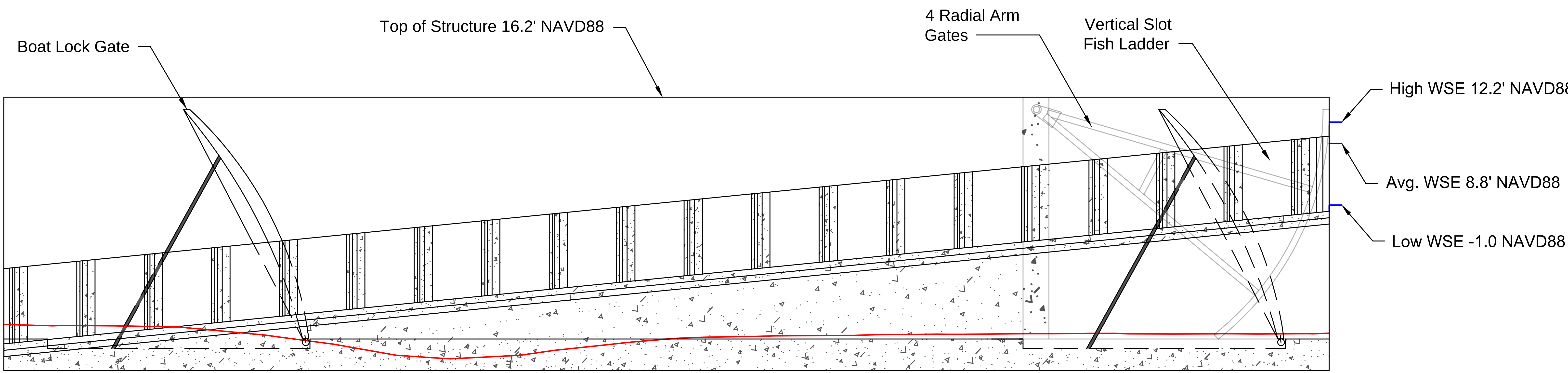
Elevation A–A: Gates with Boat Lock & Fish Ladder

Location: Turner Cut

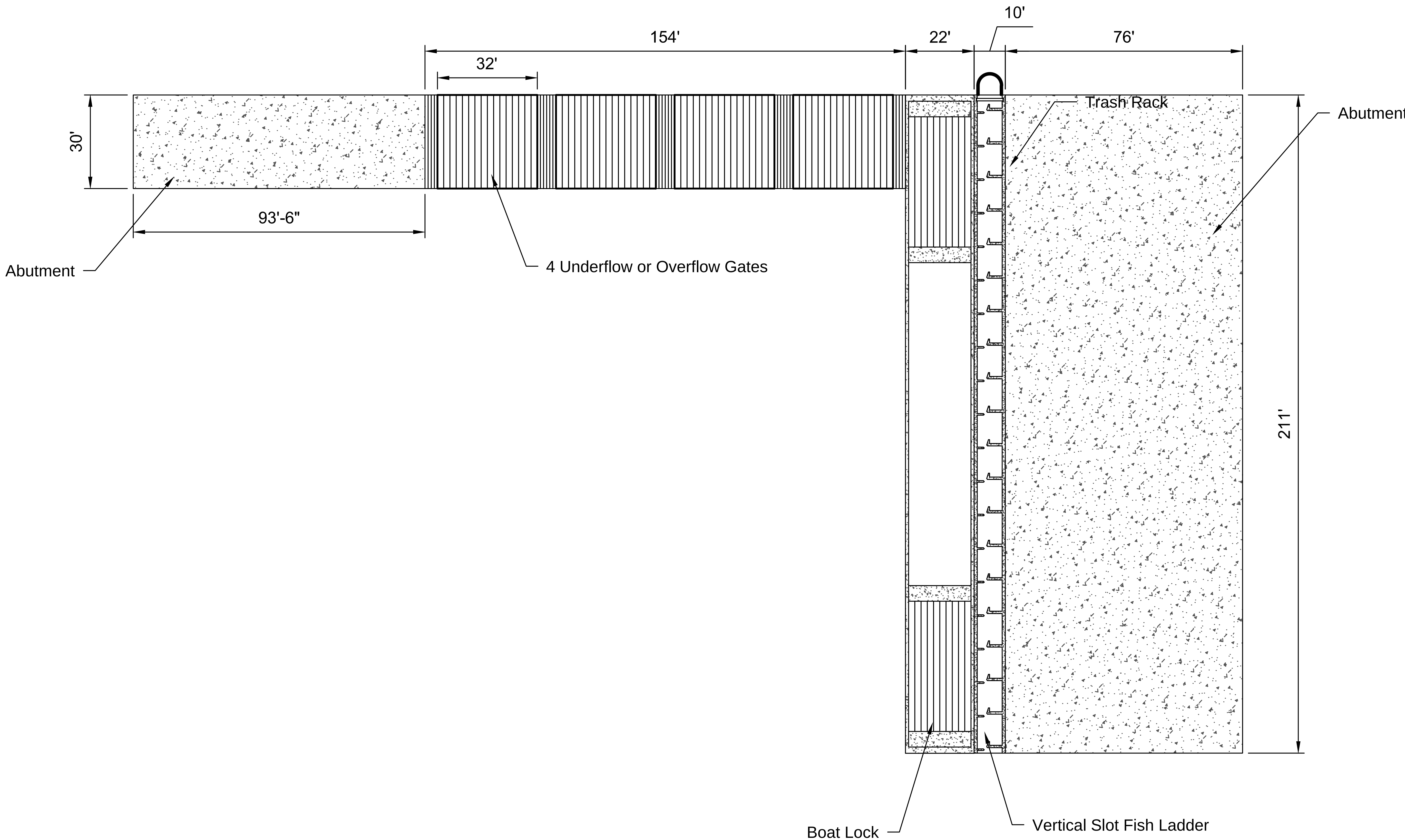
State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GATEatTC.dwg

SHEET 13 OF 20



Date Drawn: 05-06-2014 Drawn By: Khalid Ameri	Section B-B: Radial Arm Gates with Boat Lock & Fish Ladder Location: Turner Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	GATEatTC.dwg SHEET 14 OF 20



Date Drawn: 05-06-2014

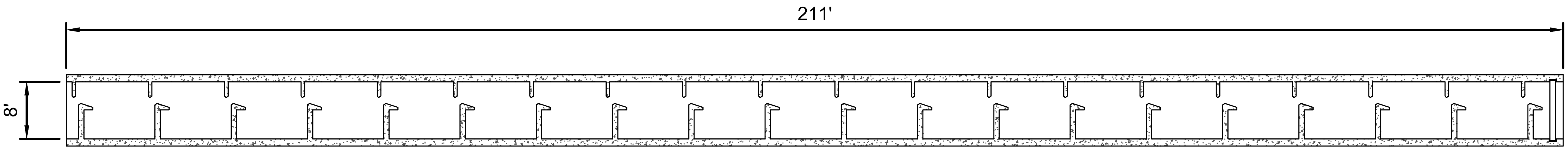
Drawn By: Khalid Ameri

Detail: Gates with Boat Lock & Fish Ladder

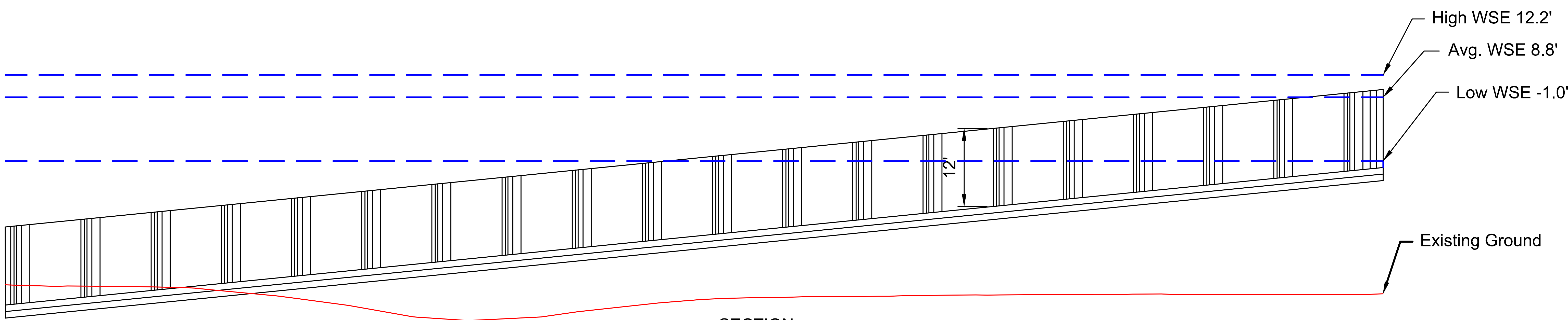
Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatTC.dwg



PLAN



SECTION

Date Drawn: 05-06-2014

Drawn By: Khalid Ameri

Detail: Vertical Slot Fish Ladder

Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatTC.dwg

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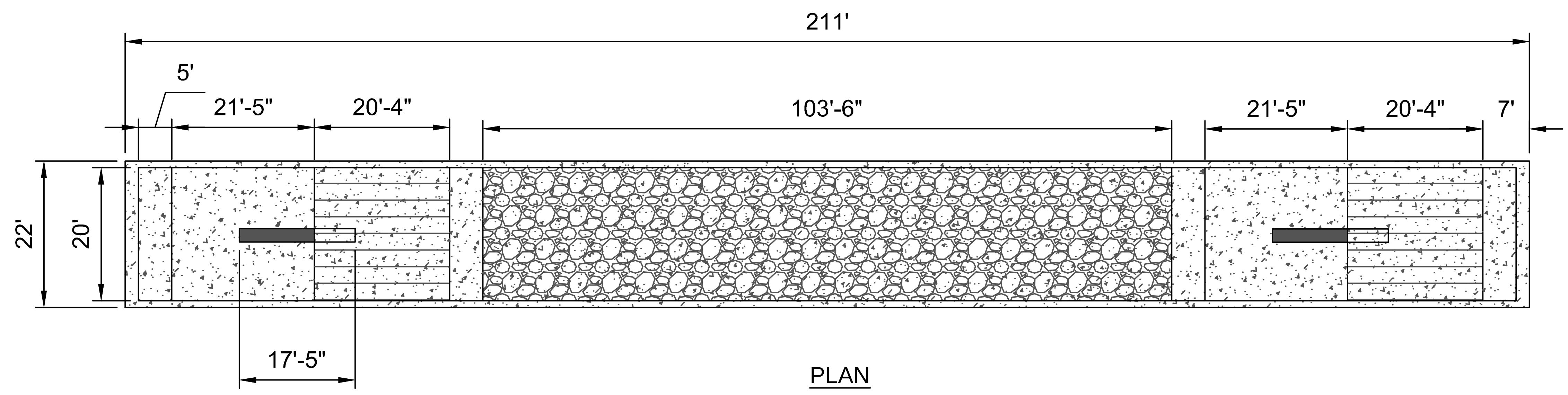
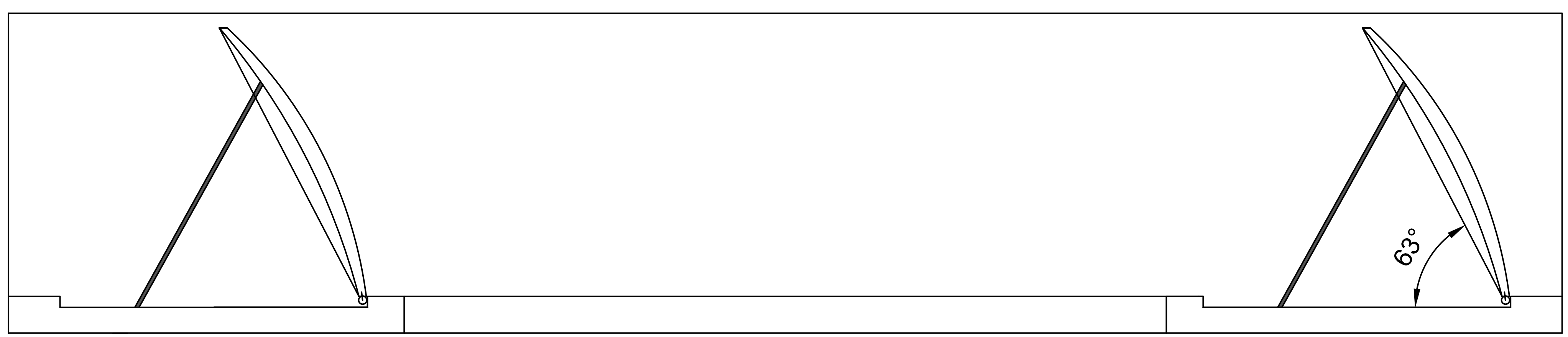


PLAN



SECTION

Date Drawn: 05-06-2014

Drawn By: Khalid Ameri

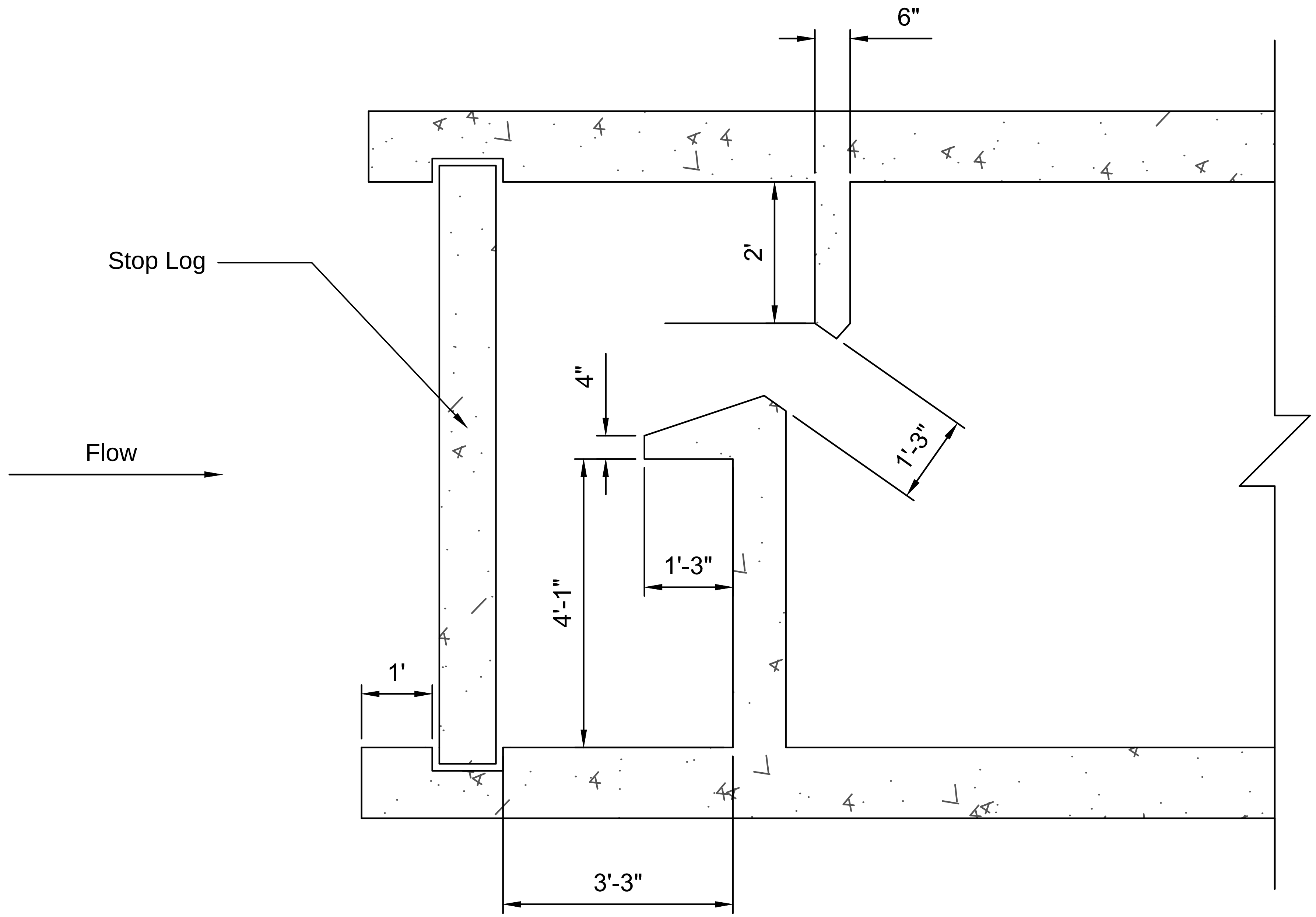
Detail: Boat Lock

Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatTC.dwg

SHEET 17 OF 20



Date Drawn: 05-06-2014

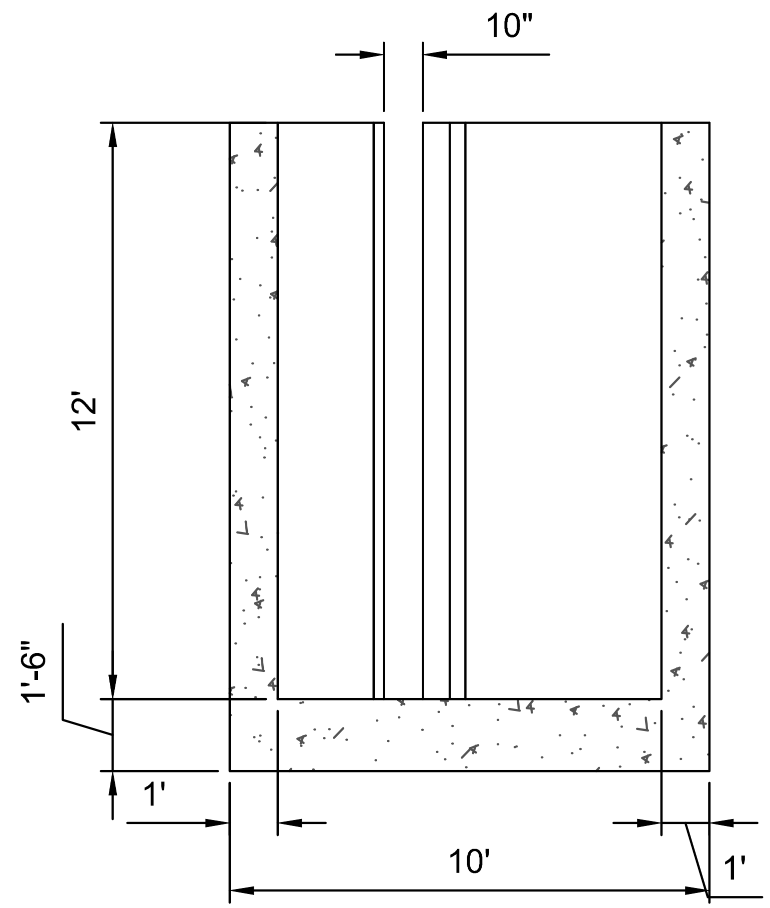
Drawn By: Khalid Ameri

Detail: Vertical Slot Fish Ladder

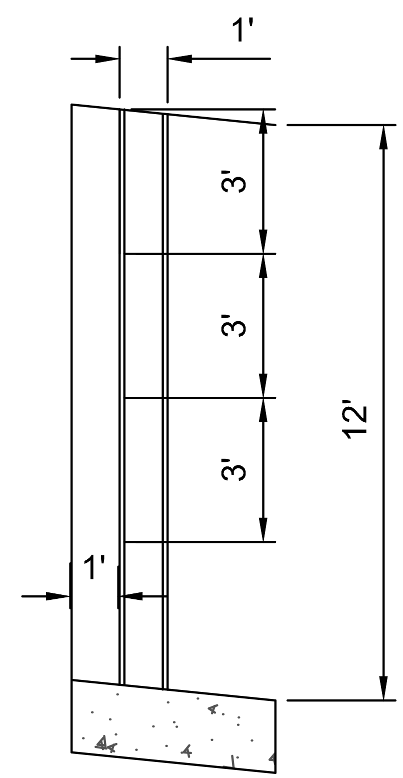
Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatTC.dwg



SECTION A-A



Date Drawn: 05-06-2014

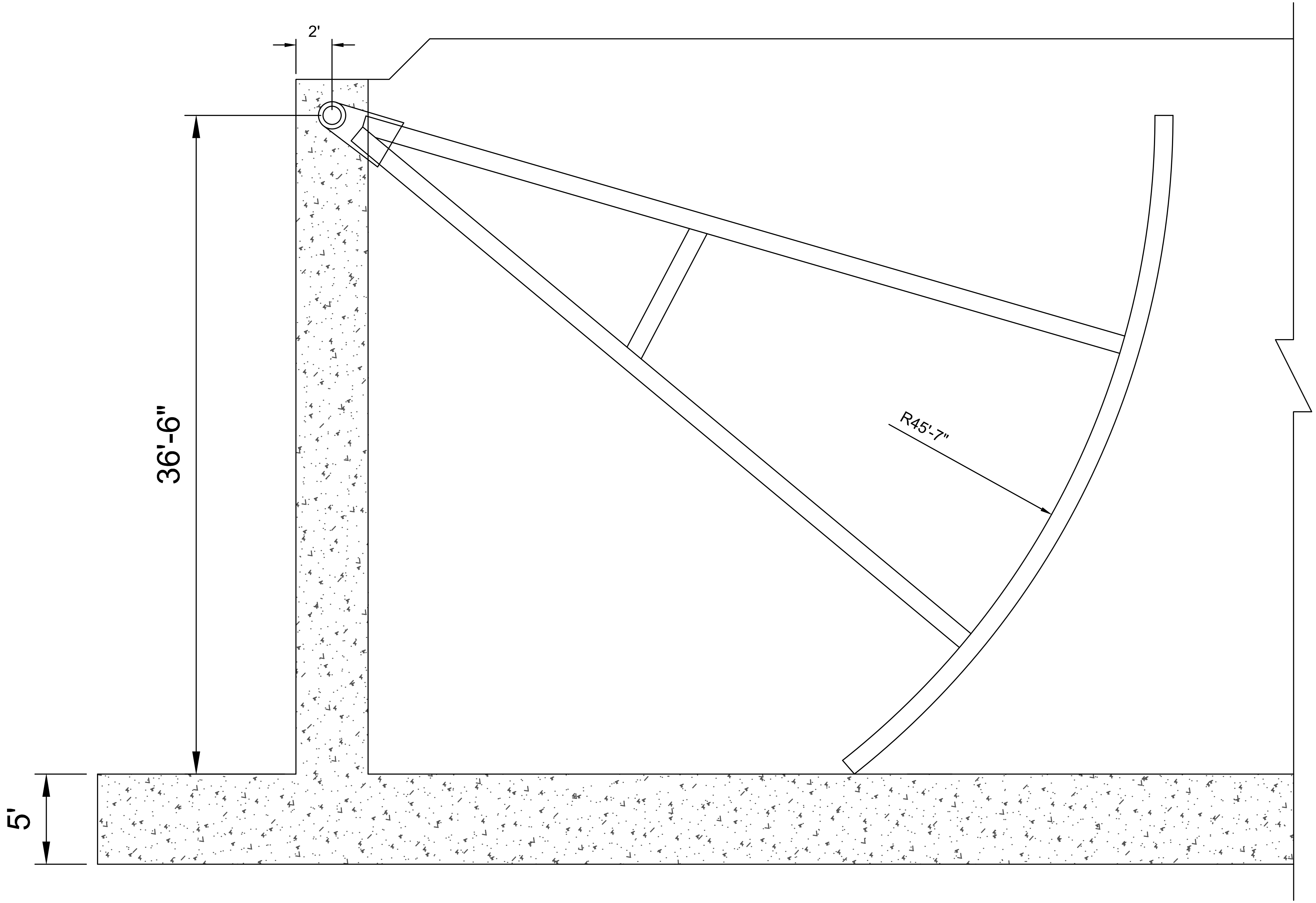
Drawn By: Khalid Ameri

Detail: Vertical Slot Fish Ladder

Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GATEatTC.dwg



Date Drawn: 05–06–2014

Drawn By: Khalid Ameri

Detail: Radial Arm Gate

Location: Turner Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

GATEatTC.dwg

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CONCEPTUAL ENGINEERING DRAWINGS FOR

COLUMBIA CUT
NMFS BiOp RPA ACTION IV.1.3

SAN JOAQUIN COUNTY, CALIFORNIA

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PRELIMINARY SUBJECT TO REVISION

Date Drawn: 10-7-2014 Drawn By: Ben Geske	Title Sheet and Area Map Location: Columbia Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	CC.dwg SHEET 1 OF 19

Date Drawn: 06-24-2014

Drawn By: Ben Geske

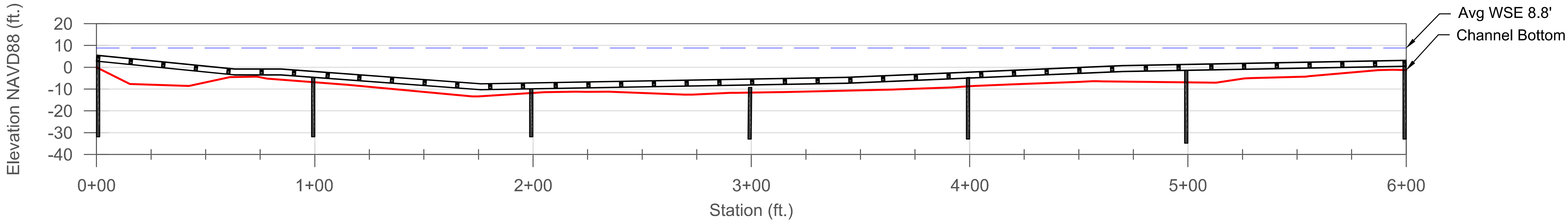
Plan: Bio-Acoustic Fish Fence

Location: Columbia Cut

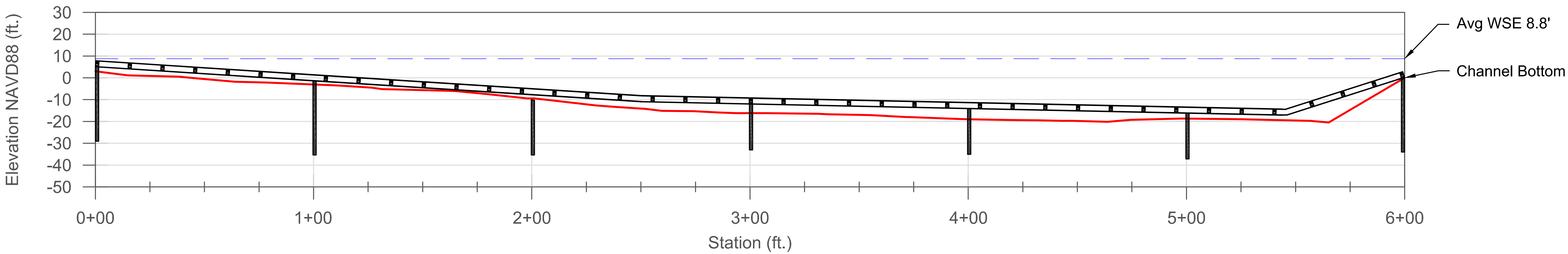
State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

BAFFatCC.dwg

SHEET 2 OF 19

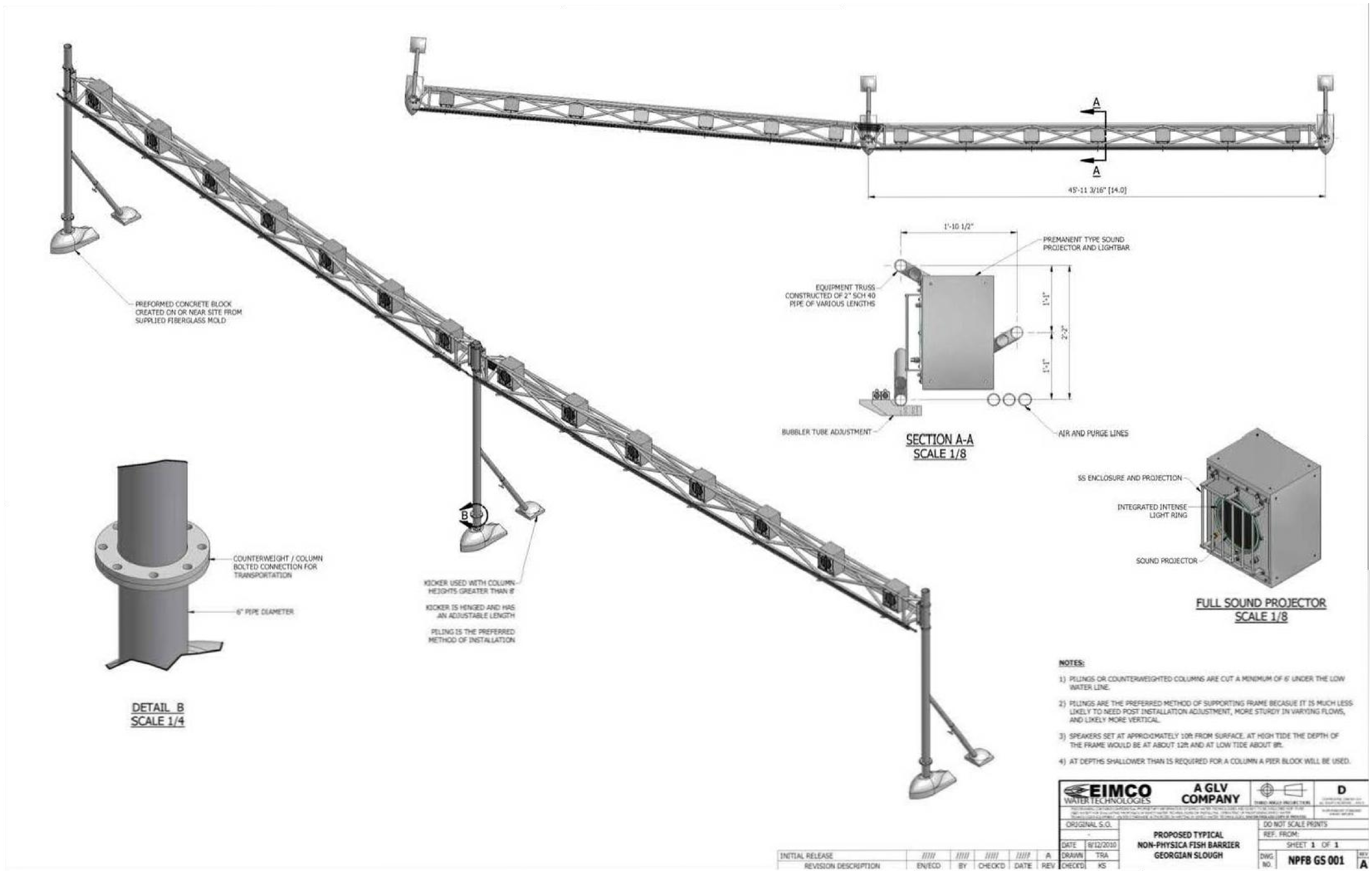


ELEVATION - WEST



ELEVATION - EAST

Date Drawn: 06-24-2014 Drawn By: Ben Geske	Elevation: Bio-Acoustic Fish Fence Location: Columbia Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		BAFFatCC.dwg SHEET 3 OF 19



Date Drawn: 08-12-2010 Drawn By: EIMCO	**Detail: Bio-Acoustic Fish Fence** Location: Columbia Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	BAFFatCC.dwg SHEET 4 OF 19

Date Drawn: 06-02-2014

Drawn By: Ben Geske

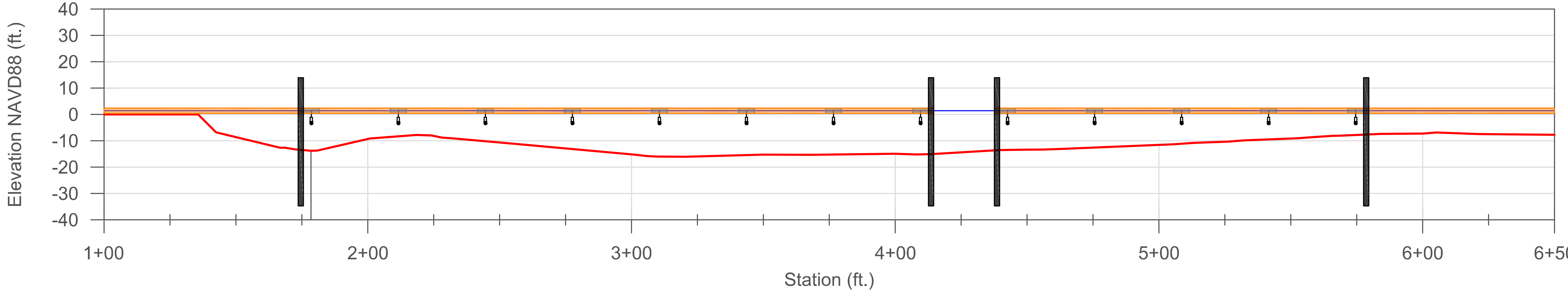
Plan: Infrasound Fish Fence

Location: Columbia Cut

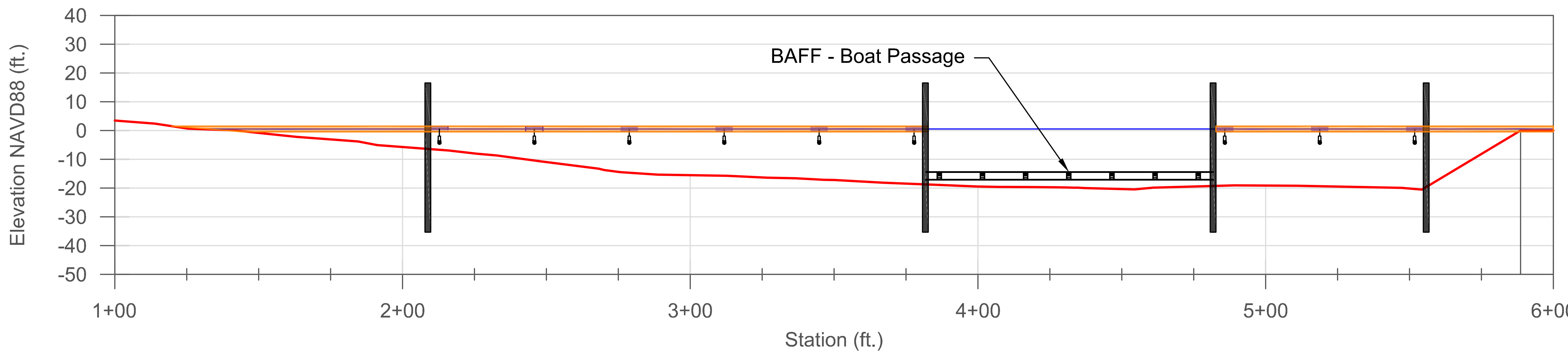
State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

IFFatCC.dwg

SHEET 5 OF 19

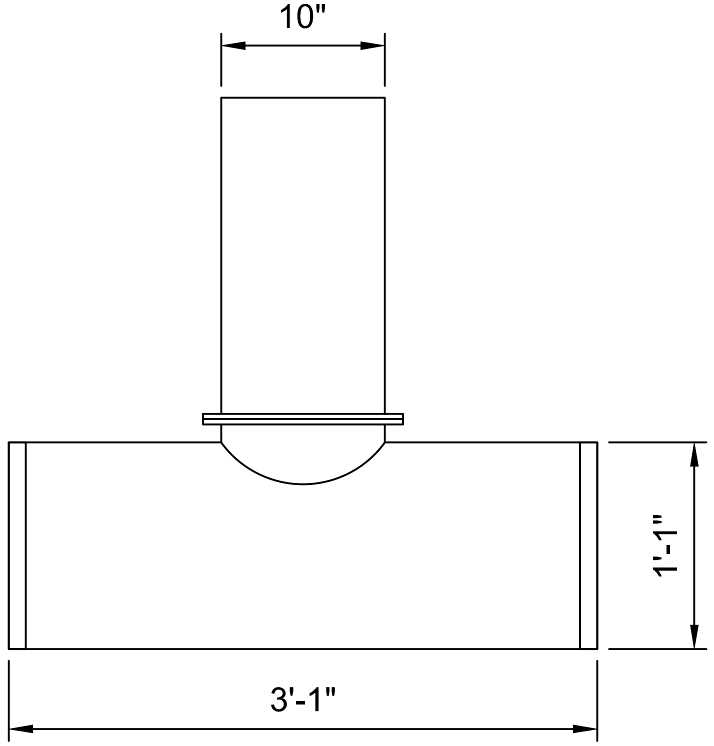


West Channel

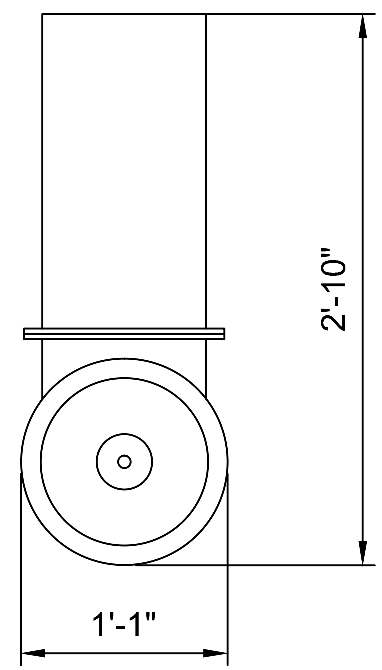


East Channel

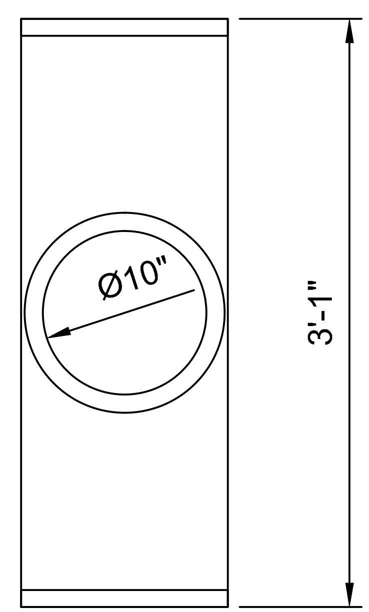
Date Drawn: 06-02-2014 Drawn By: Ben Geske	Elevation: Infrasound Fish Fence Location: Columbia Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		IFFatCC.dwg SHEET 6 OF 19



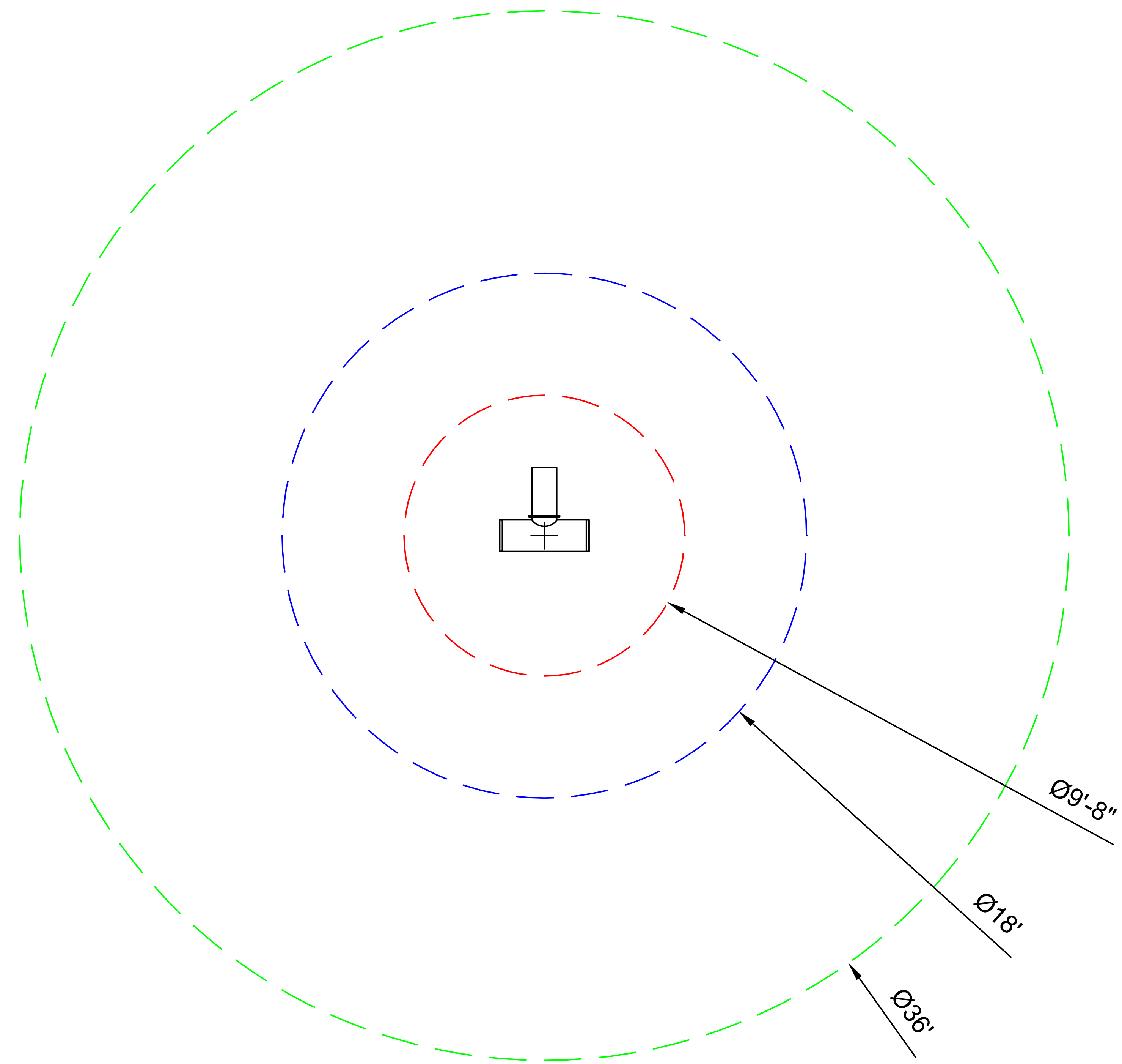
Front View



Side View



Top View



Red = Zone of exclusion from structural entities.

Blue = Fish dterrence zone.

Green = Boundary for measurable particle acceleration.

Date Drawn: 06–24–2014

Drawn By: Ben Geske

Detail: Infrasound Fish Fence

Location: Columbia Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

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SHEET 7 OF 19

Date Drawn: 06-24-2014

Drawn By: Ben Geske

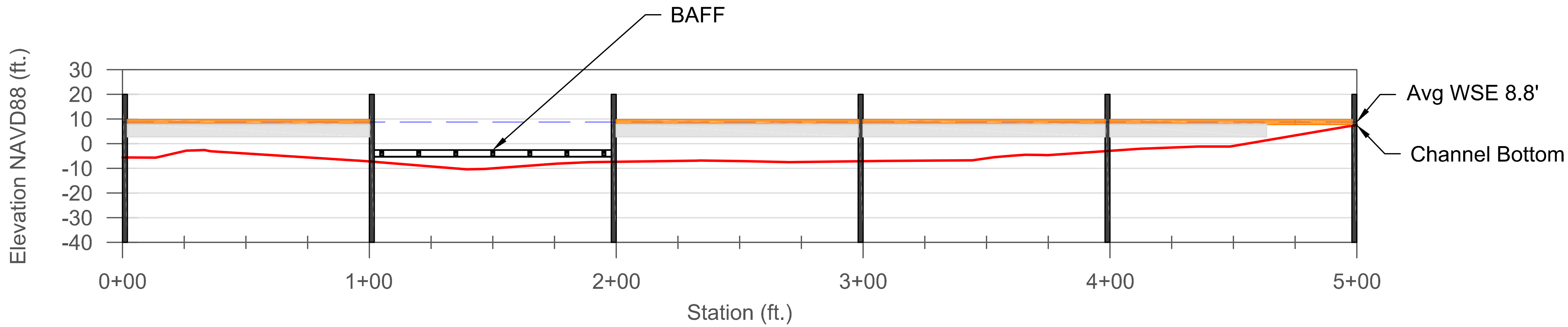
Plan: Floating Fish Guidane Structure

Location: Columbia Cut

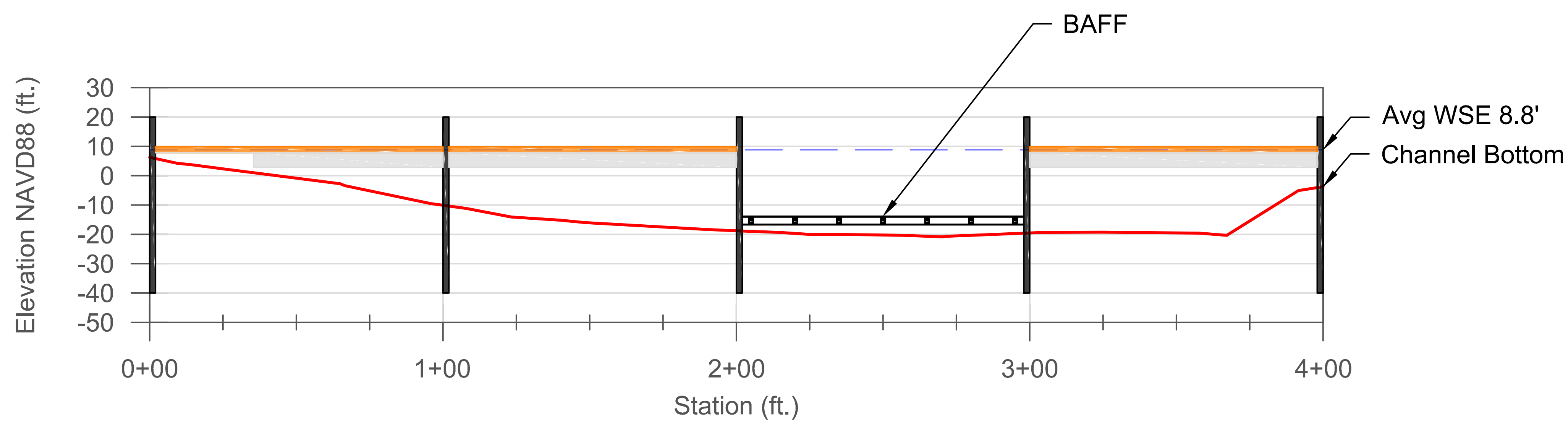
State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

FFGSatCC.dwg

SHEET 8 OF 19



ELEVATION - WEST



ELEVATION - EAST

Date Drawn: 06–24–2014

Drawn By: Ben Geske

Elevation: Floating Fish Guidance Structure

Location: Columbia Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

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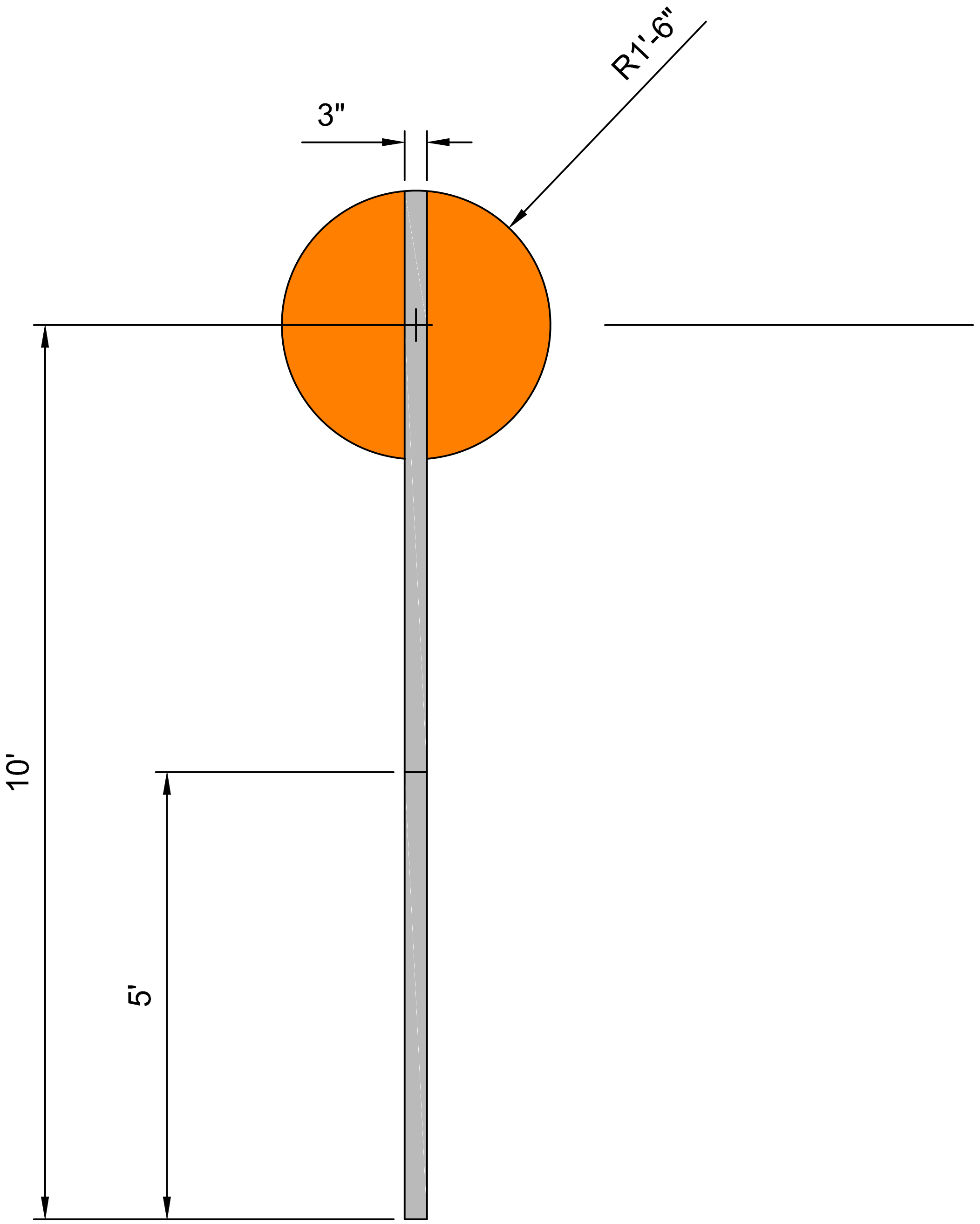
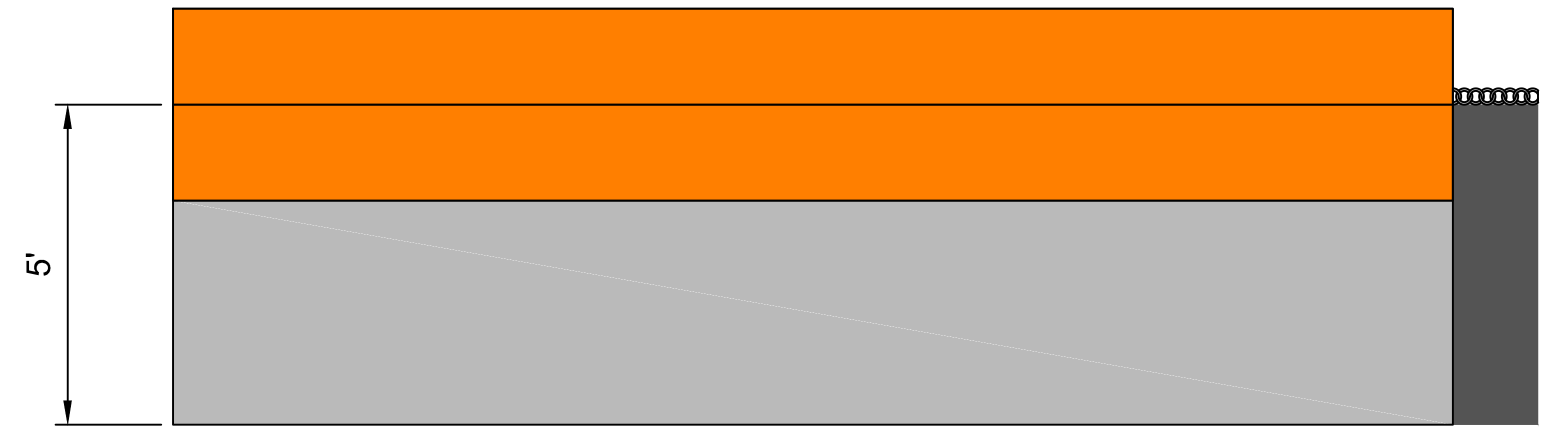
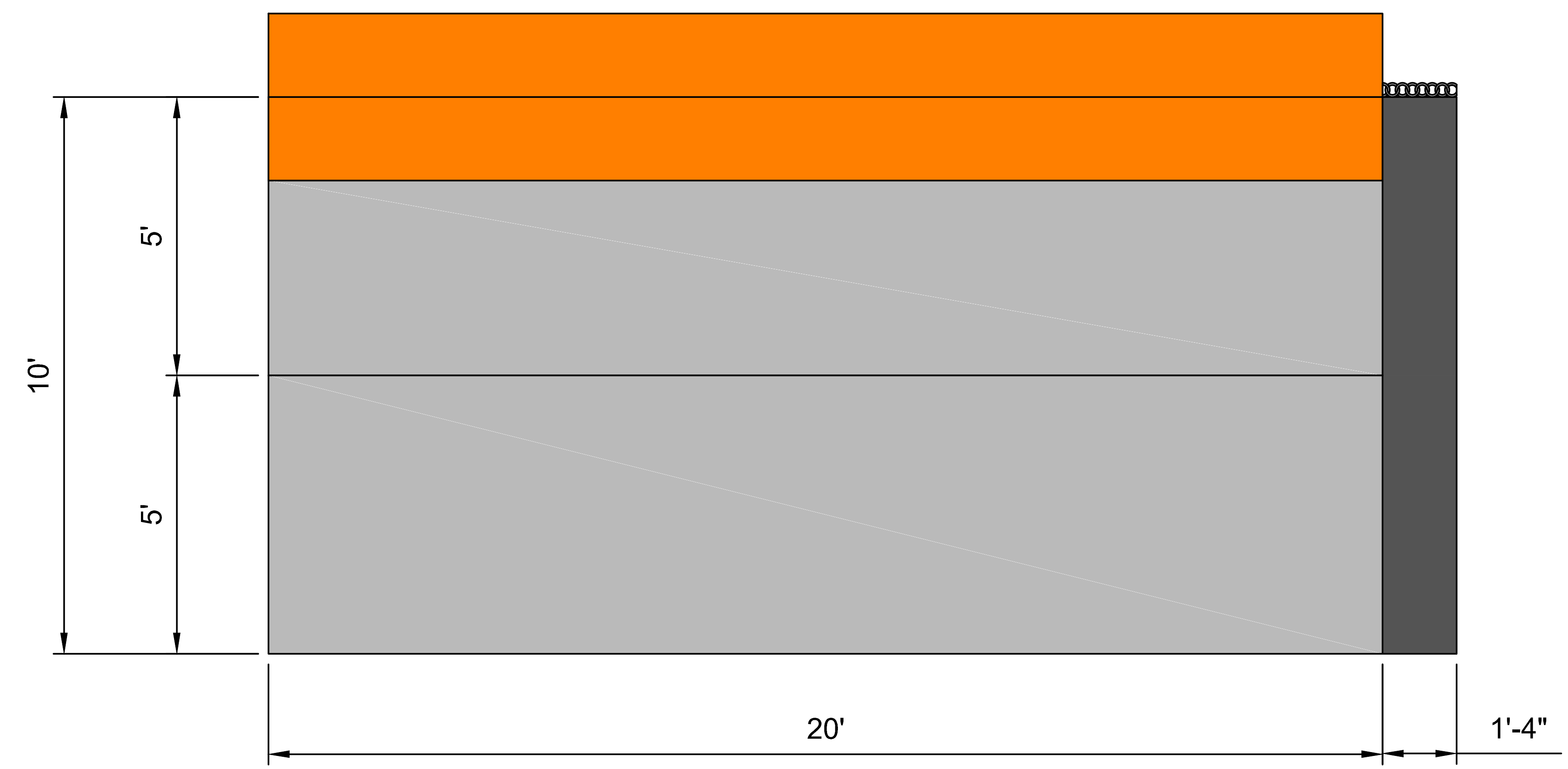
SHEET 9 OF 19



DETAIL: SINGLE FFGS SECTION - SIDE VIEW



DETAIL: SINGLE 5' FFGS SECTION - FRONT/FACE



DETAIL: SINGLE 10' FFGS SECTION - FRONT/FACE

Date Drawn: 06-24-2014

Drawn By: Ben Geske

Detail: Floating Fish Guidance Structure

Location: Columbia Cut

State of California
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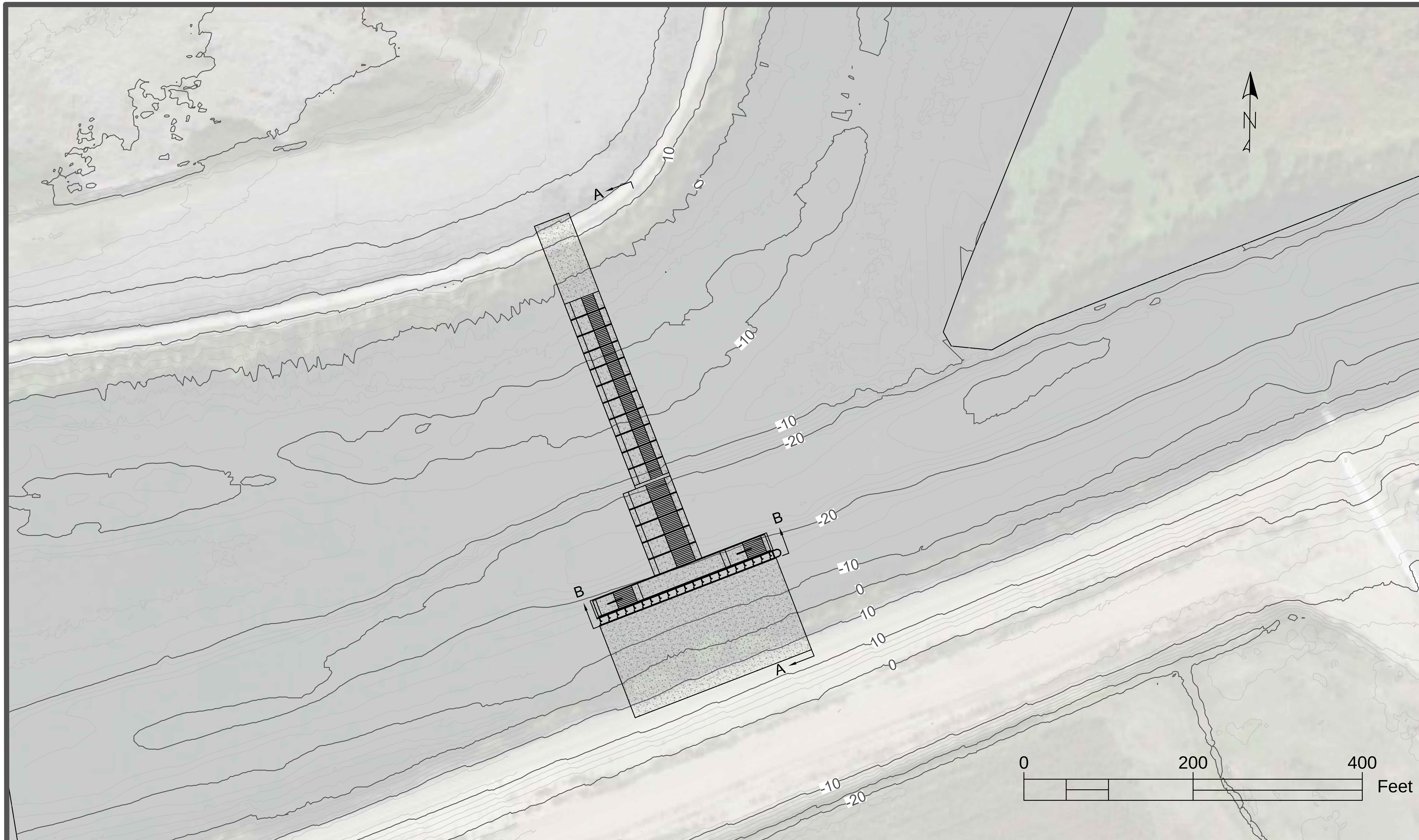
SHEET 10 OF 19



Date Drawn: 06-24-2014

Drawn By: Ben Geske

Plan: Gate, Boat Lock, and Fish Ladder

Location: Columbia Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

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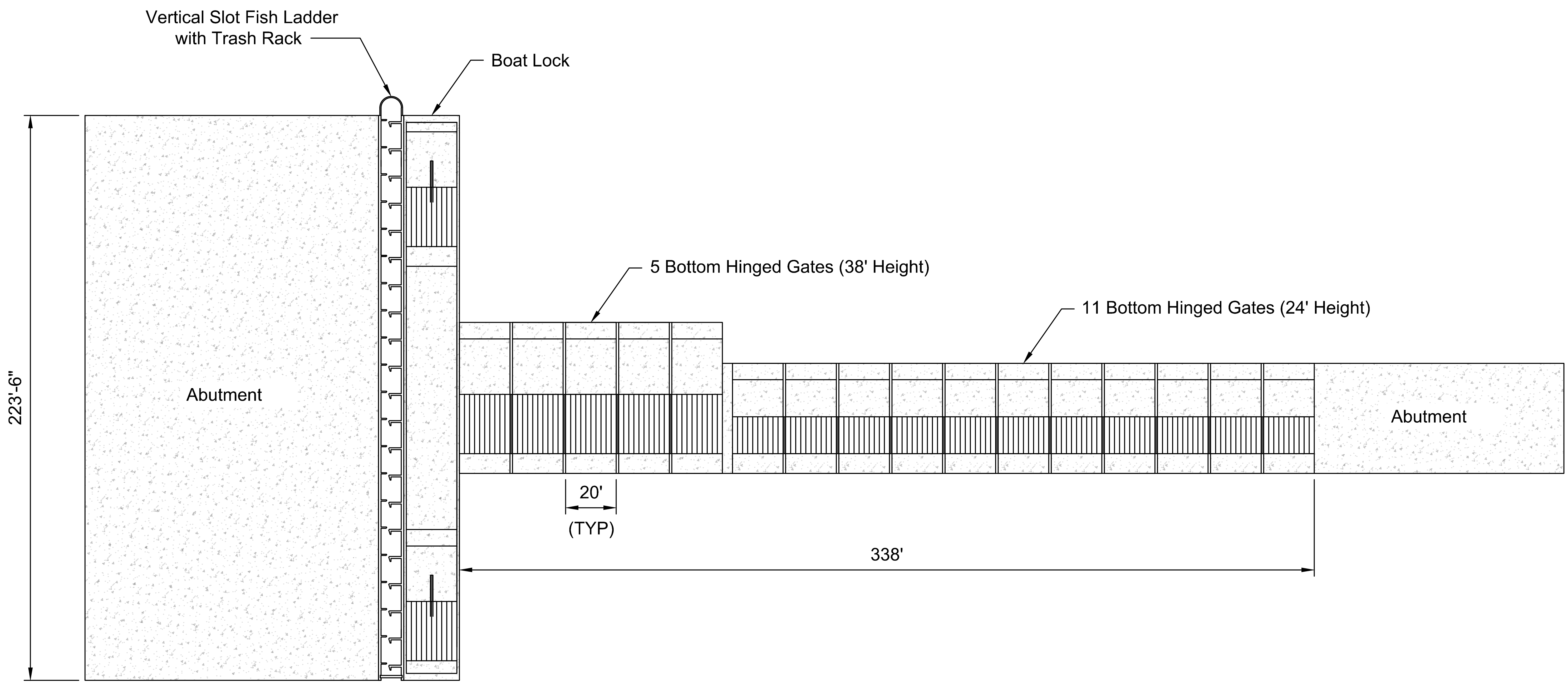
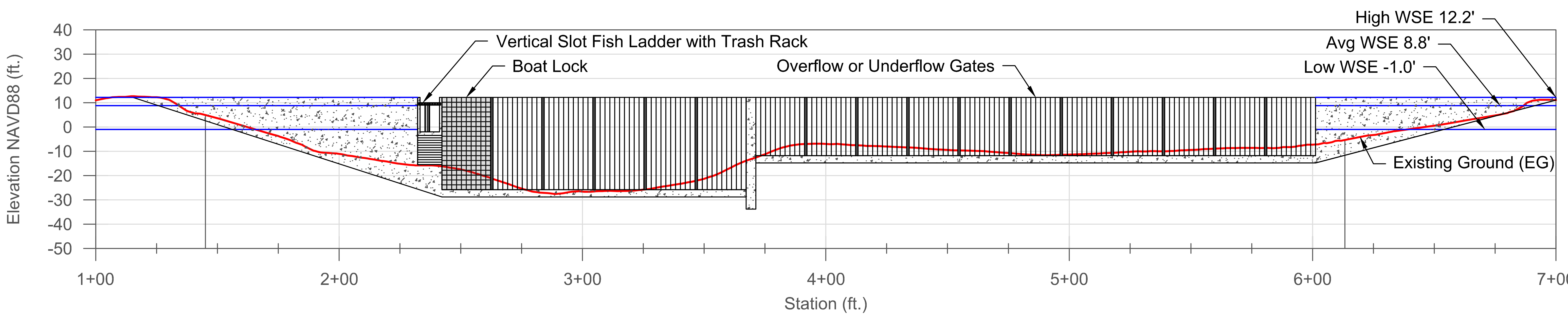
SHEET 11 OF 19

Bottom Hinged Gates with Boat Lock & Fish Ladder - Columbia Cut



Date Drawn: 06-24-2014 Drawn By: Ben Geske	Plan: Gate, Boat Lock, and Fish Ladder Location: Columbia Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		GateatCC.dwg SHEET 12 OF 19

Gates with Boat Lock & Fish Ladder @ Columbia Cut

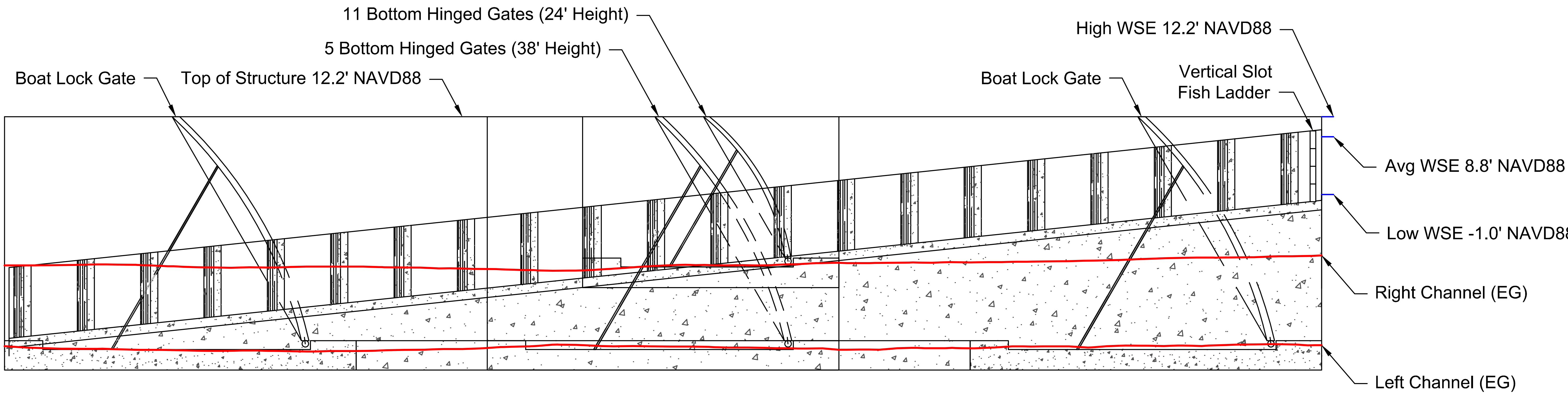


ELEVATION A - A

Looking Downstream

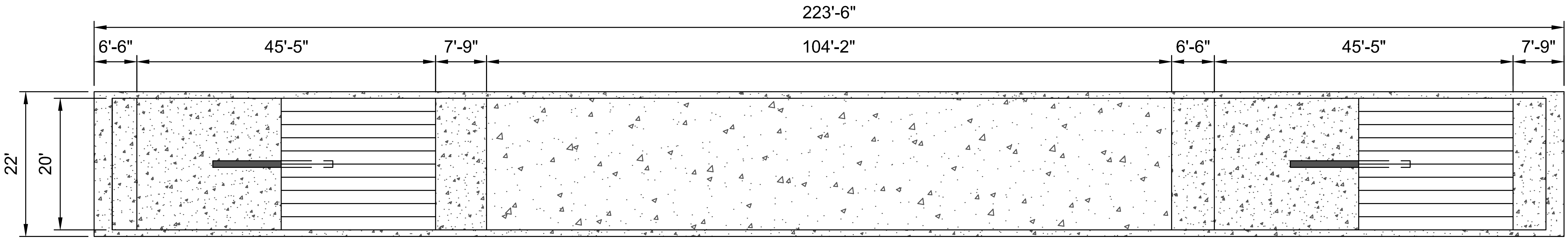
Date Drawn: 06-24-2014 Drawn By: Ben Geske	Elevation: Gate, Boat Lock, and Fish Ladder Location: Columbia Cut	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office	GateatCC.dwg SHEET 13 OF 19

Gates with Boat Lock & Fish Ladder @ Columbia Cut

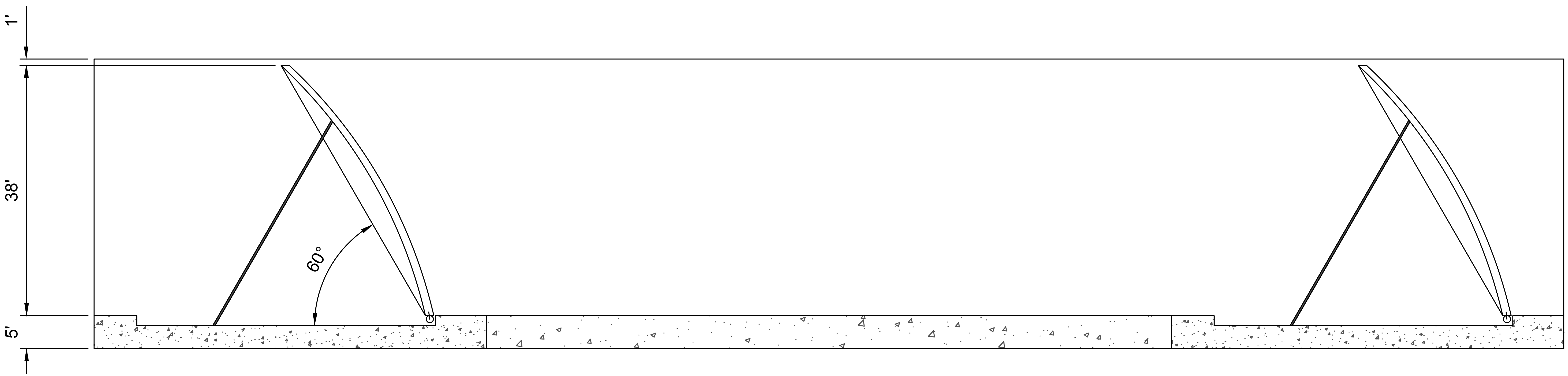


SECTION B - B

Date Drawn: 06–24–2014 *Drawn By: Ben Geske*	*Section: Gate, Boat Lock, and Fish Ladder* *Location: Columbia Cut*	*State of California* *Natural Resources Agency* *Department of Water Resources* *Bay–Delta Office*		*GateatCC.dwg* *SHEET 14 OF 19*



PLAN



SECTION

Date Drawn: 06–24–2014

Drawn By: Ben Geske

Plan & Section: Boat Lock

Location: Columbia Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay–Delta Office

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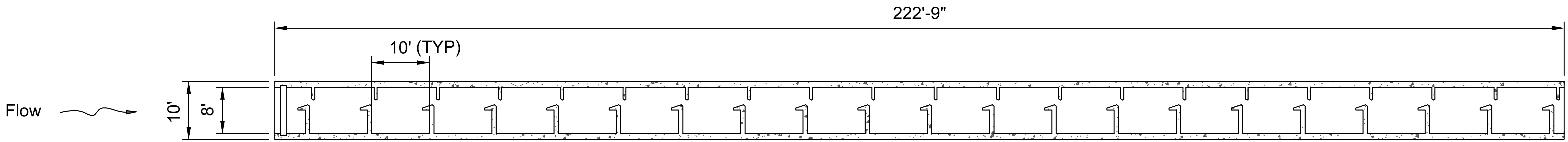
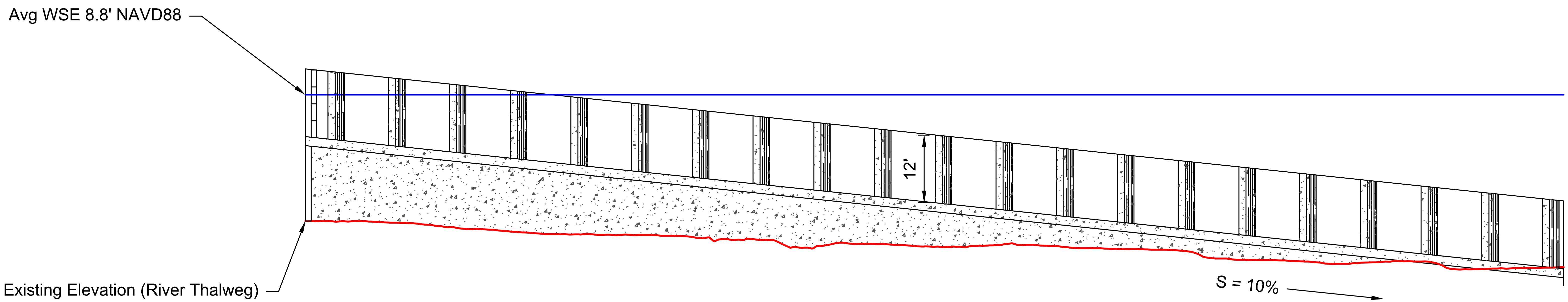
SHEET 15 OF 19

20 Bay Vertical Slot Fish Ladder for Columbia Cut

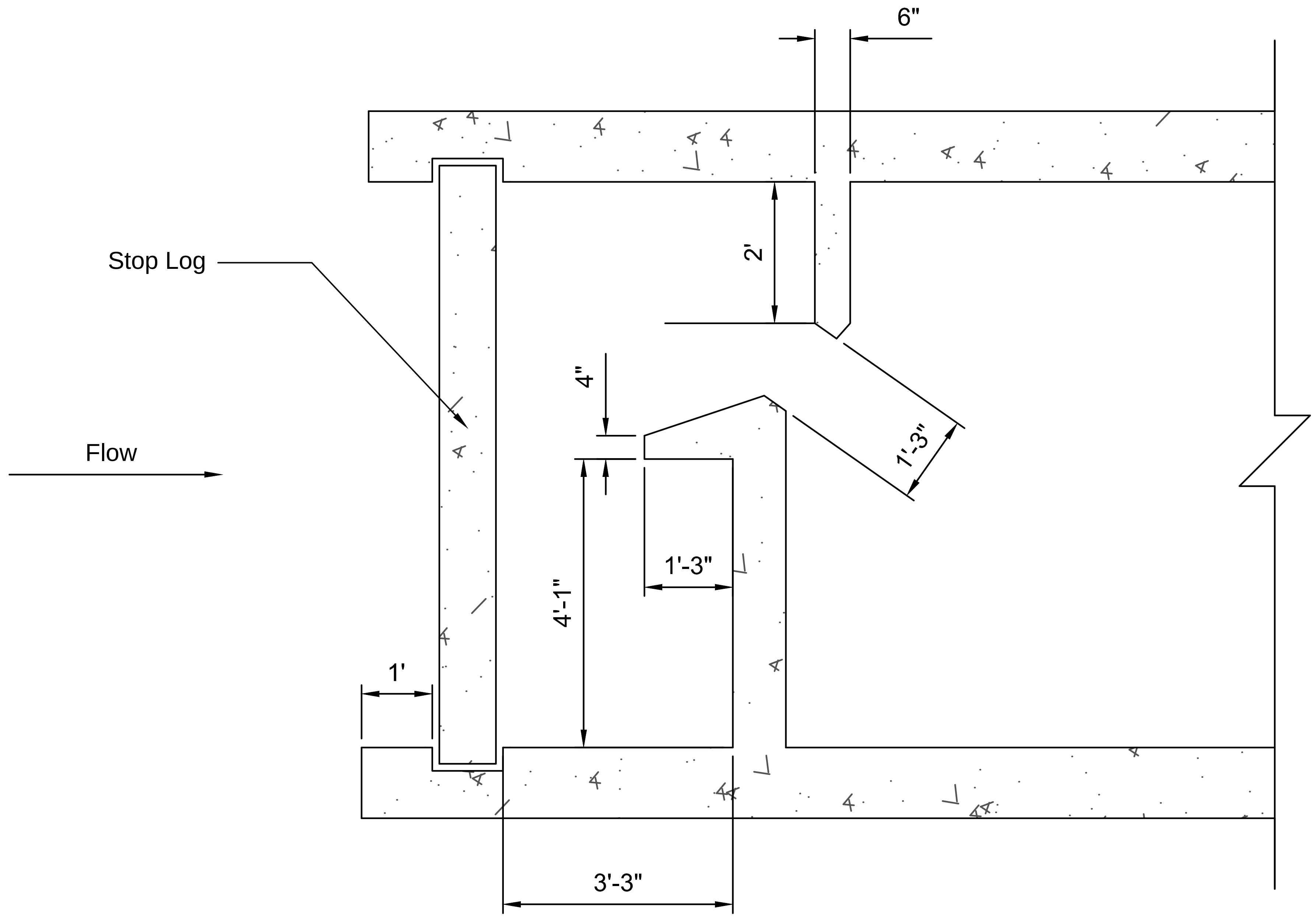


PLAN



SECTION

Date Drawn: 06-24-2014 Drawn By: Ben Geske	*Plan & Section: Fish Ladder* *Location: Columbia Cut*	State of California Natural Resources Agency Department of Water Resources Bay-Delta Office		GateatCC.dwg SHEET 16 OF 19



Date Drawn: 04-10-2014

Drawn By: Ben Geske

Detail: Vertical Slot Fish Ladder

Location: Columbia Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

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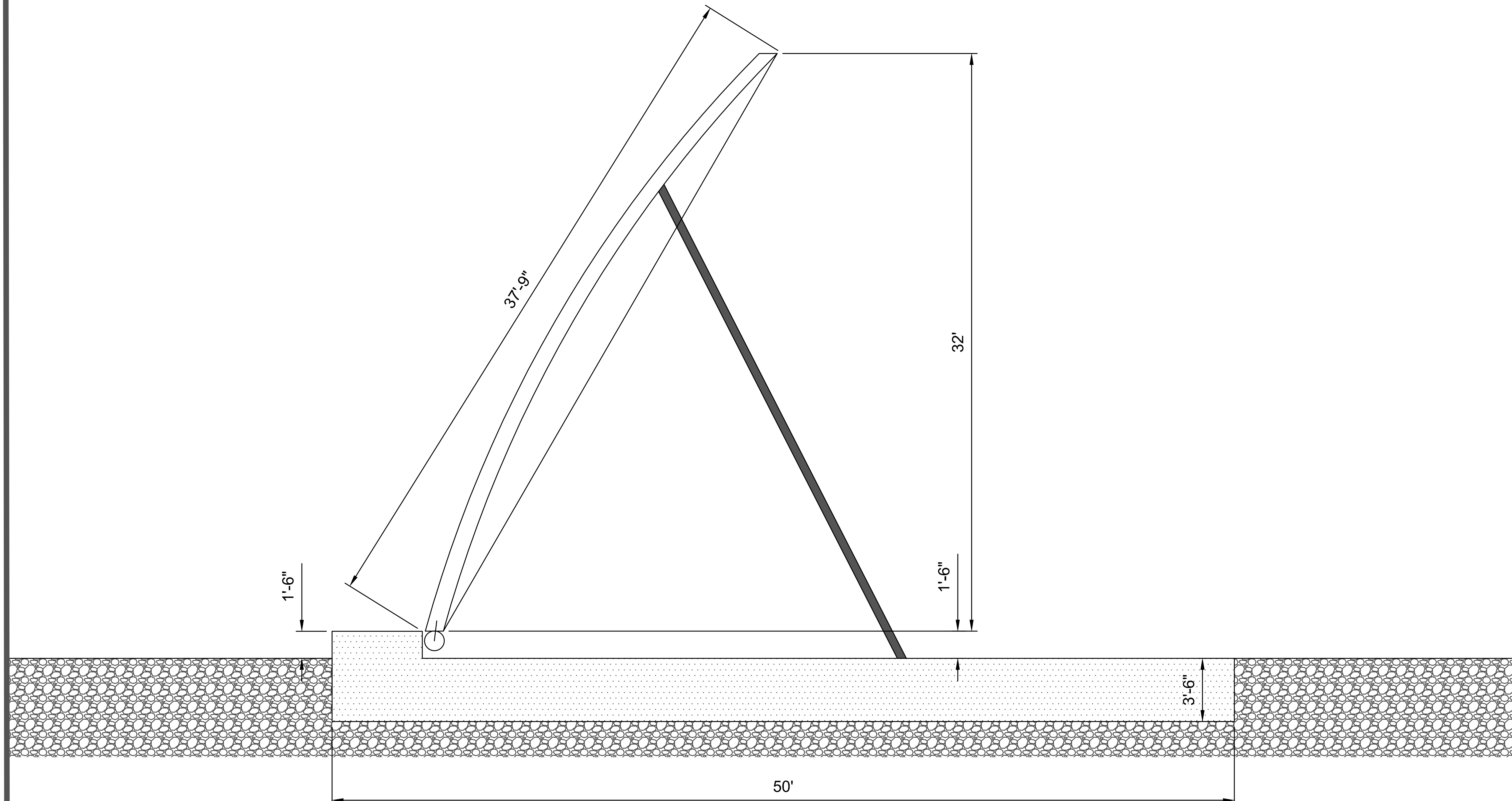


Date Drawn: 06-24-2014

Drawn By: Ben Geske

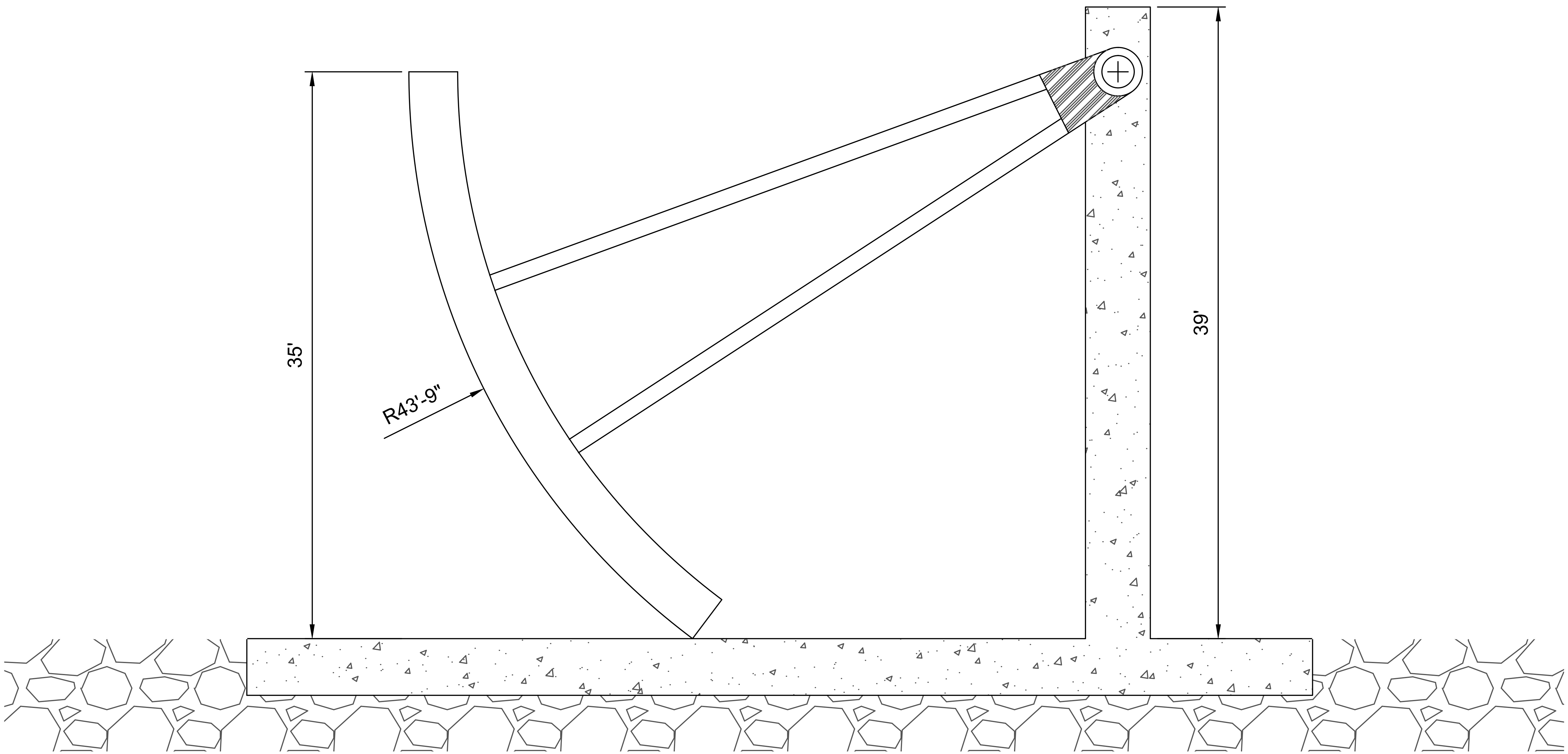
Detail: Overflow Gate

Location: Columbia Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

GateatCC.dwg

SHEET 18 OF 19



Date Drawn: 06-24-2014

Drawn By: Ben Geske

Detail: Underflow Gate

Location: Columbia Cut

State of California
Natural Resources Agency
Department of Water Resources
Bay-Delta Office

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SHEET 19 OF 19

APPENDIX C

Environmental Checklists

AECOM
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Memorandum

To: Bill McLaughlin, Senior Engineer, California Department of Water Resources

From: Jennifer Aranda, Senior Project Manager, AECOM

Date: August 22, 2014

Subject: Preliminary Environmental Evaluation of the Georgiana Slough Study Site

---

AECOM technical staff conducted a preliminary evaluation of the Georgiana Slough study site under consideration for engineering solutions to reduce diversion of emigrating juvenile salmonids to the interior and southern portions of the Sacramento–San Joaquin Delta (Delta), and to reduce salmonid exposure to Central Valley Project and State Water Project export facilities.

METHODS

A preliminary list of potential environmental issues associated with the Georgiana Slough study site is presented in Table 1. AECOM evaluated the study site within the boundary that was provided by the California Department of Water Resources (DWR) (Figure 1); site access, staging areas, and materials stockpile areas were not identified outside the site boundary, and therefore were not assessed for potential environmental issues. Potentially significant environmental issues have been identified that would require further evaluation before beginning final design because they may influence project design, timing, and project construction options. In addition, informal consultation with the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE), Central Valley Regional Water Quality Control Board (RWQCB), and California Department of Fish and Wildlife (CDFW) should occur before final project design. This informal consultation would help identify the in-channel construction period and would help develop mitigation and avoidance measures to minimize short-term construction-related impacts on species protected under the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA).

BIOLOGICAL RESOURCES

The sensitive species included in Table 2 are known to occur in the study site vicinity, and suitable habitat for the species may present within the study site, based on a review of aerial photography and limited site access. Special-status fish species are known to occur within the study site and have the potential to be directly affected by project implementation. Furthermore, field surveys would be required for special-status plants, and the surveys should be timed to coincide with the blooming period (see notes in Table 2) of target species. One occurrence of Sanford’s arrowhead is documented along the banks of Georgiana Slough. The preliminary site evaluation suggests that the trees along the waterways provide suitable nest locations for Swainson’s hawk and white-tailed kite. Avoidance and minimization measures should be developed for all special-status species that have the potential to occur within the study site, as well as including these measures as “environmental commitments” as part of the project description or as mitigation measures for any potentially significant impacts.

Source: AECOM 2014

Figure 1. Location Map

CULTURAL RESOURCES

A record search of pertinent cultural resources information was conducted, curated at the California Historical Resources Information System at the North Central Information Center (NCIC). According to NCIC, the southwest portion of the study site has been inventoried (NCIC report #4171). Two cultural resources have been identified within the study site: CA-SAC-329 and P-34-4297.

CA-SAC-329 is a prehistoric cultural midden site with human remains. Although this site was partially excavated in 1975, it has not been formally evaluated for National Register of Historic Places (NRHP) and California Register of Historic Resources (CRHR) significance. However, sites containing human remains are treated as eligible for inclusion in the NRHP and CRHR. DWR would need to implement avoidance measures, to avoid directs impacts on this unique resource that also possess sacred Native American values.

P-34-4297 is Bridge #24C0005, constructed in 1950. This bridge has been formally evaluated and has been determined not to be eligible for inclusion in the NRHP and CRHR.

In addition to the NCIC record search, the California State Lands Commission Shipwreck Database was consulted, and no cultural resources were identified within the study site. Bridge #24C0005 is within the study site boundary but previously was determined not eligible for the NRHP and the CRHR. Commercial buildings more than 50 years old are within the study site, and they would need to be evaluated for NRHP and CRHR significance. Portions of the levees within the study site also are more than 50 years old, and they also would need to be evaluated for NRHP and CRHR significance.

PERMITS AND AUTHORIZATIONS

Work at the Georgiana Slough study site may require permits or authorizations from federal, state, and regional and local agencies with regulatory jurisdiction over the environmental resources that are present (Table 3). USACE 408 permission would be required if the project would affect the levees in the study site, all of which are USACE project levees. DWR may need a permit (Nationwide or Individual) from USACE under Section 404 of the Clean Water Act (CWA), if project implementation requires placement of dredge and fill materials into waters of the United States. An Individual Permit and CWA Section 404(b)(1) alternatives analysis are required if permanent wetland impacts exceed the 0.5 acre threshold of the Nationwide Permit program. Impacts on waters of the United States may require implementation of mitigation measures. Compliance with Section 106 of the National Historic Preservation Act would be required to obtain a Section 404 permit. Placement of structures in navigable waterways would require authorization from USACE under Section 10 of the Rivers and Harbors Act of 1899.

The 404 permit would provide the federal nexus for an ESA Section 7 consultation. Formal ESA consultation requires up to 135 days for agency review after project design, timing, and avoidance and mitigation measures have been identified. However, USFWS has recently acknowledged achieving the 135-day consultation timeline may no longer be possible for all projects, especially for projects without multi-benefits. As a result, USFWS is prioritizing workload and not all projects will conclude formal ESA consultation within 135 days. High-level discussion with USFWS will be needed to expedite ESA compliance. Consultation with NMFS would also be required because of potential impacts to anadromous fish. A Rivers and Harbors Act Section 9 Permit may be required from the U.S. Coast Guard. Compliance with the National Environmental Policy Act (NEPA) would be required if any federal funding is used by the project.

Water quality certification from the Central Valley RWQCB would be required for compliance with Section 401 of the CWA. This certification would identify project-specific best management practices (BMPs) to minimize project impacts, such as criteria to reduce erosion, sedimentation, and releases of hazardous material. BMPs also would provide criteria for dewatering and construction methods, revegetation, and monitoring requirements. A National Pollutant Discharge Elimination System (NPDES) Construction General Permit for discharges of stormwater associated with the construction activity would be required if total soil disturbance exceeds 1 acre. Soil disturbance typically occurs from access improvements, staging areas, material stockpile areas, and construction areas.

A Lake and Streambed Alteration Agreement (LSAA) would be required from CDFW under Section 1600 et seq. of the California Fish and Game Code, to address potential project-related impacts on the bed, banks, and channel of any natural stream and associated riparian vegetation. Both water quality certification and the LSAA would require evidence of compliance with the California Environmental Quality Act (CEQA) before issuance of permits.

Species protected under CESA could occur within the study site or in the study site vicinity. If the potential exists for the project to result in "take" (i.e., kill) of a special-status species that is protected under CESA, an incidental take permit would be required from CDFW. Typically, avoidance and minimization measures can be implemented before project construction to avoid the direct mortality of species protected under CESA.

Encroachment permits may need to be obtained from the Central Valley Flood Protection Board and Reclamation District No. 0003, No. 0554, and No. 0556. DWR has a Memorandum of Understanding with the California State Lands Commission (CSLC), which became effective on October 19, 1979. DWR is authorized to perform certain types of activities without obtaining a lease from CSLC. The project would need to be evaluated further for compliance with the lease after detailed, project-specific information is available.

The project may require a consistency determination from the Delta Stewardship Council, if the project achieves the criteria of a "covered action" and "will have a significant [positive or negative] impact on the achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta." The coequal goals are: (1) providing a more reliable water supply for California; and (2) protecting, restoring, and enhancing the Delta ecosystem.

A Sacramento County grading permit may be required, if clearing and grubbing exceeds 1 acre or fill exceeds 350 cubic yards of material. A Sacramento County tree permit may be required, if tree removal or trimming of any tree located on public premises is proposed.

If you have any questions about the information provided or need additional information, please contact me at (916) 414-5858, or by e-mail (jennifer.aranda@aecom.com).

Table 1 Potential Environmental Issues Associated with the Georgiana Slough Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Aesthetics	Potential short-term impacts on State Route 160, officially designated as a State and County Scenic Highway, may require a Caltrans encroachment permit. DWR would need to coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage; and would have to remove all equipment, lights, buoys, and signage at the end of the project.
Agriculture and Forestry Resources	Temporary construction-related impacts may occur if agricultural lands are used for staging or materials storage. There are no forestry resources on site.
Air Quality	Short-term impacts from construction emissions (from construction equipment and vehicles, or fugitive dust) may require measures to minimize emissions.
Biological Resources	Potentially significant ESA and CESA take issues related to construction activities, including in-channel work and dewatering activities, may occur.
Cultural Resources	An NRHP-eligible/CRHR-significant prehistoric site is within the study site. The project design should avoid direct impacts on this resource. Assessment of the NRHP/CRHR significance of the commercial buildings and levees would be required. Potential impacts on built environment cultural resources are unlikely to occur; however, DWR would be required to conduct an inventory and evaluation by a cultural resources specialist for permitting. The study site is not considered to be paleontologically sensitive, and therefore no impacts to this resource would occur.
Environmental Justice	No issues or impacts have been identified.
Geology and Soils	Short-term construction-related erosion could result in sediment transport from land into Georgiana Slough, and short-term water-based construction could increase turbidity in the channel. Mitigation measures will be required to prevent erosion and decrease turbidity. Construction in unstable soils, subsidence, and liquefaction could represent hazards; however, these issues could be addressed during the engineering phase of project design.
Greenhouse Gas Emissions	Short-term construction-related greenhouse gas emissions may occur, but they are not likely to exceed the greenhouse gas thresholds developed by DWR.
Hazards and Hazardous Materials	A potential risk exists for release of hazardous materials (e.g., cement, fuel, or lubricants) associated with the project. DWR should design the project to minimize risk. DWR may be required to implement a hazardous materials management program. Walnut Grove Elementary School is located approximately 0.2 mile east of the study site.
Hydrology and Water Quality	Potential short-term impacts on water quality may occur during project construction and operation. Potential changes to water turbidity, stage, and velocity also may occur during project construction and operation. DWR will need to implement avoidance and mitigation measures to protect water quality and monitor turbidity.
Land Use and Planning	No issues or impacts have been identified.
Mineral Resources	No issues or impacts have been identified.
Noise	Short-term construction-related impacts may occur. DWR should limit construction to daytime hours and should employ noise-reducing construction practices.
Population and Housing	No issues or impacts have been identified.
Public Health and Safety	Construction activities may temporarily affect public health from the potential release of hazardous materials associated with the project. DWR may be required to implement a hazardous materials management program.
Public Services	No issues or impacts have been identified.
Recreation	Potential impacts may occur on marinas, boating, and related recreational activities within the study site, particularly during daytime in summer. The project design should maintain navigation and DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Transportation and Traffic	Potential short-term impacts may occur on bridges in the study site, requiring a U.S. Coast Guard Section 9 permit, and work in the vicinity of State Route 160 may require a Caltrans encroachment permit. The project design should maintain navigation and DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Utilities and Service Systems	No issues or impacts have been identified.

Notes: CESA = California Endangered Species Act; CRHR = California Register of Historical Resources; DWR = California Department of Water Resources; ESA = Endangered Species Act; NRHP = National Register of Historic Places

Table 2 Potentially Occurring State and Federally Listed Species in the Georgiana Slough Study Site Vicinity

Class	Scientific Name	Common Name	Status
Plants	*Hibiscus lasiocarpos* var. *occidentalis*[2]	Wooly rose mallow	CRPR 1B
	Lathyrus jepsonii var. *jepsonii*[3]	Delta tule pea	CRPR 1B
	Lilaeopsis masonii[4]	Mason's lilaeopsis	CRPR 1B
	Limosella australis[5]	Delta mudwort	CRPR 2
	Sagittaria sanfordii[1, 6]	Sanford's arrowhead	CRPR 1B
	Symphyotrichum lentum[6]	Suisun marsh aster	CRPR 1B
Invertebrates	*Desmocerus californicus dimorphus*	Valley elderberry longhorn beetle	FT
Fish	*Acipenser medirostris*	Green sturgeon (southern DPS)	FT
	Hypomesus transpacificus	Delta smelt	FT, FX, CE
	Oncorhynchus tshawytscha	Sacramento River winter-run Chinook salmon	FE, FX, CE
	Oncorhynchus tshawytscha	Central Valley spring-run Chinook salmon	FT, FX, CT
	Oncorhynchus mykiss[1]	Central Valley steelhead DPS	FT, FX,
	Pogonichthys macrolepidotus	Sacramento splittail	SSC
	Spirinchus thaleichthys[1]	Longfin smelt	FC, CT, SSC
Amphibians	*Emys marmorata*	Western pond turtle	SSC
Birds	*Buteo swainsoni*	Swainson's hawk	CT
	Elanus leucurus	White-tailed kite	FP
Mammals	*Lasiurus blossevillii*	Western red bat	SSC

Notes: DPS = distinct population segment

[1] Known to occur within the study site; [2] Blooming Period: June-September; [3] Blooming Period: May-September; [4] Blooming Period: April-November; [5] Blooming Period: May-August; [6] Blooming Period: May-November

Status Notes:

U.S. Fish and Wildlife Service (USFWS):

FT = Listed as threatened under the federal Endangered Species Act
FC = Candidate for listing under the federal Endangered Species Act
FX = Critical Habitat

California Department of Fish and Wildlife (CDFW):

CE = Endangered (legally protected)
FP = Fully protected species—may not be taken or possessed without a permit from the Fish and Game Commission
SSC = California Species of Special Concern
CT = Threatened (legally protected)

California Native Plant Society:

CRPR 1B = Plant species considered rare or endangered in California and elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)
CRPR 2 = Plant species considered rare or endangered in California but more common elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)

Search Criteria: Database searches were conducted using the USFWS online database, CDFW's California Natural Diversity Database (CNDDB), and California Native Plant Society's (CNPS) Inventory of Rare and Endangered Plants of California to identify sensitive species that could occur in the study site. The database searches included the U.S. Geological Survey (USGS) 7.5-minute quadrangle for the study site (Isleton) and the surrounding eight quadrangles: Bouldin Island, Bruceville, Courtland, Jersey Island, Liberty Island, Rio Vista, Terminous, and Thorton.

Table 3 Environmental Permits Potentially Required for the Georgiana Slough Study Site

Jurisdiction	Agency and Permit Type
Federal	USACE 408 permission (if project would affect levees in the study site, all of which are USACE project levees), and USACE 404 Permit, Nationwide Permit (if area affected by dredge and fill activities is less than or equal to 0.5 acre of permanent impacts) or Individual Permit (if permanent impacts exceed 0.5 acre)
	USACE Section 10 Rivers and Harbors Act authorization (if structures are a required component of project design)
	Section 106 compliance with National Historic Preservation Act
	Federal ESA compliance (if federal species and critical habitat are present within the study site); consultation with USFWS and NMFS required
State	RWQCB 401 water quality certification (CEQA compliance required)
	RWQCB NPDES Construction General Permit (if ground disturbance is greater than 1 acre)
	CDFW LSAA (CEQA and CESA compliance required)
	CSLC Lease (the project may be covered under existing MOU)
	Central Valley Flood Protection Board Encroachment Permit
	Delta Stewardship Council Consistency Determination
Regional and Local	Reclamation District No. 0003, No. 0554, and No. 0556 Encroachment Permits
	Sacramento County Grading Permit (if clearing and grubbing exceed 1 acre or fill exceeds 350 cubic yards of material); Sacramento County Tree Permit (if tree removal or trimming of any tree located on public premises occurs)

Notes: CDFW = California Department of Fish and Wildlife; CEQA = California Environmental Quality Act; CESA = California Endangered Species Act; CSLC = California State Lands Commission; ESA = Endangered Species Act; LSAA = Lake or Streambed Alteration Agreement; MOU = Memorandum of Understanding; NMFS = National Marine Fisheries Service; NPDES = National Pollutant Discharge Elimination System; RWQCB = Regional Water Quality Control Board; USACE = U.S. Army Corps of Engineers; USFWS = U.S. Fish and Wildlife Service

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Memorandum

To: Bill McLaughlin, Senior Engineer, California Department of Water Resources

From: Jennifer Aranda, Senior Project Manager, AECOM

Date: August 22, 2014

Subject: Preliminary Environmental Evaluation of the Threemile Slough Study Site

---

AECOM technical staff conducted a preliminary evaluation of the Threemile Slough study site under consideration for engineering solutions to reduce diversion of emigrating juvenile salmonids to the interior and southern portions of the Sacramento–San Joaquin Delta (Delta), and to reduce salmonid exposure to Central Valley Project and State Water Project export facilities.

METHODS

A preliminary list of potential environmental issues associated with the Threemile Slough study site is presented in Table 1. AECOM evaluated the study site within the boundary that was provided by the California Department of Water Resources (DWR)(Figure 1); site access, staging areas, and materials stockpile areas were not identified outside the site boundary, and therefore were not assessed for potential environmental issues. Potentially significant environmental issues have been identified that would require further evaluation before beginning final project design because they may influence project design, timing, and project construction options. In addition, informal consultation with the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE), Central Valley Regional Water Quality Control Board (RWQCB), and California Department of Fish and Wildlife (CDFW) should occur before final project design. This informal consultation would help identify the in-channel construction period and would help develop mitigation and avoidance measures to minimize short-term construction-related impacts on species protected under the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA).

BIOLOGICAL RESOURCES

The sensitive species included in Table 2 are known to occur in the study site vicinity, and suitable habitat for the species may be present within the study site, based on a review of aerial photography and limited site access. Special-status fish species are known to occur within the study site and have the potential to be directly affected by project implementation. Furthermore, field surveys would be required for special-status plants because three species of rare plants—Mason's lilaeopsis, Delta mudwort, and Suisun marsh aster—are known to occur along the banks of Threemile Slough. Surveys for special-status plants should be timed to coincide with the blooming period (see notes in Table 2) of target species. The preliminary site evaluation suggests that the trees along the waterways would provide suitable nest locations for Swainson's hawk and white-tailed kite, and foraging habitat is present in the grasslands along the north bank and in the agricultural fields along the south bank. Burrowing owl is known to occur at Brannan Island State Park, in close proximity to the study site. Surveys should be conducted for burrowing owl if implementation of the project may alter habitat for this species. An occurrence of the song sparrow "Modesto" population is known to occur on Decker Island, south of the study site along the Sacramento River. This species was included in Table 2 because of a known occurrence in close proximity to the

Source: AECOM 2014

Figure 1. Location Map

study site; however, the study site lacks the tule, cattail, and willow thickets this species favors. Avoidance and minimization measures should be developed for all special-status species that have the potential to occur within the study site, as well as including these measures as "environmental commitments" as part of the project description or as mitigation measures for any potentially significant impacts.

CULTURAL RESOURCES

Bridge #240121 (shown on Figure 1) previously was determined eligible for the National Register of Historic Places (NRHP). The bridge should be assessed for any potential indirect project-related impacts. The levee system on Sherman Island was evaluated by AECOM in 2013, and was recommended as not eligible for the NRHP or the California Register of Historical Resources (CRHR). In 2003, one building on assessor parcel number (APN) 158-001-0054-0000 was evaluated for the NRHP and the CRHR, and was recommended as not eligible. If concurrence was received from the State Historic Preservation Officer (SHPO), the building would not need to be reassessed. If concurrence was not received, the building would need to reassessed for the NRHP and the CRHR. The remaining agricultural and residential-type buildings within the study site are more than 50 years old and would require evaluation to determine their eligibility for inclusion in the NRHP and the CRHR.

PERMITS AND AUTHORIZATIONS

Work at the Threemile Slough study site may require permits or authorizations from federal, state, and regional and local agencies with regulatory jurisdiction over the environmental resources that are present (Table 3). USACE 408 permission would be required if the project would affect the levees in the study site, all of which are USACE project levees. The project would require a permit (Nationwide or Individual) from USACE under Section 404 of the Clean Water Act (CWA), if project implementation requires the placement of dredge and fill materials into waters of the United States. An Individual Permit and CWA Section 404(b)(1) alternatives analysis are required if permanent wetland impacts exceed the 0.5 acre threshold of the Nationwide Permit program. Impacts on waters of the United States may require implementation of mitigation measures. Compliance with Section 106 of the National Historic Preservation Act would be required to obtain a Section 404 permit. Placement of structures in navigable waterways would require authorization from USACE under Section 10 of the Rivers and Harbors Act of 1899.

The 404 permit would provide the federal nexus for an ESA Section 7 consultation. Formal ESA consultation requires up to 135 days for agency review after project design, timing, and avoidance and mitigation measures have been identified. However, USFWS has recently acknowledged achieving the 135-day consultation timeline may no longer be possible for all projects, especially for projects without multi-benefits. As a result, USFWS is prioritizing workload and not all projects will conclude formal ESA consultation within 135 days. High-level discussion with USFWS will be needed to expedite ESA compliance. Consultation with NMFS would also be required because of potential impacts to anadromous fish. A Rivers and Harbors Act Section 9 Permit may be required from the U.S. Coast Guard. Compliance with the National Environmental Policy Act (NEPA) would be required if any federal funding is used by the project.

Water quality certification from the Central Valley RWQCB would be required for compliance with Section 401 of the CWA. This certification would identify project-specific best management practices (BMPs) to minimize project impacts, such as criteria to reduce erosion, sedimentation, and releases of hazardous material. BMPs also would provide criteria for dewatering and construction methods, revegetation, and monitoring requirements. A National Pollutant Discharge Elimination System (NPDES) Construction General Permit for discharges of stormwater associated with the construction activity would be required if total soil disturbance exceeds 1 acre. Soil disturbance typically occurs from access improvements, staging areas, material stockpile areas, and construction areas.

A Lake and Streambed Alteration Agreement (LSAA) would be required from CDFW under Section 1600 et seq. of the California Fish and Game Code, to address potential project-related impacts on the bed, banks, and channel of any natural stream and associated riparian vegetation. Both water quality certification and the LSAA would require evidence of compliance with the California Environmental Quality Act (CEQA) before issuance of permits.

Species protected under CESA could occur within the study site or in the study site vicinity. If the potential exists for the project to result in “take” (i.e., kill) of a special-status species that is protected under CESA, an incidental take permit would be required from CDFW. Typically, avoidance and minimization measures can be implemented before project construction to avoid the direct mortality of species protected under CESA.

Encroachment permits may need to be obtained from the Central Valley Flood Protection Board and Reclamation District No. 0341. DWR has a Memorandum of Understanding (MOU) with the California State Lands Commission (CSLC) that became effective on October 19, 1979. DWR is authorized to perform certain types of activities without obtaining a lease from CSLC. The project would need to be evaluated further for compliance with the lease after detailed, project-specific information is available.

A portion of the study site at Threemile Slough falls within Brannan Island State Park, along the north bank of the channel. An MOU may need to be developed between DWR and the California Department of Parks and Recreation for use of study site land within Brannan Island State Park.

An encroachment permit from California Department of Transportation (Caltrans) may be needed for work on or near State Route 160.

The project may require a consistency determination from the Delta Stewardship Council, if the project achieves the criteria of a “covered action” and “will have a significant [positive or negative] impact on the achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta.” The coequal goals are: (1) providing a more reliable water supply for California; and (2) protecting, restoring, and enhancing the Delta ecosystem.

A Sacramento County grading permit may be required if clearing and grubbing exceed 1 acre or fill exceeds 350 cubic yards of material. A Sacramento County tree permit may be required if tree removal or trimming of any tree located on public premises is proposed.

If you have any questions about the information provided or need additional information, please contact me at (916) 414-5858, or by e-mail (jennifer.aranda@aecom.com).

Table 1 Potential Environmental Issues Associated with the Threemile Slough Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Aesthetics	Potential short-term impacts on State Route 160, officially designated as a State Scenic Highway, may require a Caltrans encroachment permit. DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys and signage; and should remove all equipment, lights, buoys, and signage at the end of the project.
Agriculture and Forestry Resources	Temporary construction-related impacts may occur if agricultural lands are used for staging or materials storage. There are no forestry resources on site.
Air Quality	Short-term impacts from construction emissions (from construction equipment and vehicles, or fugitive dust) may require mitigation measures to minimize emissions.
Biological Resources	Potentially significant ESA and CESA take issues related to construction activities, including in-channel work and dewatering activities, may occur.
Cultural Resources	Assessment for potential indirect impacts on Bridge #240121 would be required. Assessment of the historical significance of buildings more than 50 years old would be required. Potential reassessment of a previously evaluated building should occur if SHPO concurrence was not received for that evaluation. Potential impacts on cultural resources are unlikely; however, the project would require an inventory and evaluation by a cultural resources specialist for permitting. The study site is not considered to be paleontologically sensitive, and therefore no impacts to this resource would occur.
Environmental Justice	No issues or impacts have been identified.
Geology and Soils	Short-term construction-related erosion could result in sediment transport from land into Threemile Slough, and short-term water-based construction could increase turbidity in the channel. Mitigation measures will be required to prevent erosion and decrease turbidity. Construction in unstable soils, subsidence, and liquefaction could represent hazards; however, these issues could be addressed during the engineering phase of project design.
Greenhouse Gas Emissions	Short-term construction-related greenhouse gas emissions may occur, but they are not likely to exceed the greenhouse gas thresholds developed by DWR.
Hazards and Hazardous Materials	A potential risk exists for release of hazardous materials (e.g., cement, fuel, or lubricants) associated with the project. DWR should design the project to minimize risk. DWR may be required to implement a hazardous materials management program.
Hydrology and Water Quality	Potential short-term impacts on water quality may occur during project construction and operation. Potential changes to water turbidity, stage, and velocity also may occur during project construction and operation. DWR will need to implement avoidance and mitigation measures to protect water quality and monitor turbidity.
Land Use and Planning	No issues or impacts have been identified.
Mineral Resources	No issues or impacts have been identified.
Noise	Short-term construction-related impacts may occur. DWR should limit construction to daytime hours and employ noise-reducing construction practices.
Population and Housing	No issues or impacts have been identified.
Public Health and Safety	Construction activities may temporarily affect public health from the potential release of hazardous materials associated with the project. DWR may be required to implement a hazardous materials management program.
Public Services	A potential short-term impact on U.S. Coast Guard response time may occur if access from Rio Vista Station to the San Joaquin River is impeded. The project design should maintain navigation within the study site.
Recreation	Potential short-term impacts to Brannan Island State Recreation Area, and boating and related recreational activities within the study site, particularly during the daytime in summer. Maintain navigation and coordinate with U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Transportation and Traffic	Potential short-term impacts may occur on State Route 160 and the State Route 160 drawbridge; this may require a Caltrans encroachment permit. Potential short-term navigation impacts also may occur; thus, the project design should maintain navigation and DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Utilities and Service Systems	No issues or impacts have been identified.
Notes: Caltrans = California Department of Transportation; CESA = California Endangered Species Act; DWR = California Department of Water Resources; ESA = Endangered Species Act; SHPO = State Historic Preservation Office	

Table 2 Potentially Occurring State and Federally Listed Species in the Threemile Slough Study Site Vicinity

Class	Scientific Name	Common Name	Status
Plants	*Hibiscus lasiocarpos* var. *occidentalis*[2]	Wooly rose mallow	CRPR 1B
	Lathyrus jepsonii var. *jepsonii*[3]	Delta tule pea	CRPR 1B
	Lilaeopsis masonii[1, 4]	Mason's lilaeopsis	CRPR 1B
	Limosella australis[1, 5]	Delta mudwort	CRPR 2
	Sagittaria sanfordii[6]	Sanford's arrowhead	CRPR 1B
	Symphyotrichum lentum[1, 6]	Suisun marsh aster	CRPR 1B
Invertebrates	*Desmocerus californicus dimorphus*	Valley elderberry longhorn beetle	FT
Fish	*Acipenser medirostris*	Green sturgeon (southern DPS)	FT
	Hypomesus transpacificus[1]	Delta smelt	FT, FX, CE
	Oncorhynchus tshawytscha	Sacramento River winter-run Chinook salmon	FE, FX, CE
	Oncorhynchus tshawytscha	Central Valley spring-run Chinook salmon	FT, FX, CT
	Oncorhynchus mykiss[1]	Central Valley steelhead DPS	FT, FX,
	Pogonichthys macrolepidotus	Sacramento splittail	SSC
	Spirinchus thaleichthys[1]	Longfin smelt	FC, CT, SSC
Amphibians	*Emys marmorata*	Western pond turtle	SSC
Birds	*Athene cunicularia*	Burrowing owl	SSC
	Buteo swainsoni	Swainson's hawk	CT
	Elanus leucurus	White-tailed kite	FP
	Melospiza melodia	Song sparrow "Modesto" population	SSC
Mammals	*Lasiurus blossevillii*	Western red bat	SSC

Notes: DPS = distinct population segment

[1] Known to occur within the study site; [2] Blooming Period: June-September; [3] Blooming Period: May-September; [4] Blooming Period: April-November; [5] Blooming Period: May-August; [6] Blooming Period: May-November

Status Notes:

U.S. Fish and Wildlife Service (USFWS):

FE = Endangered (legally protected)
FT = Listed as threatened under the federal Endangered Species Act
FC = Candidate for listing under the federal Endangered Species Act
FX = Critical Habitat

California Department of Fish and Wildlife (CDFW):

CE = Endangered (legally protected)
FP = Fully protected species—may not be taken or possessed without a permit from the Fish and Game Commission
SSC = California Species of Special Concern
CT = Threatened (legally protected)

California Native Plant Society:

CRPR 1B = Plant species considered rare or endangered in California and elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)
CRPR 2 = Plant species considered rare or endangered in California but more common elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)

Search Criteria: Database searches were conducted using the USFWS online database, CDFW's California Natural Diversity Database (CNDDB), and California Native Plant Society's (CNPS) Inventory of Rare and Endangered Plants of California to identify sensitive species that could occur in the study site. The database searches included the U.S. Geological Survey (USGS) 7.5-minute quadrangle for the study site (Jersey Island) and the surrounding eight quadrangles: Antioch North, Antioch South, Birds Landing, Bouldin Island, Brentwood, Isleton, Rio Vista, and Woodward Island.

Table 3 Environmental Permits Potentially Required for the Threemile Slough Study Site

Jurisdiction	Agency and Permit Type
Federal	USACE 408 permission (if project would affect levees in the study site, all of which are USACE project levees), and USACE 404 Permit, Nationwide Permit (if area affected by dredge and fill activities is less than or equal to 0.5 acre of permanent impacts) or Individual Permit (if permanent impacts exceed 0.5 acre)
	USACE Section 10 Rivers and Harbors Act authorization (if structures are a required component of project design)
	Section 106 compliance with National Historic Preservation Act
	Federal ESA compliance (if federal species and critical habitat are present within the study site); consultation with USFWS and NMFS required
	U.S. Coast Guard Rivers and Harbors Act Section 9 Permit
State	RWQCB 401 water quality certification (CEQA compliance required)
	RWQCB NPDES Construction General Permit (if ground disturbance is greater than 1 acre)
	CDFW LSAA (CEQA CESA compliance required)
	CSLC Lease (the project may be covered under existing MOU)
	Central Valley Flood Protection Board Encroachment Permit
	California Department of Parks and Recreation MOU
	Delta Stewardship Council Consistency Determination
Regional and Local	Reclamation District No. 0341 Encroachment Permit
	Sacramento County Grading Permit (if clearing and grubbing exceed 1 acre or fill exceeds 350 cubic yards of material); Sacramento County Tree Permit (if tree removal or trimming of any tree located on public premises)

Notes: CDFW = California Department of Fish and Wildlife; CEQA = California Environmental Quality Act; CESA = California Endangered Species Act; CSLC = California State Lands Commission; ESA = Endangered Species Act; LSAA = Lake or Streambed Alteration Agreement; MOU = Memorandum of Understanding; NMFS = National Marine Fisheries Service; NPDES = National Pollutant Discharge Elimination System; RWQCB = Regional Water Quality Control Board; USACE = U.S. Army Corps of Engineers; USFWS = U.S. Fish and Wildlife Service

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Memorandum

To: Bill McLaughlin, Senior Engineer, California Department of Water Resources

From: Jennifer Aranda, Senior Project Manager, AECOM

Date: August 22, 2014

Subject: Preliminary Environmental Evaluation of the Head of Old River Study Site

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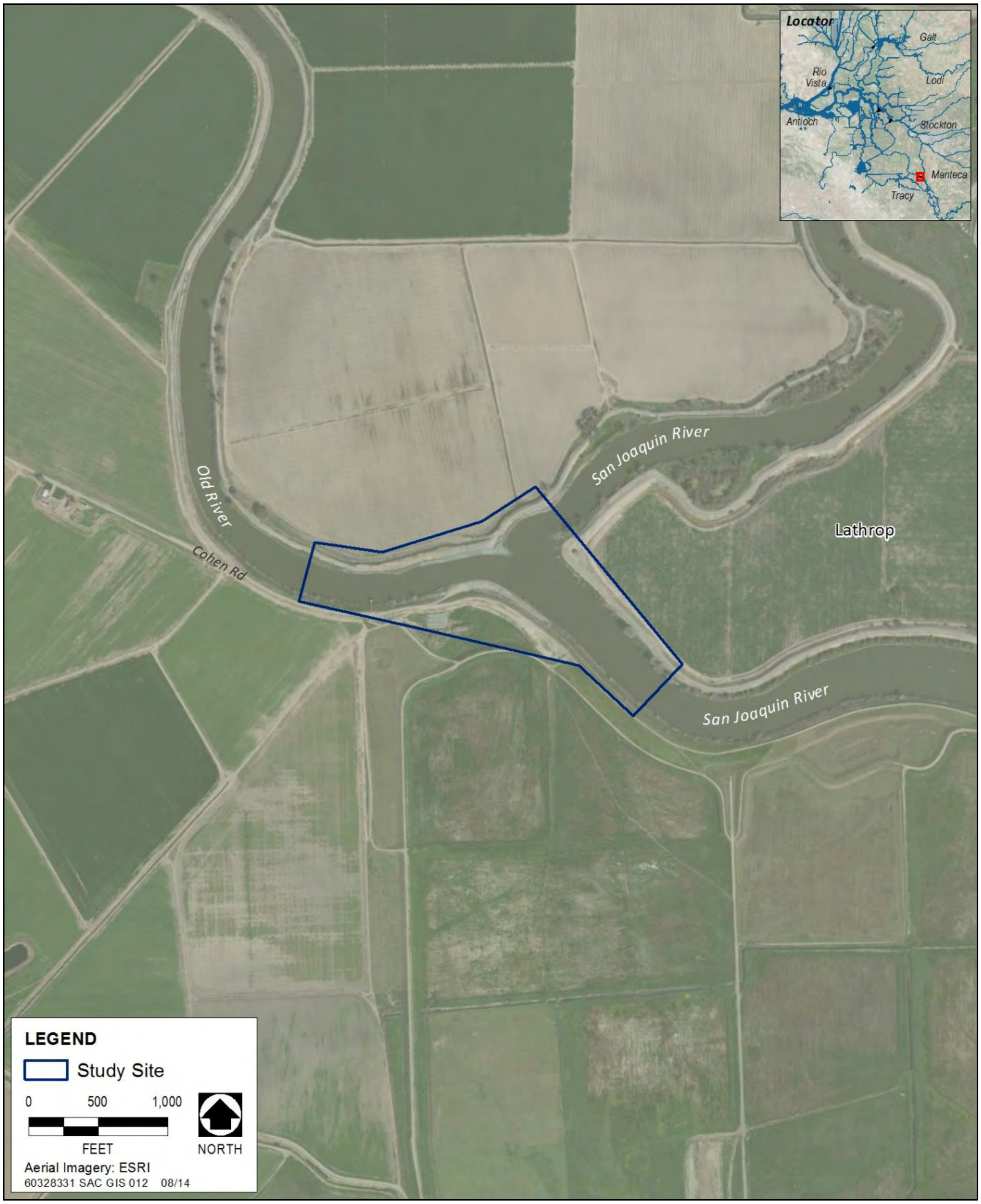
AECOM technical staff conducted a preliminary evaluation of the Head of Old River study site under consideration for engineering solutions to reduce diversion of emigrating juvenile salmonids to the interior and southern portions of the Sacramento–San Joaquin Delta (Delta), and to reduce salmonid exposure to Central Valley Project and State Water Project export facilities.

METHODS

A preliminary list of potential environmental issues associated with the Head of Old River study site is presented in Table 1. AECOM evaluated the study site within the boundary that was provided by the California Department of Water Resources (DWR) (Figure 1); site access, staging areas, and materials stockpile areas were not identified outside the site boundary, and therefore were not assessed for potential environmental issues. Potentially significant environmental issues have been identified that would require further evaluation before beginning final project design because they may influence project design, timing, and project construction options. In addition, informal consultation with the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE), Central Valley Regional Water Quality Control Board (RWQCB), and California Department of Fish and Wildlife (CDFW) should occur before final project design. This informal consultation would help identify the in-channel construction period and would help develop mitigation and avoidance measures to minimize short-term construction-related impacts on species protected under the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA).

BIOLOGICAL RESOURCES

The sensitive species included in Table 2 are known to occur in the study site vicinity, and suitable habitat for the species may be present within the study site, based on a review of aerial photography and limited site access. Special-status fish species are known to occur within the study site and have the potential to be directly affected by project implementation. Special-status plants are not anticipated to occur at the Head of Old River study site because uplands areas have been heavily altered for agricultural land use and have historically been the site of the annual spring and fall temporary fish barriers, and much of the waterside toes of the levees are armored with riprap. The preliminary site evaluation suggests that the trees along the waterways provide suitable nest locations for Swainson’s hawk and white-tailed kite, and foraging habitat is present in the agricultural lands surrounding the study site. Avoidance and minimization measures should be developed for all special-status species that have the potential to occur within the study site, as well as including these measures as “environmental commitments” as part of the project description or as mitigation measures for any potentially significant impacts.



Source: AECOM 2014

Figure 1. Location Map

CULTURAL RESOURCES

The levees within the boundary of the study site previously were evaluated for the National Register of Historic Places and the California Register of Historical Resources, and were recommended as not eligible. That determination was concurred with by the State Historic Preservation Officer in 2006.

PERMITS AND AUTHORIZATIONS

Work at the Head of Old River study site may require permits or authorizations from federal, state, and regional and local agencies with regulatory jurisdiction over the environmental resources that are present (Table 3). USACE 408 permission would be required if the project would affect the levees in the study site, all of which are USACE project levees. DWR may need a permit (Nationwide or Individual) from USACE under Section 404 of the Clean Water Act (CWA), if project implementation requires placement of dredge and fill materials into waters of the United States. An Individual Permit and CWA Section 404(b)(1) alternatives analysis are required if permanent wetland impacts exceed the 0.5 acre threshold of the Nationwide Permit program. Impacts on waters of the United States may require implementation of mitigation measures. Compliance with Section 106 of the National Historic Preservation Act would be required to obtain a Section 404 permit. Placement of structures in navigable waterways would require authorization from USACE under Section 10 of the Rivers and Harbors Act of 1899.

The 404 permit would provide the federal nexus for an ESA Section 7 consultation. Formal ESA consultation requires up to 135 days for agency review after project design, timing, and avoidance and mitigation measures have been identified. However, USFWS has recently acknowledged achieving the 135-day consultation timeline may no longer be possible for all projects, especially for projects without multi-benefits. As a result, USFWS is prioritizing workload and not all projects will conclude formal ESA consultation within 135 days. High-level discussion with USFWS will be needed to expedite ESA compliance. Consultation with NMFS would also be required because of potential impacts to anadromous fish. Compliance with the National Environmental Policy Act (NEPA) would be required if any federal funding is used by the project.

Water quality certification from the Central Valley RWQCB would be required for compliance with Section 401 of the CWA. This certification would identify project-specific best management practices (BMPs) to minimize project impacts, such as criteria to reduce erosion, sedimentation, and releases of hazardous material. BMPs also would provide criteria for dewatering and construction methods, revegetation, and monitoring requirements. A National Pollutant Discharge Elimination System (NPDES) Construction General Permit for discharges of stormwater associated with the construction activity would be required if total soil disturbance exceeds 1 acre. Soil disturbance typically occurs from access improvements, staging areas, material stockpile areas, and construction areas.

A Lake and Streambed Alteration Agreement (LSAA) would be required from CDFW under Section 1600 et seq. of the California Fish and Game Code, to address potential project-related impacts on the bed, banks, and channel of any natural stream and associated riparian vegetation. Both water quality certification and the LSAA would require evidence of compliance with the California Environmental Quality Act (CEQA) before issuance of permits.

Species protected under CESA could occur within the study site or in the study site vicinity. If the potential exists for the project to result in “take” (i.e., kill) of a special-status species that is protected under CESA, an incidental take permit would be required from CDFW. Typically, avoidance and minimization measures can be implemented before project construction to avoid the direct mortality of species protected under CESA.

Encroachment permits may need to be obtained from the Central Valley Flood Protection Board and Reclamation District No. 0017, No. 0544, and No. 2062. DWR has a Memorandum of Understanding with the California State Lands Commission (CSLC) that became effective on October 19, 1979. DWR is authorized to perform certain types of activities without obtaining a lease from CSLC. The project would need to be evaluated further for compliance with the lease after detailed, project-specific information is available.

The project may require a consistency determination from the Delta Stewardship Council, if the project achieves the criteria of a “covered action” and “will have a significant [positive or negative] impact on the achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta.” The coequal goals are; (1) providing a more reliable water supply for California; and (2) protecting, restoring, and enhancing the Delta ecosystem.

A San Joaquin County grading permit may be required.

If you have any questions about the information provided or need additional information, please contact me at (916) 414-5858, or by e-mail (jennifer.aranda@aecom.com).

Table 1 Potential Environmental Issues Associated with the Head of Old River Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Aesthetics	No issues or impacts have been identified.
Agriculture and Forestry Resources	Temporary construction-related impacts may occur if agricultural lands are used for staging or materials storage. There are no forestry resources on site.
Air Quality	Short-term impacts from construction emissions (from construction equipment and vehicles, or fugitive dust) may require mitigation measures to minimize emissions.
Biological Resources	Potentially significant ESA and CESA take issues related to construction activities, including in-channel work and dewatering activities, may occur.
Cultural Resources	No cultural resources issues or impacts have been identified. The study site is not considered to be paleontologically sensitive, and therefore no impacts to this resource would occur.
Environmental Justice	No issues or impacts have been identified.
Geology and Soils	Short-term construction-related erosion could result in sediment transport from land into Old River or the San Joaquin River, and short-term water-based construction could increase turbidity in the channel. Mitigation measures will be required to prevent erosion and decrease turbidity. Construction in unstable soils, subsidence, and liquefaction could represent hazards; however, these issues could be addressed during the engineering phase of project design.
Greenhouse Gas Emissions	Short-term construction-related greenhouse gas emissions may occur, but they are not likely to exceed the greenhouse gas thresholds developed by DWR.
Hazards and Hazardous Materials	A potential risk exists for release of hazardous materials (e.g., cement, fuel, or lubricants) associated with the project. DWR should design the project to minimize risk. DWR may be required to implement a hazardous materials management program.
Hydrology and Water Quality	Potential short-term impacts on water quality may occur during project construction and operation. Potential changes to water turbidity, stage, and velocity also may occur during project construction and operation. DWR will need to implement avoidance and mitigation measures to protect water quality and monitor turbidity.
Land Use and Planning	No issues or impacts have been identified.
Mineral Resources	No issues or impacts have been identified.
Noise	Short-term construction-related impacts may occur. DWR should limit construction to daytime hours and employ noise-reducing construction practices.

Table 1 Potential Environmental Issues Associated with the Head of Old River Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Population and Housing	No issues or impacts have been identified.
Public Health and Safety	Construction activities may temporarily affect public health from the potential release of hazardous materials associated with the project. DWR may be required to implement a hazardous materials management program.
Public Services	No issues or impacts have been identified.
Recreation	Potential short-term impacts may occur on boating and related recreational activities within the study site, particularly during daytime in summer. The project design should maintain navigation and DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Transportation and Traffic	The project design should maintain navigation and DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Utilities and Service Systems	No issues or impacts have been identified.
Notes: CESA = California Endangered Species Act; CRHR = California Register of Historical Resources; DWR = California Department of Water Resources; ESA = Endangered Species Act; NRHP = National Register of Historic Places	

Table 2 Potentially Occurring State and Federally Listed Species in the Head of Old River Study Site Vicinity

Class	Scientific Name	Common Name	Status
Plants	*Cirsium crassicaule*[1, 2]	Slough thistle	CRPR 1B
Invertebrates	*Desmocerus californicus dimorphus*	Valley elderberry longhorn beetle	FT
Fish	*Acipenser medirostris*	Green sturgeon (southern DPS)	FT
	Hypomesus transpacificus	Delta smelt	FT, FX, CE
	Oncorhynchus tshawytscha	Sacramento River winter-run Chinook salmon	FE, FX, CE
	Oncorhynchus tshawytscha	Central Valley spring-run Chinook salmon	FT, FX, CT
	Oncorhynchus mykiss[1]	Central Valley steelhead DPS	FT, FX
	Pogonichthys macrolepidotus	Sacramento splittail	SSC
	Spirinchus thaleichthys[1]	Longfin smelt	FC, CT, SSC
Amphibians	*Emys marmorata*	Western pond turtle	SSC
Birds	*Buteo swainsoni*[1]	Swainson's hawk	CT
	Elanus leucurus	White-tailed kite	FP
	Melospiza melodia	Song sparrow "Modesto" population	SSC
Mammals	*Lasiurus blossevillii*	Western red bat	SSC

Notes: DPS = distinct population segment

[1] Known to occur within the study site; [2] Blooming Period: June-September

Status Notes:

U.S. Fish and Wildlife Service (USFWS):

FE = Endangered (legally protected)
FT = Listed as threatened under the federal Endangered Species Act
FC = Candidate for listing under the federal Endangered Species Act
FX = Critical Habitat

California Department of Fish and Wildlife (CDFW):

CE = Endangered (legally protected)
FP = Fully protected species—may not be taken or possessed without a permit from the Fish and Game Commission
SSC = California Species of Special Concern
CT = Threatened (legally protected)

California Native Plant Society:

CRPR 1A = Plant species presumed extinct in California

Table 2 Potentially Occurring State and Federally Listed Species in the Head of Old River Study Site Vicinity

CRPR 1B = Plant species considered rare or endangered in California and elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)
CRPR 2 = Plant species considered rare or endangered in California but more common elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)

Search Criteria: Database searches were conducted using the USFWS online database (USFWS 2014), CDFW's California Natural Diversity Database (CNDDB), and California Native Plant Society's (CNPS) Inventory of Rare and Endangered Plants of California to identify sensitive species that could occur in the study site. The database searches included the U.S. Geological Survey (USGS) 7.5-minute quadrangle for the study site (Lathrop) and the surrounding eight quadrangles: Holt, Manteca, Ripon, Stockton East, Stockton West, Tracy, Union Island, and Vernalis.

Table 3 Environmental Permits Potentially Required for the Head of Old River Study Site

Jurisdiction	Agency and Permit Type
Federal	USACE 408 permission (if project would affect levees in the study site, all of which are USACE project levees), and 404 Permit, Nationwide Permit (if area affected by dredge and fill activities is less than or equal to 0.5 acre of permanent impacts) or Individual Permit (if permanent impacts exceed 0.5 acre)
	USACE Section 10 Rivers and Harbors Act authorization (if structures are a required component of project design)
	Section 106 compliance with National Historic Preservation Act
	Federal ESA compliance (if federal species and critical habitat are present within the study site); consultation with USFWS and NMFS required
State	RWQCB 401 Water Quality Certification (CEQA compliance required)
	RWQCB NPDES Construction General Permit (if ground disturbance is greater than 1 acre)
	CDFW LSAA (CEQA and CESA compliance required)
	CSLC Lease (the project may be covered under existing MOU)
	Central Valley Flood Protection Board Encroachment Permit
	Delta Stewardship Council Consistency Determination
Regional and Local	Reclamation District No. 0017, No. 0544, and No. 2062 Encroachment Permits
	San Joaquin County Grading Permit (unless the project is exempt)

Notes: CDFW = California Department of Fish and Wildlife; CEQA = California Environmental Quality Act; CESA = California Endangered Species Act;
CSLC = California State Lands Commission; ESA = Endangered Species Act; LSAA = Lake or Streambed Alteration Agreement;
MOU = Memorandum of Understanding; NMFS = National Marine Fisheries Service; NPDES = National Pollutant Discharge Elimination System;
RWQCB = Regional Water Quality Control Board; USACE = U.S. Army Corps of Engineers; USFWS = U.S. Fish and Wildlife Service

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Memorandum

To: Bill McLaughlin, Senior Engineer, California Department of Water Resources

From: Jennifer Aranda, Senior Project Manager, AECOM

Date: August 22, 2014

Subject: Preliminary Environmental Evaluation of the Turner Cut Study Site

---

AECOM technical staff conducted a preliminary evaluation of the Turner Cut study site under consideration for engineering solutions to reduce diversion of emigrating juvenile salmonids to the interior and southern portions of the Sacramento–San Joaquin Delta (Delta), and to reduce salmonid exposure to Central Valley Project and State Water Project export facilities.

METHODS

A preliminary list of potential environmental issues associated with the Turner Cut study site is presented in Table 1. AECOM evaluated the study site within the boundary that was provided by the California Department of Water Resources (DWR)(Figure 1); site access, staging areas, and materials stockpile areas were not identified outside the site boundary, and therefore were not assessed for potential environmental issues. Potentially significant environmental issues have been identified that would require further evaluation before beginning final project design because they may influence project design, timing, and project construction options. In addition, informal consultation with the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE), Central Valley Regional Water Quality Control Board (RWQCB), and California Department of Fish and Wildlife (CDFW) should occur before final project design. This informal consultation would help identify the in-channel construction period and would help develop mitigation and avoidance measures to minimize short-term construction-related impacts on species protected under the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA).

BIOLOGICAL RESOURCES

The sensitive species included in Table 2 are known to occur in the study site vicinity, and suitable habitat for the species may be present within the study site, based on a review of aerial photography. Special-status fish species are known to occur within the study site and have the potential to be directly affected by project implementation. Furthermore, field surveys would be required for special-status plants because two species of rare plants—wooly rose mallow and Suisun marsh aster—are known to occur both up and downstream from the study site. Surveys for special-status plants should be timed to coincide with the blooming period (see notes in Table 2) of target species. The preliminary site evaluation suggests that the trees along the waterways and on Acker Island would provide suitable nest locations for Swainson's hawk and white-tailed kite, and foraging habitat is present in the agricultural lands surrounding the study site. Avoidance and minimization measures should be developed for all special-status species that have the potential to occur within the study site, as well as including these

Source: AECOM 2014

Figure 1. Location Map

measures as “environmental commitments” as part of the project description or as mitigation measures for any potentially significant impacts.

CULTURAL RESOURCES

A commercial building within the study site (shown on Figure 1) is likely 45 years old and would need to be evaluated for the National Register of Historic Places (NRHP) and the California Register of Historical Resources (CRHR). Portions of the levees within the study site also are more than 50 years old, and they also would need to be evaluated to determine their eligibility for the NRHP and the CRHR.

PERMITS AND AUTHORIZATIONS

Work at the Turner Cut study site may require permits or authorizations from federal, state, and regional and local agencies with regulatory jurisdiction over the environmental resources that are present (Table 3). USACE 408 permission would be required if the project would affect the Lower Roberts Island levee, which is a USACE project levee. The project would require a permit (Nationwide or Individual) from USACE under Section 404 of the Clean Water Act (CWA), if project implementation requires the placement of dredge and fill materials into waters of the United States. An Individual Permit and CWA Section 404(b)(1) alternatives analysis are required if permanent wetland impacts exceed the 0.5 acre threshold of the Nationwide Permit program. Impacts on waters of the United States may require implementation of mitigation measures. Compliance with Section 106 of the National Historic Preservation Act would require a Section 404 permit. Placement of structures in navigable waterways would require authorization from USACE under Section 10 of the Rivers and Harbors Act of 1899.

The 404 permit would provide the federal nexus for an ESA Section 7 consultation. Formal ESA consultation requires up to 135 days for agency review after project design, timing, and avoidance and mitigation measures have been identified. However, USFWS has recently acknowledged achieving the 135-day consultation timeline may no longer be possible for all projects, especially for projects without multi-benefits. As a result, USFWS is prioritizing workload and not all projects will conclude formal ESA consultation within 135 days. High-level discussion with USFWS will be needed to expedite ESA compliance. Consultation with NMFS would also be required because of potential impacts to anadromous fish. Compliance with the National Environmental Policy Act (NEPA) would be required if any federal funding is used by the project.

Water quality certification from the Central Valley RWQCB would be required for compliance with Section 401 of the CWA. This certification would identify project-specific best management practices (BMPs) to minimize project impacts, such as criteria to reduce erosion, sedimentation, and releases of hazardous material. BMPs also would provide criteria for dewatering and construction methods, revegetation, and monitoring requirements. A National Pollutant Discharge Elimination System (NPDES) Construction General Permit for discharges of stormwater associated with the construction activity would be required if total soil disturbance exceeds 1 acre. Soil disturbance typically occurs from access improvements, staging areas, material stockpile areas, and construction areas.

A Lake and Streambed Alteration Agreement (LSAA) would be required from CDFW under Section 1600 et seq. of the California Fish and Game Code, to address potential project-related impacts on the bed, banks, and channel of any natural stream and associated riparian vegetation. Both Water Quality Certification and the LSAA would require evidence of compliance with the California Environmental Quality Act (CEQA) before issuance of permits.

Species protected under CESA could occur within the study site or in the study site vicinity. If the potential exists for the project to result in “take” (i.e., kill) of a special-status species that is protected under CESA, an incidental take permit would be required from CDFW. Typically, avoidance and minimization measures can be implemented before project construction to avoid the direct mortality of species protected under CESA.

Encroachment permits may need to be obtained from the Central Valley Flood Protection Board and Reclamation District No. 0684 and No. 2030. DWR has a Memorandum of Understanding with the California State Lands Commission (CSLC) that became effective on October 19, 1979. DWR is authorized to perform certain types of activities without obtaining a lease from CSLC. The project would need to be evaluated further for compliance with the lease after detailed project-specific information is available.

The project may require a consistency determination from the Delta Stewardship Council, if the project achieves the criteria of a “covered action” and “will have a significant [positive or negative] impact on the achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta.” The coequal goals are: (1) providing a more reliable water supply for California; and (2) protecting, restoring, and enhancing the Delta ecosystem.

A San Joaquin County grading permit may be required, unless the project is exempt.

If you have any questions about the information provided or need additional information, please contact me at (916) 414-5858, or by e-mail (jennifer.aranda@aecom.com).

Table 1 Potential Environmental Issues Associated with the Turner Cut Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Aesthetics	DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage; and should remove all equipment, lights, buoys, and signage at the end of the project.
Agriculture and Forestry Resources	Temporary construction-related impacts may occur if agricultural lands are used for staging or materials storage. There are no forestry resources on site.
Air Quality	Short-term impacts from construction emissions (from construction equipment and vehicles, or fugitive dust) may require mitigation measures to minimize emissions.
Biological Resources	Potentially significant ESA and CESA take issues related to construction activities, including in-channel work and dewatering activities, may occur.
Cultural Resources	Assessment of the historical significance of the levees and buildings 45 years and older would be required. Potential impacts on cultural resources are unlikely; however, the project would require an inventory and an evaluation by a cultural resources specialist for permitting. The study site is not considered to be paleontologically sensitive, and therefore no impacts to this resource would occur.
Environmental Justice	No impacts or issues have been identified.
Geology and Soils	Short-term construction-related erosion could result in sediment transport from land into Turner Cut or the adjacent river channels, and short-term water-based construction could increase turbidity in the channel. DWR will be required to implement avoidance and mitigation measures to prevent erosion and decrease turbidity. Construction in unstable soils, subsidence, and liquefaction could represent hazards; however, these issues could be addressed during the engineering phase of project design.
Greenhouse Gas Emissions	Short-term construction-related greenhouse gas emissions may occur, but they are not likely to exceed the greenhouse gas thresholds developed by DWR.
Hazards and Hazardous Materials	A potential risk exists for release of hazardous materials (e.g., cement, fuel, or lubricants) associated with the project. DWR should design the project to minimize risk. DWR may be required to implement a hazardous materials management program.

Table 1 Potential Environmental Issues Associated with the Turner Cut Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Hydrology and Water Quality	Potential short-term impacts on water quality may occur during project construction and operation. Potential changes to water turbidity, stage, and velocity also may occur during project construction and operation. DWR will need to implement avoidance and mitigation measures to protect water quality and monitor turbidity.
Land Use and Planning	No issues or impacts have been identified.
Mineral Resources	No issues or impacts have been identified.
Noise	Short-term construction-related impacts may occur. DWR should limit construction to daytime hours and employ noise-reducing construction practices.
Population and Housing	No issues or impacts have been identified.
Public Health and Safety	Construction activities temporarily may affect public health from the potential release of hazardous materials associated with the project. DWR may be required to implement a hazardous materials management program.
Public Services	No issues or impacts have been identified.
Recreation	Potential short-term impacts may occur on marinas at Acker Island, as well as on boating and related recreational activities within the study site, particularly during daytime in summer. DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Transportation and Traffic	Potential short-term navigation impacts may occur; access is anticipated to be available to the north of the study site. DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Utilities and Service Systems	No issues or impacts have been identified.
Notes: CESA = California Endangered Species Act; DWR = California Department of Water Resources; ESA = Endangered Species Act	

Table 2 Potentially Occurring State and Federally Listed Species in the Turner Cut Study Site Vicinity

Class	Scientific Name	Common Name	Status
Plants	*Hibiscus lasiocarpos* var. *occidentalis*[2]	Wooly rose mallow	CRPR 1B
	Lathyrus jepsonii var. *jepsonii*[3]	Delta tule pea	CRPR 1B
	Lilaeopsis masonii[4]	Mason's lilaeopsis	CRPR 1B
	Limosella australis[5]	Delta mudwort	CRPR 2
	Sagittaria sanfordii[6]	Sanford's arrowhead	CRPR 1B
	Symphyotrichum lentum[6]	Suisun marsh aster	CRPR 1B
Invertebrates	*Desmocerus californicus dimorphus*	Valley elderberry longhorn beetle	FT
Fish	*Acipenser medirostris*	Green sturgeon (southern DPS)	FT
	Hypomesus transpacificus[1]	Delta smelt	FT, FX, CE
	Oncorhynchus tshawytscha	Sacramento River winter-run Chinook salmon	FE, FX, CE
	Oncorhynchus tshawytscha	Central Valley spring-run Chinook salmon	FT, FX, CT
	Oncorhynchus mykiss[1]	Central Valley steelhead DPS	FT, FX
	Pogonichthys macrolepidotus	Sacramento splittail	SSC
	Spirinchus thaleichthys[1]	Longfin smelt	FC, CT, SSC
Amphibians	*Emys marmorata*	Western pond turtle	SSC
Reptiles	*Thamnophis gigas*	Giant garter snake	FT, CT
Birds	*Buteo swainsoni*	Swainson's hawk	CT
	Elanus leucurus	White-tailed kite	FP
	Laterallus jamaicensis coturniculus	California black rail	CT, FP
	Melospiza melodia	Song sparrow "Modesto" population	SSC
Mammals	*Lasiurus blossevillii*	Western red bat	SSC

Table 2 Potentially Occurring State and Federally Listed Species in the Turner Cut Study Site Vicinity

Notes: DPS = distinct population segment

[1] Known to occur within the study site; [2] Blooming Period: June-September; [3] Blooming Period: May-September; [4] Blooming Period: April-November; [5] Blooming Period: May-August; [6] Blooming Period: May-November

Status Notes:

U.S. Fish and Wildlife Service (USFWS):

FE = Endangered (legally protected)
FT = Listed as threatened under the federal Endangered Species Act
FC = Candidate for listing under the federal Endangered Species Act
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California Department of Fish and Wildlife (CDFW):

CE = Endangered (legally protected)
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SSC = California Species of Special Concern
CT = Threatened (legally protected)

California Native Plant Society:

CRPR 1B = Plant species considered rare or endangered in California and elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)
CRPR 2 = Plant species considered rare or endangered in California but more common elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)

Search Criteria: Database searches were conducted using the USFWS online database, CDFW's California Natural Diversity Database (CNDDB), and California Native Plant Society's (CNPS) Inventory of Rare and Endangered Plants of California to identify sensitive species that could occur in the study site. The database searches included the U.S. Geological Survey (USGS) 7.5-minute quadrangle for the study site (Holt) and the surrounding eight quadrangles: Bouldin Island, Clifton Court Forebay, Lathrop, Lodi South, Stockton West, Terminous, Union Island, and Woodward Island.

Table 3 Environmental Permits Potentially Required for the Turner Cut Study Site

Jurisdiction	Agency and Permit Type
Federal	USACE 408 permission (if project would affect the Lower Roberts Island levee, which is a USACE project levee), and USACE 404 Permit, Nationwide Permit (if area affected by dredge and fill activities is less than or equal to 0.5 acre of permanent impacts) or Individual Permit (if permanent impacts exceed 0.5 acre)
	USACE Section 10 Rivers and Harbors Act authorization (if structures are a required component of project design)
	Section 106 compliance with National Historic Preservation Act
	Federal ESA compliance (if federal species and critical habitat are present within the study site); consultation with USFWS and NMFS required
State	RWQCB 401 water quality certification (CEQA compliance required)
	RWQCB NPDES Construction General Permit (if ground disturbance is greater than 1 acre)
	CDFW LSAA (CEQA and CESA compliance required)
	CSLC Lease (the project may be covered under existing MOU)
	Central Valley Flood Protection Board Encroachment Permit
	Delta Stewardship Council Consistency Determination
Regional and Local	Reclamation District No. 0684 and No. 2030 Encroachment Permits
	San Joaquin County Grading Permit (unless the project is exempt)

Notes: CDFW = California Department of Fish and Wildlife; CEQA = California Environmental Quality Act; CESA = California Endangered Species Act; CSLC = California State Lands Commission; ESA = Endangered Species Act; LSAA = Lake or Streambed Alteration Agreement; MOU = Memorandum of Understanding; NMFS = National Marine Fisheries Service; NPDES = National Pollutant Discharge Elimination System; RWQCB = Regional Water Quality Control Board; USACE = U.S. Army Corps of Engineers; USFWS = U.S. Fish and Wildlife Service

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Memorandum

To: Bill McLaughlin, Senior Engineer, California Department of Water Resources

From: Jennifer Aranda, Senior Project Manager, AECOM

Date: August 22, 2014

Subject: Preliminary Environmental Evaluation of the Columbia Cut Study Site

---

AECOM technical staff conducted a preliminary evaluation of the Columbia Cut study site under consideration for engineering solutions to reduce diversion of emigrating juvenile salmonids to the interior and southern portions of the Sacramento–San Joaquin Delta (Delta), and to reduce salmonid exposure to Central Valley Project and State Water Project export facilities.

METHODS

A preliminary list of potential environmental issues associated with the Columbia Cut study site is presented in Table 1. AECOM evaluated the study site within the boundary that was provided by the California Department of Water Resources (DWR) (Figure 1); site access, staging areas, and materials stockpile areas were not identified outside the site boundary, and therefore were not assessed for potential environmental issues. Potentially significant environmental issues have been identified that would require further evaluation before beginning final project design because they may influence project design, timing, and project construction options. In addition, informal consultation with the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE), Central Valley Regional Water Quality Control Board (RWQCB), and California Department of Fish and Wildlife (CDFW) should occur before final project design. This informal consultation would help identify the in-channel construction period and would help develop mitigation and avoidance measures to minimize short-term construction-related impacts on species protected under the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA).

BIOLOGICAL RESOURCES

The sensitive species included in Table 2 are known to occur in the study site vicinity, and suitable habitat for the species may be present within the study site, based on a review of aerial photography. Special-status fish species are known to occur within the study site and have the potential to be directly affected by project implementation. Furthermore, field surveys would be required for special-status plants because five species of rare plants—Mason’s lilaeopsis, Delta mudwort, wooly rose mallow, Suisun marsh aster, and Delta tule pea—are known to occur along the banks of Columbia Cut within the study site, or in close proximity. Surveys for special-status plants should be timed to coincide with the blooming period (see notes in Table 2) of target species. The preliminary site evaluation suggests that the trees along the waterways provide suitable nest locations for Swainson’s hawk and white-tailed kite, and foraging habitat is present in the agricultural lands surrounding the study site. California black rail also is known to occur on the unnamed island situated between Columbia Cut, Whiskey Slough, and the

Source: AECOM 2014

Figure 1. Location Map

San Joaquin River. Avoidance and minimization measures should be developed for all special-status species that have the potential to occur within the study site, as well as including these measures as “environmental commitments” as part of the project description or as mitigation measures for any potentially significant impacts.

CULTURAL RESOURCES

The study site has not been inventoried for archaeological resources and would need an archaeological survey completed before beginning construction. The levees are more than 50 years old and would require evaluation for inclusion in the National Register of Historic Places and the California Register of Historical Resources.

PERMITS AND AUTHORIZATIONS

Work at the Columbia Cut study site may require permits or authorizations from federal, state, and regional and local agencies with regulatory jurisdiction over the environmental resources that are present (Table 3). USACE 408 permission would be required if the project would affect the McDonald Island levee, which is a USACE project levee. DWR may need a permit (Nationwide or Individual) from USACE under Section 404 of the Clean Water Act (CWA), if project implementation requires placement of dredge and fill materials into waters of the United States. An Individual Permit and CWA Section 404(b)(1) alternatives analysis are required if permanent wetland impacts exceed the 0.5 acre threshold of the Nationwide Permit program. Impacts on waters of the United States may require implementation of mitigation measures. Compliance with Section 106 of the National Historic Preservation Act would be required to obtain a Section 404 permit. Placement of structures in navigable waterways would require authorization from USACE under Section 10 of the Rivers and Harbors Act of 1899.

The 404 permit would provide the federal nexus for an ESA Section 7 consultation. Formal ESA consultation requires up to 135 days for agency review after project design, timing, and avoidance and mitigation measures have been identified. However, USFWS has recently acknowledged achieving the 135-day consultation timeline may no longer be possible for all projects, especially for projects without multi-benefits. As a result, USFWS is prioritizing workload and not all projects will conclude formal ESA consultation within 135 days. High-level discussion with USFWS will be needed to expedite ESA compliance. Consultation with NMFS would also be required because of potential impacts to anadromous fish. Compliance with the National Environmental Policy Act (NEPA) would be required if any federal funding is used by the project.

Water quality certification from the Central Valley RWQCB would be required for compliance with Section 401 of the CWA. This certification would identify project-specific best management practices (BMPs) to minimize project impacts, such as criteria to reduce erosion, sedimentation, and releases of hazardous material. BMPs also would provide criteria for dewatering and construction methods, revegetation, and monitoring requirements. A National Pollutant Discharge Elimination System (NPDES) Construction General Permit for discharges of stormwater associated with the construction activity would be required if total soil disturbance exceeds 1 acre. Soil disturbance typically occurs from access improvements, staging areas, material stockpile areas, and construction areas.

A Lake and Streambed Alteration Agreement (LSAA) would be required from CDFW under Section 1600 et seq. of the California Fish and Game Code, to address potential project-related impacts on the bed, banks, and channel of any natural stream and associated riparian vegetation. Both water quality certification and the LSAA would require evidence of compliance with the California Environmental Quality Act (CEQA) before issuance of permits.

Species protected under CESA could occur within the study site or in the study site vicinity. If the potential exists for the project to result in “take” (i.e., kill) of a special-status species that is protected under CESA, an incidental take permit would be required from CDFW. Typically, avoidance and minimization measures can be implemented before project construction to avoid the direct mortality of species protected under CESA.

Encroachment permits may need to be obtained from the Central Valley Flood Protection Board and Reclamation District No. 2030 and No. 2041. DWR has a Memorandum of Understanding with the California State Lands Commission (CSLC), which became effective on October 19, 1979. DWR is authorized to perform certain types of activities without obtaining a lease from CSLC. The project would need to be evaluated further for compliance with the lease after detailed, project-specific information is available.

The project may require a consistency determination from the Delta Stewardship Council, if the project achieves the criteria of a “covered action” and “will have a significant [positive or negative] impact on the achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta.” The coequal goals are: (1) providing a more reliable water supply for California; and (2) protecting, restoring, and enhancing the Delta ecosystem.

A San Joaquin County grading permit may be required.

If you have any questions about the information or need additional information, please contact me at (916) 414-5858, or by e-mail (jennifer.aranda@aecom.com).

Table 1 Potential Environmental Issues Associated with the Columbia Cut Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Aesthetics	DWR would need to coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage, and would have to remove all equipment, lights, buoys, and signage at the end of the project.
Agriculture and Forestry Resources	Temporary construction-related impacts may occur if agricultural land is used for staging or materials storage. There are no forestry resources on site.
Air Quality	Short-term impacts from construction emissions (from construction equipment and vehicles, or fugitive dust) may require measures to minimize emissions.
Biological Resources	Potentially significant ESA and CESA take issues related to construction activities, including in-channel work and dewatering activities, may occur.
Cultural Resources	The study site has not been inventoried for archaeological or built environment resources. Although potential impacts on cultural resources are unlikely, the project will require an inventory and evaluation by a cultural resources specialist for permitting purposes, including an assessment of the NRHP/CRHR significance of the levees. The study site is not considered to be paleontologically sensitive, and therefore no impacts to this resource would.
Environmental Justice	No issues or impacts have been identified.
Geology and Soils	Short-term construction-related erosion could result in sediment transport from land into Columbia Cut or the adjacent river channels, and short-term water-based construction could increase turbidity in the channel. Mitigation measures will be required to prevent erosion and decrease turbidity. Construction in unstable soils, subsidence, and liquefaction could represent hazards; however, these issues could be addressed during the engineering phase of project design.
Greenhouse Gas Emissions	Short-term construction-related greenhouse gas emissions may occur, but they are not likely to exceed the greenhouse gas thresholds developed by DWR.
Hazards and Hazardous Materials	A potential risk exists for release of hazardous materials (e.g., cement, fuel, or lubricants) associated with the project. DWR should design the project to minimize risk. DWR may be required to implement a hazardous materials management program.

Table 1 Potential Environmental Issues Associated with the Columbia Cut Study Site

Environmental Issue Area	Preliminary Evaluation Findings
Hydrology and Water Quality	Potential short-term impacts on water quality may occur during project construction and operation. Potential changes to water turbidity, stage, and velocity also may occur during project construction and operation. DWR will need to implement avoidance and mitigation measures to protect water quality and monitor turbidity.
Land Use and Planning	No issues or impacts have been identified.
Mineral Resources	No issues or impacts have been identified.
Noise	Short-term construction-related impacts may occur. DWR should limit construction to daytime hours and employ noise-reducing construction practices.
Population and Housing	No issues or impacts have been identified.
Public Health and Safety	Construction activities may temporarily affect public health from the potential release of hazardous materials associated with the project. DWR may be required to implement a hazardous materials management program.
Public Services	No issues or impacts have been identified.
Recreation	Potential short-term impacts may occur on St. Francis Yacht Club on Tinsley Island, and on other nearby marinas, boating, and related recreational activities within the study site, particularly during daytime in summer. DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Transportation and Traffic	Potential short-term navigation impacts may occur; access to the north and south of the study site anticipated to be available. DWR should coordinate with the U.S. Coast Guard on the positioning of any in-water lights, navigational buoys, and signage.
Utilities and Service Systems	No issues or impacts have been identified.
Notes: CESA = California Endangered Species Act; CRHR = California Register of Historical Resources; DWR = California Department of Water Resources; ESA = Endangered Species Act; NRHP = National Register of Historic Places	

Table 2 Potentially Occurring State and Federally Listed Species in the Columbia Cut Study Site Vicinity

Class	Scientific Name	Common Name	Status
Plants	*Hibiscus lasiocarpos* var. *occidentalis*[1, 2]	Wooly rose mallow	CRPR 1B
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	Lilaeopsis masonii[1, 4]	Mason's lilaeopsis	CRPR 1B
	Limosella australis[1, 5]	Delta mudwort	CRPR 2
	Sagittaria sanfordii[6]	Sanford's arrowhead	CRPR 1B
	Symphyotrichum lentum[1, 6]	Suisun marsh aster	CRPR 1B
Invertebrates	*Desmocerus californicus dimorphus*	Valley elderberry longhorn beetle	FT
Fish	*Acipenser medirostris*	Green sturgeon (southern DPS)	FT
	Hypomesus transpacificus[1]	Delta smelt	FT, FX, CE
	Oncorhynchus tshawytscha	Sacramento River winter-run Chinook salmon	FE, FX, CE
	Oncorhynchus tshawytscha	Central Valley spring-run Chinook salmon	FT, FX, CT
	Oncorhynchus mykiss[1]	Central Valley steelhead DPS	FT, FX,
	Pogonichthys macrolepidotus	Sacramento splittail	SSC
	Spirinchus thaleichthys[1]	Longfin smelt	FC, CT, SSC
Amphibians	*Emys marmorata*	Western pond turtle	SSC
Reptiles	*Thamnophis gigas*	Giant garter snake	FT, CT
Birds	*Buteo swainsoni*[1]	Swainson's hawk	CT
	Elanus leucurus	White-tailed kite	FP
	Laterallus jamaicensis coturniculus[1]	California black rail	CT, FP
	Melospiza melodia	Song sparrow "Modesto" population	SSC
Mammals	*Lasiurus blossevillii*	Western red bat	SSC

Table 2 Potentially Occurring State and Federally Listed Species in the Columbia Cut Study Site Vicinity

Notes: DPS = distinct population segment

[1] Known to occur within the study site; [2] Blooming Period: June-September; [3] Blooming Period: May-September; [4] Blooming Period: April-November; [5] Blooming Period: May-August; [6] Blooming Period: May-November

Status Notes:

U.S. Fish and Wildlife Service (USFWS):

FE = Endangered (legally protected)
FT = Listed as threatened under the federal Endangered Species Act
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California Department of Fish and Wildlife (CDFW):

CE = Endangered (legally protected)
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California Native Plant Society:

CRPR 1B = Plant species considered rare or endangered in California and elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)
CRPR 2 = Plant species considered rare or endangered in California but more common elsewhere (protected under the California Environmental Quality Act, but not legally protected under the Endangered Species Act or California Endangered Species Act)

Search Criteria: Database searches were conducted using the USFWS online database, CDFW's California Natural Diversity Database (CNDDB), and California Native Plant Society's (CNPS) Inventory of Rare and Endangered Plants of California to identify sensitive species that could occur in the study site. The database searches included the U.S. Geological Survey (USGS) 7.5-minute quadrangles for the study site (Bouldin Island and Terminous) and the surrounding seven quadrangles: Holt, Isleton, Lodi North, Lodi South, Stockton West, Thorton, and Woodward Island.

Table 3 Environmental Permits Potentially Required for the Columbia Cut Study Site

Jurisdiction	Agency and Permit Type
Federal	USACE 408 permission (if project would affect the McDonald Island levee, a USACE project levee), and USACE 404 Permit, Nationwide Permit (if area affected by dredge and fill activities is less than or equal to 0.5 acre of permanent impacts) or Individual Permit (if permanent impacts exceed 0.5 acre)
	USACE Section 10 Rivers and Harbors Act authorization (if structures are a required component of project design)
	Section 106 compliance with National Historic Preservation Act
	Federal ESA compliance (if federal species and critical habitat are present within the study site); consultation with USFWS and NMFS required
State	RWQCB 401 water quality certification (CEQA compliance required)
	RWQCB NPDES Construction General Permit (if ground disturbance is greater than 1 acre)
	CDFW LSAA (CEQA compliance and CESA compliance required)
	CSLC Lease (the project may be covered under existing MOU)
	Central Valley Flood Protection Board Encroachment Permit
	Delta Stewardship Council Consistency Determination
Regional and Local	Reclamation District No. 2030 and No. 2041 Encroachment Permits
	San Joaquin County Grading Permit (unless the project is exempt)

Notes: CDFW = California Department of Fish and Wildlife; CEQA = California Environmental Quality Act; CESA = California Endangered Species Act; CSLC = California State Lands Commission; ESA = Endangered Species Act; LSAA = Lake or Streambed Alteration Agreement; MOU = Memorandum of Understanding; NMFS = National Marine Fisheries Service; NPDES = National Pollutant Discharge Elimination System; RWQCB = Regional Water Quality Control Board; USACE = U.S. Army Corps of Engineers; USFWS = U.S. Fish and Wildlife Service

APPENDIX D

Hydrodynamics

Memo:	Hydrodynamic Data Collection, Processing, Interpolation, and Analysis in San Joaquin River Junctions at the Head of Old River, Turner and Columbia Cuts in 2013 and 2014
Task Order No.:	ESS-01
Author:	Jon Burau and Paul Stumpner
Dated:	October 23, 2014

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Acknowledgements

The USGS, California Water Science Center collected the sideward-looking Acoustic Doppler Current Profiler (SL-ADCP) data, moving boat discharge measurements, and provided discharge and water level data in the junction region. The California Department of Water Resources (CA-DWR), North Central Region Office provided bathymetry, discharge and water level data at several of their long term sites. CA-DWR, Bay-Delta Office, provided model discharge output from DSM2. The authors are grateful for a number of helpful reviews of initial drafts of this report by DWR staff.

1. INTRODUCTION

This report describes hydrodynamic measurements and entrainment potential at three junctions on the San Joaquin River (SJR) (Figure 1) as a means of evaluating the feasibility of behavioral barriers to reduce entrainment of juvenile salmonids in these junctions into the central delta, where their survival is lower (Holbrook et.al. 2009; 2013 Buchanan et.al., 2013). Hydrodynamic data were collected at: (1) Head of Old River (HOR) in the summer of 2013 (equipment deployed for 113 days); (2) a pilot study at Turner Cut (SJTC) in the summer of 2013 (230 days); (3) Columbia Cut (SJCC) during the winter of 2013-2014 (78 days), and (4) a “full scale” study at SJTC and the summer of 2014 (69 days) (Figure 1). Whereas there are numerous factors involved in siting barriers at junctions to increase population level survival of juvenile salmon; factors such as the local geometry, habitat, and predation rates as well as the spatial and temporal distribution of juvenile salmon in the junction, to name a few, the recommendations in this report are based purely on hydrodynamic arguments using field data collected over a relatively narrow set of hydrologic conditions represented by mostly low San Joaquin River inflows. All of these junctions are strongly tidally influenced and thus a major objective of our experimental design was to capture the tidal timescale dynamics, which would, necessarily include measurements that capture spring/neap cycle variability, a well-known fortnightly period (14 day) oscillation in tidal energy (Conomos et.al., 1979). To capture spring/neap cycle variability, it is necessary to measure several spring/neap cycles, a minimum of 2, the Nyquist frequency based on the fundamental Sampling Theorem (Hamming, 1983; Stearns and David, 1988). For these studies, we met this objective by collecting data for ~8 spring/neap cycles at HOR; ~16 cycles during the pilot SJTC and ~5 cycles during the full study at SJTC; and ~5 cycles at SJCC. Clearly, though, these data collection periods are too short to capture seasonal and multi-year variability in the net flows in these junctions caused primarily by seasonal scale variability in the San Joaquin River inflows and export rates, which would involve multi-year deployments. Nevertheless, even though most of the data collected in this report were made during low San Joaquin River inflows, the conditions measured are appropriate for first cut barrier evaluations because: (1) Columbia and Turner Cuts are strongly tidally affected and thus are only weakly influenced by San Joaquin River inputs and exports, except during extremely high San Joaquin River flows (Figure 2, Figure 3, Figure 4) and (2) increased San Joaquin river flows decrease entrainment potential in these junctions by increasing the ebb tide (e.g. outgoing) or bypass flow relative to the flow entering either Columbia or Turner Cuts. Following the nomenclature used in fish screen evaluations (NMFS, 2008), we define the bypass flow as the amount of water flowing in the main channel past a side channel (Figure 5); in this case the water flowing in the San Joaquin River flowing past Turner, Columbia Cuts and Old River. Therefore, entrainment potential at all three junctions was measured in this study under worse case conditions for entrainment into the central delta (e.g. low flow, drought conditions; more on this later).

1.1 Background

1.1.1 Overview of Hydrodynamics of the San Joaquin River in the Central and South Delta

Very little has been written in the published literature on how San Joaquin River inflows and exports affect the exchange of water between the mainstem San Joaquin and the central delta. Yet this information is particularly relevant in formulating a general understanding of the mechanics of entrainment of juvenile salmonids into the central delta from the San Joaquin River. In this section, we use historical data to get at a "big picture" understanding of San

Joaquin River/central delta exchange and to justify the use of low San Joaquin River conditions as appropriate for behavioral barrier scoping exercises at Columbia and Turner Cuts.

1.1.2 San Joaquin River Junction at Old River

The hydrodynamics at the head of Old River are fundamentally different than at San Joaquin River junctions with either Turner or Columbia Cuts. Because Old River is roughly 20 San Joaquin river miles (32 km) upstream of Turner Cut, it is less tidally dominated and more strongly influenced by San Joaquin River inputs and exports than either Columbia or Turner Cuts. Because of Head of Old River is located at a greater distance from the Bay and the San Joaquin River has a smaller cross section at this junction, the San Joaquin River input can completely "push" reversing tidal conditions downstream of the head of Old River in response to large winter storms, thereby increasing the bypass flow in the San Joaquin relative to the flow into Old River, reducing the entrainment potential there.

1.1.3 San Joaquin River Junctions at Turner and Columbia Cuts

In contrast, the hydrodynamics of the junctions at Turner and Columbia Cuts are dominated by the tides (Figure 2, Figure 3, Figure 4) which allows us to reasonably use data collected during low San Joaquin River inflows to scope behavioral barrier efficacy under moderate/typical wintertime San Joaquin River inflows. To evaluate the influence of moderately high San Joaquin River wintertime inflows on junctions at Turner and Columbia Cuts we looked at historical data, within Turner Cut and on the San Joaquin River at Prisoner's Point (Figure 3) during WY2011, the last time the San Joaquin River inflows were moderately high, at roughly 30,000 cfs. Prisoner's Point is more strongly tidally forced than the San Joaquin River at Turner Cut and Columbia Cut,. However the general response at Turner and Columbia Cut is analogous to Prisoners Point during increased San Joaquin River inflows and exports..

The net flows, at Prisoners Point, show the influence of the San Joaquin River inflows and exports (Figure 3B). We discuss the response at Prisoners point to three events as indicated by the vertical lines. In March, 2011, vertical line (1), the San Joaquin River flows increased from 10k cfs to roughly 30k cfs and pumping was curtailed (Figure 3B). The effect at Prisoner's Point, and by extension to the San Joaquin River at Turner and Columbia Cuts, is a rapid increase in the net flow out of the estuary (positive discharge), although this effect is still order of magnitudes less than the strength of the tides in this region (Figure 3A). The San Joaquin River inflows gradually decrease until around the 1st of July, where exports jump from near zero to 10k cfs with little effect on the net flows at Prisoners Point (red curve in Figure 3B). Remarkably, between the beginning of June and the beginning of August, the San Joaquin River inflows and exports were virtually identical at 10k cfs with corresponding near zero net flows at Prisoners Point – the net flows at this location were in balance. Under these conditions, juvenile salmonids wouldn't be getting any help out of the system from the San Joaquin River at this location. Interestingly, around the first of August, the San Joaquin inflows dropped from 10k cfs to 5k cfs, while exports remained constant at 10k cfs and the net flows at Prisoners Point switched from going toward the bay (positive) to being directed toward the south delta (negative). In other words, the net flows at Prisoners Point would be moving salmon outmigrants into the central/south delta under these conditions. In summary, the mainstem San Joaquin reacts more strongly to changes in San Joaquin River inputs than to exports, yet both influences are relatively weak compared to the tides.

In contrast, the relative influence of San Joaquin River inflows and exports are reversed on side channels to the San Joaquin, where exports have a greater influence at Columbia and Turner Cut, than do the San Joaquin River inputs, as can be seen in Figure 4. For example, the large increase in discharge at Vernalis in late March, condition (1), does increase the flow of water at Turner Cut, but the influence in Turner Cut is much less than on the San Joaquin at Prisoner's Point. Mechanistically, water from large San Joaquin River inflow events is largely moved through the delta by the mainstem, where the side channels convey water through the central delta out to the bay only during the time the inflows on the San Joaquin are ***increasing***, ($^{\partial Q_{SJR}}/_{\partial t} > 0$) as is typical of barotropic (water surface slope) flows; where Q_{SJR} is the discharge in the San Joaquin River at Vernalis, ∂ is the partial derivative, and t is time, Once the Vernalis inflows stop ***increasing*** the flows into Turner Cut fall back to pre-peak levels even though the San Joaquin River inflows remain relatively high at 3k to 2.5k cfs for several weeks. The increase in exports, around the first of June, vertical line (2), immediately increases the net flows into the central delta through Turner Cut whereas the drop in San Joaquin River inflows at the end of July from 10k to 5k cfs (vertical line 3) has virtually no effect on the exchange of water into the Central delta from Turner Cut. We would expect a similar response in Columbia Cut.

In summary, the net flows in the mainstem San Joaquin River are more strongly influenced by changes in Vernalis flows whereas, net exchanges into the Central Delta from Turner and Columbia Cut are more strongly influenced by exports. This makes intuitive sense since exports create a barotropic pressure gradient ***between*** the mainstem San Joaquin River and the south delta export facilities. Whereas, increases in Vernalis flows, create a barotropic pressure gradient across the ***entire delta*** between the south delta and the bay, but, because the mainstem San Joaquin River has the larger conveyance capacity, it takes most of the load during high inflow events on the San Joaquin River compared to Turner and Columbia Cut. Importantly, because the water surface gradient during high San Joaquin River flows is between the south delta and the bay, and specifically not between the San Joaquin and the export facilities, then there is not an increase flow toward the central delta through Columbia and Turner Cut.

To quantify the dominance of the tides on the net flows on the mainstem San Joaquin River and in Turner and Columbia Cuts, we plotted a time series of the net discharge <Q> divided by the tidal range, <Q'>, at Prisoner's Point and at Turner Cut. Figure 4B shows that, except during the high outflow event, the net flows are less than 5 percent of the tidal discharge range at Prisoner's Point. Even during a 30k cfs Vernalis flow, the net flow at Prisoners point is less than 2% of the tidal discharge range. At Turner Cut, the influence of exports and *changes in* the Vernalis flows are greater than on the mainstem San Joaquin River. Still, at low export rates the net flows are less than 1%, during 10k cfs export rates less than 3% and on the order of 4% during the big increase in Vernalis flows from 10k to 30k cfs. Thus, we conclude, given the strength of the tides in this region, the data collected during low flow conditions are sufficient for barrier scoping exercises at Turner and Columbia Cuts.

1.2 Methods: General Approach

In this report, we focus purely on the analysis of water velocity patterns as a means determining (1) the suitability of behavioral barriers in junctions as a means of reducing entrainment in the central delta, and, if suitable, (2) the placement of behavioral barriers within a junction.

The analysis of water velocity patterns as a means of understanding juvenile salmon entrainment has been thoroughly studied in the Walnut Grove region (at the Delta Cross Channel and at Georgiana Slough) and is discussed in detail in Horn and Blake, 2003, Blake and Horn2006; DWR, 2012). In these reports, a conceptual framework is presented that characterizes juvenile salmon entrainment rates in junctions as the interaction between the up-current fish spatial distribution and entrainment zones created by the velocity fields in *the* junction (Figure 5). For the purpose of discussion, entrainment in junctions occurs as a two-step process: (1) processes that occur upstream of the junction, within a Lagrangian frame of reference (e.g. moving with the mean advection), which create the fish entrance distributions in the junction, and (2) processes that occur within a junction, in an Eulerian frame (DWR, 2012 GSNPB report -in review, for a more detailed description). This separation is useful because the processes that govern each of these steps operate at different time and space scales (e.g. within different reference frames). For instance, fish entrance distributions in junctions typically are created at timescales that are much longer than the transit time in the junction and occur over varying distances upstream, depending on the interaction between the tidal forcing and river flows at any given time.

We focus on the junction hydrodynamics only in this report as an initial behavioral barrier scoping exercise – leaving the more difficult and experimentally expensive study of actual entrainment rates, which involve the interaction between the fish entrance distributions and hydrodynamics, for follow-up studies. As we discuss in this report, it is possible to assess the potential that a behavioral barrier will work at a given junction based on an analysis of the hydrodynamics alone. *How well* a behavioral barrier will work will depend on the temporal evolution of the up-current fish spatial distributions in combination with the velocity fields discussed here.

In general, hydrodynamic conditions favor behavioral barriers where the bypass flow is large relative to the flow into the side channel. Or, in terms of junction geometry, behavioral barriers can work if the main channel is much larger (e.g. has a greater channel capacity), than the side channel (Figure 6). These conditions are met for both Turner (Figure 7) and Columbia Cut

(Figure 8), whereas, these conditions are not generally met for Old River (Figure 9). In the next sections, we go beyond these general qualitative geometric observations, which are useful in initial scoping exercises, to develop/discuss quantitative metrics that have the specificity necessary to not only inform initial assessments of behavioral barrier efficacy but also provide the level of detail necessary to begin defining barrier location and design.

1.3 Critical Streakline: Introduction and Relevance

Evidence from past studies on juvenile Chinook salmon entrainment in Georgiana Slough suggest that instantaneous water velocity patterns in the immediate vicinity of the Georgiana Slough junction affect entrainment in Georgiana Slough (Horn and Blake, 2004, 2011 GSNPB report). While it would be ideal to directly measure water velocity patterns within junctions at high spatial and temporal resolution over the full range of conditions that outmigrating salmon are likely to encounter during the outmigration period, typically winter through spring, the costs associated with measuring a junction-scale velocity field on a continuous basis makes this impractical. Instead, side-looking Horizontal Acoustic Doppler Current Profilers (H-ADCPs) were used to make numerous velocity measurements in the junction areas, and a novel interpolation scheme was used to interpolate the surface water velocity fields in the junction at 15 minute intervals for a subset of the 2012 GSNPB study period (GSNPB - Appendix F). The goal of this exercise is to develop techniques to estimate the location of entrainment zones within tidally forced junctions without measuring the full 2D velocity field.

Particles (or drifters, or fish that are minimally behaving) that enter any junction are either transported into side channel or bypass it, as is shown in Figure 5. We can summarize our knowledge about the location of the entrainment zones shown in Figure 5 by defining the location in the river cross section where the two entrainment zones meet. We define the critical streakline as the spatial divide between entrainment zones, expressed as the distance from the side of the river with the side channel, in this case the river left bank. This concept is illustrated in Figure 5, which shows the critical streakline as the location in the main channel that separates the entrainment zone for particles that enter the side channel (red) and the entrainment zone for particles that bypass it (green). This concept is documented in the field by the tracks of surface drifters released by DWR during the 2011 BAFF™ experiment; drifter tracks for downstream flow conditions are given in Figure 10, and for reversing conditions in Figure 11 which show drifter paths diverging in the region around the critical streakline.

The critical streakline concept is a way of collapsing a complex flow field into its essence with regard to fish fates, providing a simple metric for comparing the entrainment potential under a variety of conditions within a junction and between junctions. For example, at any instant in time, the critical streakline reduces the complexity of the entire flow field down to a single Lagrangian trajectory that can be represented simply by the distance from the shore, Xu, to the trajectory's location in the river cross section (Figure 5). The advantages and limitations of various techniques for computing the location of the critical streakline are discussed in detail in appendix F (DWR, GSNPB report), but in general, critical streakline calculations are most informative if detailed velocity measurements, drifter tracks, or fish entrainment data are used to verify the simplified calculations in appendix F.

As we will see, a behavioral barrier will work well if there are a large number of fish within a side channel entrainment zone that is narrow and temporally stable. In other words, a behavioral barrier will work well when there are a large number of fish within the side channel entrainment zone that can be moved a relatively short distance across the streakline to avoid entrainment (Figure 6). Still, for the purposes of this report we ignore the consequences of space and time varying fish spatial distributions and leave this for a more detailed investigation that would include hydrodynamic monitoring AND multidimensional acoustic telemetry, an experiment that would be much more complicated and expensive than simply collecting hydrodynamic data alone.

1.4 Critical Streakline: Computation

In the absence of detailed, junction specific hydrodynamic data, the location of the critical streakline can be estimated using flow station discharge records to compute junction Discharge Ratios which then can then be scaled by the cross-sectional width of the river to produce critical streakline location estimates. Detailed analysis of critical streakline estimates produced using this approach suggests that, in the absence of detailed junction information, it is preferable to use the junction discharge ratios (see below) as a surrogate for entrainment zone location for statistical purposes, rather than scaling these ratios to produce low precision estimates of the critical streakline location (Appendix F in the GSNPB report). For this reason, discharge ratios, described below, provide a better general metric for understanding the effects of tidally forced velocity patterns on juvenile salmon entrainment in junctions because discharge ratios can be computed accurately for all junctions in the Delta using existing flow station data and are comparable between junctions.

1.4.1 Discharge Ratio

The streakline position is extremely useful because it can be used to quantify the degree to which physical processes contribute to entrainment by comparing streakline positions with observed tagged fish spatial distributions. However, streakline positions are site specific and depend on the local bathymetry, and, in the absence of detailed bathymetry and velocity data they collapse to the discharge ratio scaled by the width of the channel (Appendix F in the GSNPB report)), although this estimate will likely be biased towards the bank, which is why we measured the velocity and bathymetry profiles. Thus, if we define the discharge ratio R_U as the proportion of the flow that enters the side channel from the main channel from upstream and R_D as the proportion of the flow that enters the side channel from downstream (Appendix F), we have

$$X_u = W_u \left(\frac{Q_s}{Q_u}\right) = W_u R_u \qquad (3.25)$$

and

$$X_d = -W_d \left(\frac{Q_s}{Q_d}\right) = W_d R_d \qquad (3.26)$$

Where X_u, X_d is the distance from river left of the streakline position when water is entering a side channel from upstream and downstream, respectively.

Many tidally forced junctions in the delta, including Columbia and Turner Cuts, experience a third set of velocity conditions where the flow converges into the side channel from both upstream and downstream. To account for these time periods, we define the discharge ratio under converging flow conditions as R_C, which is identically 1 (or 100%). Defining the discharge ratios in this way suggests a series of six states shown in Figure 12 and Figure 13 that represent all of the conditions that must be considered to correctly compute the discharge ratio in junctions where the tidal currents are reversing.

Since each of the states shown in Figure 12 and Figure 13 are mutually exclusive we define the total discharge ratio as

$$R_Q = R_U + R_C + R_D \qquad (3.27)$$

which varies from zero to one and encompasses all possible flow conditions. Conceptually, R_Q represents the fraction of the total flow entering the junction that enters the side channel of interest, and by extension, R_Q provides a general idea of the size of the side channel's entrainment zone relative to the junction. If R_Q is close to 0, we know that the channel's entrainment zone is small and entrainment probability is low. On the other hand, if R_Q is close to 1 then we know that the channel's entrainment zone covers most of the junction area and that entrainment probability will be near 100%. During times when R_Q varies between these extremes the location of a side channel's entrainment zone relative to the spatial distribution of fish in the junction will determine the overall entrainment probability.

By convention, the component R's are all strictly positive for water entering a side channel (Figure 13), and negative for water exiting a side channel into the main channel (Figure 12). In this way, we account for conditions in which fish may be entrained in a side channel but returns when the flows reverse in the side channel into the main channel.

By maintaining all three of these variables separate from the total discharge ratio (R_Q) we can independently quantify how each of the conditions in Figure 12 and Figure 13 varies throughout the tidal cycle, which is important in understanding what types of fish guidance technologies may work in a given junction. In addition, the total discharge ratio will tell us how each of the flow conditions contribute to the tidally averaged discharge ratio under a variety of hydrologic conditions, especially when the flows from the side channel are reversing. The value of the discharge ratio can then be correlated with entrainment rates to quantify, in a simple way, the effect of flow patterns on entrainment rates.

The streakline concept and its non-dimensional counterpart the discharge ratio, R_Q, are conceptually useful because they focus our attention on only those hydrodynamic/behavioral interactions that are relevant to entrainment, greatly simplifying an extremely complex problem.

One of the seminal observation in this paper is that the only behaviors that lead to a change in fate within a junction are those that lead to a crossing of the critical streakline (Figure 5).

Behaviors that result in fish remaining within each entrainment zone do not ultimately change their fate. Therefore, the farther a fish is away from the critical streakline the more it is “committed” to one channel or the other and thus the greater the effort it would take for fish to change fates – or, the harder it will be for a behavioral barrier to change a fish’s fate.

In the absence of behavior within the junction, we can influence entrainment by either changing the streakline position (X_u), by changing the velocity distribution within the junction, or by changing the entrance fish distribution. Since changing the location of the critical streakline within the junction would require making massive physical changes to channel geometries in the junction area, altering fish entrance distributions is the most practical way to change entrainment in tidally forced junctions, which we discuss next. We first describe hydrodynamic conditions that suggest a behavioral barrier may or may not work, then we explore the hydrodynamic data at Head of Old River and in Columbia and Turner Cuts to see if these conditions are met.

1.5 Location, design and efficacy of behavioral barriers based on hydrodynamics

The critical streakline or discharge ratio is the principal metric we use in evaluating whether a behavioral barrier is likely to work in a given junction and its location. In order for a behavioral barrier to work, it must move fish from within the side channel entrainment zone across the critical streakline. Therefore, the barrier should extend from as near to the side channel bank as is practical and extend into the main channel so that it extends beyond the streakline position. In general, then, a narrow and relatively stable entrainment zone is optimal for a behavioral guidance structure because the distance that fish have to be moved to cross the streakline, Xu, is short and has a consistent position in space (Figure 6). Large and/or inconsistent side channel entrainment zones are undesirable because they require very long (and thus expensive) barriers (Figure 14) to maintain an escape velocity (see section 1.5.1) at the barrier that is less than the swimming capabilities of the fish. Therefore, Floating Fish Guidance Structure (FFGS) manufactured by Worthington Industries and/or so-called non-physical barriers, such as Bio Acoustic Fish Fence (BAFF™), which used sound, light and bubbles to deter fish, will require a long barrier to maintain an acceptable escape velocity when there are large and/or inconsistent side channel entrainment zones. Additionally, depending on the barrier type, a long/large barrier can adversely affect navigation, can increase the hydrodynamic forces on the barrier and large barriers are more likely to be damaged from floating debris that can occur during the outmigration season. For example, even though the BAFF™ is considered a non-physical barrier, it requires a structure in the water column that can limit vessel traffic (e.g. vessels with a deep draft) and is subject to damage from floating debris.

In short, temporal stability of a streakline position relatively close to the side channel shore is the most important metric for recommending a behavioral barrier. If the streakline position is relatively close to shore and stable, then the details of the hydrodynamics in the junction can further inform barrier design.

From a design perspective, the streakline position tells how far out into the main channel the barrier must extend from the side channel bank. Additional design considerations include: (1) the angle a barrier makes with flow direction, (2) barrier length, (3) along-main-channel barrier location and (4) the potential relaxation of fish downstream of the barrier. We take these in turn in the next section.

1.5.1 Barrier Angle

Narrow side channel entrainment zones or high densities of fish near the streakline within the side channel entrainment zone is desirable because the angle of the barrier, α (Figure 6a) relative to the principal velocity direction (usually aligned with the prevailing bathymetry) must be small so that a typical salmon outmigrants has the ability to avoid the barrier given the strong tidal currents that can occur in these junctions.

The angle of the barrier, α, must be small so that the component of the velocity normal to the barrier, the escape velocity, is less than the swimming performance of the typical salmon outmigrant (Figure 15b). And, the alignment of the barrier needs to minimize the hydrodynamic forces on the barrier (Ben Geske, personal communication).

Thus, the angle-to-flow of the river, α, is a critical element of barrier design. The general principle of angled barrier design used in louver screen arrangements requires that water velocity meets the barrier at a small acute angle so that fish need only make a relatively small turn to be guided along the face of the barrier. This arrangement also ensures that fish require a relatively low sustained swimming speed to avoid passing through the barrier (Rainey 1985; Turnpenny and O'Keeffe 2005).

The swimming direction requiring the lowest escape speed is at 90 degrees to the line of the barrier and thus the design of the barrier should ensure that this velocity component is kept below the maximum sustainable swimming speed of the fish over the range of river flows for which the barrier is designed to work. Figure 15 shows the relevant velocity components for an angled fish barrier.

The main channel velocity is the approach velocity, denoted U_a. The velocity perpendicular to the barrier face is the fish's escape velocity, U_e. For a barrier angle α, this is calculated as:

$$U_e = U_a \sin \alpha$$

The sweeping velocity, U_s, is the component parallel to the barrier face. This is used to calculate the time taken for the fish to traverse the screen from any given point, when swimming at velocity U_e. It is calculated as:

$$U_s = U_a \cos \alpha$$

Typical swimming performance of juvenile Chinook salmon was determined by Swanson, Young, and Cech (2004), who reported a sustained swimming speed of 3.4 body lengths per second (BL/s). It should be noted that use of sustained swimming speed provides a margin of safety, as fish can develop significantly higher prolonged and burst speeds for short periods (Beamish 1978).

1.5.2 Barrier Length

The length of the barrier is determined by a combination of (1) the distance the barrier must be out in the main channel to cross the streakline, (2) the barrier angle so that the escape velocity does not exceed the swimming performance requirements, (3) how close the barrier can be to the river bank. Physical conditions, such as obstructions and shallow depths may restrict how close a barrier may be placed near the river bank. Moreover, near-bank fish distributions determined from acoustic telemetry data may suggest the barrier doesn't have to extend completely to the bank.

1.5.3 Barrier Location

The barrier should be located sufficiently upstream of the junction so the streaklines haven't started to bend into the junction increasing the escape velocity (Figure 15; option A) but not so far away that the fish spatial distributions immediately downstream of the barrier shift back towards the side channel (Figure 16).

For instance, the more the streaklines begin to bend the shallower the barrier angle must be relative to the prevailing channel orientation to maintain an acceptable barrier angle, α. The extreme case of a behavioral barrier angle that won't work is the placement of a behavioral barrier within the junction (Figure 15; option C), where all of the streaklines are perpendicular (e.g. α = 90 degrees) to the barrier.

1.5.4 Dispersive mixing – relaxation of fish spatial distributions - due to natural river hydraulics

We can make some generalizations regarding the potential relaxation of fish distributions due to physical mixing, but any statements about relaxation due to fish behavior would be pure speculation at this point. We can quantify the relaxation by equating it to complete cross-sectional mixing, caused primarily by large-scale horizontal turbulent structures (e.g. the surface boils in Figure 16, which at high flows can have horizontal length scales on the order of the depth – roughly 10 m). Cross-section mixing is due to turbulent dispersion and can be quantified by the transverse mixing coefficient (E_t) for natural stream with little curvature and little along channel change in bathymetry given by Fischer et al. 1979 as:

$$E_t = 0.6\, du^*$$

Where d is the channel depth and u^* is the shear velocity due to bottom shear stress. For a barrier that extends about mid-channel the length of channel (L) required for complete cross-sectional mixing can then be described as:

$$L = 0.3\, \bar{u}\, W^2/E_t$$

Where $\bar{u}$ is the averaged cross-sectional velocity, and *W* is the channel width (Fischer et al. 1979). An example of this calculation is at Columbia Cut where a barrier that extends about half the width of the river is recommended (see section 4.2). The variables are d = 8m, $\bar{u}$= 0.3 m/s and W = 140m. The shear velocity was not measured, but typically these are an order of magnitude or less than the mean channel velocity: for this exercise we assume u^*= 0.1 $\bar{u}$. Therefore L required before complete cross channel mixing would be ~ 12 km. Importantly, this estimate of the distance to achieve complete cross-sectional mixing is much longer than the width of Columbia Cut (0.1 km), or the length of proposed barriers and a much greater distance than we would want to place the barrier upstream of the junction. We can also make a general statement about L over a wide range of variables. The calculation of L will be most sensitive to changes in the width to depth ratio (*W/d*) and u^*. Decreasing *W/d* by an order of magnitude or increasing $u^*$by an order of magnitude will decrease L by an order of magnitude to ~ 1.2 km.

This analysis is primarily valid for a riverine environment, where flow is uni-directional. In an estuarine environment L will decrease as the number of tidal cycles increases, due to physical mixing as a result of oscillatory flow. Therefore this analysis would only be valid for the length of a tidal cycle. Generally, on the San Joaquin River the tidal excursions on the order of 6.5 km's (~4 mi) (based on typical peak tidal velocities measured at Prisoners Point of 45 cm/s). We can then safely assume that placing a barrier upstream on the order of 100 m will yield minimal relaxation due to physical mixing, especially when flow divergence at a junction is typically on the order of 10's of meters upstream of a junction. Nonetheless, a reasonable relatively short distance upstream of the junction would be preferable since the relaxation due to fish behavior and the enhanced physical mixing downstream of the barrier due to the barrier is not known.

In summary, the streakline suggests (1) how far the barrier should extend into the main channel and the velocity distribution defines: (2) the barrier angle (Figure 15) and (2) the length of the barrier, and (3) how close the barrier can be positioned in the main channel to the side channel entrance so as to avoid the up-current bending of the streaklines into the side channel) and how far the barrier can be from the side channel based on (4) some unknown combination of physical and behavioral processes downstream of the barrier that control fish distribution "relaxation".

1.5.5 Hydrodynamic conditions that recommend a behavioral barrier

In general, a narrow and relatively stable entrainment zone is optimal for a behavioral guidance structure because the distance that fish have to be moved to cross the streakline is short and has a consistent position in space. Weaker main channel current speeds, up to a point, are also desirable because they can lead to more effective barriers because the barrier angle can be steeper or can have a smaller footprint which would lessen the impact on navigation/boating, reduce hydrodynamic stresses on the barrier and reduce maintenance issues associated with debris. When the tidal velocities fall well below a fish's swimming performance, say around slack water periods, hydrodynamic interactions with a behavioral barrier alone will have a much weaker influence on keeping fish out of side channel entrainment zones.

1.5.6 Hydrodynamic conditions that do not recommend a behavioral barrier

If, for the river inflow/export conditions expected during the outmigration season, the critical streakline is: (a) significantly across the main channel from the side channel (Figure 14a), OR the standard deviation of the position is large (Figure 14b) OR the velocity distributions are converging into the side channel for a significant fraction of the tidal period (Figure 14c), then behavioral barriers are not recommended. In the case of (Figure 14a) and (Figure 14b) the behavioral barrier would be large, extending virtually across the entire main channel, depending, of course, on the fish entrance spatial distribution. Under these conditions a behavioral barrier would be expensive, a possible hazard to navigation/boating, subject to increased stresses on the barrier and at increased risk of damage from floating debris. In the case of (Figure 14c) converging flows, the complete cross section in the main channel from both upstream and downstream the side channel is engaged in supplying water to the side channel. Given that the mainstem San Joaquin River is much larger than either Turner or Columbia Cut, converging flow patterns were only measured < 1% of the time. Converging flow patterns do occur at the Head of Old River for about 17 % of the conditions measured and at most of the upstream junctions in the north delta. A solid barrier that completely blocks the flow under converging conditions is the only solution to reducing entrainment in the side channel under these conditions, since the entire junction is supplying water and fish to the side channel.

We next discuss the hydrodynamic data we collected at Head of Old River and at Turner and Columbia Cuts, to see if the hydrodynamics meet the criteria to recommend a behavioral barrier at these locations. Of course, ultimately the efficacy of the barrier at reducing entrainment will also depend on the fish entrance distributions.

After a discussion of the data we will evaluate the temporal evolution of the streakline position at each of these junctions to determine the suitability of behavioral barriers for keeping salmon outmigrants on the San Joaquin and out of the central delta (Figure 6). It should be recognized, however, that additional studies will be needed to determine if juvenile salmon outmigrants are significantly utilizing the side channel entrainment zone (Figure 6b) by concurrently collecting hydrodynamic measurements and 2D acoustic telemetry data.

2. HYDRODYNAMIC ANALYSIS

Hydrodynamic data were collected primarily from side-looking acoustic Doppler current profilers (SL-ADCP's) and also several up-looking ADCP's. These data provide velocity data used for discharge estimation and two-dimensional (2D) interpolated velocity fields.

Supplementary data sets used for processing, interpolation and analyses are: (1) Bathymetry data collected at HOR on January 6, 2012, and at SJCC and SJTC in May of 2012. These data sets are available from the California Department of Water Resources (CA-DWR), (2) discharge and/or water level data from the following gage stations operated by CA-DWR: Old River at Head (OH1), San Joaquin River at Mossdale (MSD), San Joaquin River near Dos Reis (SJD), and San Joaquin Venice Island (VNI), (3) discharge and stage data from a gage station operated by USGS-CAWSC near SJTC: Tuner Cut near Holt, CA (TRN) and (4) modeled discharge data for each of these junctions from Delta Simulation Model II (DSM2).

2.1 CRITICAL STREAKLINE ESTIMATION

The critical streakline is estimated using two methods (Burau and Stumpner, 2013). The first method (discharge ratio) assumes rectangular cross-section, and no horizontal or vertical velocity variability. The second method (integral method) assumes a fully discretized natural channel with accurate bathymetry and velocity. This calculation is made using equations outlined in Appendix B of Burau and Stumpner (2013). The integral method is more accurate but requires more detailed information. A least square regression between the discharge ratio and integral methods will be presented for each junction. At junctions where longer term flow data exists, at gage station or where applicable model data exists, the discharge ratio method can be corrected using the regression curve to yield more accurate results.

2.1.1 Head of Old River

The critical streakline is estimated upstream and downstream of the HOR junction using the discharge ratio and integral methods. For the discharge ratio method the variables in the calculation are defined as follows (Figure 17): the discharge estimated at HORu is the upstream discharge (Q_u), the flow estimated at HORe is the downstream discharge (Q_d), the discharge estimated at HORs is the side channel discharge (Q_s), the width of the upstream cross-section (W_u) is estimated to be 93 m and the width of the downstream cross-section (W_d) is estimated to be 76 m. For the integral method additional parameters are needed: the cumulative sum of the discharge along the upstream (Qc_u) and downstream (Qc_d) cross-sections.

The tidally filtered time-series of discharge shows net positive discharge into Old River for the entire record (Figure 21a). The net discharge from the upstream location on the San Joaquin is positive and the net discharge from the downstream location is negative (Figure 21a). Water entrainment into Old River is high, about 60% of the water from the San Joaquin enters Old

River, at the net San Joaquin River inflow and export rate during the study period, according to the discharge ratio calculation (Figure 21b). Similarly, the critical streakline at both the upstream and downstream locations is positive into Old River (Figure 21c). These results show that entrainment into Old River from the San Joaquin occurs on both phases of the tide (flood and ebb), and on average about half of the water flowing down the SJR is entrained into Old River.

In terms of managing fish passage at this junction, in order to effectively deter fish entrainment into Old River, barriers would need to be placed at both the upstream and downstream locations. The mean critical streakline at the upstream location is 26.48 m (SD = 36.33 m) using the integral method and 22.35 m (SD = 35.00 m) using the discharge ratio method (Figure 22). The linear correlation between these two methods is good ($R^2 = 0.972$) but there is lots of spread and overall the integral method is biased towards the left bank (Figure 23a). This is a counterintuitive result and given the inaccurate results of the VPM for estimating discharge this is probably not the correct method for evaluating the critical streakline at this location.

The mean critical streakline at the downstream location is 66.32 m (SD = 10.82 m) using the integral method and 59.90 m (SD = 13.95 m) using the discharge ratio method (Figure 22). The discharge ratio method is biased towards the left bank. The non-linear relationship has a low correlation ($R^2 = 0.715$) and there is a lot of spread in the data (Figure 23b). Nonetheless these results show that the majority of water from downstream enters Old River. Given the poor correlation and variability in the streakline results (both upstream and downstream), using the streakline estimate for engineering purposes, such as barrier placement, is not recommended. Nevertheless, the temporal variability and general trends are valid and suggest that the Head of Old River is not an ideal place for soley a non-physical behavioral barrier, for the San Joaquin River inflows and export rates studied, because the streakline takes up the majority of the channel AND significant flow enters Old River from both up and downstream. These conditions would imply moving the fish across half the river using barriers both upstream and downstream in the junction. At higher San Joaquin River inflows, say when the tidal flows are not reversing with the tides into Old River and the export rates are lower relative to the San Joaquin inputs, an upstream behavioral barrier may work.

2.1.2 San Joaquin River near Turner Cut - Pilot study

The discharge ratio and critical streakline are estimated upstream and downstream of the junction of the SJTC using the discharge ratio method. The variables in the calculation are defined as follows (Figure 18): the upstream discharge (Q_u) is based on the index velocity rating at SJTC, the side channel discharge (Q_s) is from the USGS gage station TRN, the downstream discharge is $Q_u + Qs$, the width of the upstream cross-section (W_u) is estimated to be 240 m and the width of the downstream cross-section (W_d) is estimated to be 280 m.

The tidally filtered time-series of discharge shows that for most of the record the net discharge is into TC, and that net negative (into Turner Cur or toward the central delta) discharge is greater during low river discharge (Figure 24a). The mean total ratio of water entering TC is less than 0.10 (Figure 24b). From mid-March to end of June the net discharge into TC is close to zero and therefore the discharge ratio and critical streakline are low (Figure 24b,c). When the net discharge on the SJR (July-October) is reduced the net discharge into TC increases, and the discharge ratio and critical streakline increases. This increase is more pronounced at the downstream location due to greater negative discharges. Still the total discharge ratio is never exceeds 0.3, and the downstream critical streakline never exceeds 100m. This finding is consistent with the bathymetry data that shows deeper water depth on the northwest channel to TC can hold more discharge (Figure 29).

To put these results in the context of fish passage at this junction, the highest entrainment is likely to result from low river discharge and reversing discharge from downstream on the SJR. The critical streakline (upstream and downstream) show that entrainment of water into TC is likely to occur outside the dredged shipping channel on the SJR, which could simplify the placement of diversion barriers. Because the critical streaklines positions are low, or close to the left bank, Turner Cut is a good candidate for a non-physical behavioral barrier placed in the San Joaquin, perhaps both upstream and downstream of the junction.

2.1.3 San Joaquin River near Columbia Cut

The critical streakline is estimated upstream and downstream at SJCC (Figure 19) using the discharge ratio and integral methods. The discharge estimated at CCuu is the upstream discharge (Q_u), the downstream discharge (Q_d) is the combined estimated discharge from CCdd and CCe, the side channel discharge is the combined estimated discharge from CCus and CCds, the width of the upstream cross-section (W_u) is estimated to be 120 m and the width of the downstream cross-section (W_d) is estimated to be 110 m. For the integral method additional parameters are needed: the cumulative sum of the discharge along the upstream (Qc_u) and downstream (Qc_d) cross-sections.

The tidally filtered time-series of discharge at SJCC shows net positive discharge at both the upstream and downstream locations and net negative discharge into the side channel (Figure 25a). The tidally filtered upstream discharge ratio at the upstream location is variable around zero, but generally is below zero (Figure 25b). The tidally filtered downstream ratio is very close to zero, suggesting very little to no flow is entrained from the downstream location (Figure 25b). The mean total discharge ratio is just below zero (-0.02), suggesting that on a tidal timescale there is very little net entrainment into Columbia Cut. The critical streakline shows similar trends at both the upstream and downstream locations with the critical streakline never exceeding 10 m, less than 10 % of the channel width (Figure 25c).

The length of Columbia Cut is shorter than the average tidal excursion therefore entrainment on shorter timescales may be important. The length of Columbia Cut is ~ 2100 m and on a strong ebb time that last ~ 6 hours the average mean channel velocity is ~ 0.12 m/s. This equates to a distance of ~ 2500 m, which is longer than the length of the channel. It is likely that mixing at the junction of Middle River and Columbia Cut would result in some portion of water exiting Columbia Cut into the San Joaquin is different from water that enters.

The most effective barrier solution would therefore minimize entrainment on of the ebb tide into the upstream channel at Columbia Cut (CCus). On an ebb tide ~ 40% of the flow from CCuu enters Columbia Cut. The mean critical streakline is 51.4 m (SD = 23.0 m), using the integral method and 48.8 m (SD = 25.6 m) using the discharge ratio method (Figure 26). The critical streakline calculations are very close between the two methods, but the discharge ratio method biases the streakline towards the left bank. The non-linear relationship between the two methods is very good (R^2 = 0.96) (Figure 27), and the water entrainment has been accurately characterized using the methodology presented for this junction.

2.1.4 San Joaquin River near Turner Cut – Full Study

The critical streakline is estimated upstream and downstream at SJTC (Figure 20) using the discharge ratio and integral methods. The discharge estimated at TCuu is the upstream discharge (Q_u), the downstream discharge (Q_d) is the combined estimated discharge from TCdde and TCddw, the side channel discharge is the combined estimated discharge from TCds and TCus, the width of the upstream cross-section (W_u) is estimated to be 240 m and the width of the downstream cross-section (W_d) is estimated to be 280 m. For the integral method additional parameters are needed: the cumulative sum of the discharge along the upstream (Qc_u) and downstream (Qc_d) cross-sections.

The tidally filtered discharge at SJTC shows a net negative discharge at all three locations (upstream, downstream, and side channel) (Figure 28a). The upstream and downstream discharge ratios are very low, the average combined discharge ratio is 0.05 and never exceeds 0.1 (Figure 28b). Similarity, the critical streakline at the upstream and downstream locations is very close to the left bank (Figure 28c). During the start of the ebb tide a small fraction of flow enters Turner Cut from the San Joaquin, but for most of the ebb tide water is exiting TC into the SJR. During the flood tide is when most of the water is entrained into TC from the downstream location. Timeseries plot of the upstream (TCus) and downstream (TCds) side channels show that more water is conveyed through TCds on the flood tide. Once again this finding is consistent with the bathymetry data that shows deeper water in TCds than TCus (Figure 29).

In terms of fish passage and water entrainment at this junction, several barriers could be placed to divert fish from entrainment into TC. The most effective would be downstream of the downstream side channel (TCddw) to deter fish from entering that channel on the flood tide. The next most effective would be upstream of the upstream side channel (TCuu) to deter fish from entering on the ebb tide.

At the upstream location (TCuu) the mean critical streakline is 16.25 m (SD = 38.70 m) using the integral method and 13.59 m (SD = 38.36 m) using the discharge ratio method (Figure 29). The non-linear relationship between the two methods is good (R^2 = 0.99), with the discharge ratio showing significant bias towards the left bank at lower values (Figure 30a). At the downstream location (TCddw) the mean critical streakline is 82.37 m (SD = 25.89 m) using the integral method and 89.17 m (SD = 22.43 m) using the discharge ratio method (Figure 29). The discharge ratio and integral methods for critical streakline show an interesting non-linear relationship (Figure 30b), but the majority of the flow from TCddw is conveyed down TCds on the flood tide. Therefore, a barrier would probably be most effective that diverted fish from the channel TCddw all together on the flood tide rather than having a barrier that diverted fish from TCds.

2.2 2D VELOCITY INTERPOLATION RESULTS

The results of the 2D velocity interpolation results are presented in this section. In past studies, associated with acoustic telemetry studies, interpolated velocity fields are needed to compare to the fish tracks (Stumpner 2013a). For this study, interpolated velocity fields are presented to: (1) document the water velocities at potential barrier locations (2) assess the feasibility of producing interpolated velocity fields at these locations, which are geometrically complex involving several channels and channel junctions, and (3) to determine where spatial data gaps exist.

The Appendix (Section A3) outlines the interpolation algorithm. The key metric for evaluating the performance of the algorithm is the difference between the flow ratio (Q_r) and particle pathline ratio (P_r). We assume that the distribution of particles in the interpolation is a good representation of the flow fields, because measurements to validate the interpolated velocity fields were not made. Typically, validation measurements would be either DL-ADCP transects taken within most of the domain or sets of drifters released periodically throughout a tidal cycle.

Since these junctions have not been previously studied and validation measurements were not taken, then it is likely that the velocity fields will have errors. Nonetheless, these results can provide insight into the general velocity features as part of a first cut barrier scoping exercise.

2.2.1 Head of Old River

At HOR, the interpolation algorithm was run for the entire domain and data record (Figure 17), except one data gap from 9/12- 9/19. The following parameters were used in the interpolation algorithm: grid spacing of 10m, weighting parameter of 2, and discharge estimation from the *IVM*. Interpolated fields for positive and negative flow conditions are solved with the same parameters.

For this study period, positive and negative flow conditions occur 55 % and 45 % of the time, respectively. Positive flow is defined as flow at the upstream location (HORe). The difference between the Q_r and P_r is less than 10 %, for 96 % of the time for both positive and negative flow conditions. The mean difference between Q_r and P_r is -5.8 % and -3.7 %, for positive and negative flow conditions, respectively (Figure 31).

There appear to be errors in the velocity field near the junction for both positive and negative flow conditions. For both positive and negative flow conditions the divergent flow near the junction of HOR is not well defined (Figure 32, Figure 33). For negative flow conditions the flow hooks around the junction and flows into Old River, but this sharp hook is not well defined (Figure 33). At HOR it was difficult to measure > 50 % of the cross-section at all three measurement locations, due to shallow water depth (3-4 m). We presume the interpolation errors have less to do with the lack of coverage with the SL-ADCP's but more to do with the placement of the SL-ADCP's. Having a SL-ADCP placed right at the junction looking upstream would help to better define the flow divergence right at the junction.

2.2.2 San Joaquin River near Columbia Cut

At SJCC the velocity interpolation only encompasses the domain at junction 1 (Figure 19). From the critical streakline analysis it was shown that entrainment into Columbia Cut is primarily at this junction. The interpolated velocity field can only be made if there is complete data at each of the measurement locations at this junction (CCud, CCus, and CCuu). There are four time periods of data gaps (see Appendix A1, for exact dates). The following parameters are used in the interpolation: grid spacing of 10 m, weighting parameter of 4, and the discharge estimation from the *IVM*. Interpolated velocity fields for positive and negative flow conditions are solved with the same parameters.

For this study period, positive and negative flow conditions occur 50 % of the time. Positive flow is defined as flow greater than zero at the upstream location. The difference between Q_r and P_r is less than 20% for 75 % of the positive flow conditions and 84 % for negative flow conditions. The mean difference between Q_r and P_r is 12.7 % and 7.3 %, for positive and negative flow conditions, respectively (Figure 34).

The greatest errors in the interpolated velocity fields appear to where the flow diverges or converges at the junction. During positive flow conditions, when the flow diverges, there are velocity discontinuities at the point where the velocity vectors diverge into Columbia Cut (Figure 35). During negative flow conditions, when the flow converges, there are a few velocity vectors that are perpendicular to each other (Figure 36). The reason for these discrepancies could be due to the choice of weighting parameter in the interpolation. Since no quantitative comparisons were made the weighting parameter was chosen that yielded the most accurate Q_r and P_r comparison. The velocity field could perhaps be better resolved with an instrument deployed at the point of convergence/divergence of flow. There were no quantitative comparison made, but qualitatively the velocity fields are well resolved.

2.2.3 San Joaquin River near Turner Cut – Full Study

The SJTC junction is complicated because of the size of the domain, and the multiple downstream and side channels, therefore generating interpolated velocity fields is complicated. Some of the assumptions in the interpolation algorithm may be invalid for this analysis. For instance, the distance between the upstream and downstream location is 850 meters, and our sampling average occurs over 900 seconds (15 minutes), therefore for a particle to travel this entire distance over the sampling period the water velocity would need to be 1 m/s. The average cross-sectional velocities were closer to 0.2 - 0.3 m/s, therefore our assumptions in the particle tracking algorithm would be considered invalid. We instrumented all of the channels in the domain, plus several mid-domain instruments to help with the velocity interpolation, for a total of nine instruments. Still there are probably some aspects of the velocity field that were not well resolved. The interpolation algorithm was only run for time periods when there was a complete record from all sites. Velocity interpolations were run from 6/19 – 7/29, aside from data gaps from 6/21 – 6/23 and 6/28 – 6/29 and 7/6 – 7/19. Given the difficulties stated above, we still feel the interpolated velocity fields give a good representation of the velocity fields at this junction for the purposes of and initial barrier siting exercise.

The following parameters are used in the interpolation: grid spacing of 20 m, weighting parameter of 4, and the discharge estimation from the *IVM*. Interpolated velocity fields for positive and negative flow conditions are solved with the same parameters. The velocity data from TCduw was not used in the interpolation. There was a significant phase error with the other velocity profiles, and it could not be determined what the source of the error was, whether it was an instrument biasing or time shift error. For this study period the positive and negative flow occurs 52 % and 48 % of the time, respectively. Positive flow is defined as flow greater than zero at the upstream location. The difference between Q_r and P_r is less than 20% for 75 % of the positive flow conditions and 84 % for negative flow conditions. The mean difference between Q_r and P_r is 12.7 % and 7.3 %, for positive and negative flow conditions, respectively (Figure 37).

The velocity fields appear to be well resolved from a qualitative perspective, with a few exceptions. During positive and negative flow conditions at the upstream junction (TCus) it appear the velocity field is not well-resolved (Figure 38, Figure 39). Near the junction, the velocity vectors are not aligned with the river banks, which is what we would expect. From the streakline analysis, at the TCus junction, we know that the streakline is close to the left bank on both phases of the tide. The interpolated velocity field show the same results. At the downstream locations where the main stem SJ splits between TCdde and TCddw, the diverging flow does not appear to be well represented. This is a very shallow area, and it was not possible to measure velocities in this area. From the streakline analysis we know most of the exchange of water at the downstream junctions occurs between TCddw, therefore it is not critical that the flow divergence between TCdde and TCddw was well resolved.

Based on our results it would be recommended for future studies associated with acoustic telemetry, to focus on instrumenting the upstream and downstream junctions rather than attempting to resolve the velocity fields for the whole domain.

3. COMPARISON OF DELTA SIMULATION MODEL II WITH FIELD DATA

A quantitative comparison of the discharge estimation from measured data and the output from a one-dimensional numerical model - Delta Simulation Model II (DSM2) is compared. These comparisons are needed to assess efficacy of using DSM2 as a management tool for water entrainment in these junctions. DSM2 was developed as a tool to look at macro-scale process (i.e. the whole delta), our efforts focus on micro-scale processes (i.e. junction scale) therefore it is possible that DSM2 results will not work as management tool at these locations. The following are used as comparison tools:

(1) Timeseries plots of instantaneous (15 min.) and tidally averaged data

(2) Linear regression of model vs. measured data

(3) Histogram plot of flood and ebb amplitude errors

(4) Cross-correlation to determine phase errors

Phase lag is determined to occur at the maximum cross-correlation value where a correlation value of one equals a perfect correlation. A positive phase lag indicates that the model lags behind the measured estimation and a negative phase lag indicates the measured estimation behind the model. Measured data is collected on 15 minute time intervals, whereas the modeled data is output on 60 minute time intervals. For phase and amplitude comparisons the modeled data was linearly interpolated onto 15 minute time intervals.

3.1 Head of Old River

The discharge estimation from the *IVM* is used for model comparison. The tidally filtered discharge time-series and linear regression plots show that the model does a reasonable job predicting discharge at HORu and HORe (Figure 40a,c), except during higher river discharge where the model under predicts discharge at HORu. At HORs the model consistently over predicts discharge (Figure 40b). The model under predicts discharge at HORu, as the slope of the linear relationship is over one (Figure 41). There is more spread in the relationship at positive discharge. At HORs the slope of the linear relationship is closer to one but overall the model over predicts discharge (Figure 42). There is a lot of spread in the relationship at lower discharge conditions, but the relation becomes tighter at higher positive or negative discharges. HORe shows the worst relationship between the measured and model data (Figure 43). On average the model over predicts discharge, but there is a lot spread in the data, so a generalized statement is hard to make.

The trends for each tidal phase for the entire data record is shown in Figure 44. As can be seen by the distribution of the amplitude differences for each tidal phase. The mean phase and amplitude errors for positive and negative discharge values are summarized in Table 1. Overall, the model does a fair job of predicting discharge timing at HORu and HORs but amplitude differences are greater. At HORe the amplitude differences are less but timing errors are greater. These errors should be considered when using DSM2 to evaluate junction scale hydrodynamics. Despite these errors, DSM2 could produce similar results for characterizing entrainment into Old River on the tidal timescale.

3.2 San Joaquin River near Turner Cut

Discharge estimation from SJTC using the *IVM* is used for model comparison. During peak positive and negative discharge the model under predicts the measured discharge by a factor of two or three (Figure 45a). Tidally filtered discharge time-series show that overall discharge at SJTC is under predicted by the model, and much of the variations are dampened (Figure 45b).

The mean phase errors are zero (Table 1), but the mean amplitude errors are large for both phases of the tide (Figure 46). The statistical relationship using a linear model is good (R^2 = 0.933) and there is little spread in the data, but the slope of the linear relationship shows that the model under predicts discharge on average by almost a factor or two (Figure 47). At higher positive discharge values the relationship becomes non-linear and differences in discharge are almost a factor of three. The index velocity rating did not coverage the full range of positive discharge values, the highest measured was 350 m^3/s whereas the highest estimated was 790 m^3/s. Still even at lower positive discharge values the model under predicts discharge. For negative discharge values the model under predicts discharge on average by a factor of two (Figure 47). Given the large amplitude errors, overall the model does a poor job of predicting discharge at SJTC

Table 1. Phase and Amplitude Errors in Measured Discharge Estimations compared to Model Estimations at HOR and SJTC

	Site			
	HORu	HORs	HORe	SJTC
Phase lag (hrs.)[1]	0.25	-0.25	-0.50	0.00
Cross-Correlation[2]	0.957	0.952	0.950	0.966
Positive Discharge Mean Amplitude Difference (m^3/sec)[3]	2.63	-9.27	2.13	134.93
Negative Discharge Mean Amplitude Difference (m^3/sec)[4]	-12.10	-7.77	0.42	-125.73

[1] Positive Phase lag indicates model lags behind measured estimation
[2] Cross-correlation value where phase lag occurs
[3] Positive Amplitude Difference indicates model has lower positive value than measured estimation
[4] Positive Amplitude Difference indicates model has lower negative value than measured estimation

4. SUMMARY AND RECOMMENDATIONS

Behavioral barriers have been suggested as one of the tools that we can use to increase population level survival of outmigrating juvenile salmonids throughout the delta (2009 NMFS Biological Opinion RPA IV.1.3, DWR, 2012 GSNPB report -in review). The basic idea is to encourage juvenile salmonids into routes with greater survival or away from those with lower survival by using a behavioral barrier which is designed to minimally effect the flow of water; water that then can be used to meet water quality, export objectives, increasing delta outflow, etc. For behavioral barriers to be useful, however, there needs to be a difference in the contribution a given route has on the total population level survival (e.g. to Chipps Island) versus other routes. The effect on the population level survival of any given route is not simply the survival in that route but rather the product of the survival in that route and the route entrainment probability. Thus, the survival in a given route is not the only variable to consider when evaluating whether a junction should employ a behavioral barrier to increase the population level survival. For example, the survival in a given route may be very low, yet if few fish use that route, the impact of that route on population level survival may be low and the effort associated with installing and maintaining a behavioral barrier may not be worth the cost. Thus, the product of the number of fish that use a given route and their survival in that route is the metric that should be used to assess the extent to which a behavioral barrier will contribute to population level survival. Since behavioral barriers are designed to minimally change the flow of water, their impact is aimed primarily at changing the route entrainment probability at a junction, presumably sending more fish down a higher survival route. Thus, in order for a behavioral barrier to increase population level survival there (1) needs to be a high percentage of fish that use the lower survival route in the absence of a behavioral barrier and (2) there needs to be a higher survival route to divert fish into.

Based on the recent work of (Buchanan et.al., 2013a, Buchanan et.al., 2013b, Buchanan, et.al., in prep.), we can see that survival of juvenile salmon emigrating from the San Joaquin River has been appallingly low in recent years: 5% in 2010 (Figure 48) and 2% in 2011 (Figure 49). This work clearly suggests that there is little difference in population level survival for juvenile salmon between the central delta (through the Old River route) and the mainstem San Joaquin. Thus, a behavioral barrier at Old River will have little to no effect on population level survival, even if it is one hundred percent effective at diverting fish away from the central delta and into the mainstem San Joaquin. In this case, a behavioral barrier will change where salmon die, but die they will, with virtually no difference in the total mortality rate through the delta.

In fact, based on these data, survival is greater for juvenile salmon that take the Old River route in both years (in 2010: S_{OR}=0.07 > S_{SJR}=0.04; and in 2011: S_{OR}==0.04 > S_{SJR}=0.01), most of this increase in survival is apparently due to taking a truck ride from the facilities to the central delta (e.g. salvage) (Buchanan, et.al., in prep.). These data suggest that we should increase entrainment ***into*** Old River over the mainstem San Joaquin to increase survival of juvenile salmon emigrating from the San Joaquin!

Unfortunately, we don't know the fish entrainment rates in Columbia and Turner Cuts with any level of precision because of the low sample size used in studies aimed at this question (DWR, 2014) nor do we have an assessment of the difference in the survival rates between the Turner and Columbia Cut routes versus the mainstem San Joaquin downstream of Columbia Cut.

In addition, the sample sizes in these studies shown in Figure 48 and Figure 49 are pretty low (1022 released in 2010 and 931 released in 2011, over seven releases under different hydrologic conditions) and the historical acoustic telemetry networks were not specifically designed to determine the influence of juvenile salmon taking routes associated with Turner and Columbia Cuts on the total population. Greater sample sizes could be used in future studies and the telemetry network could be changed in the future to assess the influence on population level survival of fish that take Turner and Columbia Cut routes.

Before significant effort is put into designing and constructing behavioral barriers at Turner and Columbia Cuts we must first determine: (1) what the route entrainment probability into these channels is in the absence of a behavioral barrier, and (2) if keeping fish in the mainstem provides a significant improvement in survival over those that enter the central delta through these junctions. If (1) route entrainment probability in either if these Cuts is low, then barriers will not appreciably increase population level survival and (2) if the survival in the mainstem San Joaquin is similar to juvenile salmon taking either Columbia or Turner Cuts, then changing the route entrainment probability in either of these junctions will not change population level survival. Finally, it would be useful to determine what percentage of juvenile salmon that take a "left turn" into Columbia and Turner Cuts: (1) use routes that lead to the pumps or (2) use routes that lead through the central delta toward the bay and how use of these central delta routes are influenced by San Joaquin River flows and export rates.

It is recommended that we understand the contradictory data (e.g. Figure 48 and Figure 49), and perhaps, before significant work occurs on these barriers, we study these junctions to address survival and entrainment rates of fish using these junctions. This would involve a slight modification of the existing 6-year study telemetry network and using a greater sample size.

To be absolutely clear, the data shown in Figure 48 and Figure 49 challenges the long held notion/assumption that survival is significantly less in the central delta than on the mainstem San Joaquin River (2009 NMFS Biological Opinion RPA IV.1.3). Barriers of any kind will not improve the population level survival of juvenile salmon if the assumption that central delta survival is lower than the mainstem San Joaquin is not true.

In short, designing and building multi-million dollar behavioral barriers based on the information we currently have is not recommended.

More generally, however, behavioral barriers are likely to be an effective option in increasing population level survival, if survival on the mainstem San Joaquin were increased through the creation of habitat (e.g. setback levees) and a modification of known predation hot spots, such as the straightening of sharp bends in the river, etc. Unless there is significant improvement of survival in the mainstem San Joaquin versus the central delta pathways, behavioral barriers may not increase population level survival.

The focus of this report, however, is not on whether a change in entrainment rate at Turner, Columbia Cuts and Old River is relevant to population level survival, instead this report is focused on whether behavioral barriers in Turner and Columbia Cuts and at Old River are likely to reduce entrainment of juvenile salmonids into the central delta.

Accordingly, in this report, we discussed a conceptual framework that allows us to evaluate the efficacy of behavioral barriers based on hydrodynamic principles: the entrainment zone and critical streakline. We show that, in the final analysis, the design of behavioral barriers should focus on moving fish out of side channel entrainment zones, across the critical streakline and into the main channel where they will bypass the side channel altogether, thereby avoiding entrainment into low survival pathways. We then discuss a general framework for spatial and temporal variability in streakline position that favor behavioral barriers and those that do not.

In general, hydrodynamic conditions favor behavioral barriers where the bypass flow is large relative to the flow into the side channel. Likely sites for behavioral barriers can easily be determined by looking at junction bathymetry as a first cut. Overall, a narrow and relatively stable entrainment zone is optimal for a behavioral guidance structures because the distance that fish have to be moved to cross the critical streakline is short and has a consistent position in space. From a design perspective, the critical streakline position determines how far a behavioral barrier would need to extend into the main channel from the side channel bank. A combination of fish swimming performance and the maximum velocity under stable streakline conditions determines the angle of the barrier to the main flow and how long the barrier must be. Finally, it is recommended that the along-channel position of the barrier in the main channel relative to the side channel be placed far enough up-current to avoid the bending of the streaklines into the side channel, but not so far up-current that the fish spatial distribution "relaxes" back across the critical streakline toward the side channel. We use the conceptual rubric summarized above to make recommendations based on a detailed examination of the hydrodynamic data collected at San Joaquin River junctions at Columbia and Turner Cut and at the Head of Old River. The details of how the data were collected, how calibrations were made, discussions of data quality, etc, are covered in the appendices.

4.1 Summary of Analysis

At HOR, three SL-ADCP's provided data to evaluate junction scale hydrodynamics with 2D velocity and discharge metrics over a four month period in the summer of 2013. The range of velocities measured were 0 – 0.65 m/s (0 – 2.13 ft/s) and the range of discharges measured were

-69 – 63 m^3/s (-2431 – 2219 ft^3/s). Two different methods, *IVM* and *VPM*, of discharge estimation from field data were compared and the results were encouraging. Based on mass balance metrics the results between methods are comparable. Linear regressions show non-linear patterns during reverse discharge conditions at HORu and HORe. These discrepancies are likely because the SL-ADCP's could only profile < 50 % of the cross-section width. Critical streakline and discharge ratio metrics at HOR show that on average about one-half of the water that flows down the SJR is entrained into Old River, which is consistent with the entrainment rate data for 2010 and 2011 reported by Buchanan et.al. in press, (Figure 48 and Figure 49). During lower discharge conditions (roughly < 30 m^3/s or 1060 ft^3/s) more water is transported into Old River during the flood tide, but as the river discharge increases so too does the portion of water entering on the ebb tide. DSM2 modeled output shows good agreement with all sites at HOR in terms of amplitude and phase errors and linear regressions. DSM2 could be expected to show similar results with regards to entrainment at this junction.

For the SJTC pilot study, one SL-ADCP was used as an index velocity meter to estimate discharge with the *IVM*, over a seven and one-half month period in the spring and summer of 2013. These data and data from TRN were used to evaluate junction hydrodynamics using discharge metrics. Overall entrainment potential into TC is relatively low. When river discharge is lower and the net discharge into TC is reversed, entrainment potential increases. DSM2 modeled output show very large amplitude errors, as much by a factor of two or three, on both tidal phases. Because of this we conclude that DSM2 results should not be used to evaluate entrainment into TC.

At SJCC five SL-ADCP's and two UL-ADCP's provided near surface velocity measurements and discharge estimates using the *IVM* and *VPM* methods for about two months in the winter of

2013-2014. The range of velocities measured were 0 - 0.33 m/s (0 – 1.08 ft/s) and the range of discharges measured were -248 – 236 m^3/s (-8750 – 8313 ft^3/s). The mass balance errors using the *VPM* were a bit higher than the *IVM*, but the correlations between the *IVM* and *VPM* were quite good at all five SL-ADCP sites. Our results show that net flow into Columbia Cut is very small, but considering the length of Columbia Cut is short, a barrier to divert fish into the San Joaquin on the ebb tide could be effective. Just less than half of the water that is conveyed down the San Joaquin River side channel enters Columbia Cut on the ebb tide. Therefore, the barrier would need to extend about half the width of the river to be effective, but large vessels do not use this channel, so this configuration is physically doable.

At SJTC eight SL-ADCP's and one UL-ADCP provided near surface velocity measurements and discharge estimation using the *IVM* and *VPM* methods for about two months in the summer of 2014. The range of velocities measured were 0 - 0.41 m/s (0 – 1.34 ft/s) and the range of discharges measured were -555 – 574 m^3/s (-19609 – 20,279 ft^3/s). The *VPM* over estimated discharge at several sites, but these sites were side channels sites where only about 10 % of the flow was conveyed, therefore there errors in these channels were not detrimental to evaluating junction scale hydrodynamics. The results for this study cover a lower range of San Joaquin River inflow conditions than the pilot study. The net discharge was negative during the period studied and the majority of water entrainment into SJTC occurred on the flood tide. The downstream side channel TCddw conveys the majority of water into Turner Cut, therefore diverting fish from this channel using a non-physical behavioral barrier could be an effective solution. A secondary barrier could be placed upstream of the upstream side channel (TCuu) to divert fish on the ebb tide.

Given the net flow in Turner Cut is roughly one order of magnitude lower than flow on the main stem San Joaquin the critical streakline will be relatively stable in space. Thus, the only way this level of streakline movement would significantly entrain more salmon outmigrants is if there is, on average, a large concentration of outmigrants in this region.

4.2 Barrier Recommendations

Streakline positions based on bulk flows are useful for the statistical purposes of understanding entrainment in mark recapture models (Holbrook et.al. 2009; 2013, Perry et.al., 2010; 2012; 2013) and as a first level behavioral barrier scoping exercise. However, for exact barrier placement, calculating the critical streakline based on the complete velocity field, or at least on a SL-ADCP in combination with the detailed cross sectional bathymetry, is needed.

Based on the methods defined in Section 1.5 and analysis of hydrodynamic data alone, we recommend further scoping of behavioral barriers at Turner and Columbia Cut and not at Head of Old River. We are currently evaluating the data collected during the 2008 and 2009 BAFF experiments at the Head of Old River (Buchanan et.al., 2011; and Bowen and Bark, 2010), to see if our conclusions are consistent with these data, but this analysis is beyond the scope of this report. The criteria we defined for an effective behavior barrier based on hydrodynamics are (1) The small critical streakline is close to the river bank so as to not interfere with channel navigation, and the deviation from the mean is small, (2) the angle at which the barrier is placed relative to the water velocity is small (Table 2) and the length of the barrier to achieve this angle is low, and (3) the time spent under converging flow conditions is negligible.

Design Angle Parameters for a Barrier Capable of Deflecting Juvenile Chinook Salmon	
Attribute	Value

Minimum size of fish		60 mm		
Sustained swimming speed		3.4 BL/s		
Swimming speed (prolonged)		0.204 m/s		
Maximum design channel velocity		0.5 m/s		
Required barrier angle		24 degrees		
		Angle		
Escape velocity	SIN	24	0.41	0.203 m/s
Sweeping velocity	COS	24	0.91	0.457 m/s

Table 2 – Example calculation used to compute a design barrier angle, based on the fish size, sustained swimming speed (Courtesy of Getske, DWR).

For SJCC junction all these criteria are met. Figure 50 illustrates the placement of a behavioral barrier to route fish away from Columbia Cut on the ebb tide. From the streakline analysis the best position for the barrier at CCuu would be over half the width of the channel (Figure 26) and therefore have a higher than practical angle relative to the water velocity or be an extremely long barrier. Therefore a behavioral barrier outside on the main stem San Joaquin (Figure 50; Option 2) could be a more cost effective measure. Data was not collected at this location, but an estimation of discharge for the time period of data collection could be made from existing gage station data.

For the SJTC junction all the criteria are also met. Figure 48 illustrates the placement of behavioral barriers at upstream and downstream locations to minimize entrainment into TC on both phases of the tide (ebb and flood). At the upstream location (Figure 51; positive flow barrier) the barrier would have minimal impact on navigation and would be small angle and relatively short. From the streakline analysis the downstream location in TCddw would need to encompass the entire channel in order to be effective; this would result in either a large angle with repect to the water velocity direction or a long barrier. Therefore our suggestion is to place two barriers on the mainstem San Joaquin in order to route fish away from TCddw and TCus.

At HOR all three criteria are not met, therefore a behavioral barrier alone is not recommended. Both the upstream and downstream critical streaklines are far from the river banks with a large deviations from the mean (Figure 22), therefore the barrier would need to have a large angle or be extremely long. Additionally, about 20 % of the flow observations result in converging flow. In the next section we make recommendations for a future study where a combination of a behavioral barrier and operable gate could be implemented.

4.3 Future Studies

Experimental Operations

The period from January 1, 2011 through January 1, 2012 was a remarkable period for understanding how the south/central delta works from a transport perspective. Exports and the San Joaquin River inputs, when changed, were held steady for greater than month long periods and were changed independently and dramatically in a step function fashion – an experimentalist's dream, because it allowed us to understand the effects of changes of a variety of factors and how they interact. An experimentalist trying to understand the south/central delta and how exports and San Joaquin River inflows affect entrainment of salmonids into the central delta from the mainstem San Joaquin River could not have asked for a better operational regime. Unfortunately, a limited number of flow stations were operational at this time and south/central delta flow conditions could only be inferred from the data on hand. Historically, exports are most often changed simultaneously with changes in San Joaquin inflows, and other factors, to maximize water supplies, which is understandable. Nevertheless, when changes in various factors are made nearly simultaneously, it is virtually impossible to disentangle their individual contributions and how these factors interact. Given the delta is much more completely instrumented now, a great deal could be learned regarding fundamental system response, as was discussed in section 1.1.3, if the water project operators were working with scientists on experimental operations. Experimental operations similar to January 1, 2011 through January 1, 2012 coupled with the instrument configurations given in Figure 53 and Figure 54 , and an additional few acoustic telemetry receivers to the USBR-funded 6-year study, would allow a detailed understanding of the effects of San Joaquin River inflows and exports on the hydrodynamics of entrainment of juvenile salmon at Turner and Columbia Cut, as well as Middle River (Figure 1). Whereas in this report, we were only able to infer what happens on the San Joaquin in the central delta generally, by examining the discharge ratio and streakline positions with instrumentation shown in Figure 55.

4.3.1 Experimental Sequencing

The conceptual framework of the entrainment zone suggests a multistep process for evaluating the efficacy of potential behavioral barriers based on level of effort and expense. Starting with inexpensive scoping steps first:

(1) Evaluate the bathymetry – a large difference in cross sectional area between the main channel (wide and deep) and side channel (narrow and shallow) suggests a behavioral barrier could be effective, at least from a hydrodynamic perspective.

(2) Conduct hydrodynamic experiments to evaluate streakline positions and how they vary with hydrologic conditions (e.g. San Joaquin River flows and exports).

(3) Conduct combined hydrodynamic and multi-dimensional acoustic telemetry experiments - for those junctions that pass steps (1) and (2) make sure: (a) the up-current fish distributions are not on the side opposite the side channel (Figure 6b) and warrant a behavioral barrier in the first place, (b) there are significant numbers of fish within the side channel entrainment zone (Figure 6a). It may well turn out that the side channel entrainment zone is narrow and stable but relatively few fish are in this zone and thus entrainment in this junction is low overall. Even if reach specific survival is low (i.e. within the central delta), a junction that may be well suited for a behavioral barrier base both on hydrodynamics and fish distributions may not be significant to population level survival if survival in each of the routes in a junction are similar and thus remedial actions elsewhere may be a better investment in increasing overall population level survival.

(4) Study actual barrier efficacy - place an operable barrier, which has the ability to be moved into the channel across the critical streakline and back to the near bank region (Similar to GSNPB 2014), in the context of a hydrodynamic/acoustic telemetry study as is shown for Turner and Columbia Cut (Figure 50 and Figure 51).

(5) Study "relaxation" due to physical mixing and fish behavior - a "relaxation" study could be combined with a concurrent acoustic telemetry study. Ideally, this experiment would take place over a stretch of river that is straight with small W/d and a high degree of mixing (i.e. large u^*) in order to minimize the distance required for full channel mixing and hopefully the equipment required to measure relaxation. Accurately quantifying the "relaxation" would also require a 2D acoustic telemetry array to extend at a minimum several 100 meters downstream, and an SL-ADCP recording in high frequency mode (1

ping per second or less) to resolve u^*. We could then determine what the distribution would be due to physical mixing and combine this with the fish distribution data to potentially partition how much relaxation is due to physical mixing and how much is due to fish behavior.

4.3.2 Combining technologies

As we've described, a stable, narrow side channel entrainment zone suggests that a behavioral barrier may work in a given junction. In this report, we searched for a combination of tidal, hydrological conditions and junction geometry that naturally produced such conditions. However, rather than depend on optimal streakline positions to occur naturally, we can envision controlling an operable gate to maintain the optimal streakline position for a given behavioral barrier as is shown schematically (Figure 52). For example, even though the flows are reversing at the Head of Old River, the gate opening could be simply operated on the basis of the discharge ratio (Qsj/Qold ~ 0.5) between the flow in Old River and San Joaquin River, so that the optimal streakline position is maintained (Figure 52). The gate could be closed during converging and reversing conditions, periods where the behavioral barrier shown would not work. Opening the gate during positive flow conditions could potentially reduce specific conductance levels, as fresher water tends to be transported at the end of the ebb tide. This approach may not allow much water to enter Old River during very low flow San Joaquin River flows but it may allow more water to flow into the South Delta than the culverts that are currently placed in the temporary barrier there. Specific operations would have to be explored using numerical modeling under various export rates and San Joaquin River flows to determine the impacts on maintaining water levels and water quality (e.g. electrical conductivity) for agriculture in this region. Using a combination of technologies at this location may work well during non-drought conditions and should be studied with numerical models.

In addition, an operable barrier allows for the possibility of being able to take advantage of fish behavior, such as migrating by night, holding by day behavior.

4.3.3 Understanding the influence of San Joaquin River inflows and exports on the hydrodynamics in Turner and Columbia Cuts

As we described in the introduction of this report, collecting hydrodynamic data during low San Joaquin River inflows as an initial behavioral barrier scoping exercise at Turner and Columbia Cuts is OK. Nevertheless, if we want to understand precisely how the net and tidal flows in these junctions are influenced by San Joaquin River inflows and exports as we did for the San Joaquin River at Prisoners Point (Figure 3 and Figure 4), and within Turner Cut (Figure 2) then the SL-ADCP deployments in Figure 53 and Figure 54 are recommended for periods when exports and the San Joaquin River inflows are high and independently variable. These ADCP deployments will allow us to compare the effect of elevated and variable Vernalis and export flows on both the San Joaquin River upstream of Columbia and Turner Cut as well as within these channels.

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APPENDIX. DATA PROCESSING, DISCHARGE ESTIMATION, AND COMPARISON

A.1 SL-ADCP DATA PROCESSING

The methods for processing SL-ADCP data have been described (Stumpner 2013a) and are briefly summarized here. The processing routines for the SL-ADCP profile data include geo-referencing, objective filtering of biased data, extrapolating velocity vectors in the horizontal and vertical, estimating small data gaps, and merging all data onto a common timestamp. General data processing and 2D velocity interpolation routines were developed in MATLAB. Tables A1-A3 shows the site parameters used to geo-reference the SL-ADCP data.

Table A1. Site Parameters for each SL-ADCP location at HOR and the SJTC pilot study

Site	HORe	HORs	HORu	SJTC
Easting (m)	647149	647211	647412	636911
Northing (m)	4185729	4185878	4185753	4206365
Instrument Heading (°)	349	60	220	20
Blank (m)	1.00	1.00	1.00	1.00
Bin Size (m)	1.33	1.33	1.33	3.33
Number of Bins	27	27	27	27

Three SL-ADCP's were deployed at HOR from July 8 – October 29, 2013 (Figure 17). The data was continuous for sites HORe and HORs. At HORu there was large data gap that could not be estimated from September 12 – September 19, 2014. The SL-ADCP's at HOR were only able to profile approximately 50 % of the cross-section or less, due to the shallow water depth (3-4 m). Previous data collected at HOR (Stumpner 2013b) was under higher discharge conditions (28 – 133 m^3/s or 988 -4693 ft^3/s) and the SL-ADCP profiles covered more of the cross-section. The accuracy of the extrapolated cross-sectional velocity vectors and the accuracy of the interpolated velocity field will be somewhat compromised because less than 50 % of the cross-section was measured.

The data from the SL-ADCP deployed at SJTC (for the pilot study) was continuous from March 12 – October 29, 2013 (Figure 18; Table A1). This instrument was deployed only as an index velocity meter to provide an estimate of discharge.

Table A.2. Site Parameters for SL-ADCP's and UL-ADCP's at SJCC

Site	CCdd	CCds*	CCdu	CCud	CCus	CCuu	CCe*
Easting (m)	631804	631847	631972	632333	632282	632413	632339
Northing (m)	4210894	4210812	4219771	4210259	4210200	4210127	4210675
Instrument Heading (°)	30	N/A	40	80	150	37	N/A
Blank (m)	2.00	N/A	2.00	2.00	2.00	2.00	N/A
Bin Size (m)	3.25	N/A	2.50	3.00	2.10	3.25	N/A
Number of Bins	27	N/A	27	27	27	27	N/A

* UL-ADCP deployment used only to develop index velocity rating

Five SL-ADCP's and two UL-ADCP's were deployed at SJCC from November 14, 2013 – January 22, 2014 at the SJCC (Figure 19; Table A2). The data is continuous at CCud, and CCe. There are data gaps of several days for most sites, as the result of communications cables being severed. The primary cause of this was determined to be an animal, most likely beavers. At CCdd there is one data gap from 12/22/2013- 01/03/2014, at CCdu there is one data gap from 11/29 - 12/06/2013, at CCus there is one data gap from 01/02 - 01/04/2014, at CCuu there are three data gaps from 11/14 – 11/20/2013, 12/02 – 12/06/2013, and 01/09 – 01/11/2014, and at CCds there is one data gap from 11/14 – 11/26/2013. Despite the large number of data gaps there was continuous data at each junction for two of the three sites. The mass balance errors were low enough at each junction that discharge for missing time periods can be reasonably approximated and a time-series of discharge ratio and critical streakline can be estimated for the entire study period. Interpolated velocity fields will be limited to time periods where full data set exists.

Table A.3. Site Parameters for each SL-ADCP location at SJTC.

Site	TCdde	TCddw	TCds	TCdue	TCduw	TCud	TCus	TCuu	TCe*
Easting (m)	636144	635962	636017	636237	636114	636364	636425	636654	636446
Northing (m)	4207188	4206992	4206792	4207061	4206831	4206698	4206479	4206515	4207104
Instrument Heading (°)	235	207	300	237	32	35	312	29	N/A
Blank (m)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	N/A
Bin Size (m)	2.50	1.60	1.25	2.50	1.00	4.00	1.00	2.50	N/A
Number of Bins	50	50	50	50	50	50	50	50	N/A

* UL-ADCP deployment used only to develop index velocity rating

Eight SL-ADCP's and one UL-ADCP were deployed from May 12 – July 29, 2014 at SJTC (Figure 20; Table 3). The data set at SJTC was only continuous at TCdde, TCddw, and TCdde. There are at least several day gaps at the remaining sites. The primary cause of data gaps is vegetation growth in front of the instruments that caused acoustic beam interference. The data gap periods are as follows: TCds there are two data gaps from 5/12 – 6/17/2014 and 6/21 – 6/23/2014; at TCud there is one data gap from 5/18 – 6/19/2014; at TCus there are two data gaps from 6/3 – 6/19/2014 and 7/6 – 7/17/2014; at TCuu there is one data gap from 5/12 – 5/30/2014. The UL-ADCP at TCe only provided data until the end of March due to battery issues. Calibration measurements taken on 7/21/2014 show that this channel conveys about 5 % of the water that flows down the San Joaquin, so the loss of this data set is not crucial. The large data gaps do not prevent assessment of junction scale entrainment for this time period. The low mass balance errors allow discharge to be accurately estimated for sites with large data gaps. The interpolated velocity fields will be limited to time periods when full data series exist.

A.2 UL-ADCP DATA PROCESSING

Two UL-ADCP's were deployed at SJCC and one at SJTC (Full Study). These instruments record data internally and are powered by a battery pack attached to the frame. Once the instrument is recovered at the end of the study period, then the data can be downloaded and processed. Data processing routines were developed in MATLAB. The primary purpose of the UL-ADCP was to record an index velocity, the data processing was minimal.

The UL-ADCP data is recorded in earth coordinate system, since the instrument has an internal compass. The principle flow directions (i.e. flood and ebb) were determined from histogram plots of the entire data record. After this the data is rotated into an along-stream (x-component) and cross-stream (y-component) coordinate system. For the index velocity regression only the x-component of velocity is used. The tidal variation at these study sites is on the order of one to two meters, therefore the number of bins used to calculate the index velocity will vary. The water surface is determined by finding a spike in the intensity signal, every velocity value that is recorded above this is discarded for the mean velocity calculation.

A.3 2D VELOCITY INTERPOLATION

A Lagrangian particle tracking and inverse path-length weighting (IPLW) interpolation algorithms was implemented to interpolate the 2D velocity fields at the HOR, SJCC and SJTC junctions (Stumpner 2013a , Stumpner 2013b). An initial velocity field is generated using inverse distance weighted grid interpolation. Pathlines are then generated in this velocity field. For pathlines that cross measurement locations, the velocity magnitude and direction are interpolated along these pathlines using an inverse path-length weighting (IPLW) function:

$$U(x) = \frac{\sum_{i=0}^{N} w_i(x) u_i}{\sum_{i=0}^{N} w_i(x)} \quad (1) \qquad w_i(x) = \frac{1}{d(x,x_i)^P} \quad (2)$$

Where *U(x)* is the interpolated velocity at point *x*, u_i is a known velocity at point *i*, at a distance *d* from the interpolated point *x*. The number of points *(N)* used in the interpolation are weighted by the inverse distance from the interpolated point, by the weighting parameter (w_i), which can adjusted by the power parameter *(P)*.

The number of pathlines that cross each measurement location are counted and if the ratio of particles (P_r) in two river branches is within 10 % of the discharge ratio (Q_r) then the algorithm converges. If P_r - Q_r > 10% then the pathline generation and IPLW interpolation is repeated, until the convergence criteria is met or the maximum number of iterations is reached.

A.3.1 Boundary Conditions and Interpolation Parameters

The boundary conditions and parameters are needed for the interpolation algorithm. The first boundary condition needed is the location of the river banks, which are determined from the bathymetry. At the river banks the velocity is assumed to be zero, following the no-slip condition. For the 2D interpolation only the surface velocity vectors are used. The surface velocity vectors are defined as the average velocity 0-2m below the water surface. These velocity vectors are time variable as the water surface elevation (WSE) changes. Several variables are unique to each junction, the weighting parameter (*P*) from equation 2, the distance between each grid node, and the discharge estimation either from the *IVM* or *VPM*. The discharge estimation is used to for the convergence criteria. The maximum number of iterations before the solution converges was set to 5 based on previous work (Stumpner, 2013a).

A.4 DISCHARGE MEASUREMENT, ESTIMATION AND COMPARISON

Discharge was computed with two methods, the index velocity method *(IVM)* and the velocity profile method *(VPM)*. The *IVM* is a well-established technique for computing discharge (Ruhl and Simpson 2005; Levesque and Oberg 2012). In this case, the *VPM* was used to improve the accuracy of the critical streakline, since biased estimates can result using discharge from the *IVM*. The methodology from the *VPM* is outlined in Burau and Stumper (2013). Because the *VPM* approach relies on direct numerical integration of the velocity profile the calculated discharge is free of calibration errors but the accuracy of the VPM is sensitive to accuracy of extrapolation of the velocity profile in the vertical and the unmeasured portion of the cross section in the cross channel direction (Le Coz, Pierrefeu et al. 2008). The *VPM* is not a well-established method for computing discharge. To validate this approach we compared discharge computed using both methods.

Moving boat measurements were made with a down-looking (DL) ADCP at each site to develop index velocity and stage-area ratings to compute a discharge time-series using the *IVM*. The DL-ADCP discharge measurement produces a cross-sectional average velocity and area. A linear regression with the cross-sectional velocity and averaged SL-ADCP velocity is made to determine the index velocity rating. The stage area rating is developed based on a DL-ADCP measurement that is fairly straight during high tide on the measurement day. The bathymetry from that measurement is imported into AreaComp (http://hydroacoustics.usgs.gov/indexvelocity/AreaComp.shtml). A quadratic stage-area rating is developed for the range of stage measurements from the SL-ADCP. A time series of index velocity *(V)* and cross-sectional area *(A)* is computed with the SL-ADCP data, and the product of these two produce an estimated discharge ($Q = A \cdot V$).

In this section we examine the accuracy of the *VPM* as compared to the *IVM*. The metrics that we used for a discharge comparison are:

(1) Mass balance from the three river branches

(2) Least squared regression

For the mass balance metric we compared the tidally averaged data to average out possible large errors that may have occurred in low discharge conditions and potential ebb/flood bias. The mass balance is determined from six idealized discharge conditions (Burau and Stumpner, 2013; Fig. A1). At a junction the sum of the discharges is equal to the change in storage within the junction, or $\sum_{i=1}^{I} Q_i = \Delta S$. Because these junctions are small and the water levels change over a period of roughly 12 hours, the incremental change in storage within the junctions on the 15 minute sampling interval is negligible, so we assume the change in storage is zero, or $\sum_{i=1}^{I} Q_i = 0$. For each discharge scenario the sum of two channels (Q_2) should equal the one channel (Q_1) that is either receiving the discharge or distributing the discharge to the other two channels**.** Least squared regressions are run between the two methods to test the accuracy of *VPM* with the more accepted method *IVM.*

A.4.1 Head of Old River

Due to instrument problems encountered at the start of data collection, DL-ADCP measurements taken to calibrate the SL-ADCP's using the index velocity method (*IVM*) could not be made at the Head of Old River. Therefore, DL-ADCP measurements at the instrument locations (HORe, HORs, and HORu) were linearly fit to estimated discharge data from long-term gages near the project site, DWR stations OH1, SJD, and MSD, respectively (Figure A56,Figure A57,Figure A58).

The discharge at HORu was estimated with a linear regression with San Joaquin River at Mossdale (MSD) approximately 4.5 km upstream of the site, with a 40 minute time offset applied to account for this distance. The time shift was determined by the best R^2 value over a range of time shifts. A non-linear regression (2^{nd} order polynomial) showed a better statistical correlation ($R^2 = 0.993$) than the linear regression (R^2=0.978), but the non-linear relationship did a poor job in predicting negative discharges that were outside of the rating, therefore the linear regression was used to estimate a time-series of discharge (Figure A56).

The discharge at HORe was estimated with a linear regression with Old River at Head (OH1) approximately 0.25 km downstream of the site, with no time offset applied. The linear regression showed a good fit (R^2=0.97), and close to a 1:1 relationship with OH1 (Figure A57), therefore there is greater confidence in extrapolating outside of the rating limit.

The discharge at HORs was estimated with a linear regression with San Joaquin near Dos Reis (SJD) approximately 3 km downstream of the site, with a 10 minute offset applied to account for this distance. The linear regression showed an excellent fit (R^2=0.996). The relationship was not exactly 1:1, but the goodness of fit and the lack of spread from the regression line improves the confidence in this rating (Figure A58).

The mass balance errors between the *IVM* and *VPM* for discharge estimation compare favorably (see Table A4). The mean differences in mass balance calculations for both methods is ~15% indicating the neither method did a great job of accurately estimating junction-wide discharge at this location.

Table A4. Tidally averaged error statistics for mass balance calculations at HOR

Method	Mean Square Error[1] (m^3/s)	Standard Deviation (m^3/s)	Mean Difference[1] (%)	Standard Deviation (%)
IVM	4.94	2.53	13.59	6.53
VPM	-4.11	3.65	-15.34	12.41

[1] Positive values indicate $Q_1 > Q_2$ and Negative values indicate $Q_1 < Q_2$

At HORu, the *VPM* adequately compares to the *IVM*, but there is a lot of spread at low and reversing discharge conditions. Overall, the *VPM* is not a good predictor of discharge computed with the *IVM* at this location (Figure A59). At HORs, the *VPM* compares favorably to the *IVM*, although the *VPM* under predicts at higher positive discharge and slightly under predicts during reversing conditions (Figure A60). At HORe, the *VPM* compares favorably to the *IVM*, although there is a lot of spread in the relationship and reversing discharge conditions the *VPM* under predicts the *IVM* and the relationship is non-linear (Figure A61).

The main reason for the discrepancies between the *VPM* and the *IVM* are believed to be horizontal extrapolation errors, and the reasons are two-fold. First, the complexity of the discharge at HOR and the fact that the measurement sites are close to a river junction most likely resulted in ebb-flood asymmetry in the cross-sectional velocity distribution. Anecdotal evidence from field observations during reversing discharge conditions at HORu shows stronger water velocities on the left bank. Second, at HORs and HORu <50% of the cross-section was measured and at HORu ~50% of the cross-section was measured which makes accurate extrapolations difficult, especially with asymmetrical cross channel velocity profiles.

A.4.2 San Joaquin River near Turner Cut - Pilot study

The *IVM* was used to derive a discharge time-series estimate at SJTC, based on DL-ADCP measurements on May 24, 2013. The linear regression was made with bins 1-14 (out of 27) from the SL-ADCP, as a regression including all bins showed a looping effect. The linear regression showed good correlation (R^2=0.99) with the measured velocity from discharge measurements, although some scatter exists at velocities near zero (Figure A62). The measured discharge only covered a range of values from -570 - 350 m^3/s, and the range of discharge estimated is from -655 - 790 m^3/s. There is a considerable range at the high end of the positive discharge that is not covered by the index rating. Nonetheless the *IVM* provides a good estimate of discharge for the measured range at the site. Discharge data from Turner Cut was available from a USGS gage station.

A.4.3 San Joaquin River near Columbia Cut

The IVM was used to derive discharge time-series estimates at all seven of the sites at SJCC, based on DL-ADCP measurements on January 14 and 16, 2014.

The index velocity rating at CCdd was made with a linear regression of all bins (1-27) from the SL-ADCP. The linear regression showed an excellent correlation (R^2 = 0.995) and a near 1:1 ration with the measured velocity, with the highest scatter in the lower velocities (Figure A63). The stage area rating was developed with the DL-ADCP transect taken at 16:55 on January 16, 2014. The stage area rating is: $Area = 2.5 * stage^2 + 131.8 * stage + 411$.

The index velocity rating at CCds was made with a linear regression from UL-ADCP averaged velocity with the number of bins used ranging from six to twelve. The linear regression is not great (R^2=0.923) with a lot of spread in the data (Figure A64). The stage area rating was developed with the DL-ADCP transect taken at 15:40 on January 16, 2014. The stage area rating is: $Area = 11.07 * stage^2 + 84.9 * stage + 92$. Observations during the DL-ADCP measurements and initial deployment of the UL-ADCP revealed that there is a lot of vegetation in this channel, therefore discharge and velocity measurements are difficult since the vegetation interferes with the acoustic beams on the boat mounted DL-ADCP. The flow at this site is one order of magnitude less than the adjacent channel, therefore extremely accurate flow measurement are not needed to evaluate junction hydrodynamic features.

The index velocity rating at CCdu was made with a linear regression of bins (1-20) from the SL-ADCP. The linear regressions shows a good correlation ($R^2 = 0.994$), a near 1:1 ratio with the measured velocity and the highest scatter in the lower velocities (Figure A65). The stage area rating was developed with the DL-ADCP transect taken at 16:35 on January 16, 2014. The stage area rating is $Area = 5.9 * stage^2 + 100.7 * stage + 351$.

The index velocity rating at CCe was made with a linear regression from UL-ADCP averaged velocity with the number of bins used ranging from nine to thirteen. The linear regression shows a good correlation (R^2=0.978), but some spread in the data (Figure A66). The stage area rating was developed with the DL-ADCP transect taken at 15:40 on January 16, 2014. The stage area rating is: $Area = 11.5 * stage^2 + 75.8 * stage + 65$. Observations during the DL-ADCP measurements and initial deployment of the UL-ADCP revealed that there some vegetation in this channel, complicating the accuracy of velocity and discharge measurements. The flow at this site is about a factor of five less than the adjacent channel.

The index velocity rating at CCud was made with a linear regression from bins (1-20) from the SL-ADCP. The linear regression shows a good correlation (R^2=0.995) with the measured velocity with a little scatter at the positive peak velocities (Figure A67). The stage area rating was developed with the DL-ADCP transect taken at 15:10 on January 14, 2014. The stage area rating is $Area = 4.6 * stage^2 + 104.0 * stage + 151.4$.

The index velocity rating at CCus was made with a linear regression from all bins (1-27) from the SL-ADCP. The linear regression shows a good correlation (R^2=0.971) with the measured velocity, although it is the weakest of the all the ratings and statistically there is more scatter in the data (Figure A68). During DL-ADCP measurements an eddy on the right bank was noted, that could be contributing to the error in the index velocity rating, since the SL-ADCP could not measure the full cross-section. The stage area rating was developed with the DL-ADCP transect taken at 11:15 on January 14, 2014. The stage area rating is $Area = 1.4 * stage^2 + 81.8 * stage + 249$.

The index velocity rating at CCuu was made with a linear regression from all bins (1-27) from the SL-ADCP. The linear regression shows a good correlation (R^2=0.989) with the measured velocity, although it is not as strong as the other sites and statistically there is more scatter in the data (Figure A69). The stage area rating was developed with the DL-ADCP transect taken at 13:55 on January 14, 2014. The stage area rating is $Area = 4.4 * stage^2 + 126.2 * stage + 623.1$.

Mass balance errors are examined for the three river junctions as defined in Figure 3. Based on mass balance calculations the *IVM* is a more accurate estimate of discharge at junctions 1 and 2 and the *IVM* and *VPM* are equally accurate at junction 3.

Least square regressions between the *IVM* and *VPM* are made for the five sites with SL-ADCP's. For all five sites the IVM and VPM discharge estimations correlate well with $R^2 \geq 0.994$. At CCdd the VPM under predicts discharge calculated by the IVM for positive and negative discharge values (Figure A70). This under prediction is greater at CCdu (Figure A71). At CCud the VPM and IVM follow nearly a 1:1 ratio, except during higher positive discharge the VPM slightly over predicts discharge (Figure A72). At CCus the 1:1 relationship is very good and little spread except during negative discharge conditions (Figure A73). At CCuu there 1:1 relationship is good, but more spread in the data and the VPM under predicts slightly at negative discharge values (Figure A74). Overall the VPM does a good job at predicting discharge as calculated by the IVM at all sites.

Table A5. Tidally averaged error statistics for mass balance calculations at Columbia Cut

Junction	Method	Mean Square Error (m^3/s)	Standard Deviation (m^3/s)	Mean Difference (%)	Standard Deviation (%)
J1	IVM	9.55	1.96	7.99	1.72
	VPM	17.95	2.48	-17.38	2.95
J2	IVM	8.58	1.04	-10.19	1.20
	VPM	14.21	3.57	-19.56	5.76
J3	IVM	5.41	1.06	5.24	0.97
	VPM	4.09	1.79	-4.95	2.24

A.4.4 San Joaquin at Turner Cut – Full Study

The IVM was used to derive discharge time-series estimates at six sites at SJTC, based on DL-ADCP measurements on July 21, 2014.

The index velocity rating at TCdde was made with a linear regression of bins (1-37) from the SL-ADCP. The linear regression showed good correlation (R^2 = 0.984) but a looping effect is apparent during positive flow conditions (Figure A75). The stage area rating was developed with the DL-ADCP transect taken at 16:42 on July 21, 2014. The stage area rating is: $Area = 5.0 * stage^2 + 163.7 * stage + 1183$. Observations of the DL-ADCP measurements show that several of the measurements that fall off the index rating curve (Figure A75) have higher velocities near the bottom of the river than near the surface. This could possible explain the looping effect since the SL-ADCP was positioned to measure near surface water currents.

The index velocity rating at TCddw was made with a linear regression of bins (1-45) from the SL-ADCP. The linear regression showed good correlation ($R^2 = 0.971$) but there is scatter at both positive and negative values (Figure A76). There are eddies that form on either side of the channel during flood and ebb tides. It is possible that the SL-ADCP is not capturing the full extent of these eddies and therefore the index velocity rating could be biased during these conditions. The stage area rating was developed with the DL-ADCP transect taken at 15:59 on July 21, 2014. The stage area rating is: $Area = 2.95 * stage^2 + 89.92 * stage + 361.13$.

The index velocity rating at TCds was made with a linear regression of bins (4-40) from the SL-ADCP. The DL-ADCP measurements were taken 140 m upstream of the SL-ADCP, therefore the DL-ADCP measurements were shifted by 6 minutes to account for the travel time. The linear regression showed good correlation ($R^2 = 0.971$) but there is a fair amount of scatter throughout the rating curve (Figure A77). The stage area rating was developed with the DL-ADCP transect taken at 15:59 on July 21, 2014. The stage area rating is: $Area = 4.17 * stage^2 + 63.31 * stage + 188.35$.

The index velocity rating at TCus is made with a linear regression of bins (1-35) from the SL-ADCP. The linear regression shows an excellent correlation ($R^2 = 0.993$) and there is minimal scatter and no looping effects (Figure A78). The stage area rating was developed with the DL-ADCP transect taken at 17:05 on July 21, 2014. The stage area rating is: $Area = 2.14 * stage^2 + 50.85 * stage + 89$.

The index velocity rating at TCuu was made with a linear regression of bins (1-40) from the SL-ADCP. The linear regression showed good correlation (R^2 = 0.980) but the index velocity over estimates at higher positive values and under estimates at higher negative values (Figure A79). A non-linear relationship was a better predictor of measured discharge for this day, but there was enough velocity outside the range of calibration that we felt it was a poor choice for predicting discharge for the entire record. The stage area rating was developed with the DL-ADCP transect taken at 13:35 on July 21, 2014. The stage area rating is: $Area = 7.72 * stage^2 + 199.44 * stage + 1288$.

Mass balance errors for both the *IVM* and *VPM* are good, with the *IVM* showing slightly larger mean errors but the standard deviation is less (Table A6). For this junction both methods provide reliable discharge predictions using the mass balance metric.

Table A6. Tidally averaged error statistics for mass balance calculations at Turner Cut

Method	Mean Square Error[1] (m^3/s)	Standard Deviation (m^3/s)	Mean Difference[1] (%)	Standard Deviation (%)
IVM	-16.90	6.19	-5.48	1.97
VPM	9.12	14.26	2.61	4.21

Least square regressions between the *IVM* and *VPM* for discharge estimation are made for the five sites with SL-ADCP's that had index velocity ratings. For all five sites the *IVM* and *VPM* discharge estimations have good correlations with $R^2 \geq 0.94$. At TCdde the *VPM* follows nearly a 1:1 relationship with the *IVM*, except at higher negative discharge values (Figure A80). The *VPM* over predicts the discharge for these conditions. At TCddw there is quite a bit of scatter for positive discharge conditions, and at negative discharge conditions the *VPM* over predicts discharge by a factor of two at higher negative values (Figure A81). At TCds the *VPM* over predicts discharge for the entire range (Figure A82). At TCus the *VPM* over predicts discharge for the entire range (Figure A83), but the relationship is very good with very little scatter. At TCuu the *VPM* shows a nearly 1:1 relationship with the *IVM*, with a bit more scatter at higher negative discharge (Figure A84), but overall the relationship is very good.

The *VPM* does a good job predicting flow at the sites in the main channel, TCdde and TCuu. The *VPM* is not as reliable a predictor of discharge at the side channel sites, TCds, TCddw, and TCus. The magnitude of discharge is one order of magnitude lower in the side channel sites, therefore using the *VPM* estimate of discharge should provide acceptable results for water entrainment at this junction. Given the good statistical correlation between the IVM and VPM, as well as the low error in the mass balance at the junction, sites with large periods of missing data can be reasonably estimated.

FIGURES

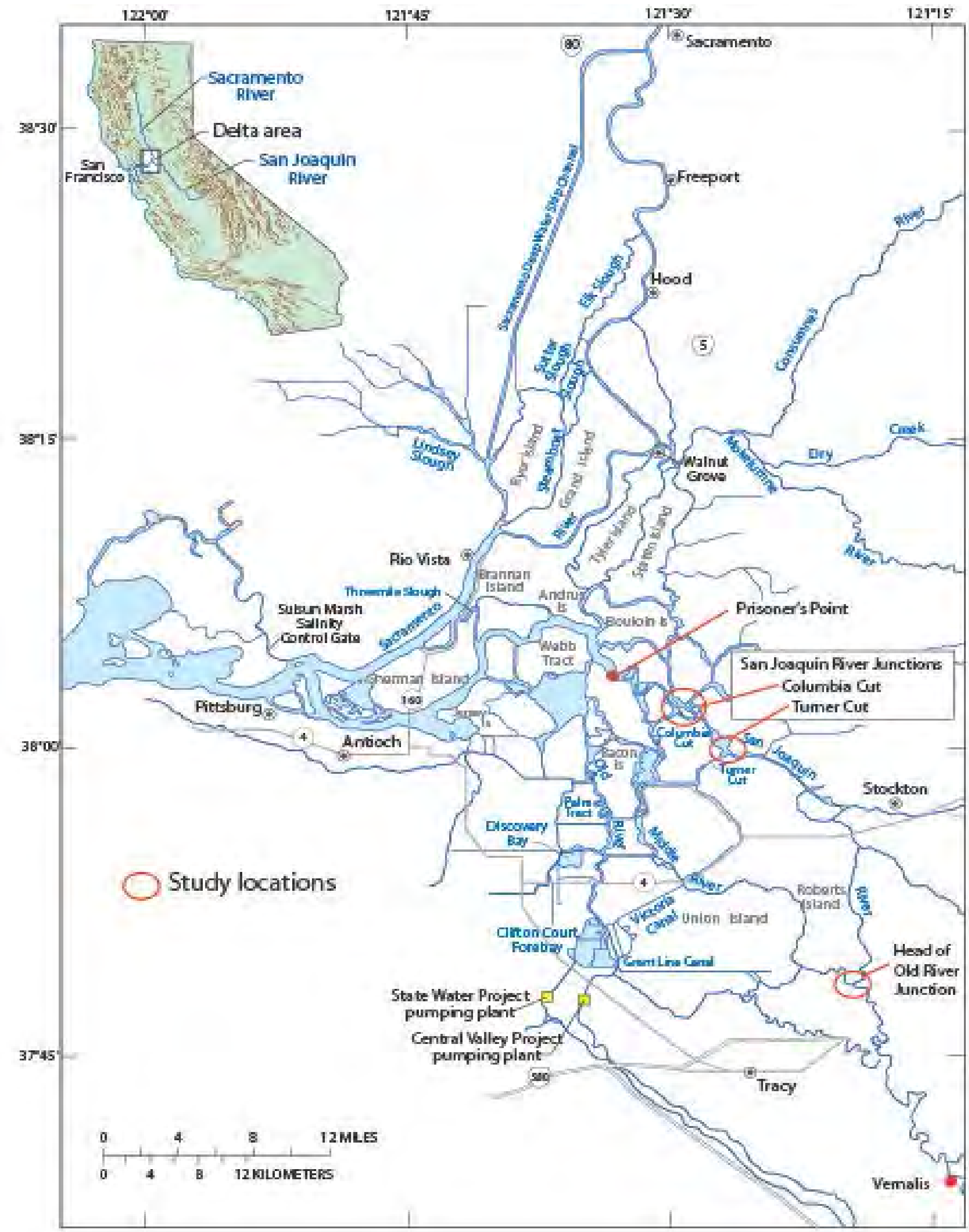


Figure 1. Map of the Sacramento/San Joaquin Delta with the locations of junctions studied for this report. Study locations are indicated by red circles.

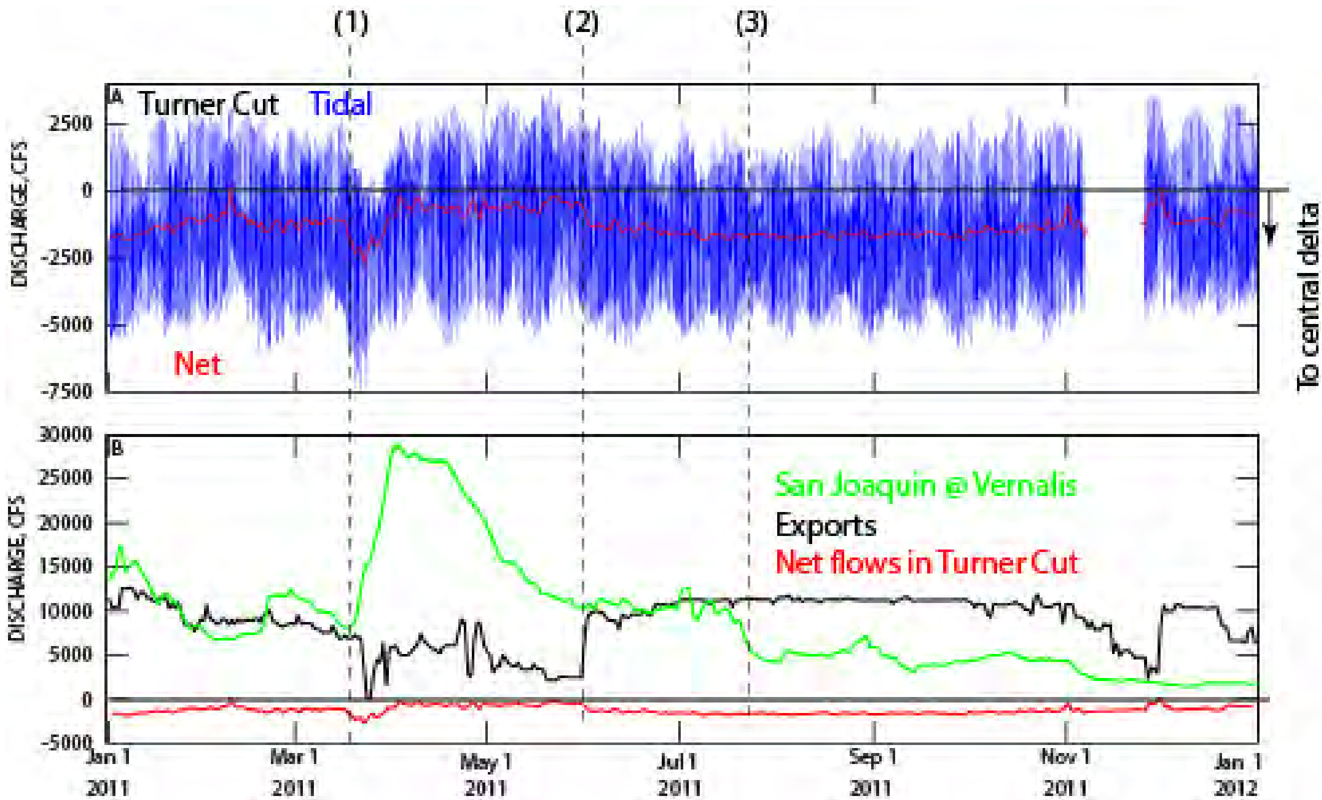


Figure 2. Time Series plot of (A) tidal (blue) and net (red) discharge at Turner Cut and (B) San Joaquin river discharge at Vernalis (green) and at net discharge Turner Cut (same as above, red) and export rate (black).

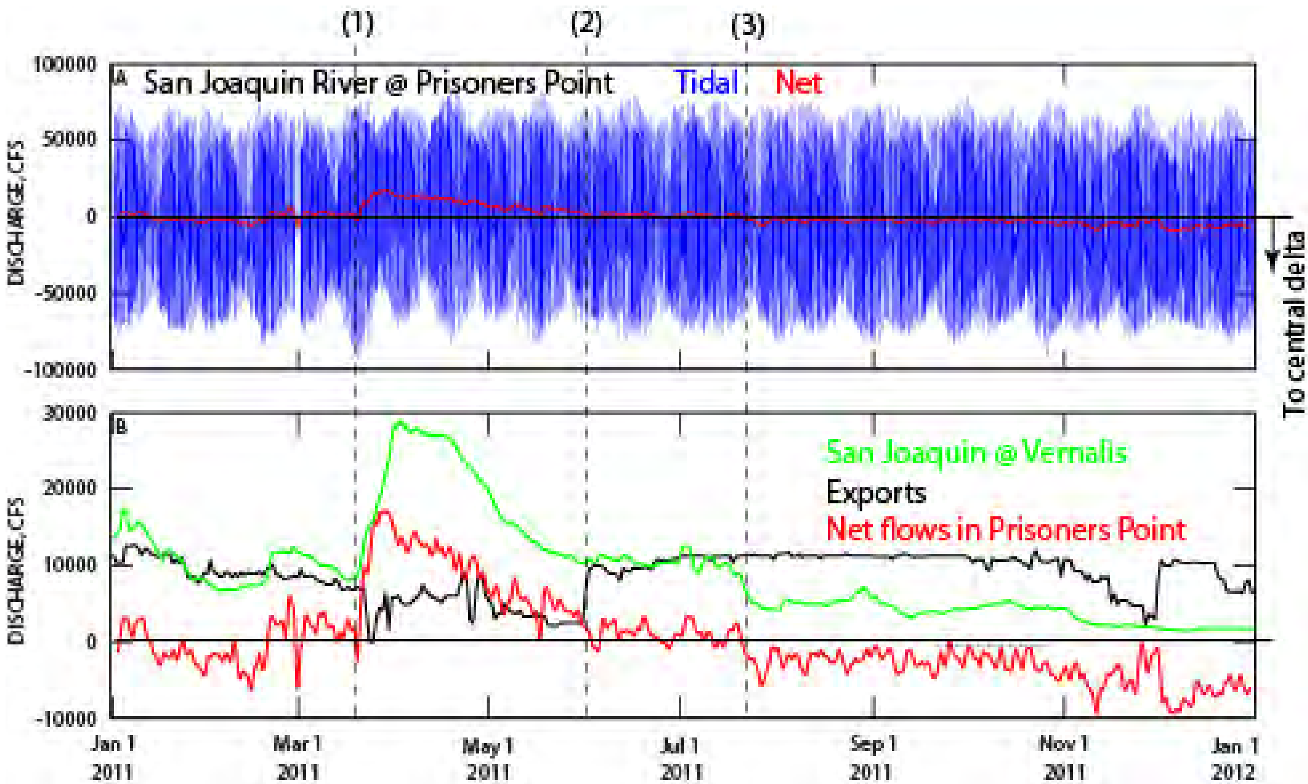


Figure 3. Time Series plot of (A) tidal (blue) and net (red) discharge at the San Joaquin River at Prisoners Point and (B) San Joaquin river discharge at Vernalis (green) and at net discharge Prisoners Point (same as above, red) and export rate (black).

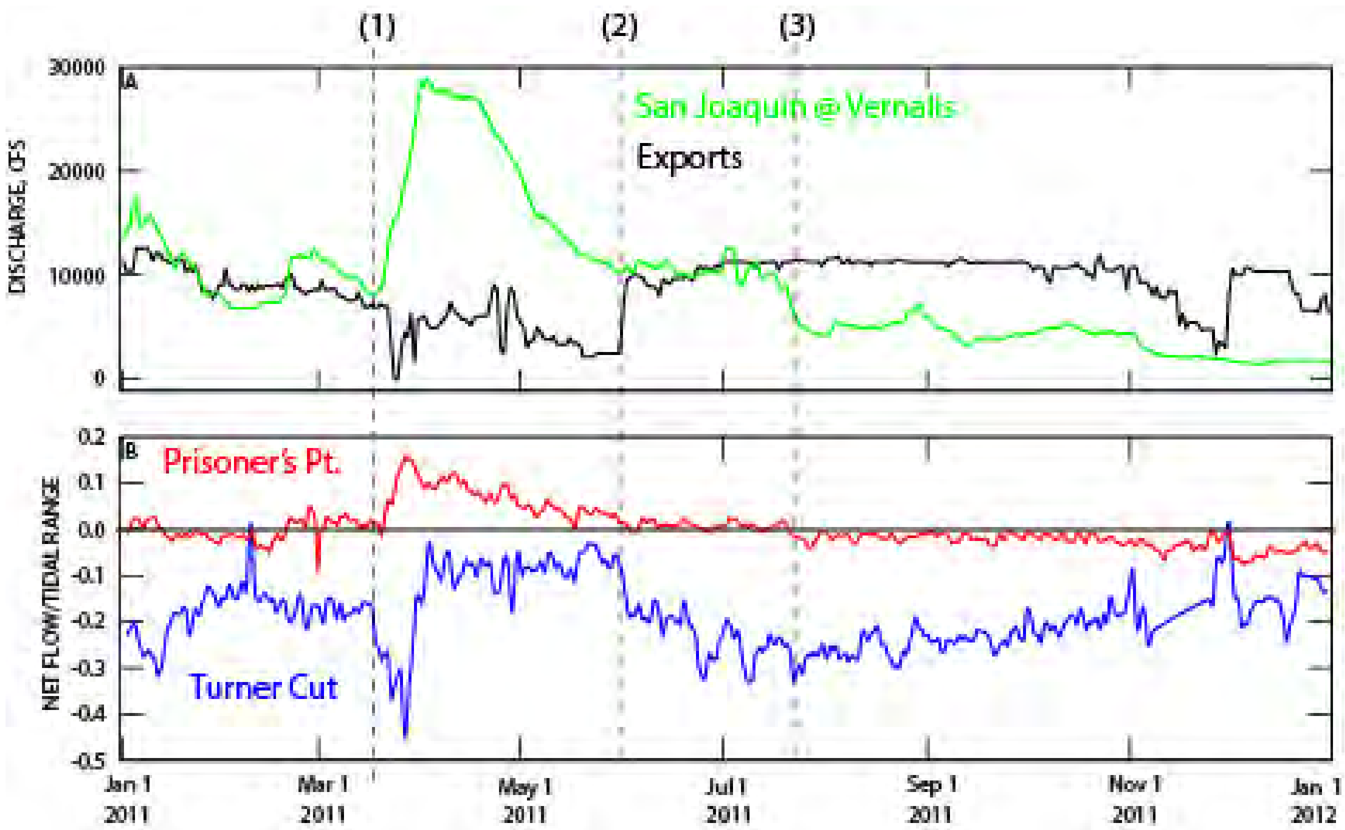


Figure 4. Time series plot of (A) San Joaquin River discharge @ Vernalis (green), exports (black), and (B) the ratio of the net flow <Q> to <Q'> tidal range at Prisoner's Point (red) and Turner Cut (blue).

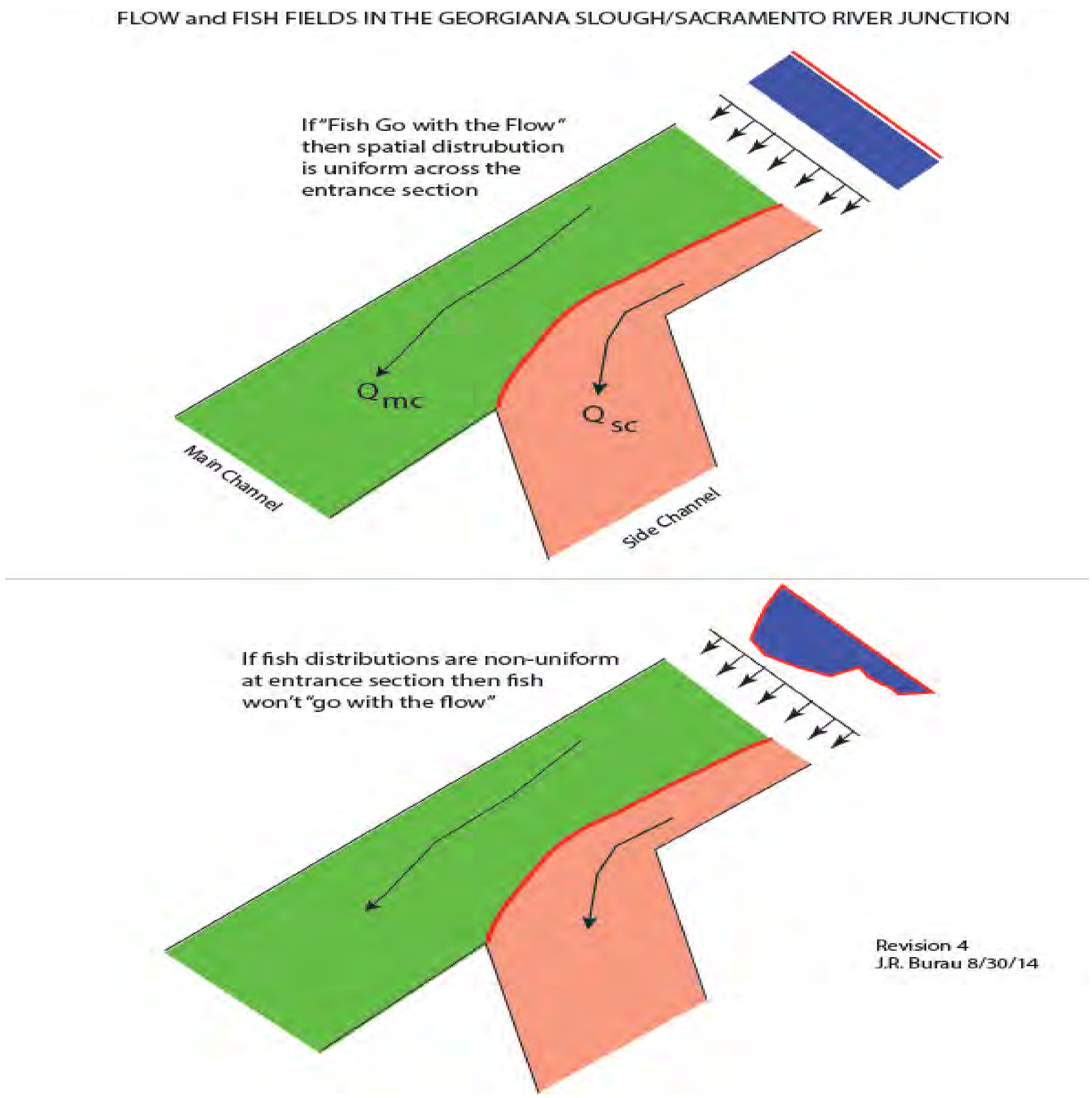


Figure 5. Conceptual diagram of entrainment in a junction. Red regions denote the entrainment zone for the side channel whereas the green regions show the region where fish continue along the main channel. The red line between these regions is the critical streakline. Top panel shows the required conditions for fish to "go with the flow" – in this case the bulk discharge in each channel. These conditions include a uniform entrance fish spatial distribution AND behaviors that don't result in fish crossing the critical streakline. In the bottom panel are indicated those conditions that create conditions where fish aren't distributed in proportion to the flows in each channel. These conditions include a non-uniform entrance fish distribution as is shown and behaviors that cause fish to transit the critical streakline.

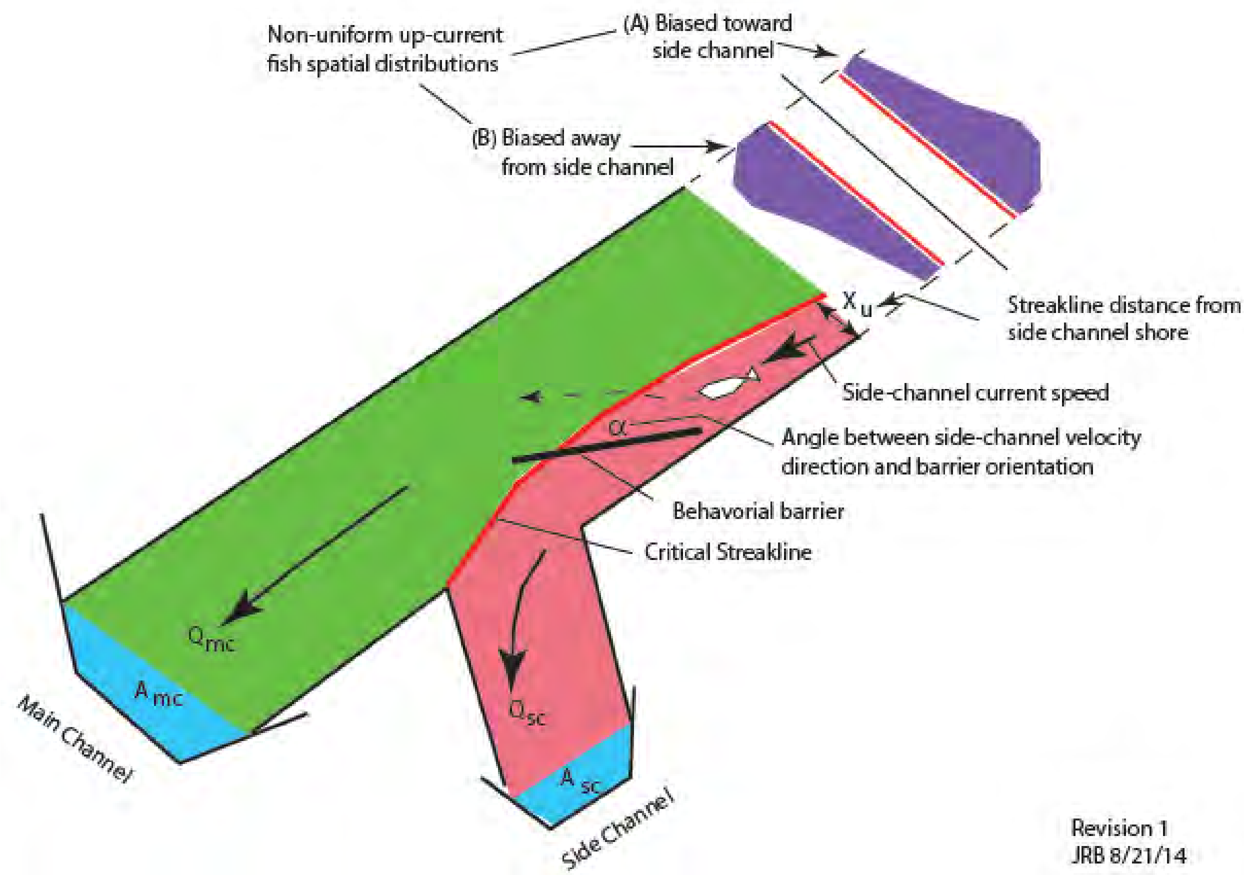


Figure 6. Conceptual schematic showing conditions that are conducive to behavioral barriers (some of which are interdependent): (1) small ratios of side channel to main channel cross sectional areas (Asc/Amc << 1), (2) small and temporally stable discharge ratios (Qsc/Qmc << 1), (3) non-uniform spatial distributions, where Asc, Amc are the side channel and main channel cross sectional areas, respectively, and Qsc, Qmc are the side channel and main channel cross sectional discharges. If the up-current spatial distributions are biased toward the side channel (spatial distribution B) then entrainment in the junction is likely to be minimal in the absense of a barrier AND there would be very few fish for a behavioral barrier to move across the streakline to reduce entrainment. Therefore, because population level survival is the product of the entrainment rate (low in the case of a spaital distribution biased away from the side channel - B above) AND reach specific survival (which is low in the delta) the impact on population level survival of a behavioral barrier under these conditions is likely to be minimal and therefore not recommended.

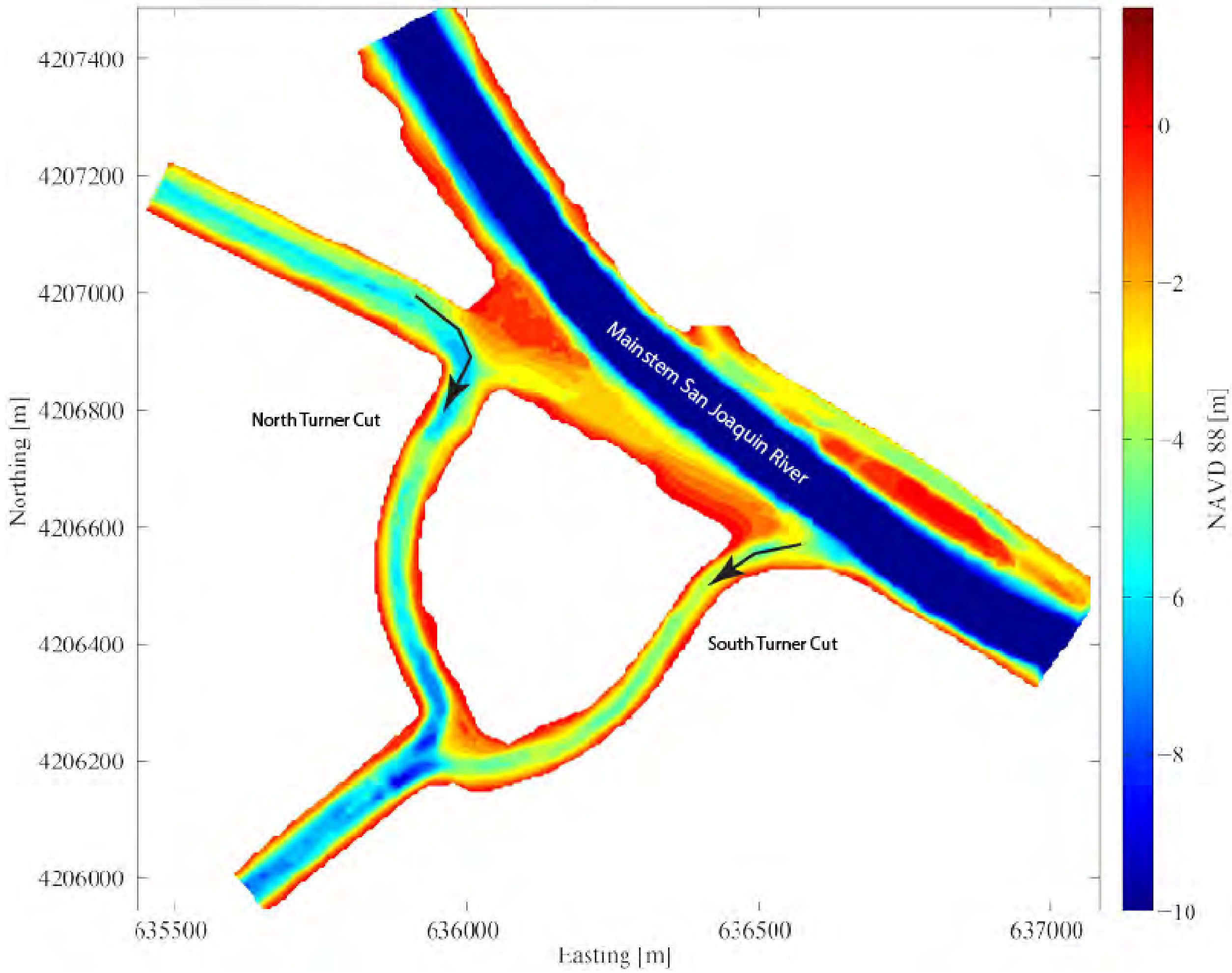


Figure 7. Bathymetry plot of Turner Cut, which suggests that the bypass flow in the San Joaquin is likely large relative to the flows in either North or South Turner Cuts. Based on channel capacity arguments, the North Turner Cut conveys most of the water into Turner Cut on flood tides and South Turner Cut conveys water on ebb tides as is indicated by the arrows.

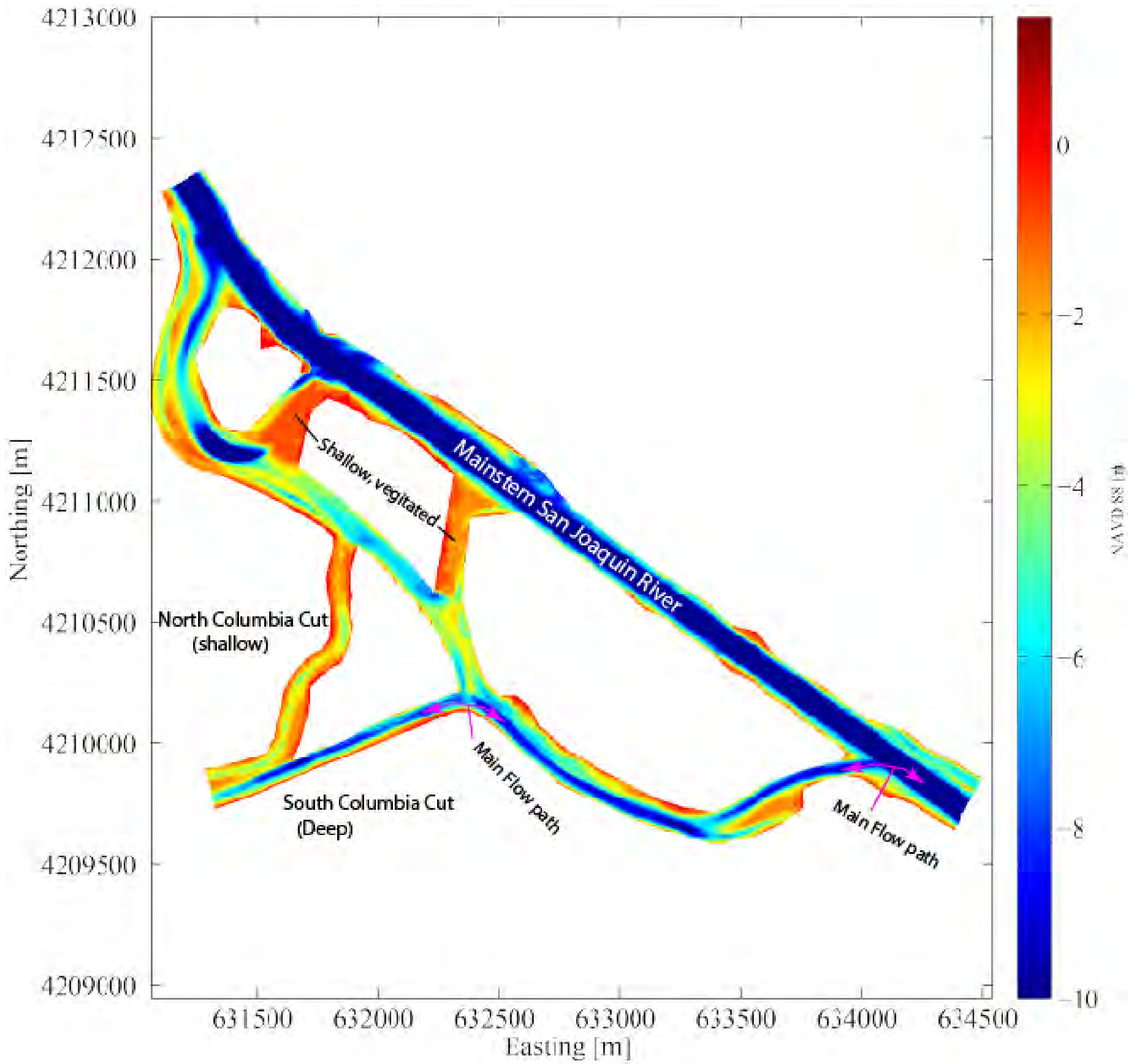


Figure 8. Bathymetry plot of Columbia Cut, which suggests that the bypass flow in the San Joaquin is likely large relative to the flows into Columbia Cut. Based on channel capacity arguments, the South Columbia Cut conveys most of the water into Columbia Cut., as is indicated by the arrows.

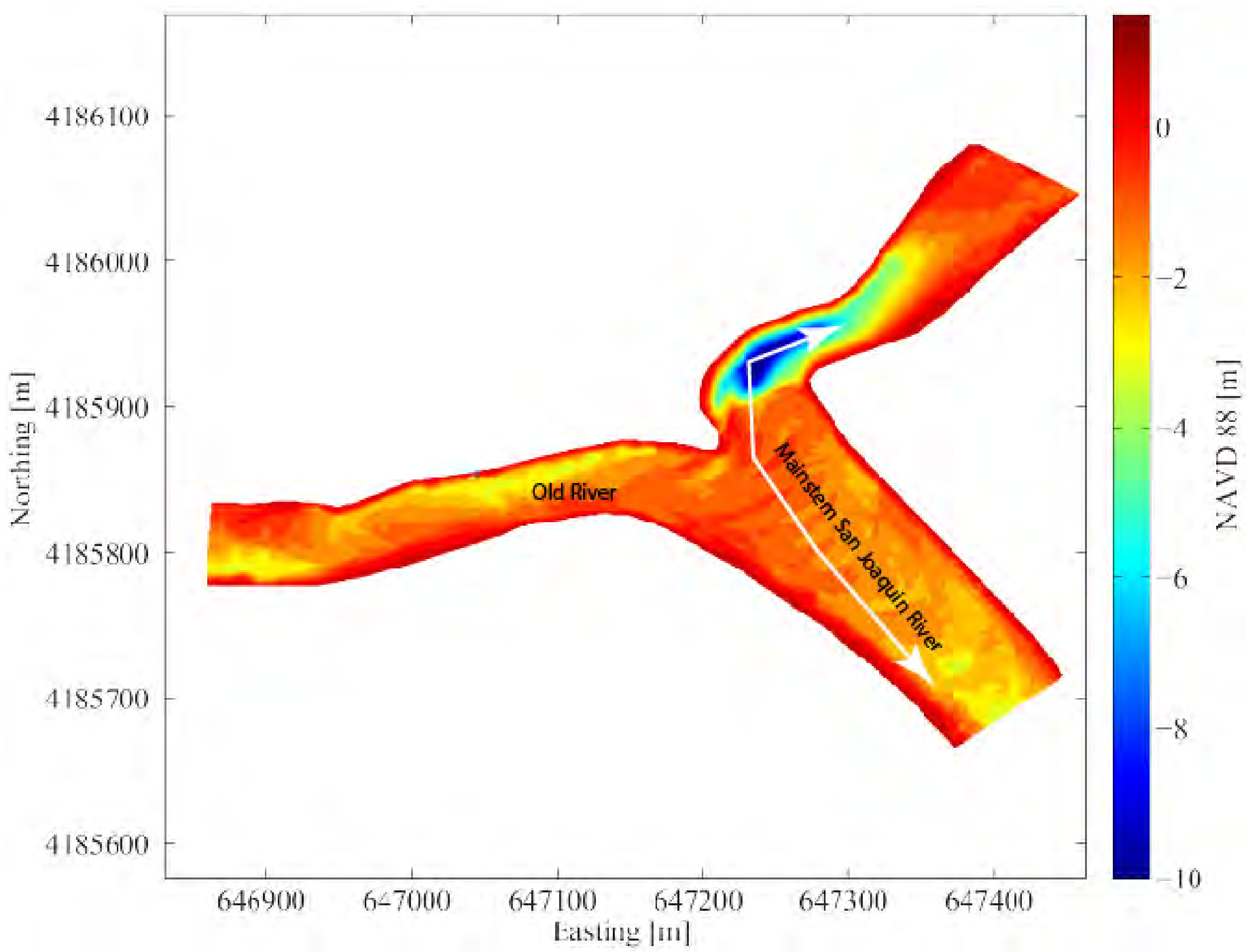


Figure 9. Bathymetry plot of Head of Old River, which suggests that since the channel capacity in the mainstem San Joaquin River and Old River very near identical that the tidal timescale bypass flow in the San Joaquin is likely on the order of the flow in Old River at this junction.

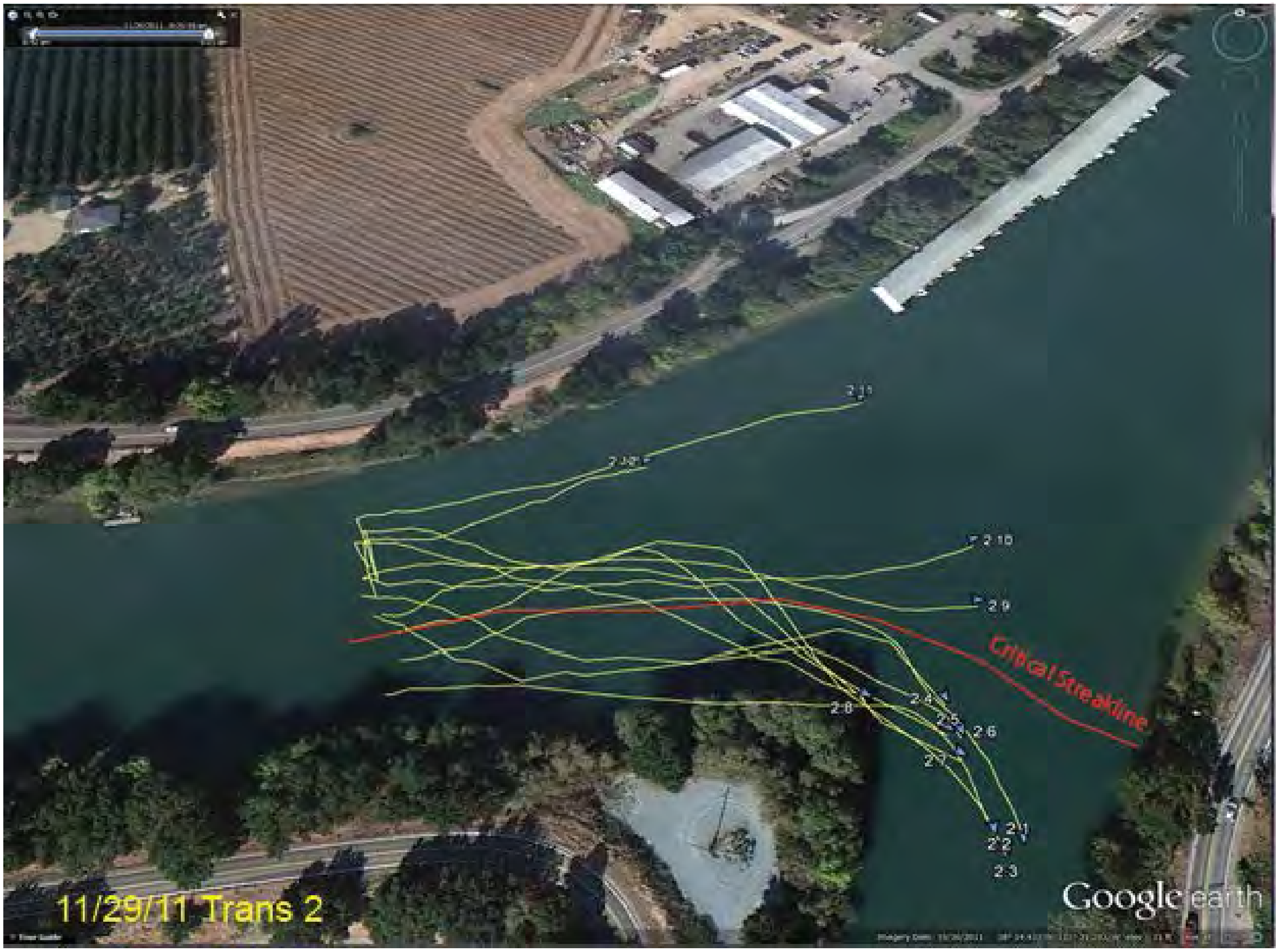


Figure 10. The paths of taken by drifters (yellow lines) deployed during the 2011 BAFF™ at experiment by the Department of Water Resources during converging flow conditions at the Georgiana Slough junction with the Sacramento River. (Data courtesy of Dave Huston, DWR). The critical streakline is shown as a red line.

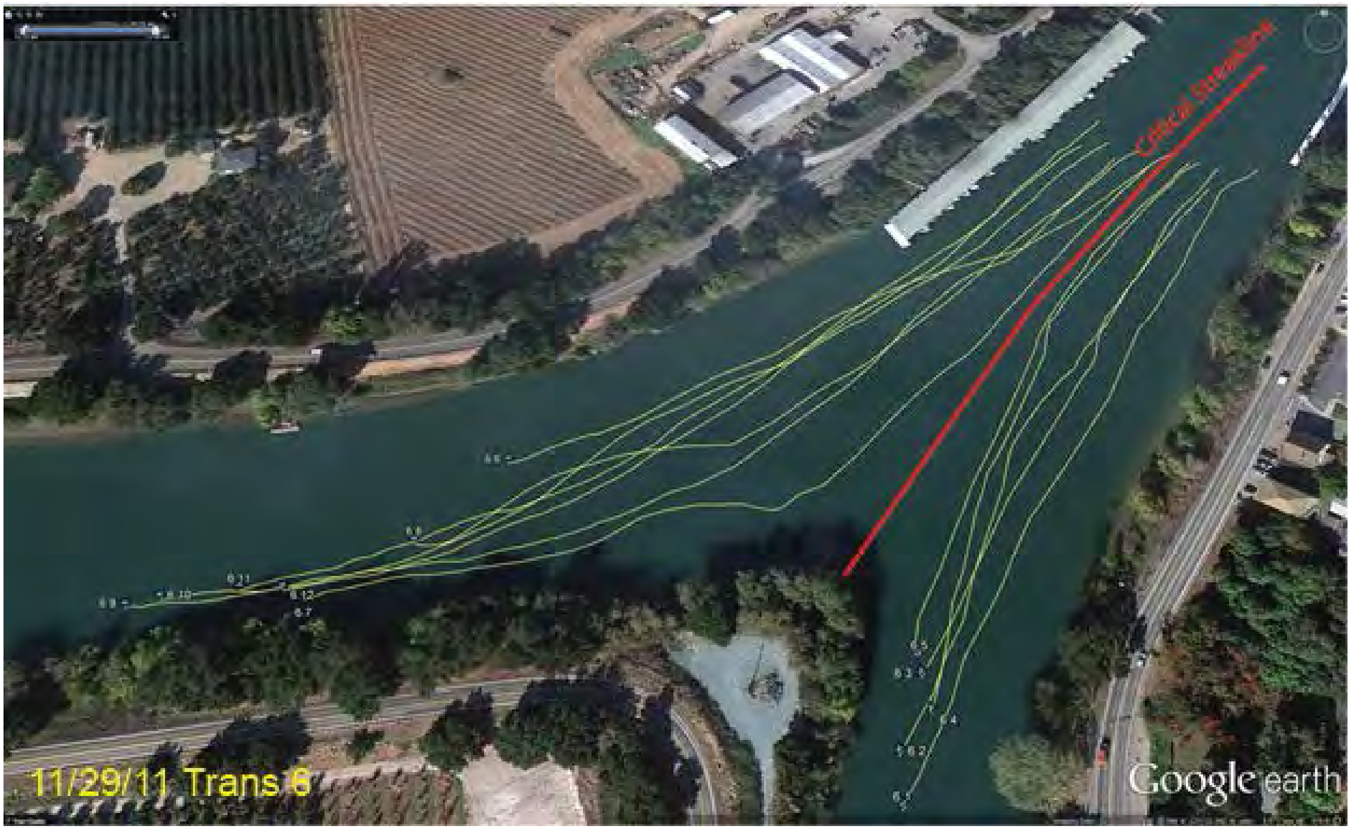


Figure 11.The paths ~~of~~ taken by drifters (yellow lines) deployed during the 2011 BAFF™ experiment by the Department of Water Resources during downstream flow conditions (Data courtesy of Dave Huston, DWR). The critical streakline is shown as a red line.

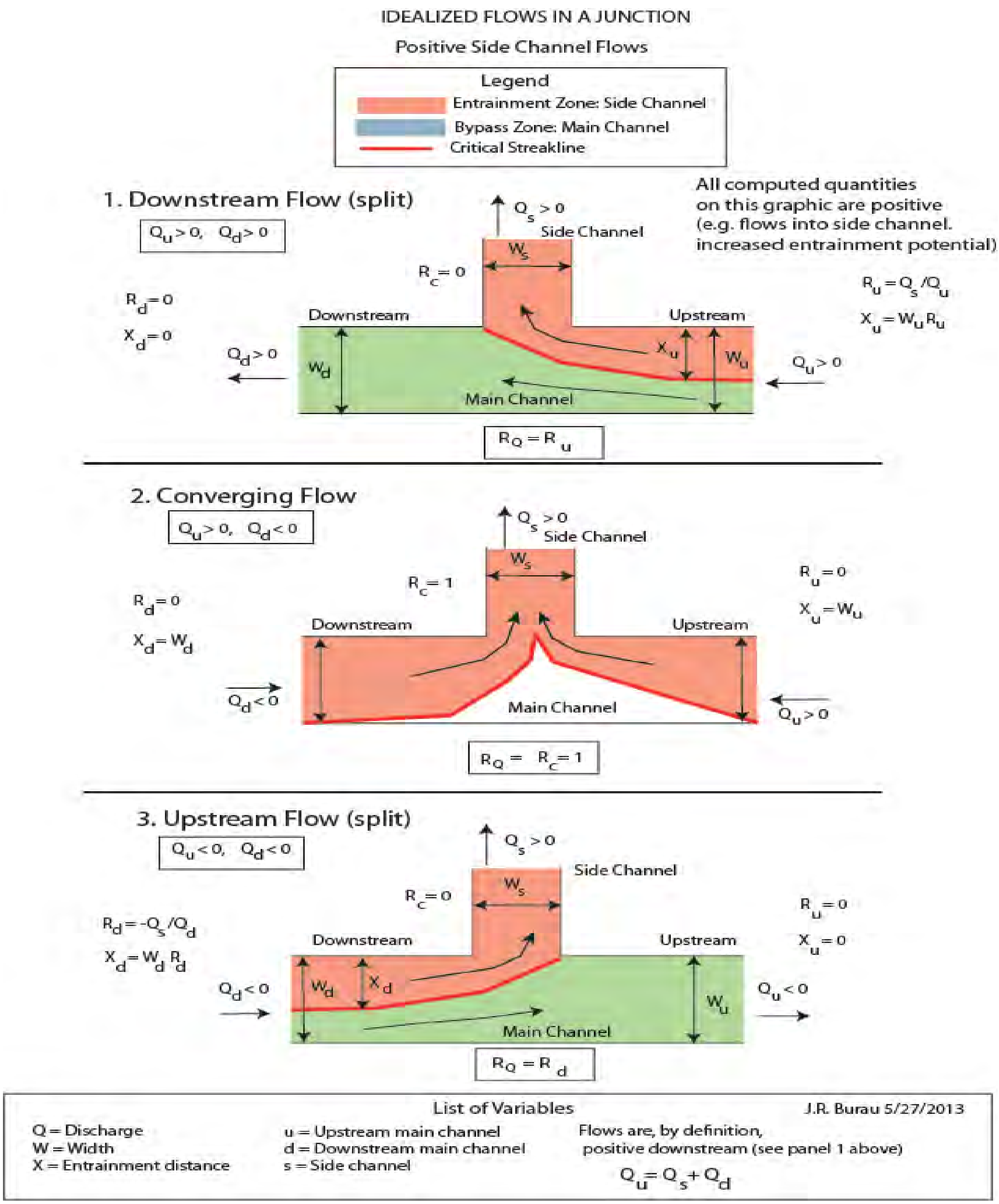


Figure 12. Definition sketch defining the three flow conditions that occur in a tidally forced junction where the water is entering a side channel: (1) downstream flow in the main channel, (2) converging flow, and (3) upstream flow.

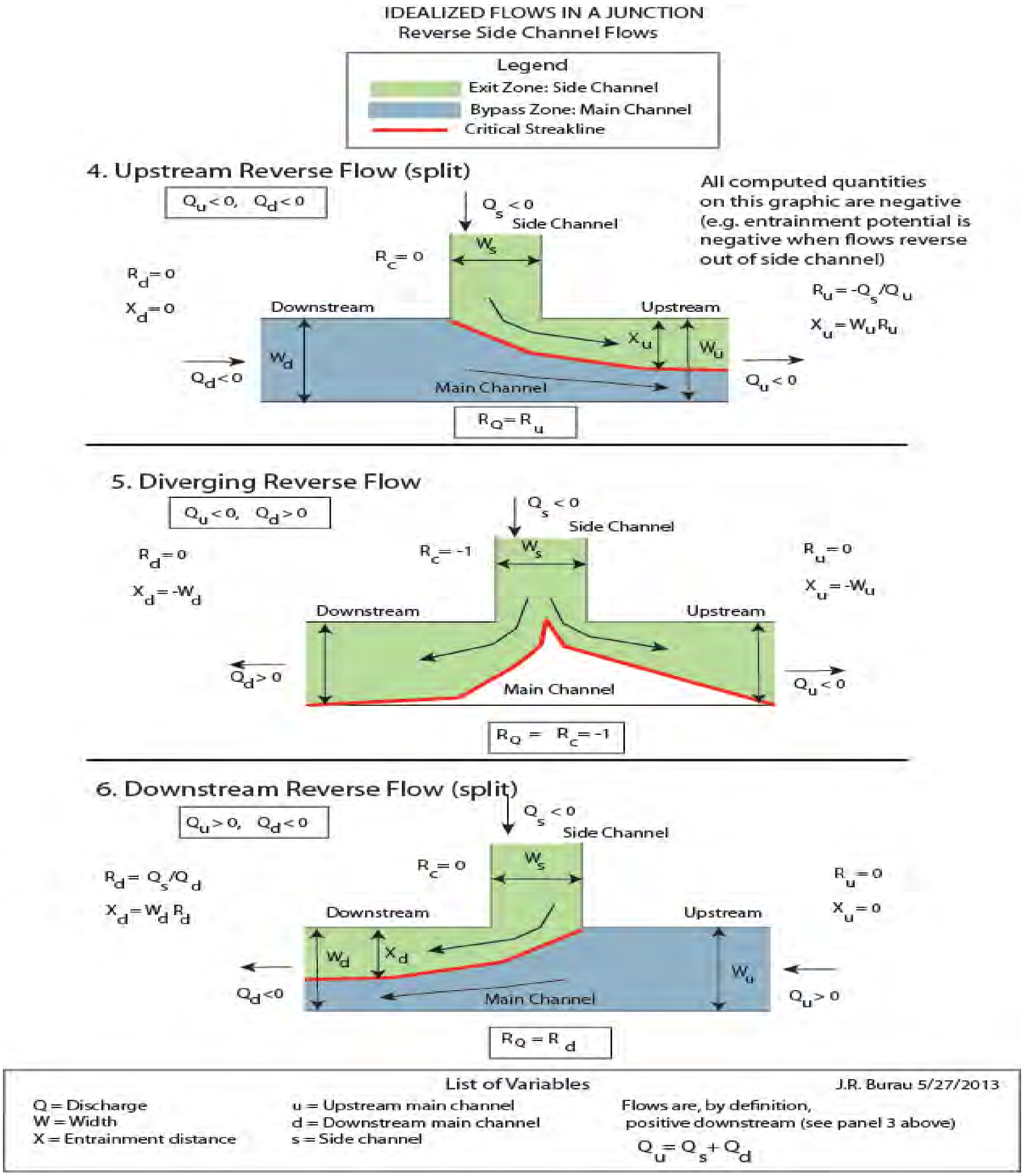


Figure 13. Definition sketch defining the three flow conditions that occur in a tidally forced junction where the water is exiting a side channel: (1) downstream flow in the main channel, (2) converging flow, and (3) upstream flow.

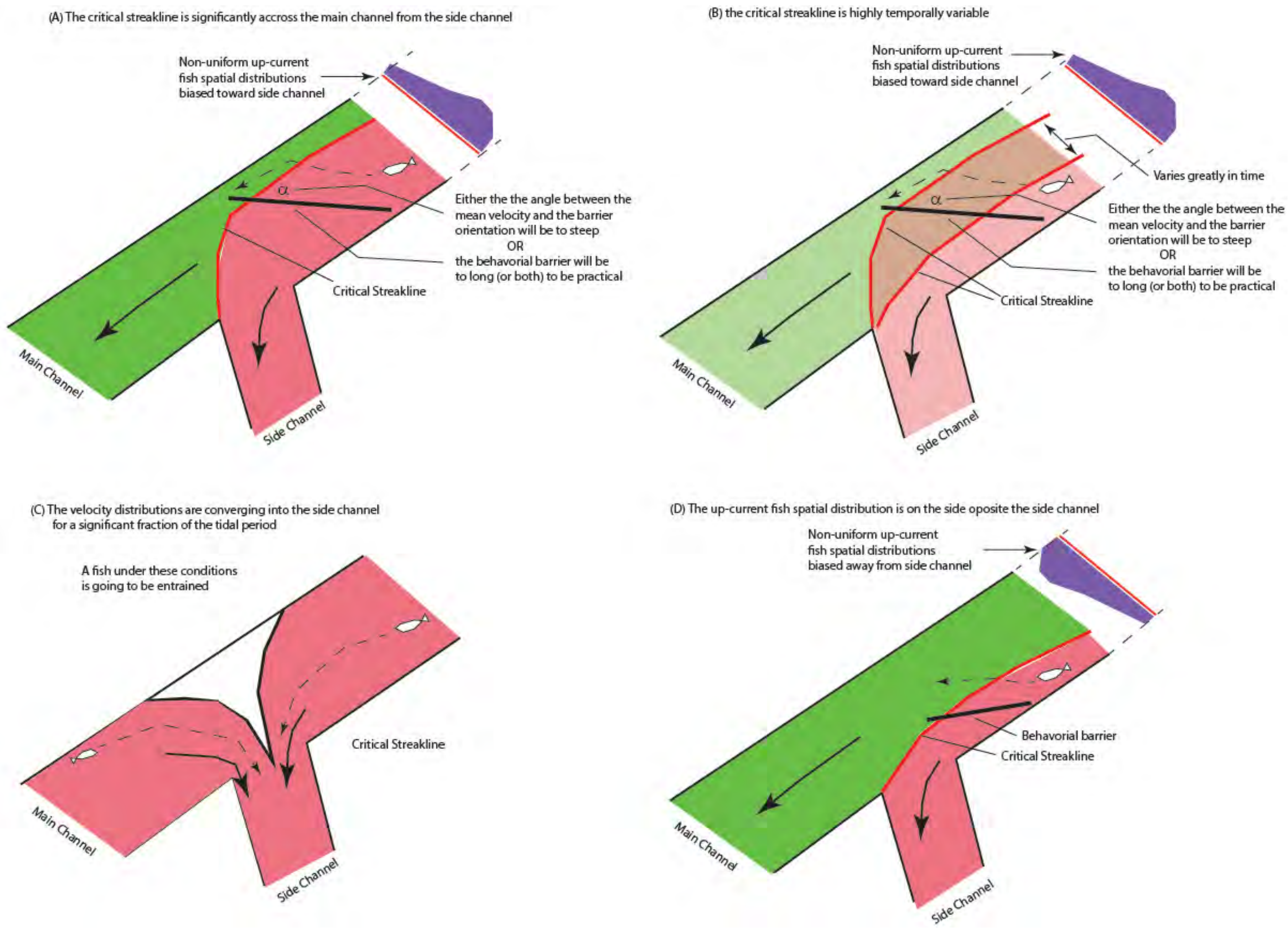


Figure 14. Schematic showing hydrodynamic conditions that suggest a behavioral barrier will not work: (A) the critical streakline is a significantly across the main channel from the side channel, (B) critical streakline is highly temporally variable (e.g. not stable), (C) the velocity distributions are converging into the side channel for a significant fraction of the tidal period, (D) the up-current fish spatial distribution is on the side opposite the side channel. We can't evaluate condition (D) with the existing data but would need to deploy and evaluate 2D acoustic telemetry data to assess this condition.

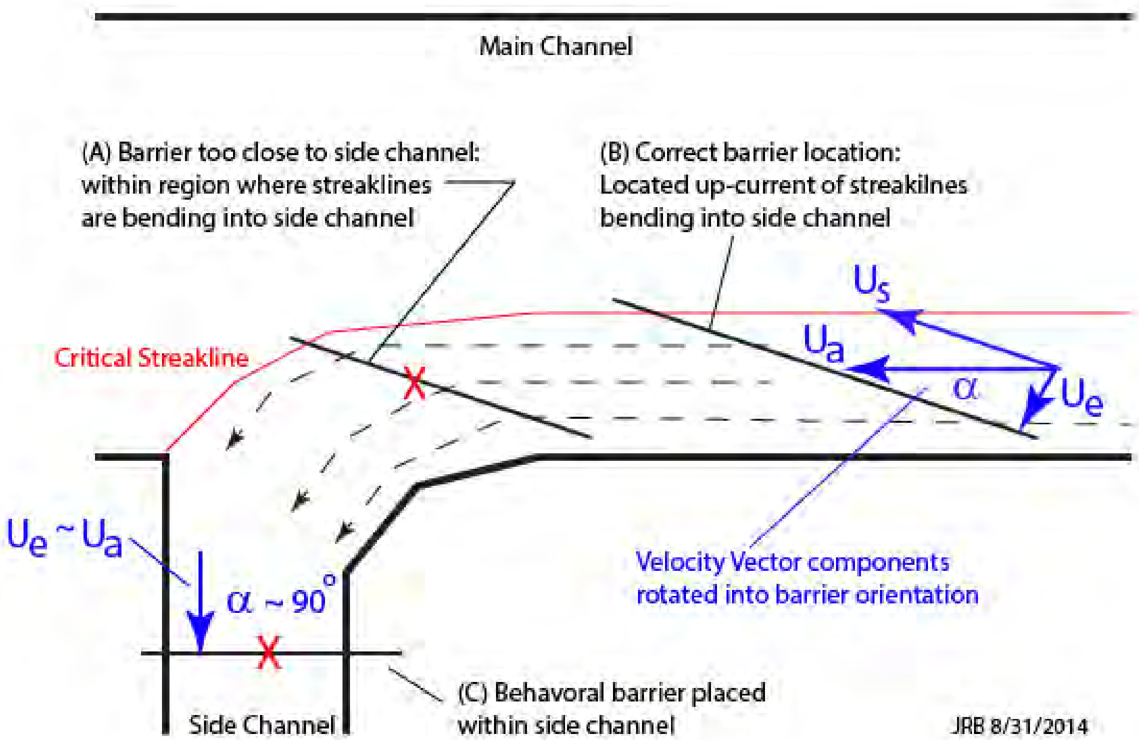


Figure 15. Conceptual schematic of two barrier alignments and the relationship between the channel velocity and barrier orientation, where *Ua* is the channel velocity, *Ue* is the fish escape velocity, and *Us* is the sweeping velocity component along the face of the barrier (Turnpenny and O'Keeffe 2005).

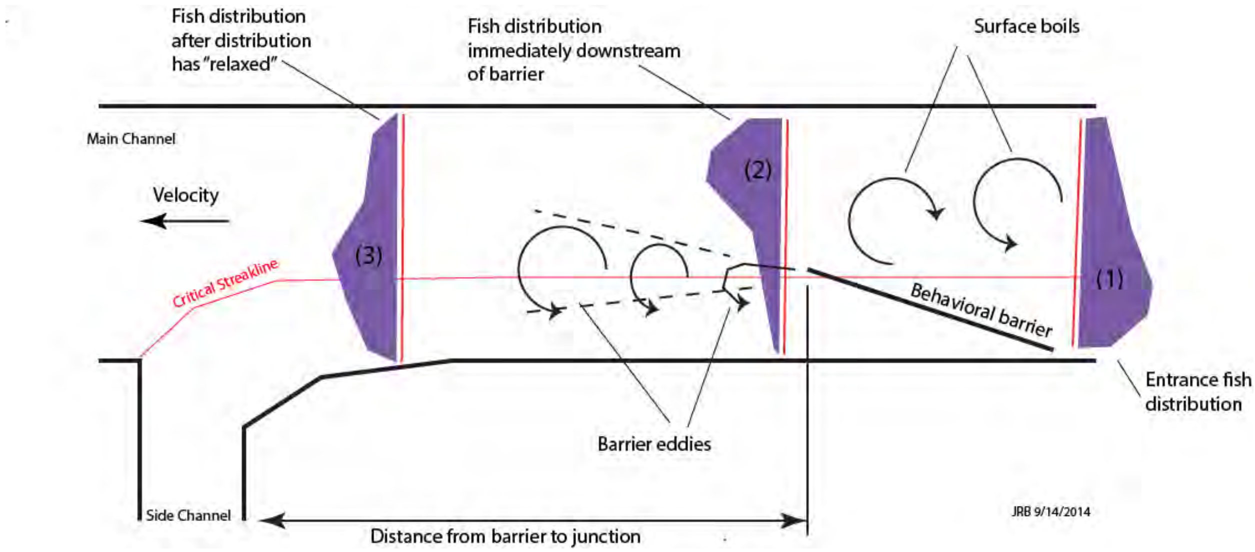


Figure 16 Conceptual schematic of the "relaxation" of the fish spatial distribution downstream of a behavioral barrier. This figure is completely conceptual since the research has not been done to verify the "relaxation" length scale, however, we know that, at some point, there exists a downstream distance where the fish spatial distribution is independent of the effects of the barrier. Shown is a fish entrance distribution that is biased to the side channel shore (label 1 above). As this distribution interacts with the barrier, it is biased to the bank opposite the side channel across the streakline (label 2), if the barrier is affective. However, once the fish move past the trailing edge of the barrier, this distribution begins to "relax" (Label 3). Lateral mixing due to natural river hydraulics such as surface boils, eddies off the trailing edge of the barrier and behavior likely all contribute to this relaxation. Therefore, behavioral barriers should not be placed to far upstream of the side channel entrance.

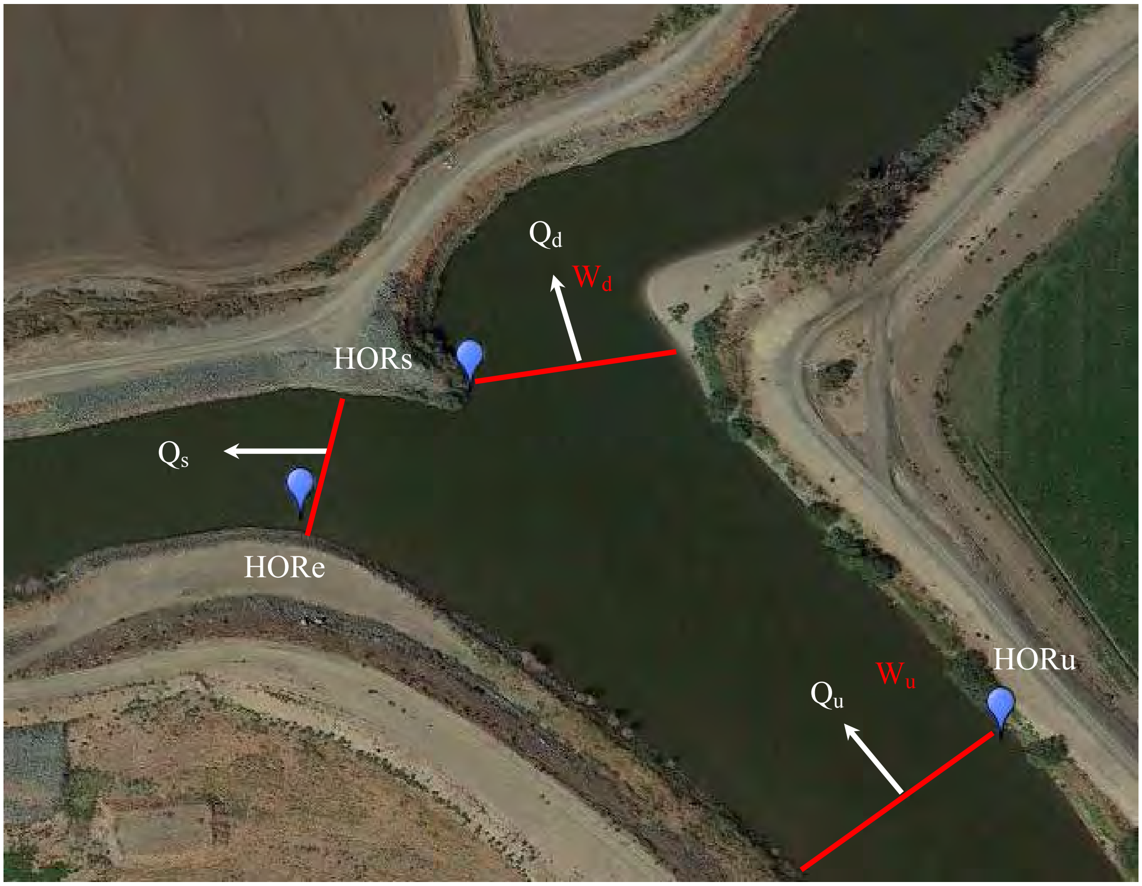


Figure 17. Aerial view of Head of Old River showing location of SL-ADCP's (HORe, HORs, and HORu), and parameters used for critical streakline calculations. The positive flow directions are indicated by white arrows.

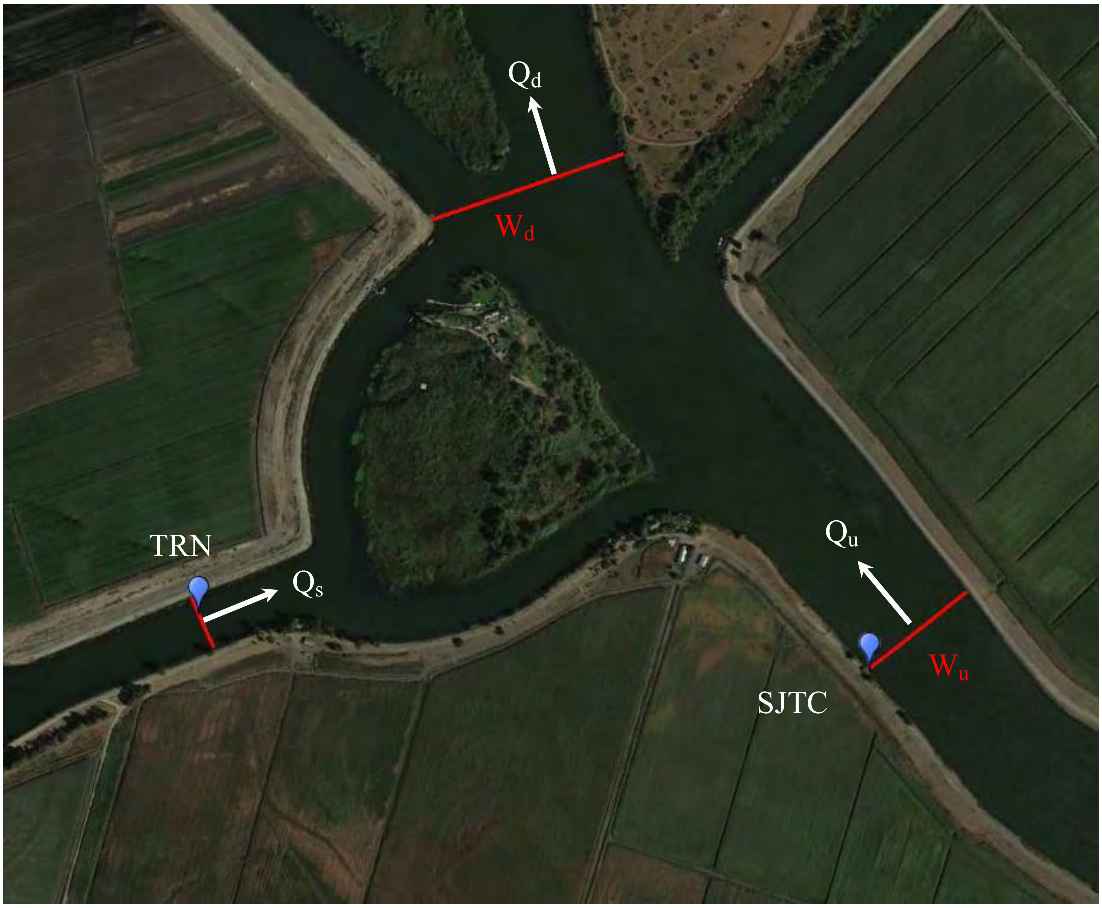


Figure 18. Ariel view of San Joaquin River near Turner Cut (Pilot Study) showing location of discharge measurements (SJTC and TRN). Parameters used critical streakline calculations (Qu, Qs, Qd, Wu, and Wd). The positive flow directions are indicated by white arrows.

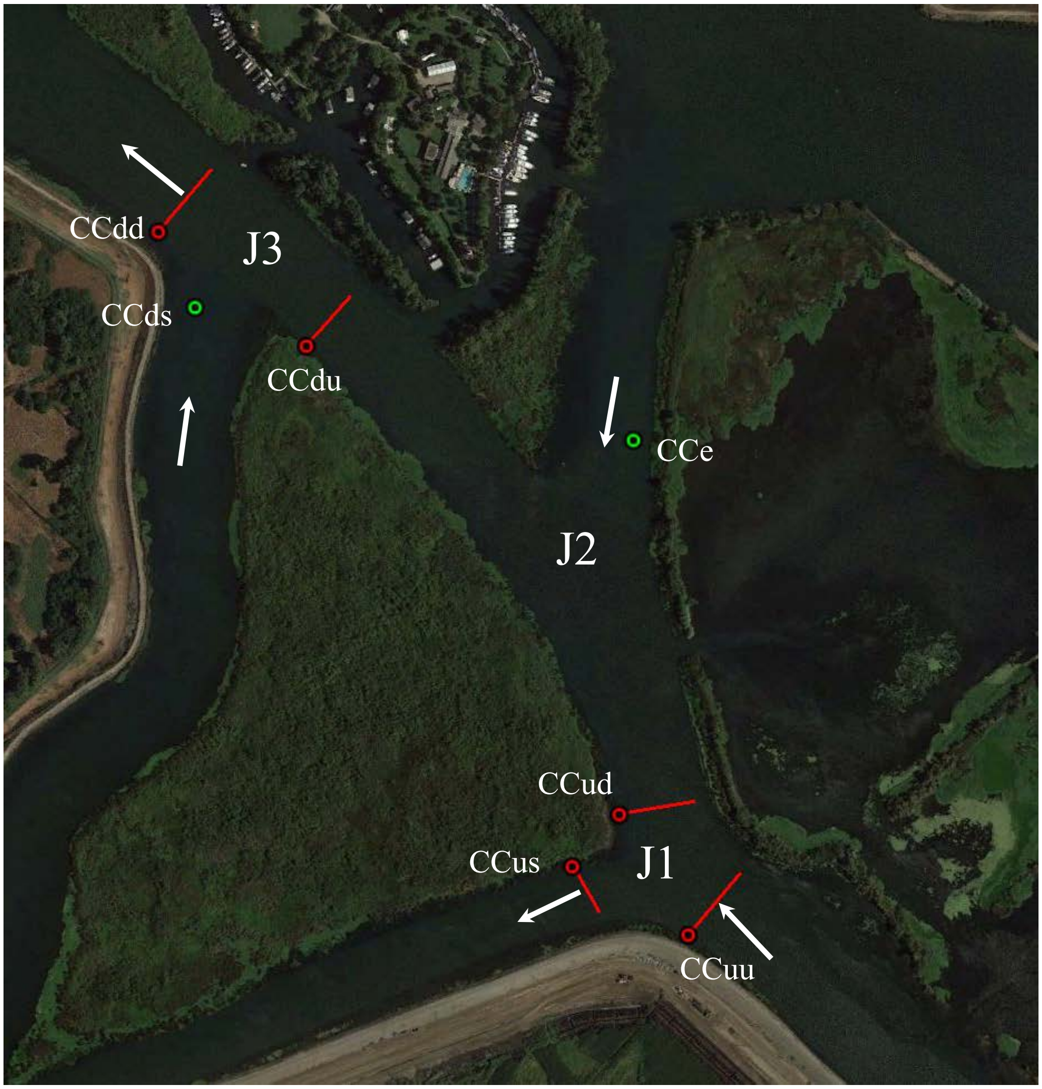


Figure 19. Ariel view of San Joaquin River near Columbia Cut showing location of SL-ADCP's (red dots and line) and locations of UL-ADCP's (green dots). Each junction in the study area is labeled (J1, J2, and J3). Positive flow direction for each channel is indicated by yellow arrows.

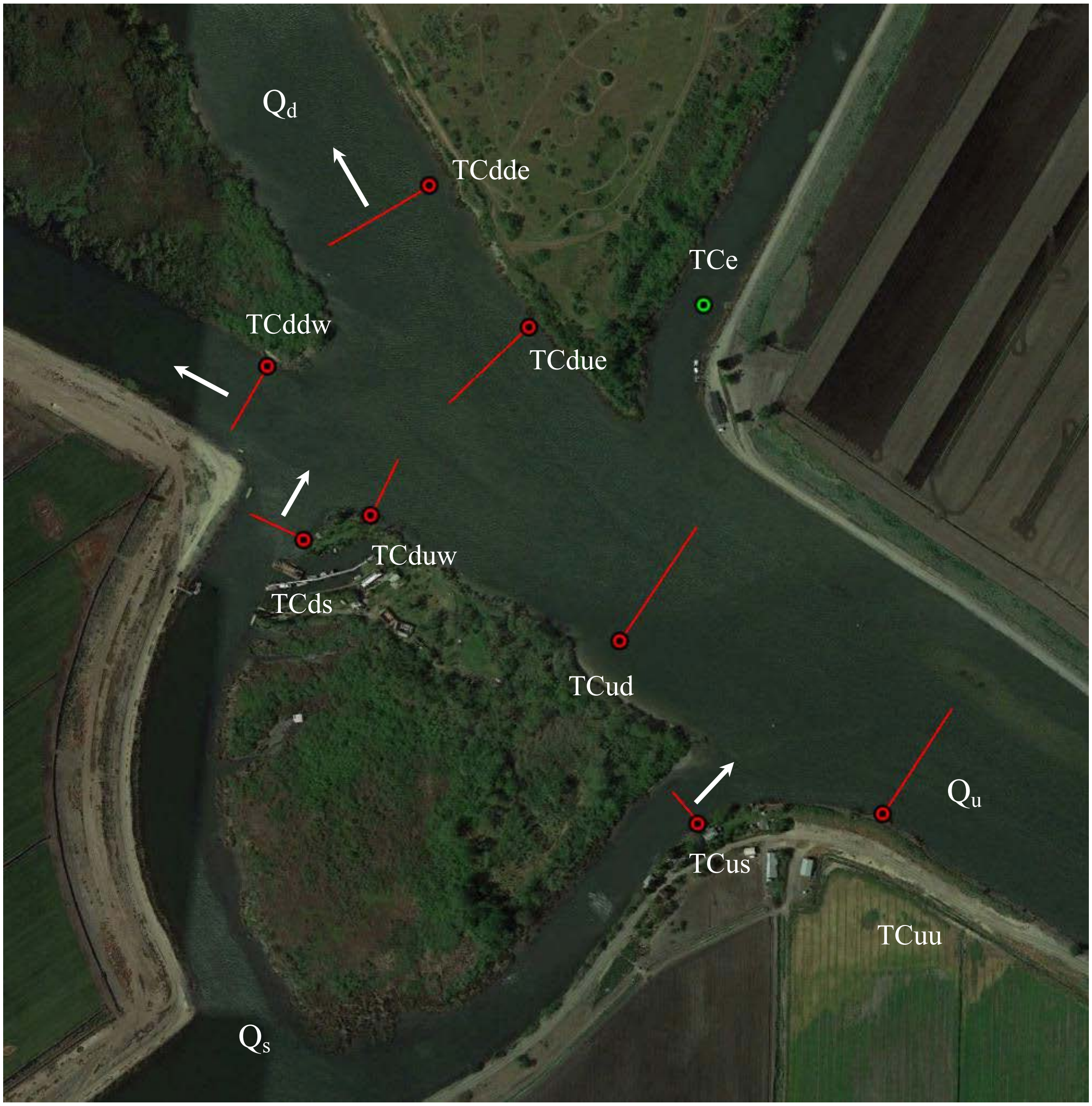


Figure 20. Aerial view of San Joaquin River near Turner Cut (Full Study) showing locations of SL-ADCP's (red dots and lines) and UL-ADCP (green dot). Positive flow direction for each channel is indicated by white arrows.

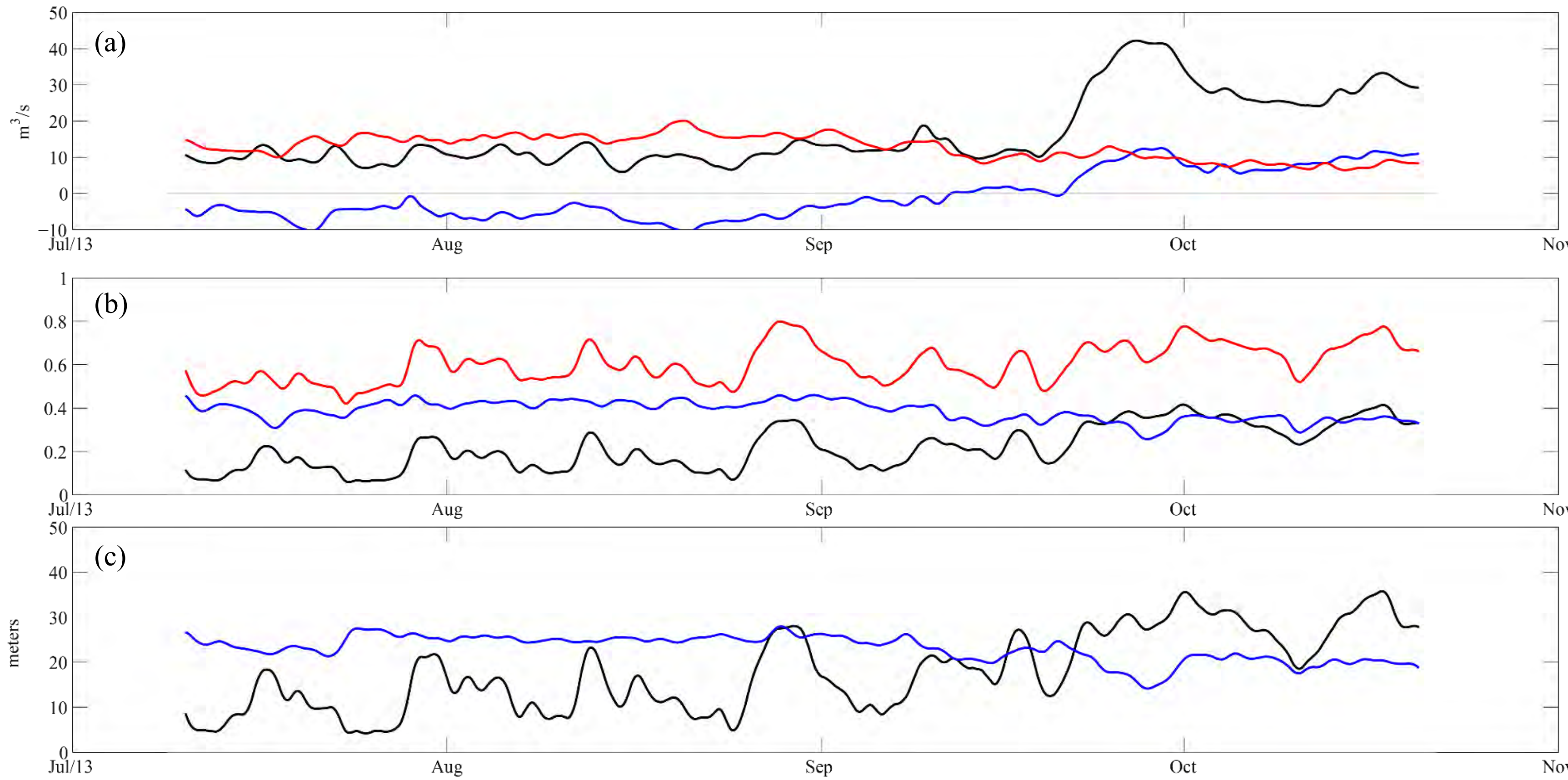


Figure 21. Time series data estimated using the velocity profile method for discharge calculation and integral method for discharge ratio and critical streakline calculation at HOR (a, top panel) tidally filtered discharge upstream (black), downstream (blue) and side channel (red) (b, middle panel) discharge ratio at upstream (black), downstream (blue) and total (red) and (c, bottom panel) critical streakline in distance from upstream left bank (black) and downstream left bank (blue).

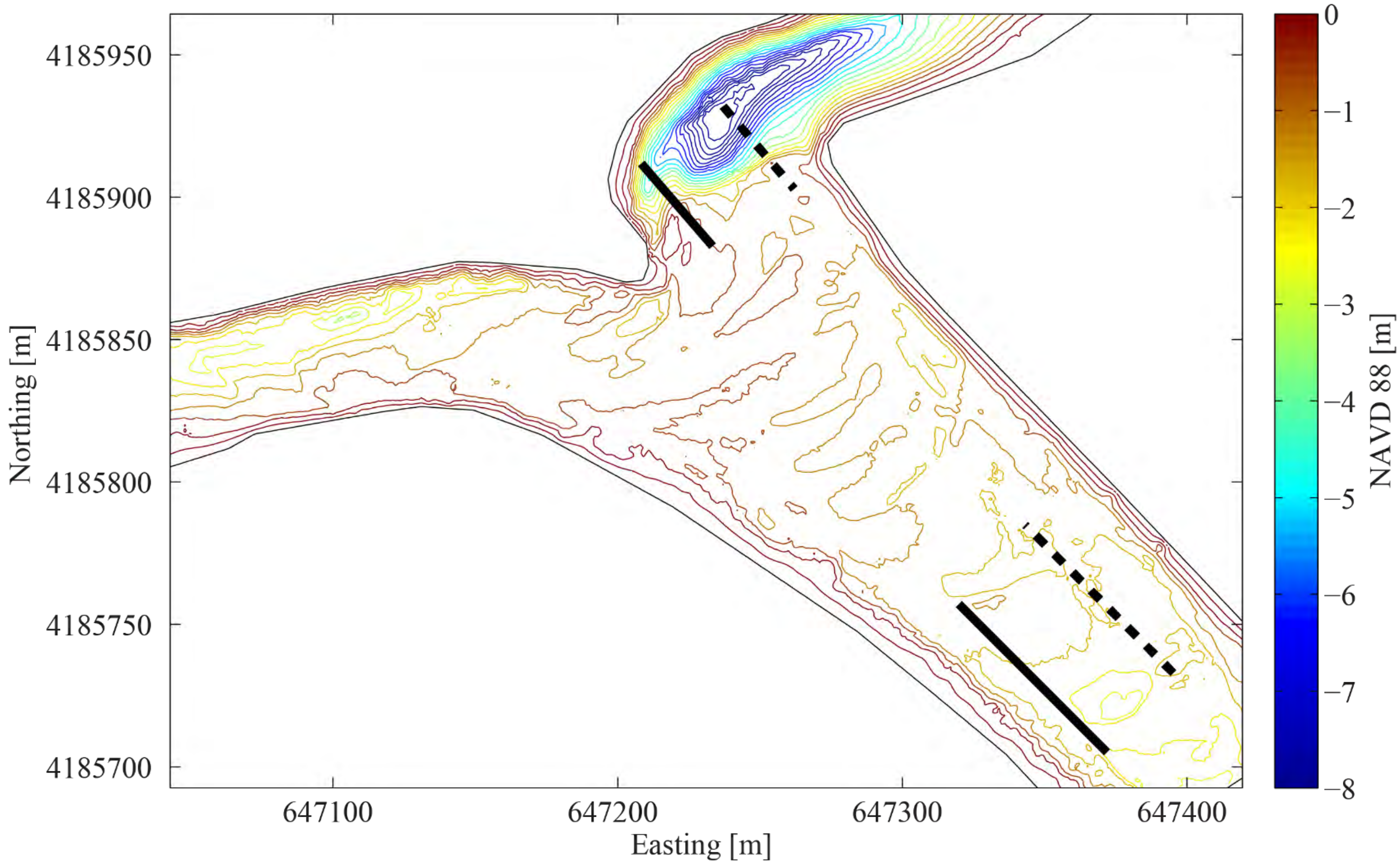
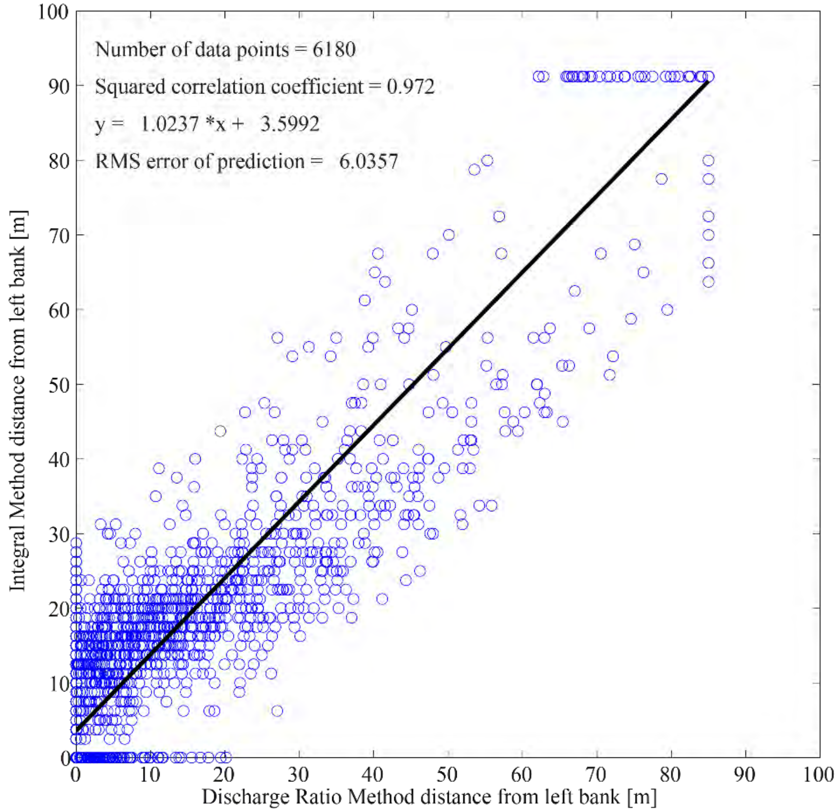


Figure 22. Upstream and downstream critical streakline positions at HOR. The solid line represents the mean critical streakline from the left and the dashed line represents one standard deviation from the mean.

(a)



(b)

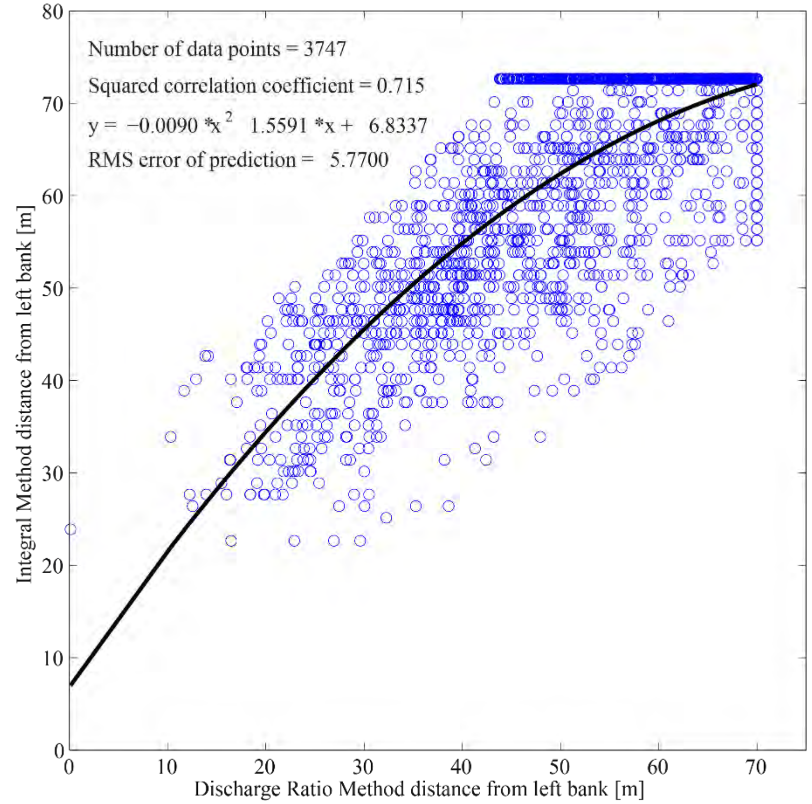


Figure 23. Non-linear regression of the critical streakline from the left bank estimated from the discharge ratio and integral methods (a) at HORu; for positive flow conditions only and (b) at HORs; for negative flow conditions only

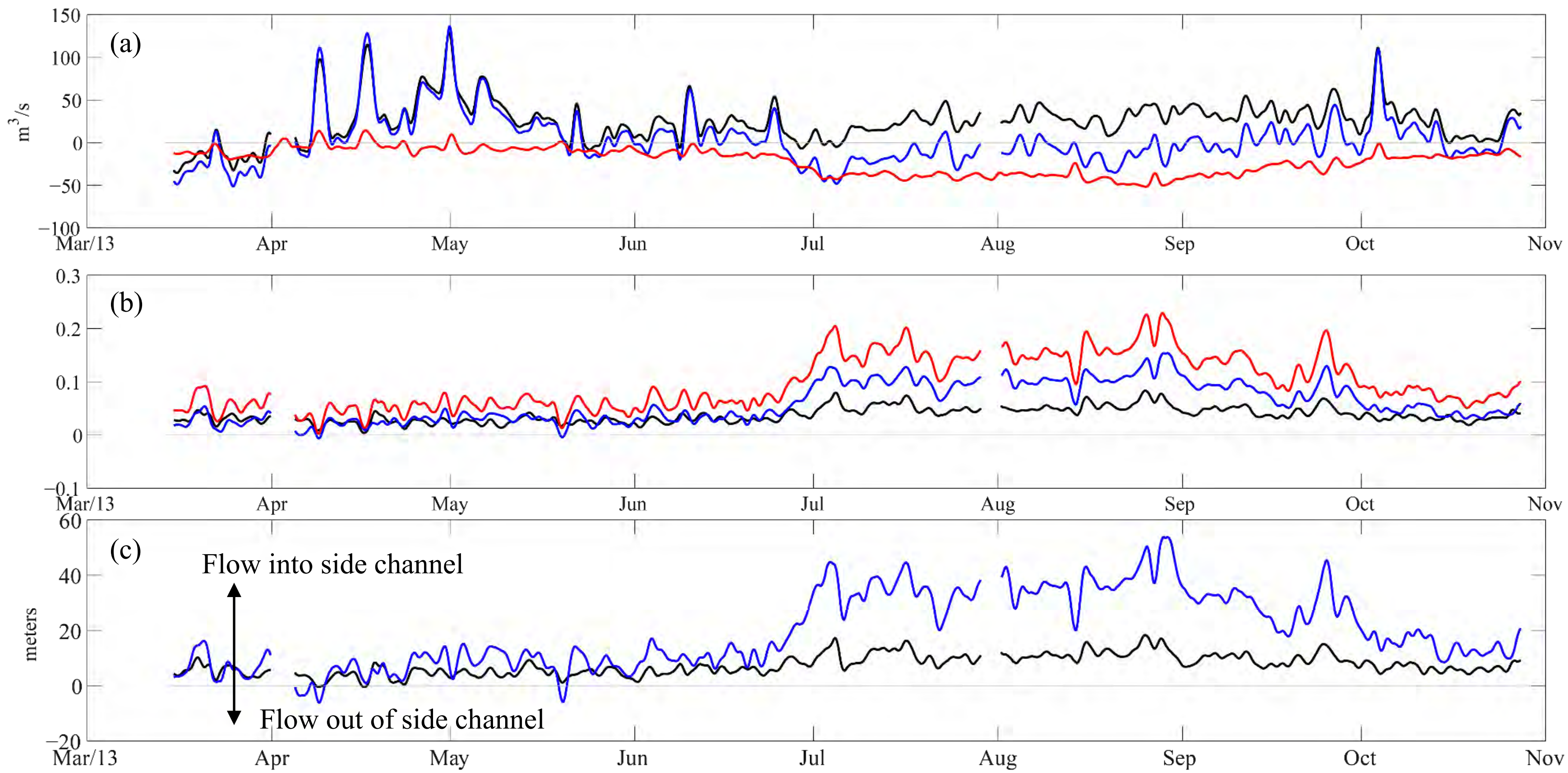


Figure 24. Timeseries data estimated using the index velocity method for discharge calculation and the discharge ratio method for discharge ratio and critical streakline calculation at SJTC (a) tidally filtered discharge upstream (black), downstream (blue) and side channel (red) (b) tidally filtered discharge ratio at upstream (black), downstream (blue) and total (red) and (c) tidally filtered critical streakline in distance from upstream left bank (black) and downstream left bank (blue). Note negative critical streakline indicate flow from side channel to main channel.

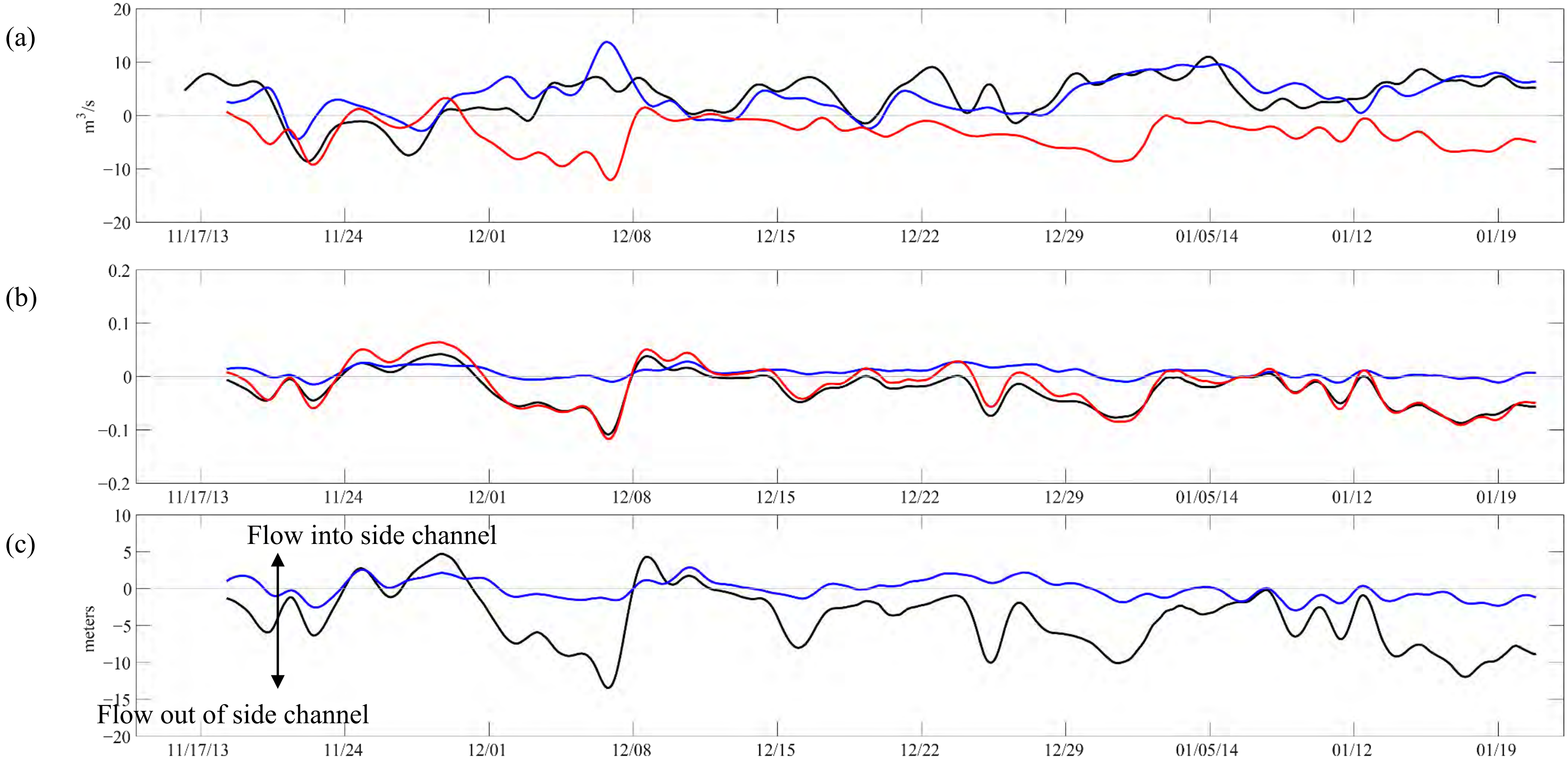


Figure 25. Time series data estimated using the velocity profile method for discharge calculation and integral method for discharge ratio and critical streakline calculation at SJCC (a) tidally filtered discharge upstream (black), downstream (blue) and side channel (red) (b) tidally filtered discharge ratio at upstream (black), downstream (blue) and total (red) and (c) tidally filtered critical streakline in distance from upstream left bank (black) and downstream left bank (blue). Note negative critical streakline indicate flow from side channel to main channel.

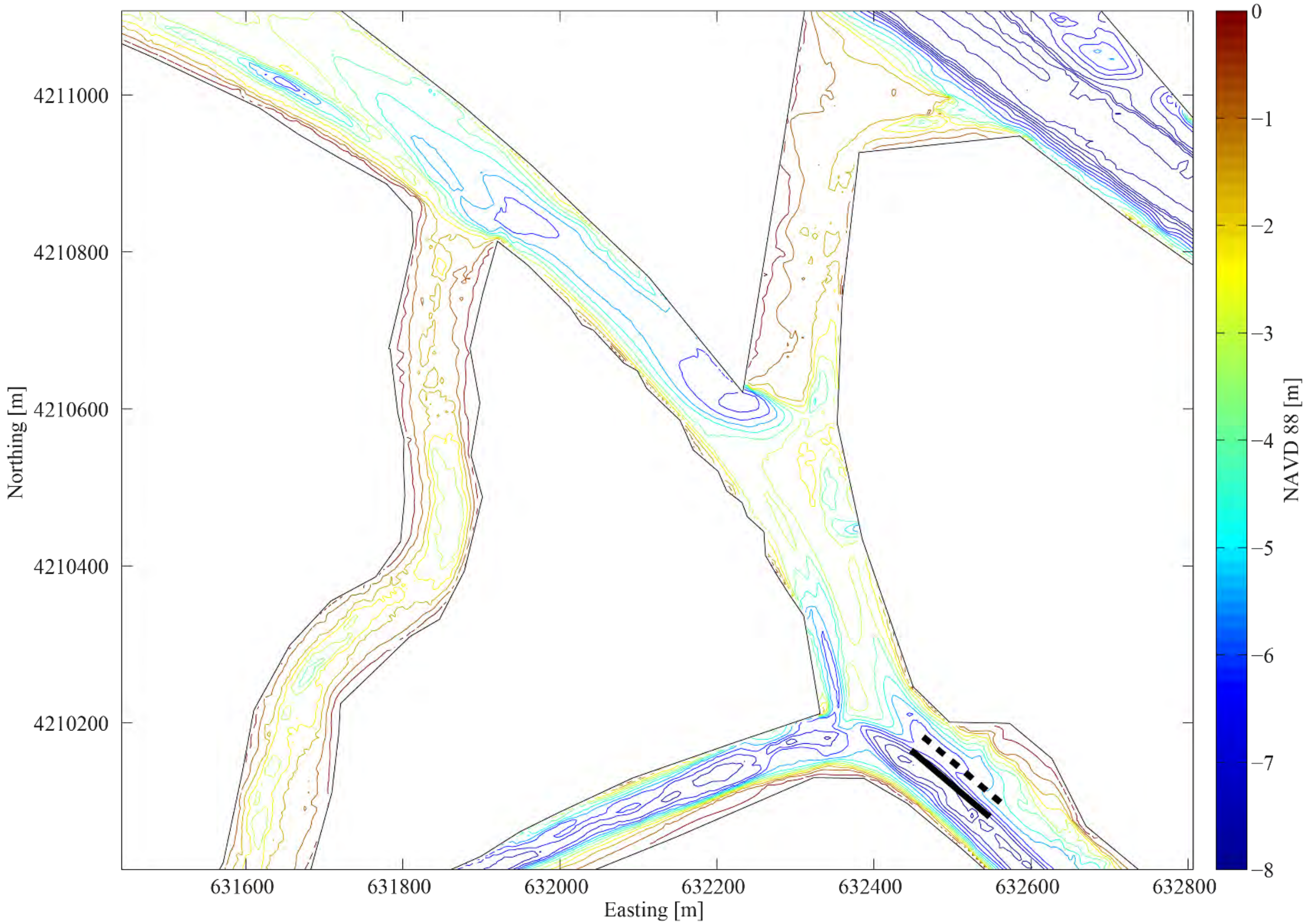


Figure 26. Upstream and downstream critical streakline positions at SJCC as reference from the left bank. The solid line represents the mean critical streakline and the dashed line represents one standard deviation from the mean.

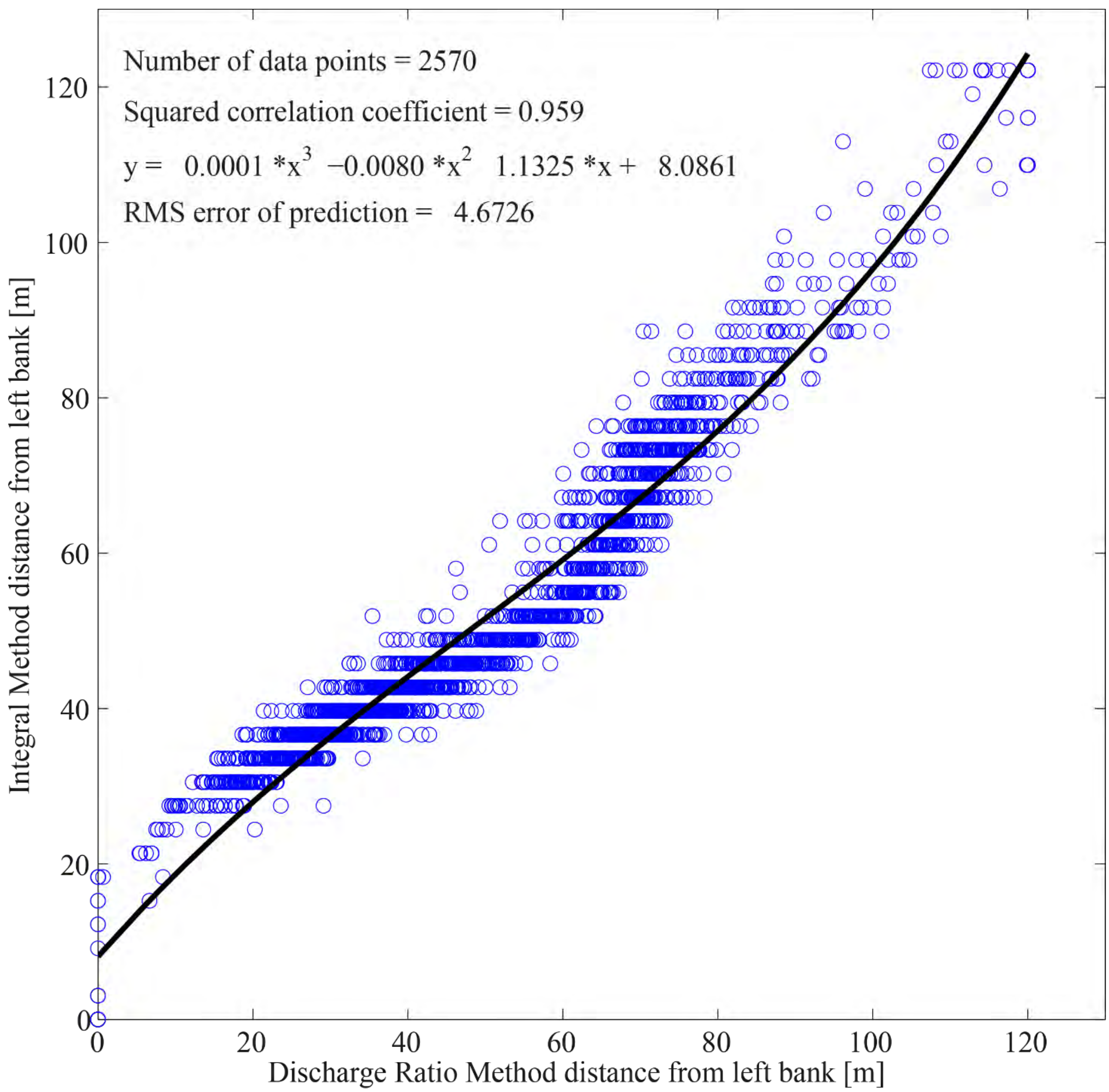


Figure 27. Non-linear regression of the critical streakline from the left bank at estimated from the discharge ratio and integral methods at CCuu; for positive flow. Note the locations of the critical streakline using the integral method is discretized into bins equal to the measurement bin spacing (3.06 m)

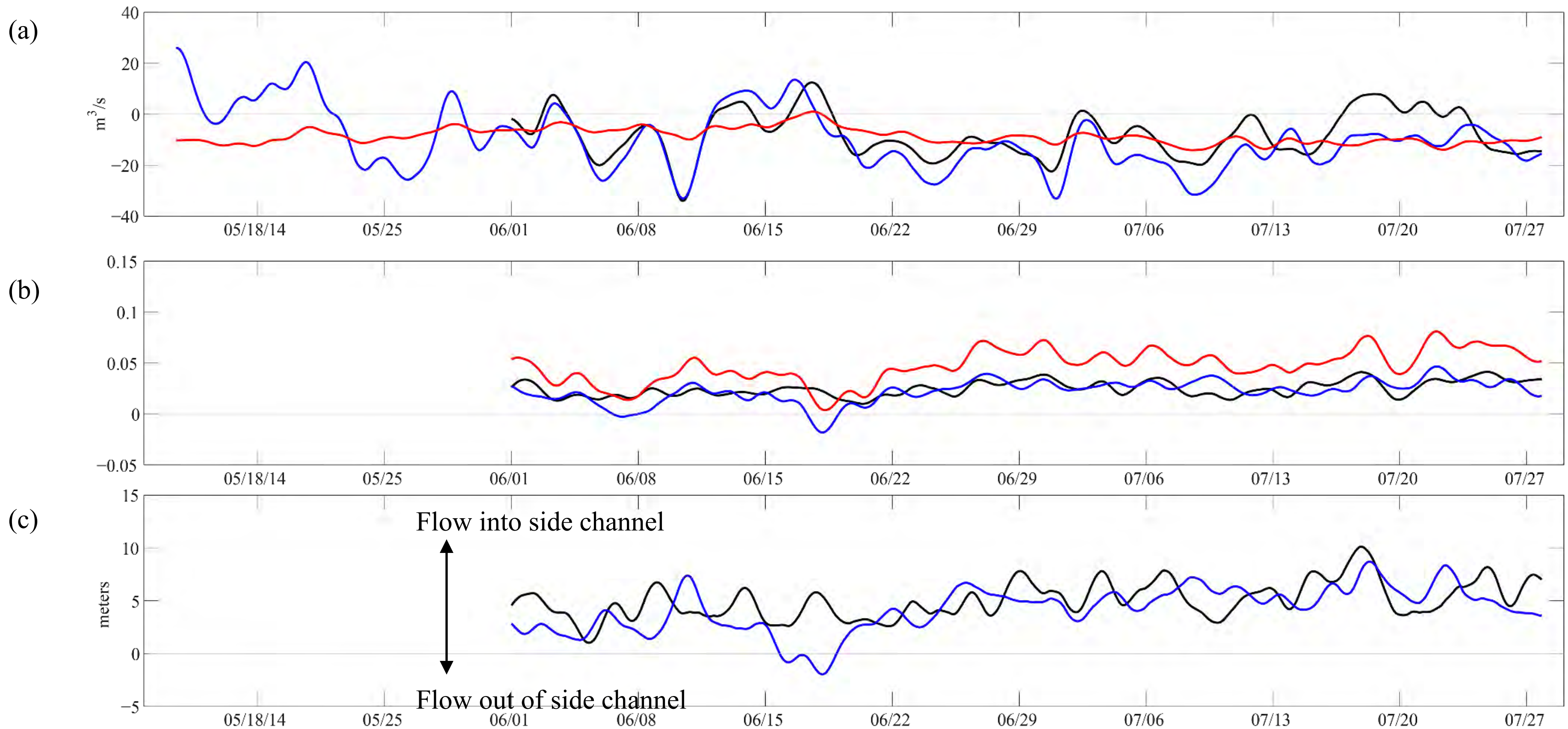


Figure 28. Time series data estimated using the velocity profile method for discharge calculation and the integral method for discharge ratio and critical streakline calculations at SJTC (a) tidally filtered discharge upstream (black), downstream (blue) and side channel (red) (b) tidally filtered discharge ratio at upstream (black), downstream (blue) and total (red) and (c) tidally filtered critical streakline in distance from upstream left bank (black) and downstream left bank (blue). Note negative critical streakline indicate flow from side channel to main channel.

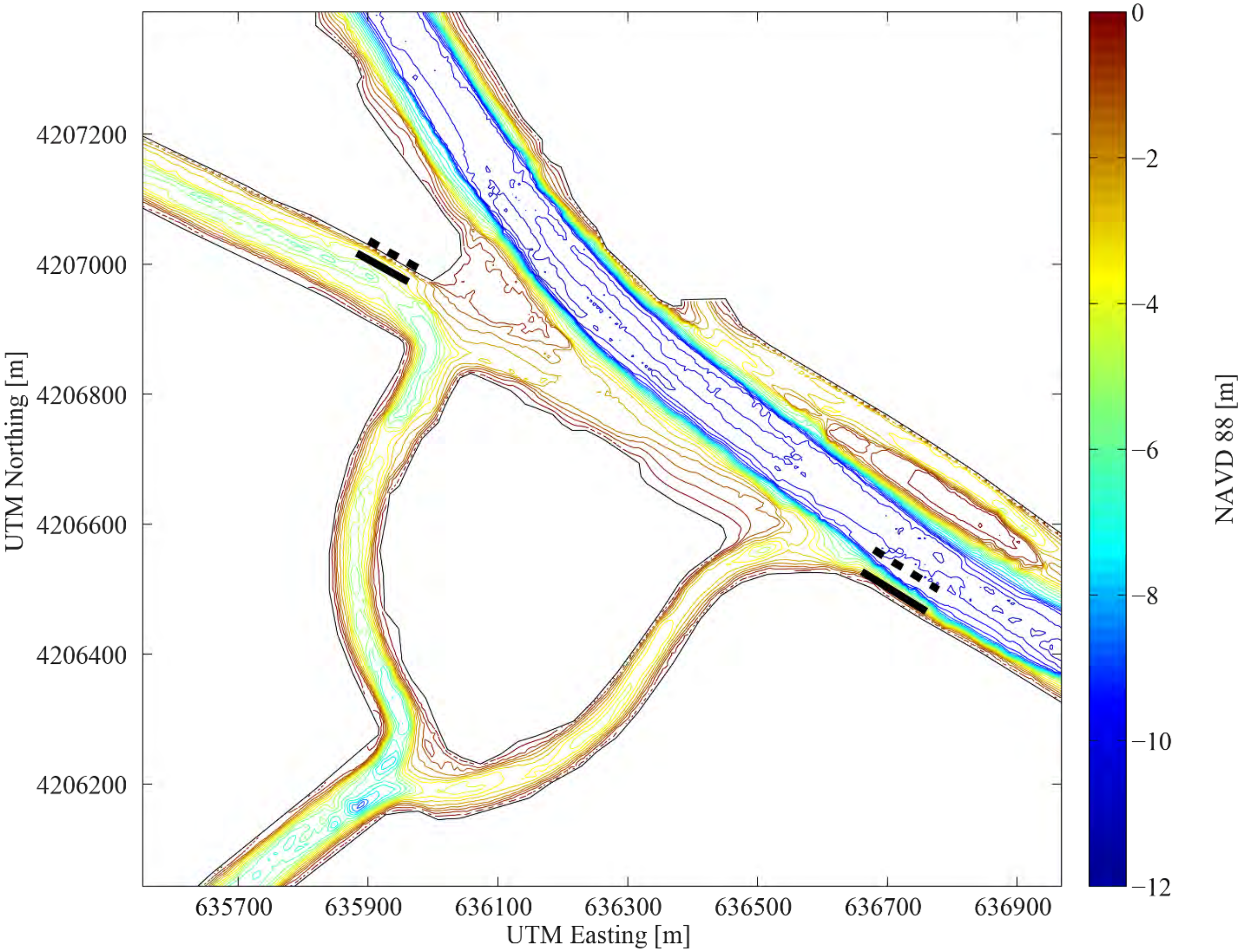


Figure 29. Upstream and downstream critical streakline positions at SJTC as reference from the left bank. The solid line represents the mean critical streakline and the dashed line represents one standard deviation from the mean.

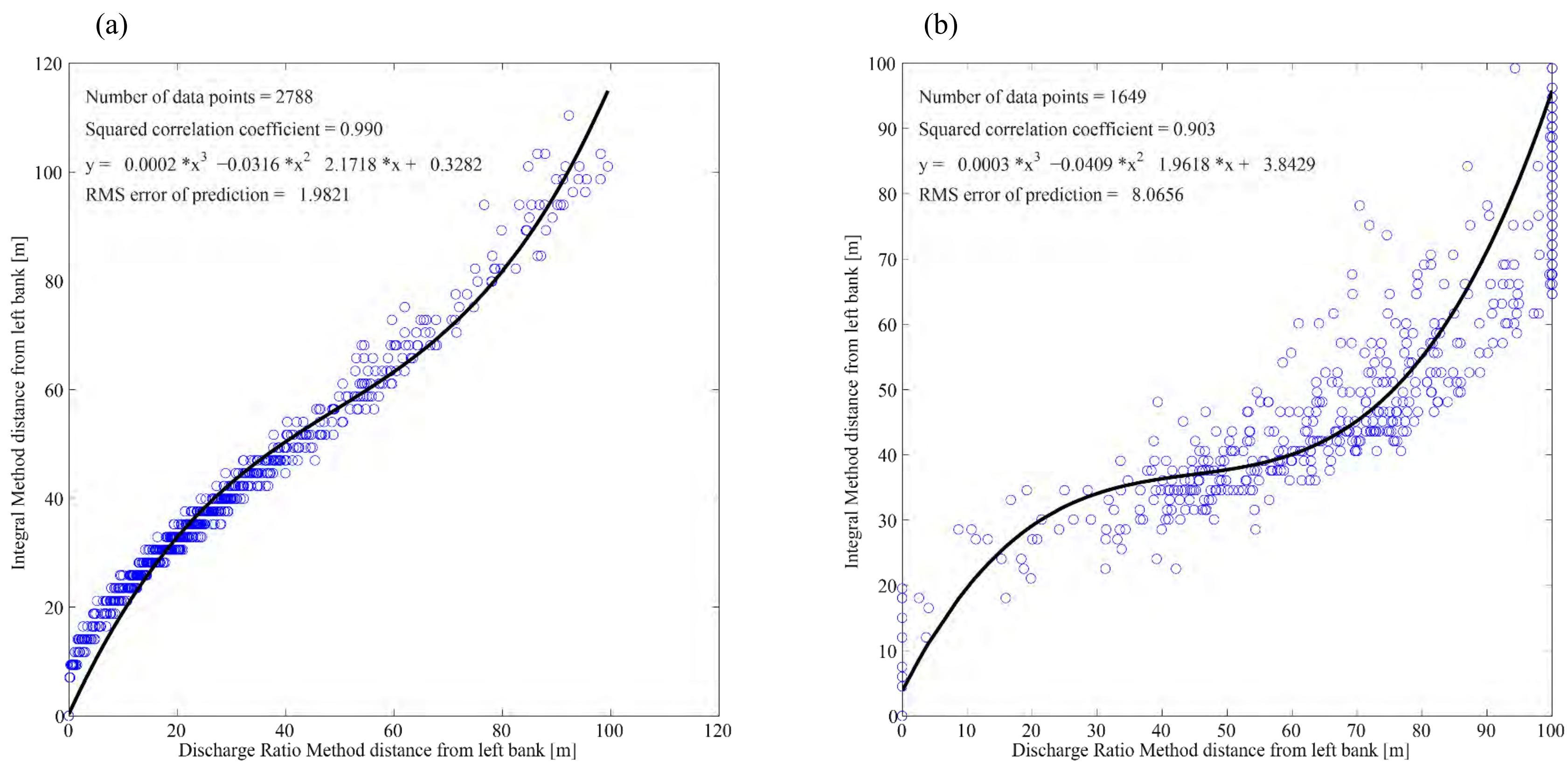


Figure 30. Non-linear regression of the critical streakline from the left bank estimated from the discharge ratio and integral methods (a) at TCuu; for positive flow conditions only and (b) at TCddw; for negative flow conditions only. Note outliers outside of 2 standard deviations from the regression curve were removed.

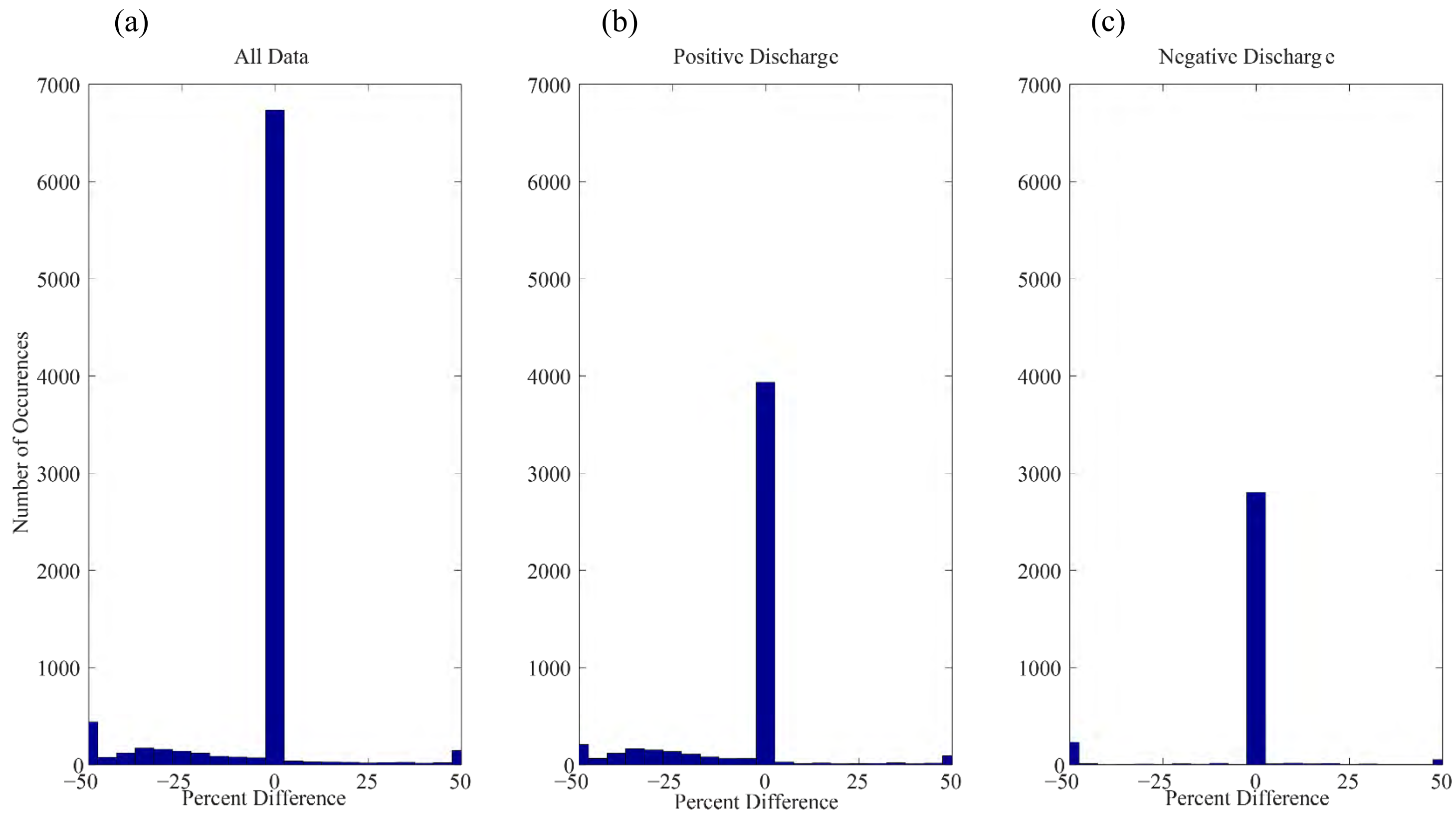


Figure 31. Histogram plot of the difference in flow ratio (Qr) and particle ratio (Pr) for velocity interpolation algorithm at HOR for (a) all data (b) positive discharge conditions (c) negative discharge conditions.

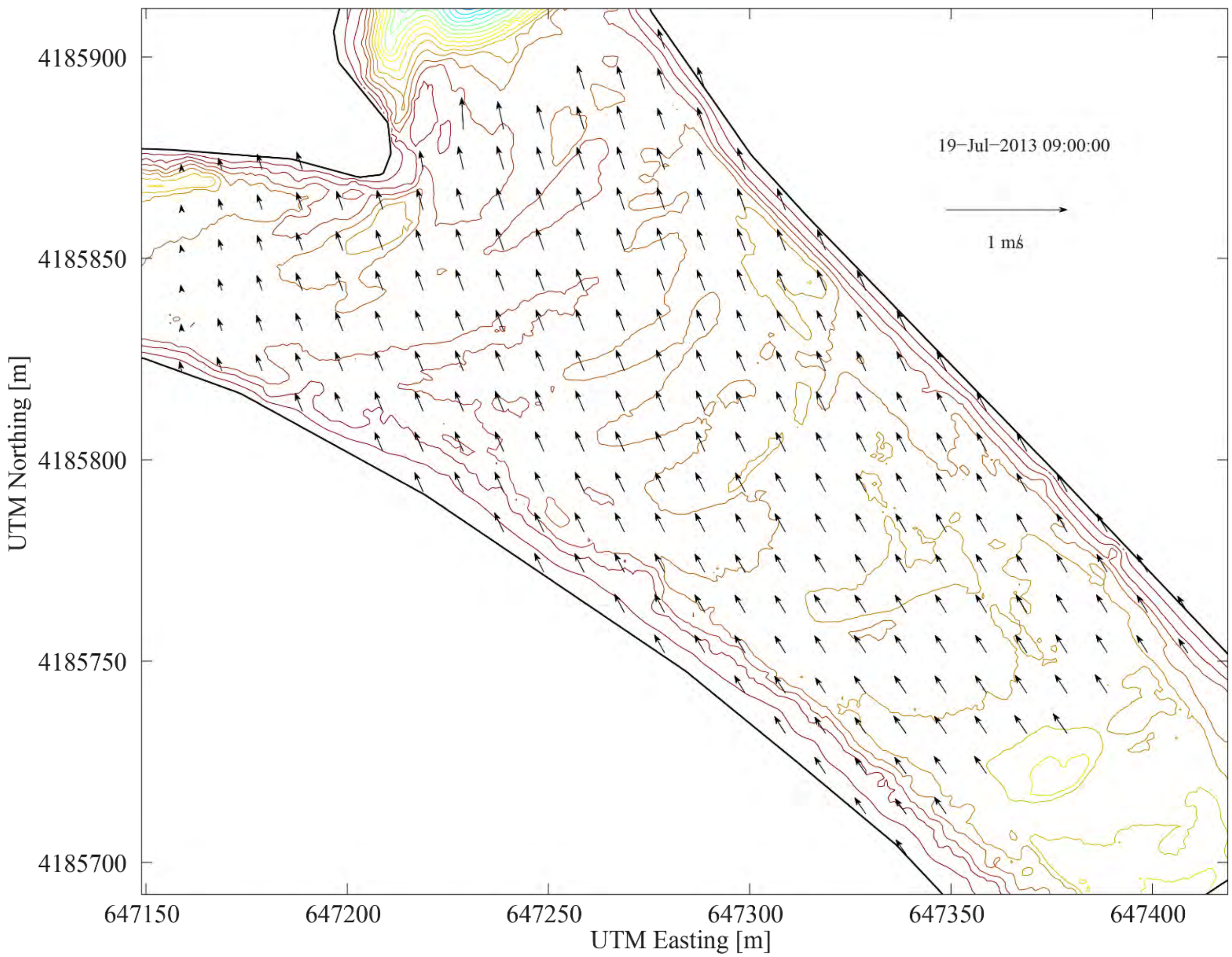


Figure 32. Interpolated Velocity Vectors overlain on bathymetry plot at HOR for typical positve flow conditions.

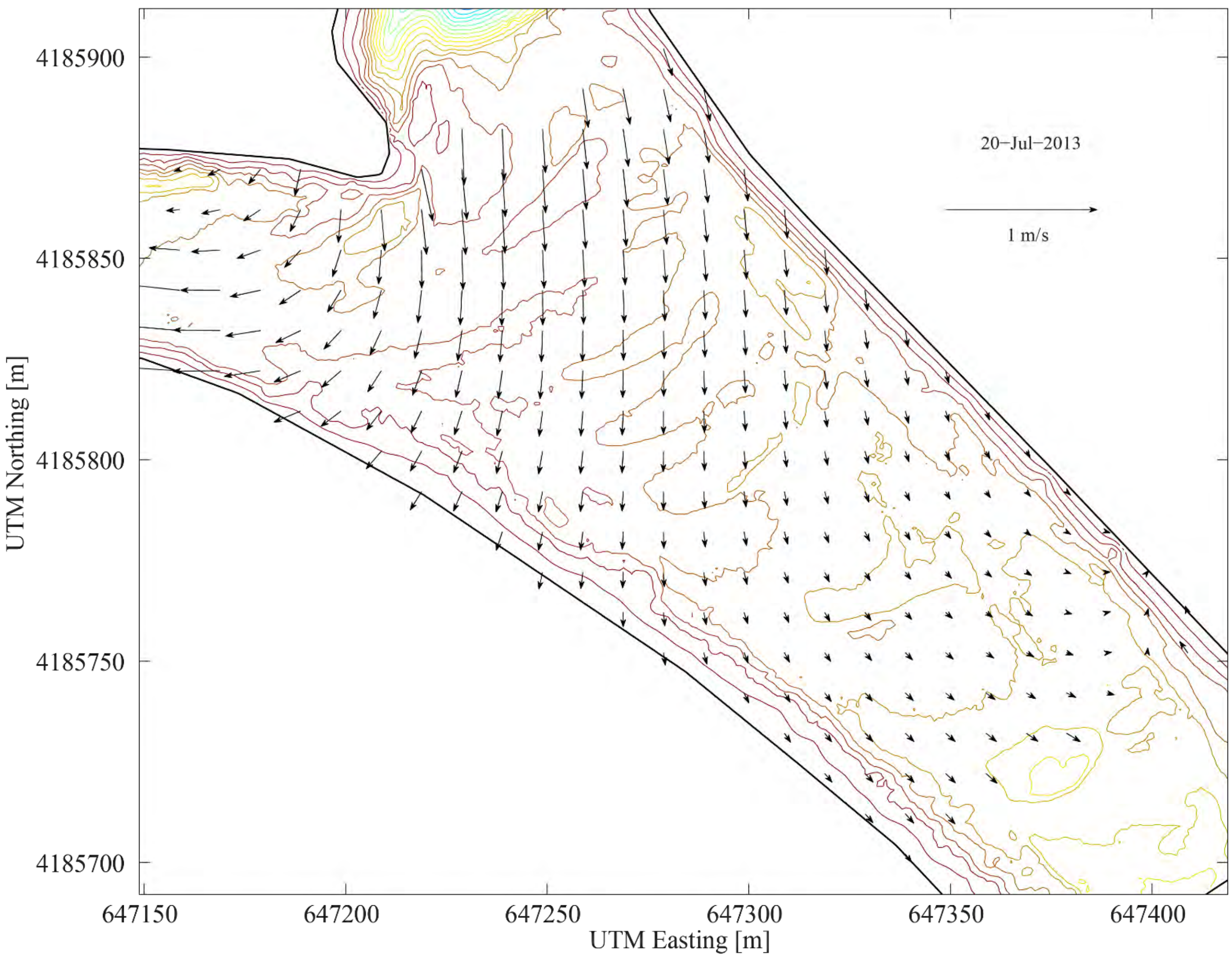


Figure 33. Interpolated Velocity Vectors overlain on bathymetry plot at HOR for typical negative flow conditions.

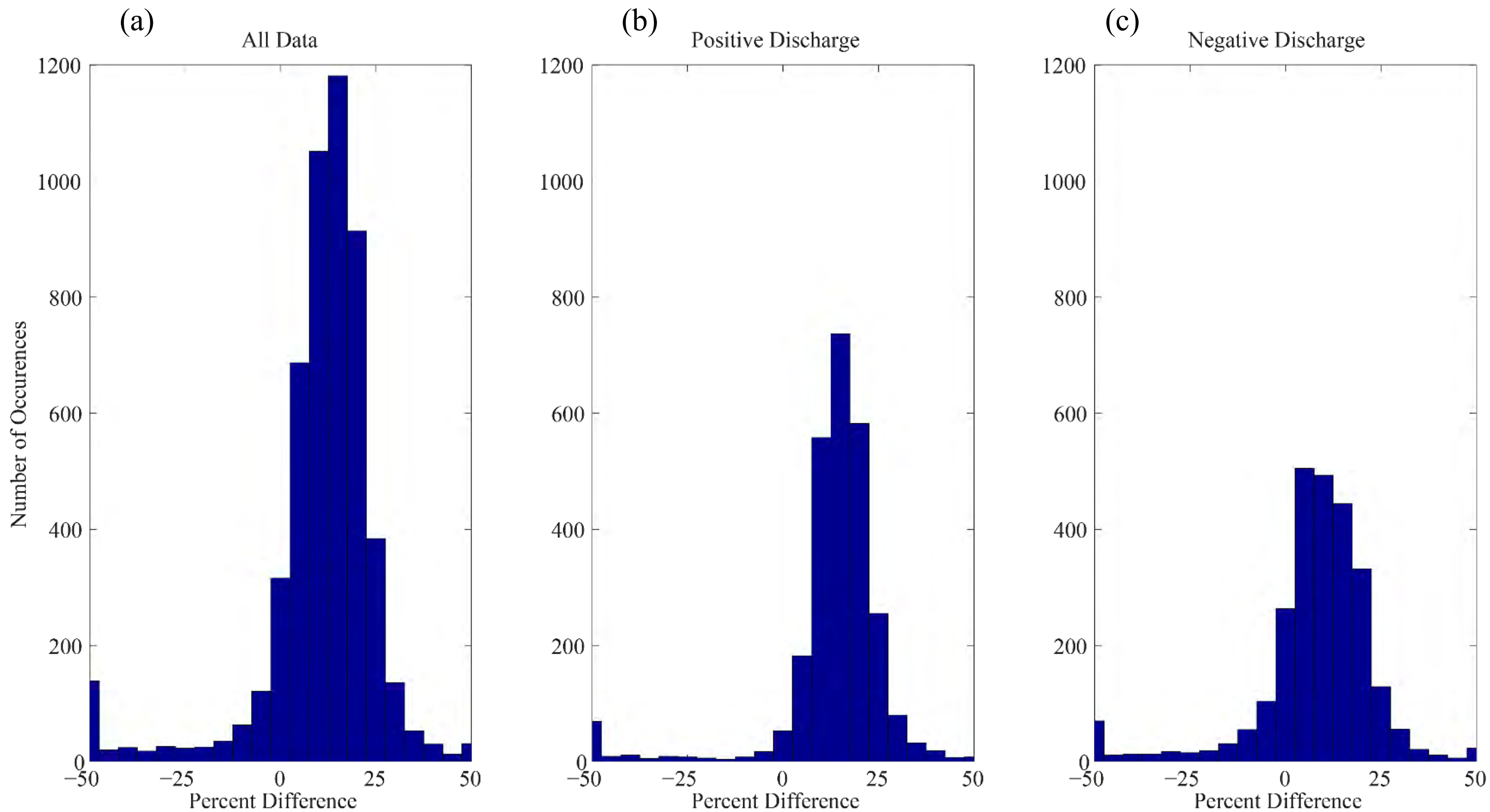


Figure 34. Histogram plot of the difference in flow ratio (Qr) and particle ratio (Pr) for velocity interpolation algorithm at SJCC junction 1 for (a) all data (b) positive discharge conditions (c) negative discharge conditions.

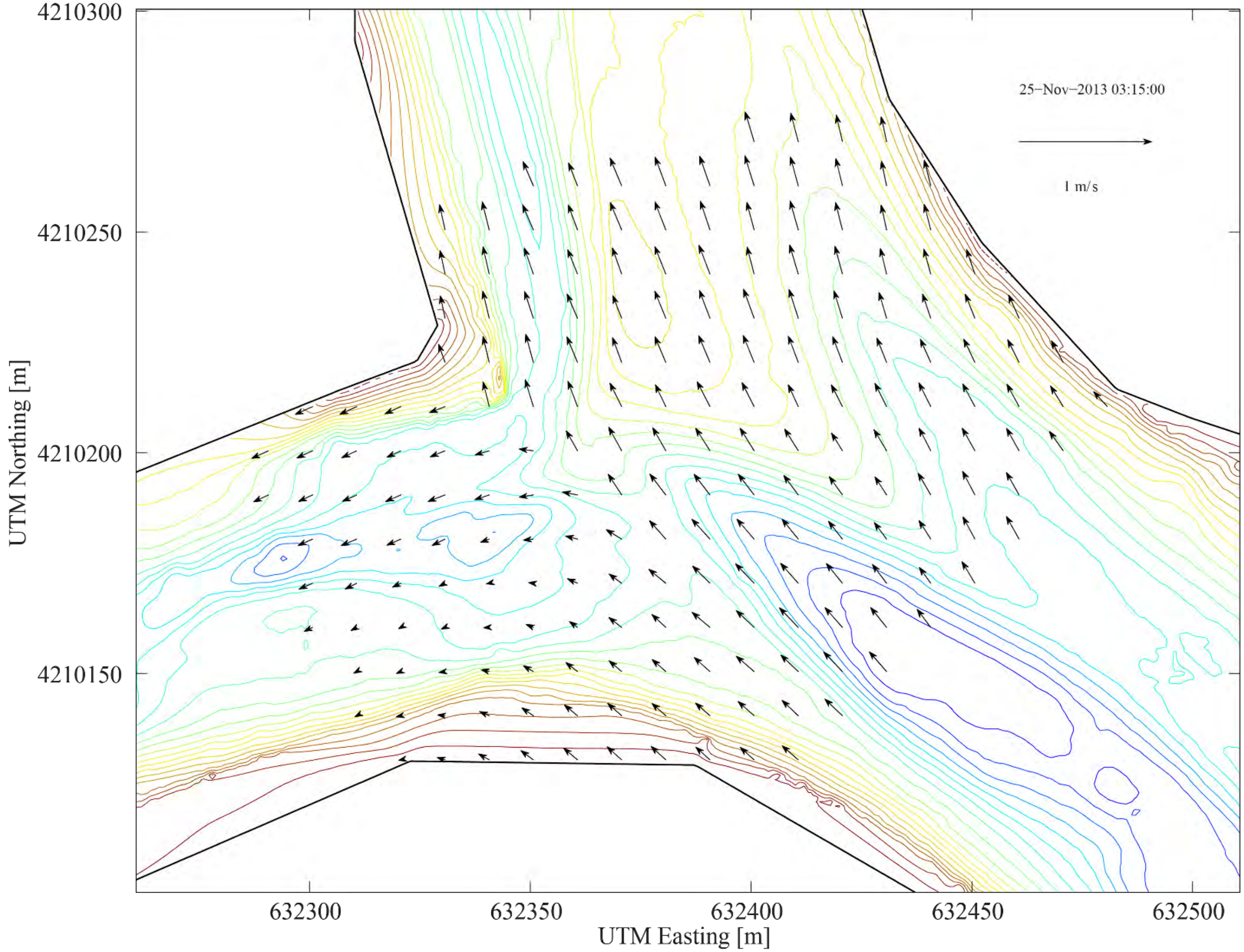


Figure 35. Interpolated Velocity Vectors overlain on bathymetry plot at SJCC junction 1 for typical positive flow conditions.

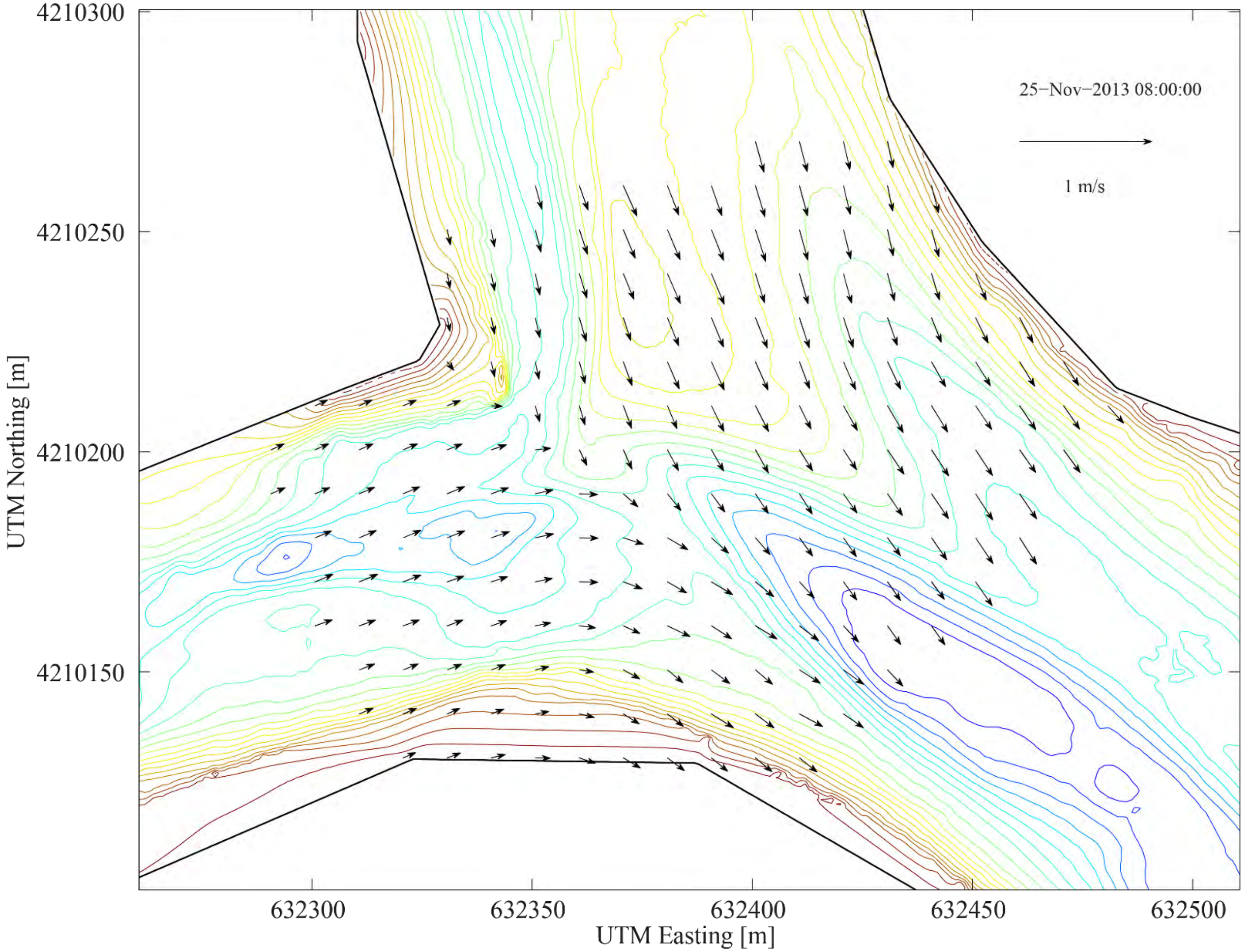


Figure 36. Interpolated Velocity Vectors overlain on bathymetry plot at SJCC junction 1 for typical negative flow conditions.

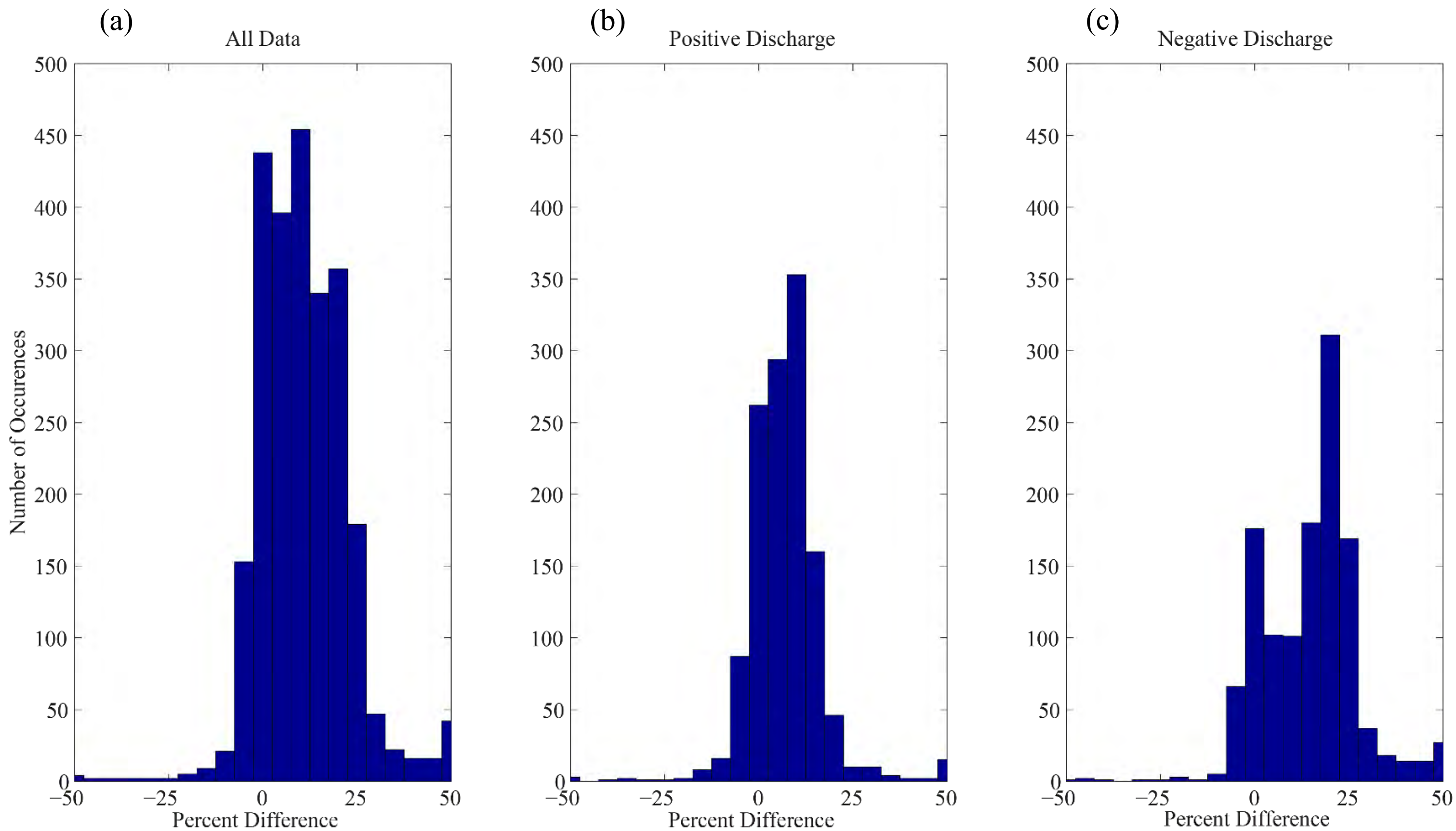


Figure 37. Histogram plot of the difference in flow ratio (Qr) and particle ratio (Pr) for velocity interpolation algorithm at SJTC for (a) all data (b) positive discharge conditions (c) negative discharge conditions.

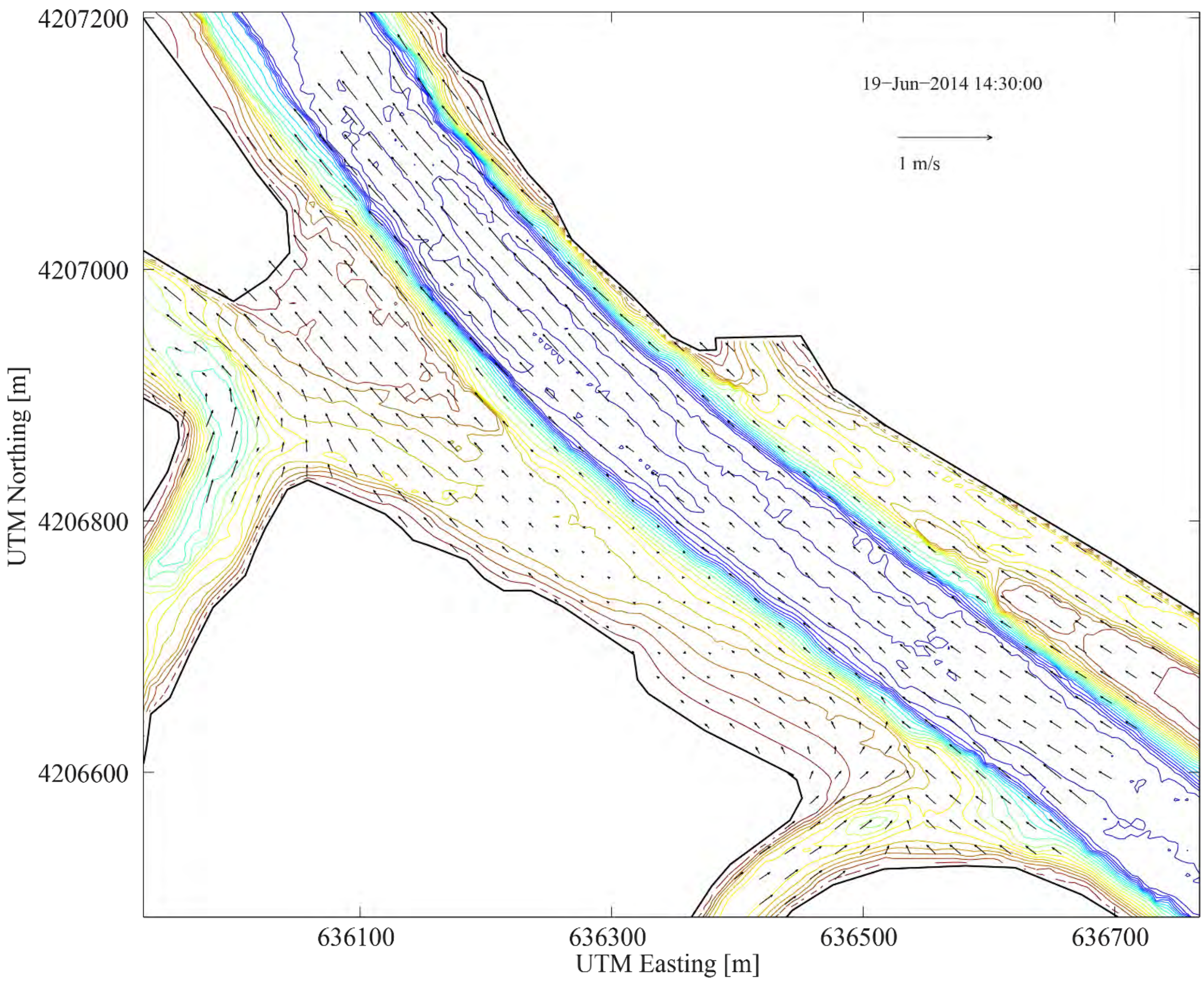


Figure 38. Interpolated Velocity Vectors overlain on bathymetry plot at SJTC for typical positive flow conditions.

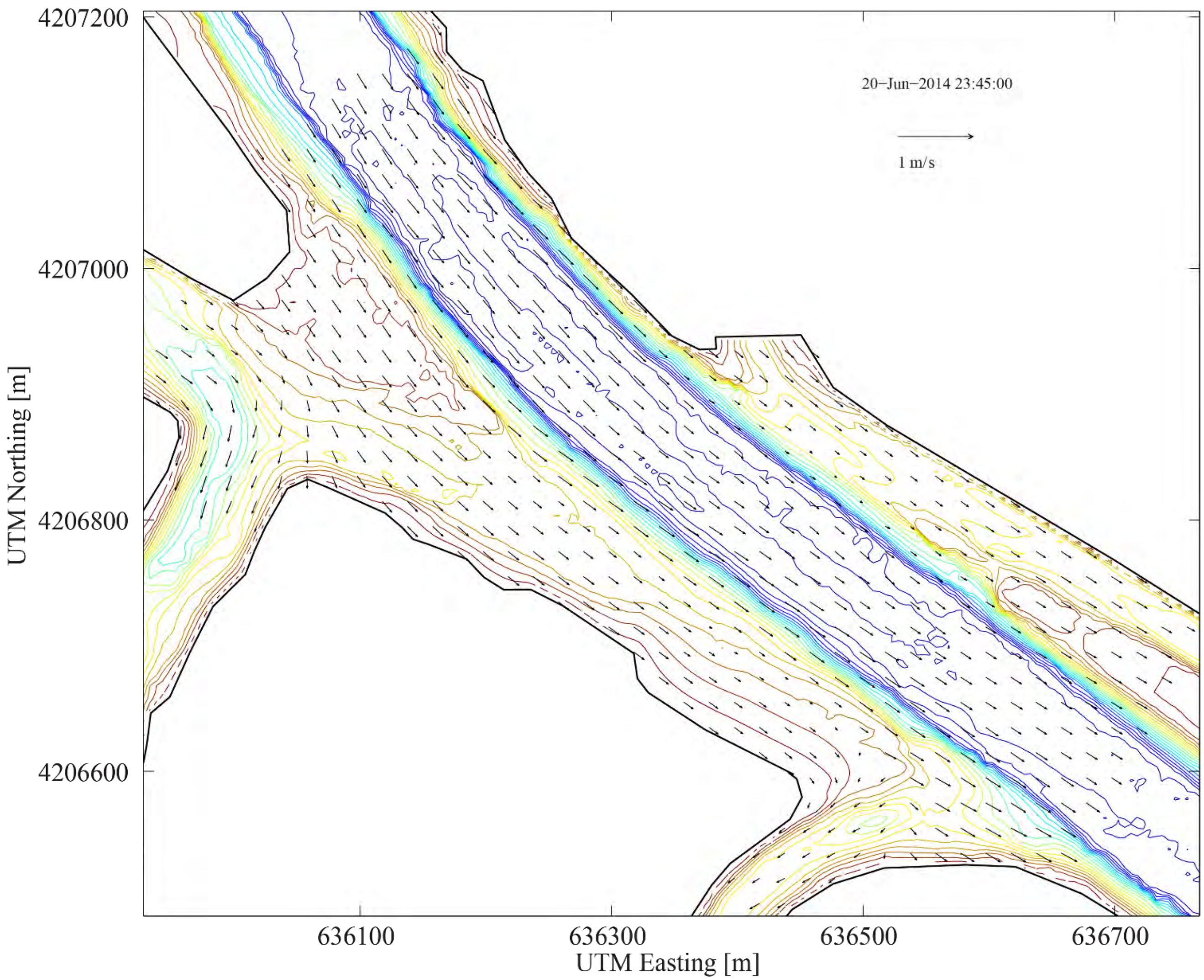


Figure 39. Interpolated Velocity Vectors overlain on bathymetry plot at SJTC for typical negative flow conditions.

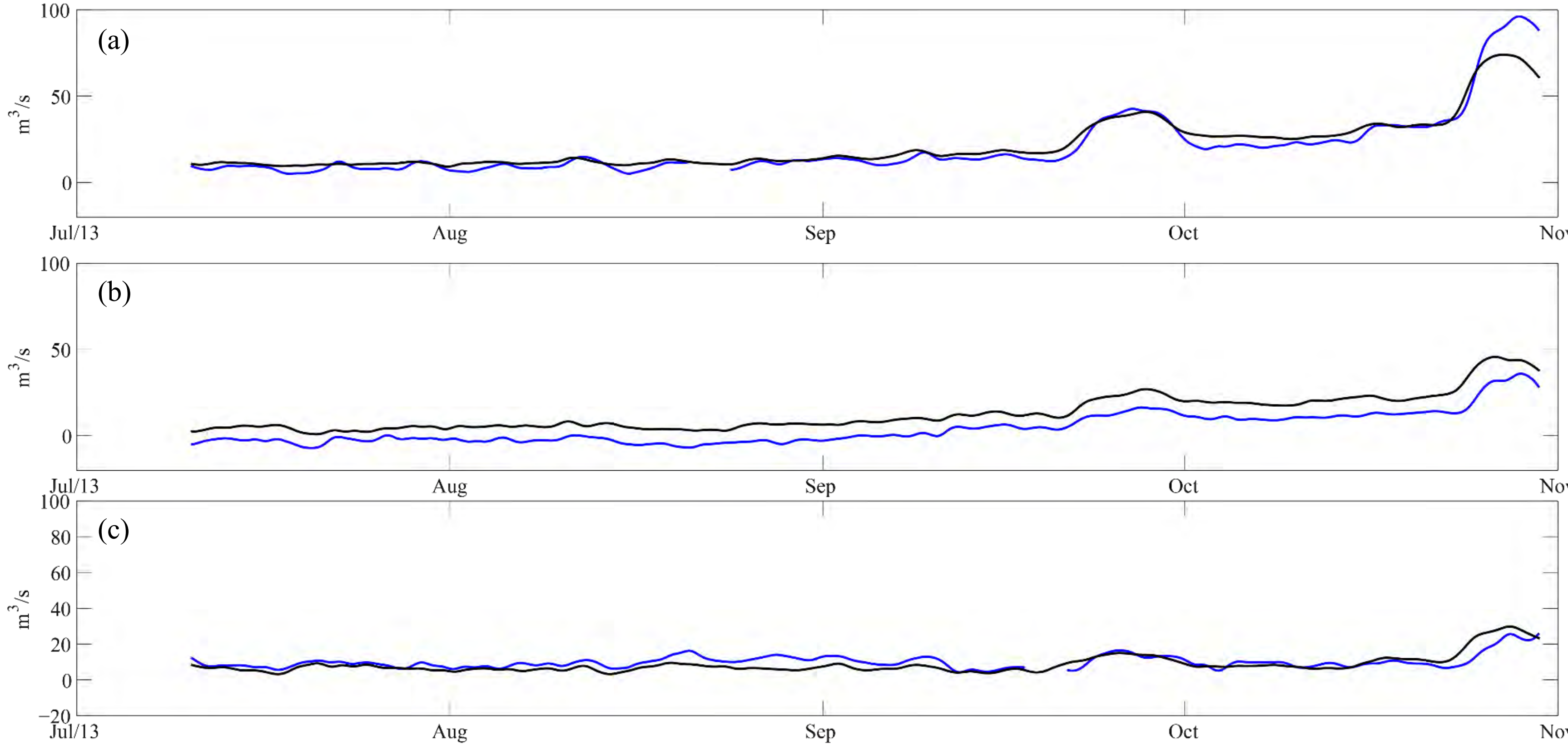


Figure 40. Tidally filtered discharge measured data (blue) and modeled data (black) at (a) HORu (b) HORs and (c) HORe.

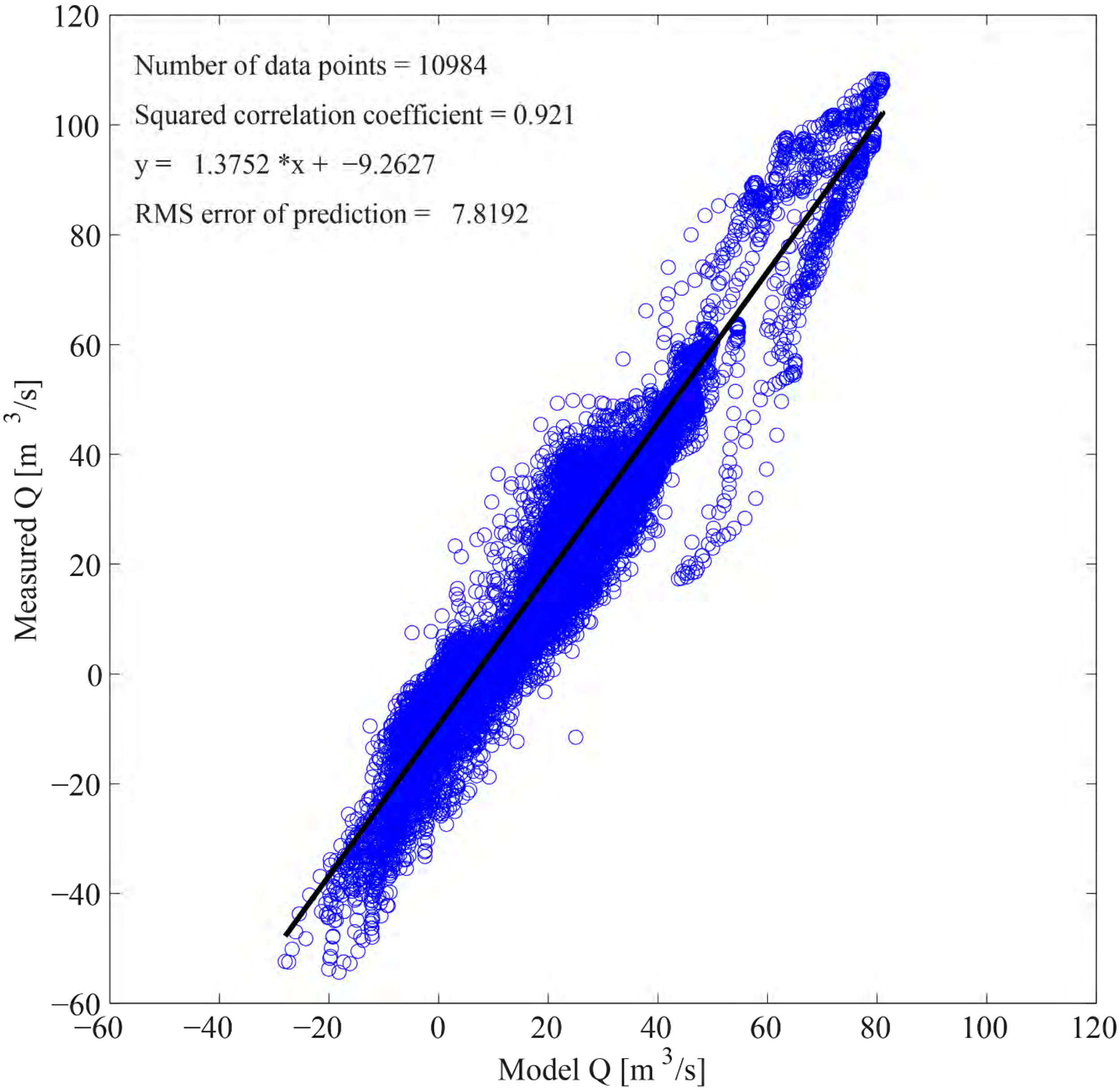


Figure 41. Linear Regression of model discharge vs. measured discharge at HORu. Modeled data is phase corrected by +0.25 hours.

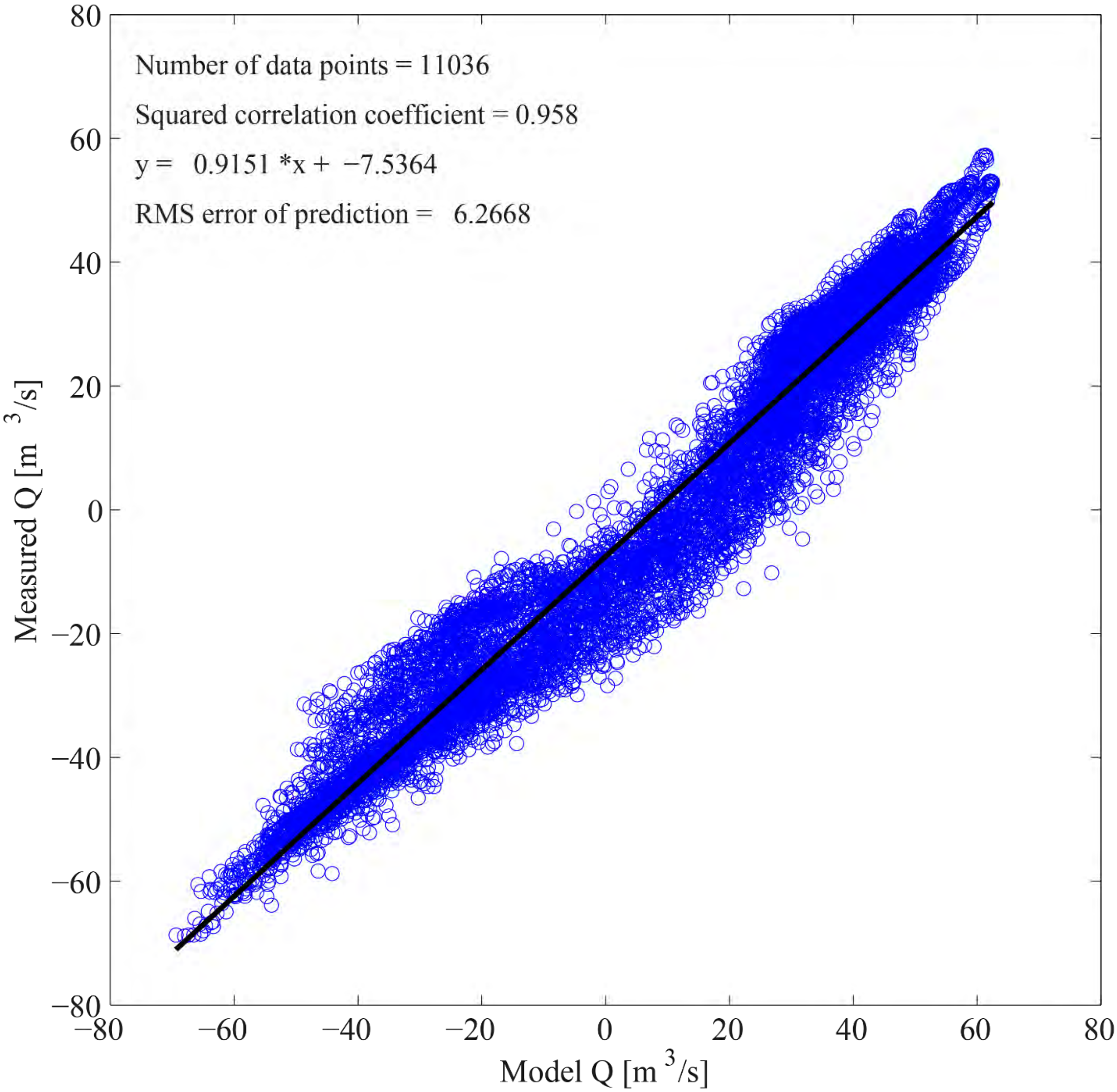


Figure 42. Linear Regression of model discharge vs. measured discharge at HORs. Modeled data is phase corrected by -0.25 hours.

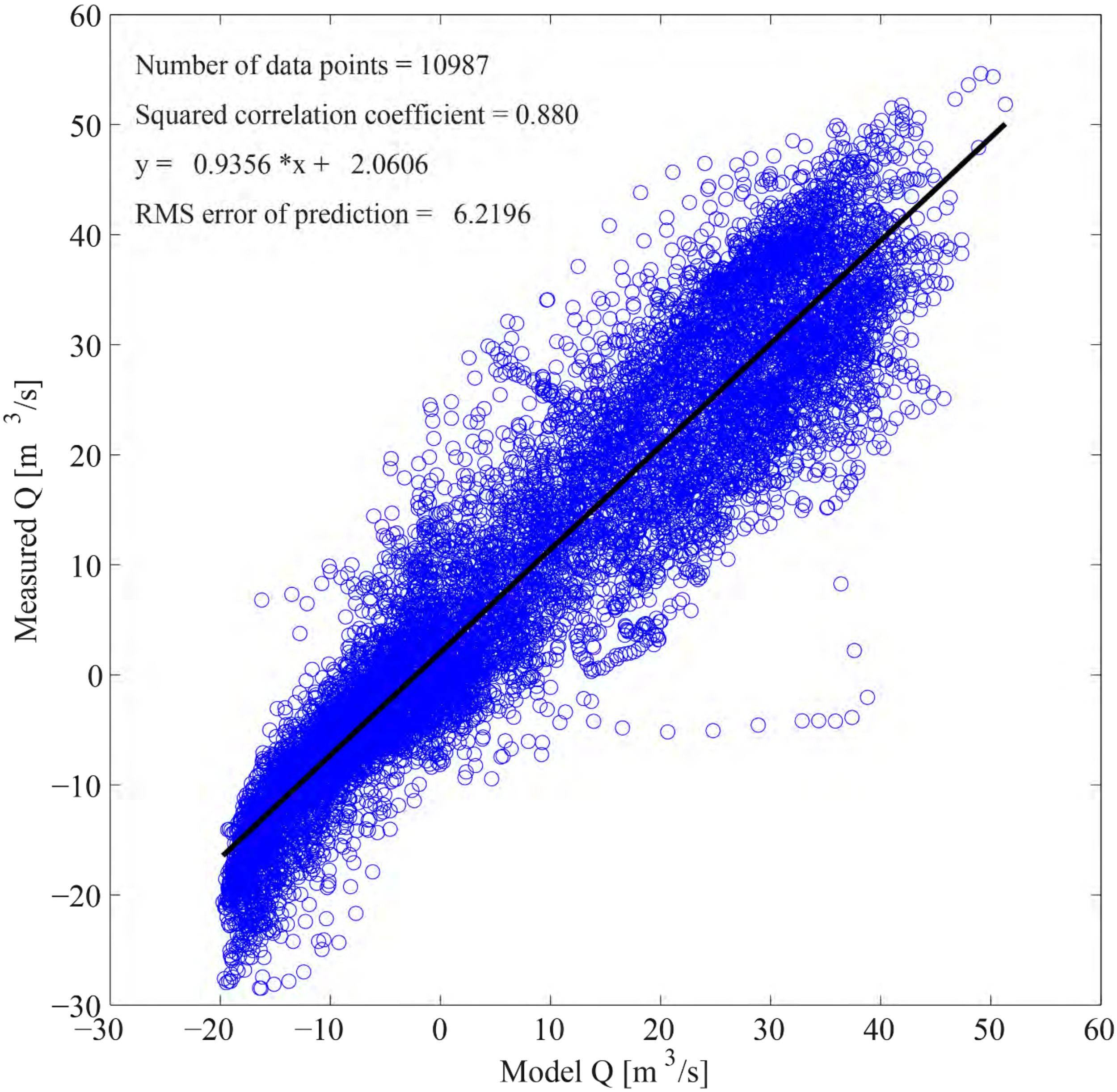


Figure 43. Linear Regression of model discharge vs. measured discharge at HORe. Modeled data is phase corrected by -0.5 hours.

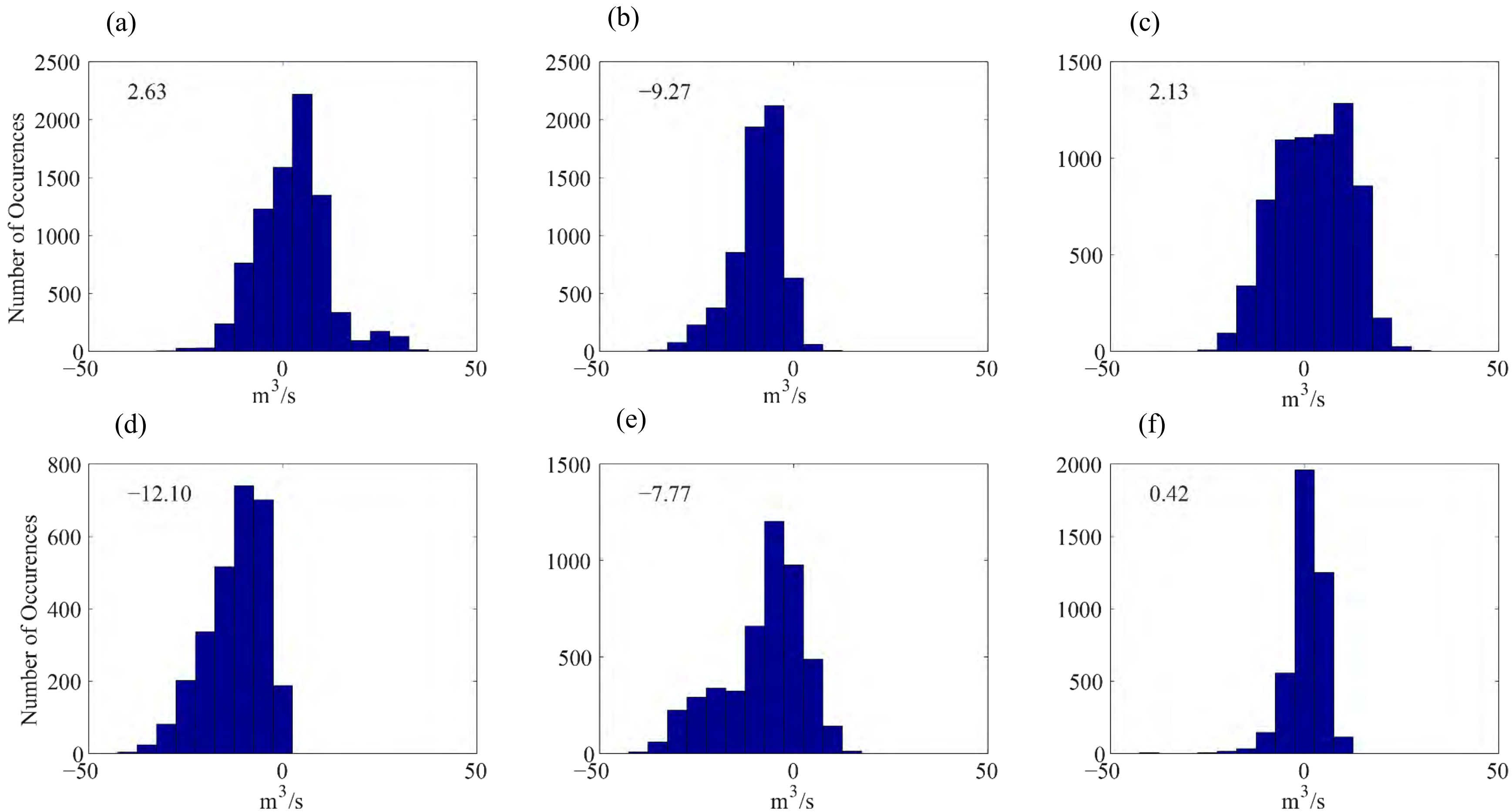


Figure 44. Histogram plots of amplitude errors between measured and modeled data. Data is separated based on tidal phase; top panels are during positive discharge and bottom panels are during negative discharge at (a,d) HORu (b,e) HORs and (c,f) HORe. Number in the top left corner indicate mean amplitude differences for that site and discharge range.

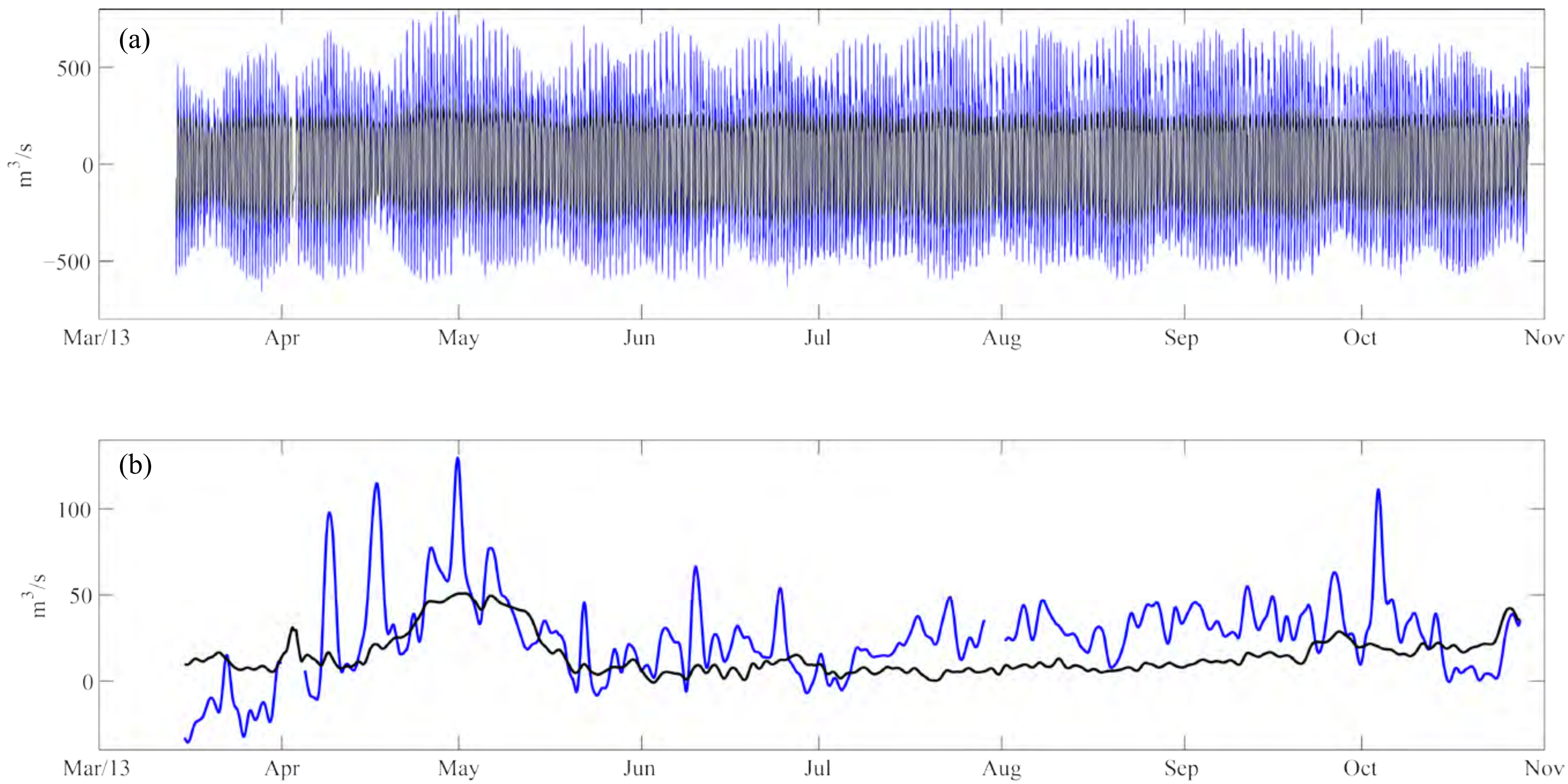


Figure 45. Time series data for SJTC (a) 15 min average discharge estimated from measured data (blue) and from model (black) (b) Tidally filtered discharge from measured data (blue) and model data (black).

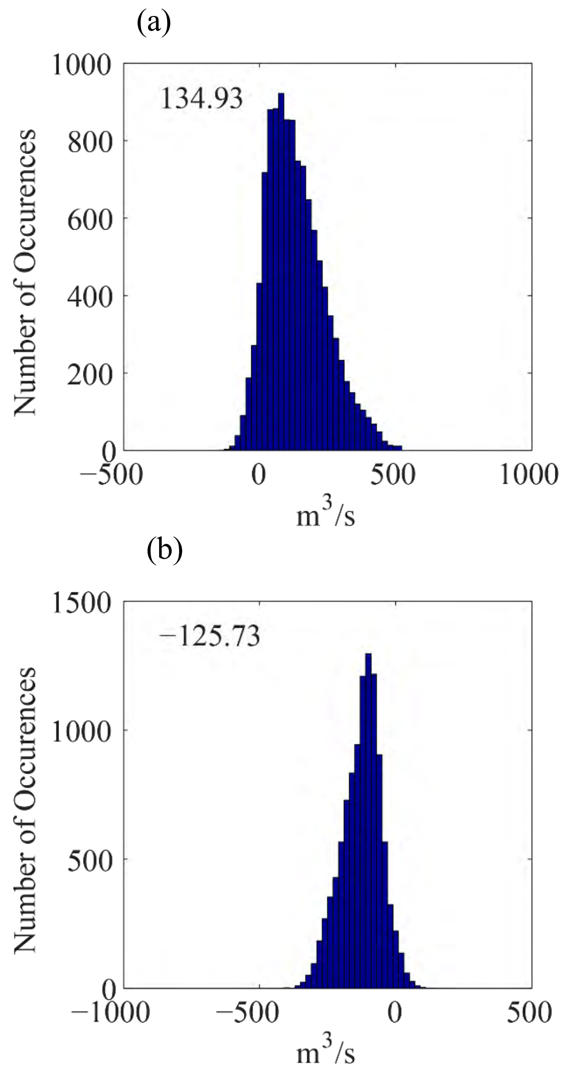


Figure 46. Histogram plots of amplitude errors between measured and modeled data at SJTC. Data is separated based on tidal phase (a) top panel is positive discharge values and (b) bottom panel is negative discharge values.

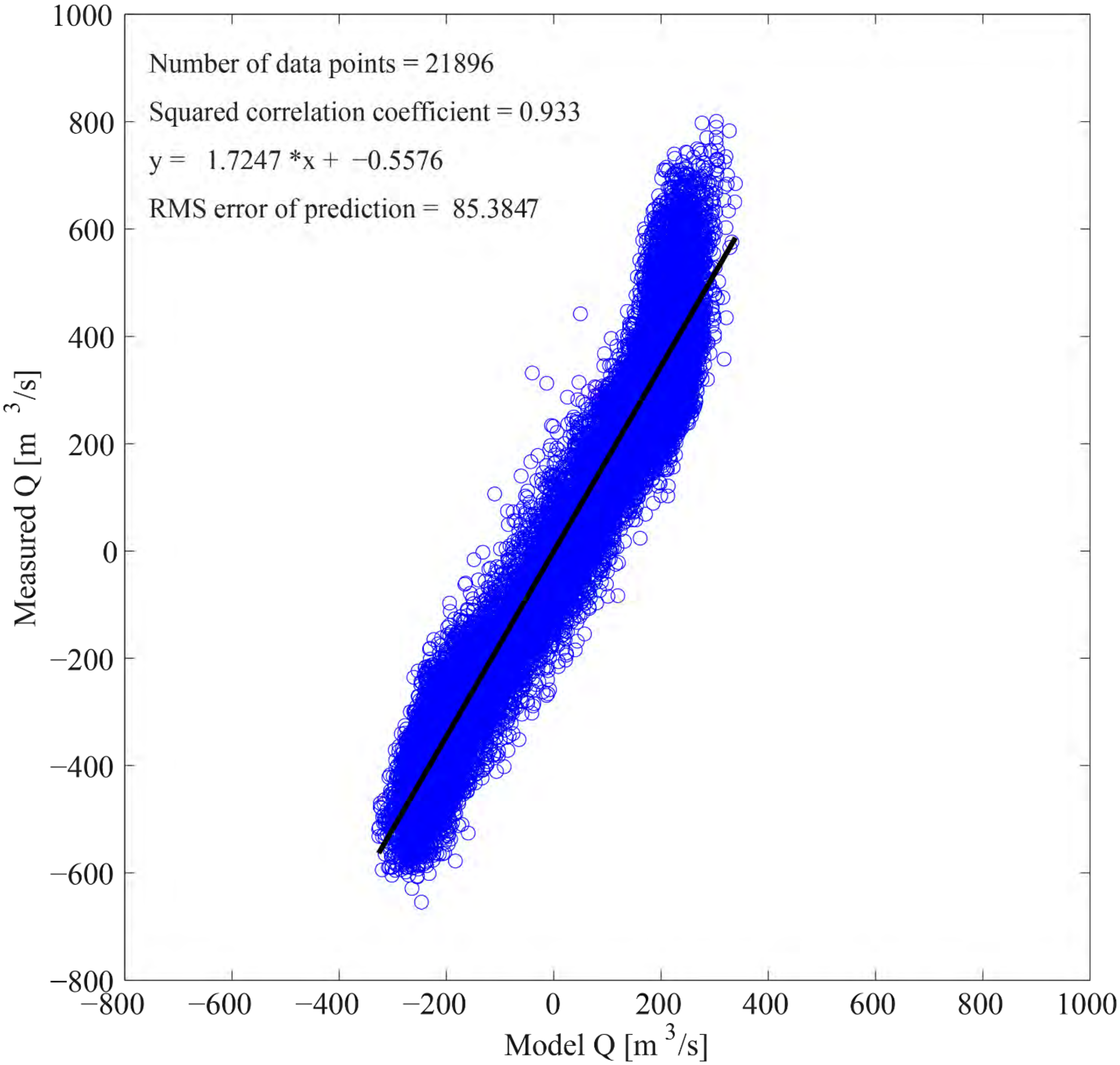


Figure 47. Linear Regression of model discharge vs. measured discharge at SJTC. Modeled data is not phase corrected.

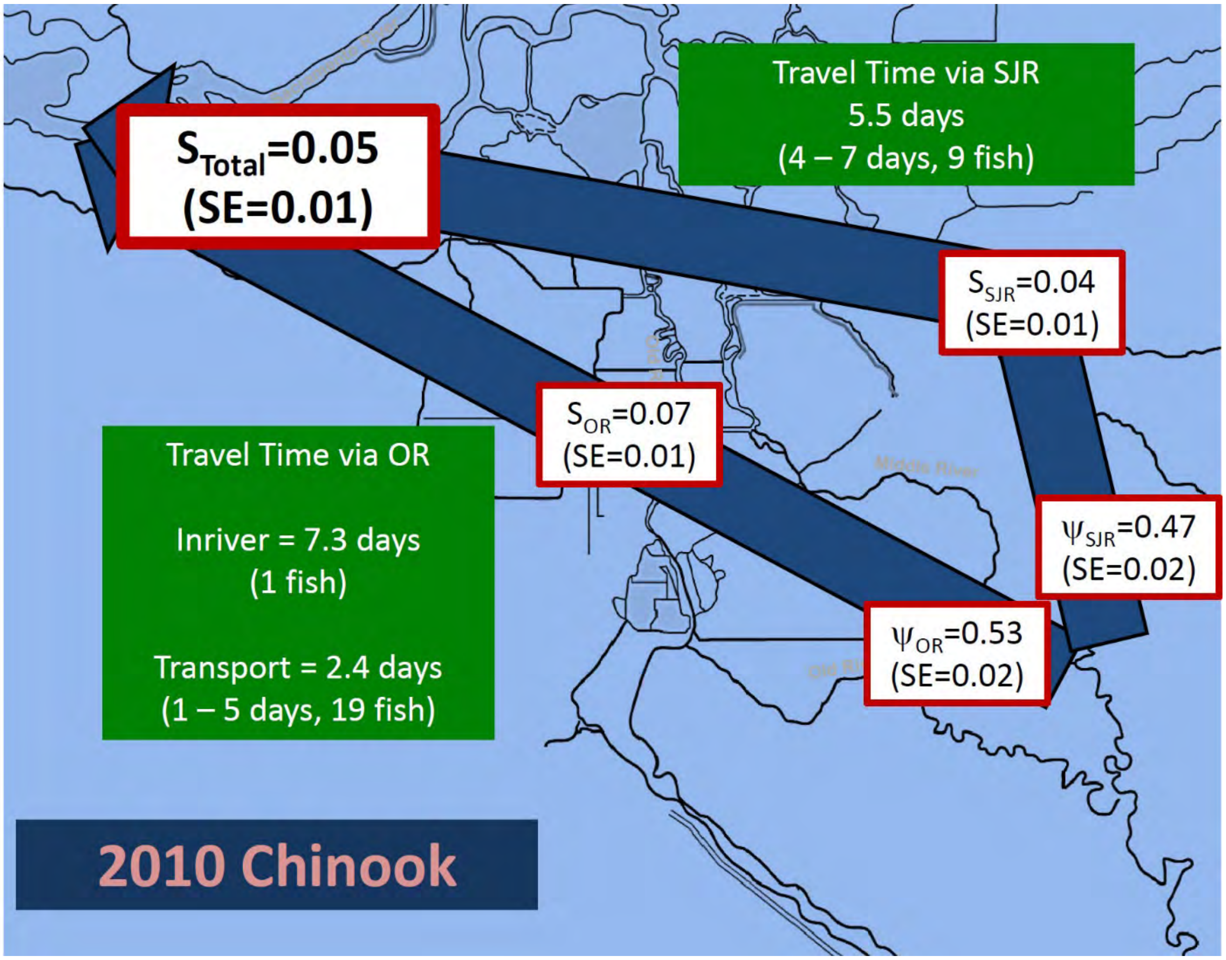


Figure 48 Comparison of entrainment rates, ψ, and survival, S, between acoustically tagged juvenile salmon taking an Old River route through the central delta versus remaining in the mainstem San Joaquin based on 6-year study data collected in 2010 (Courtesy of Rebecca Buchanan).

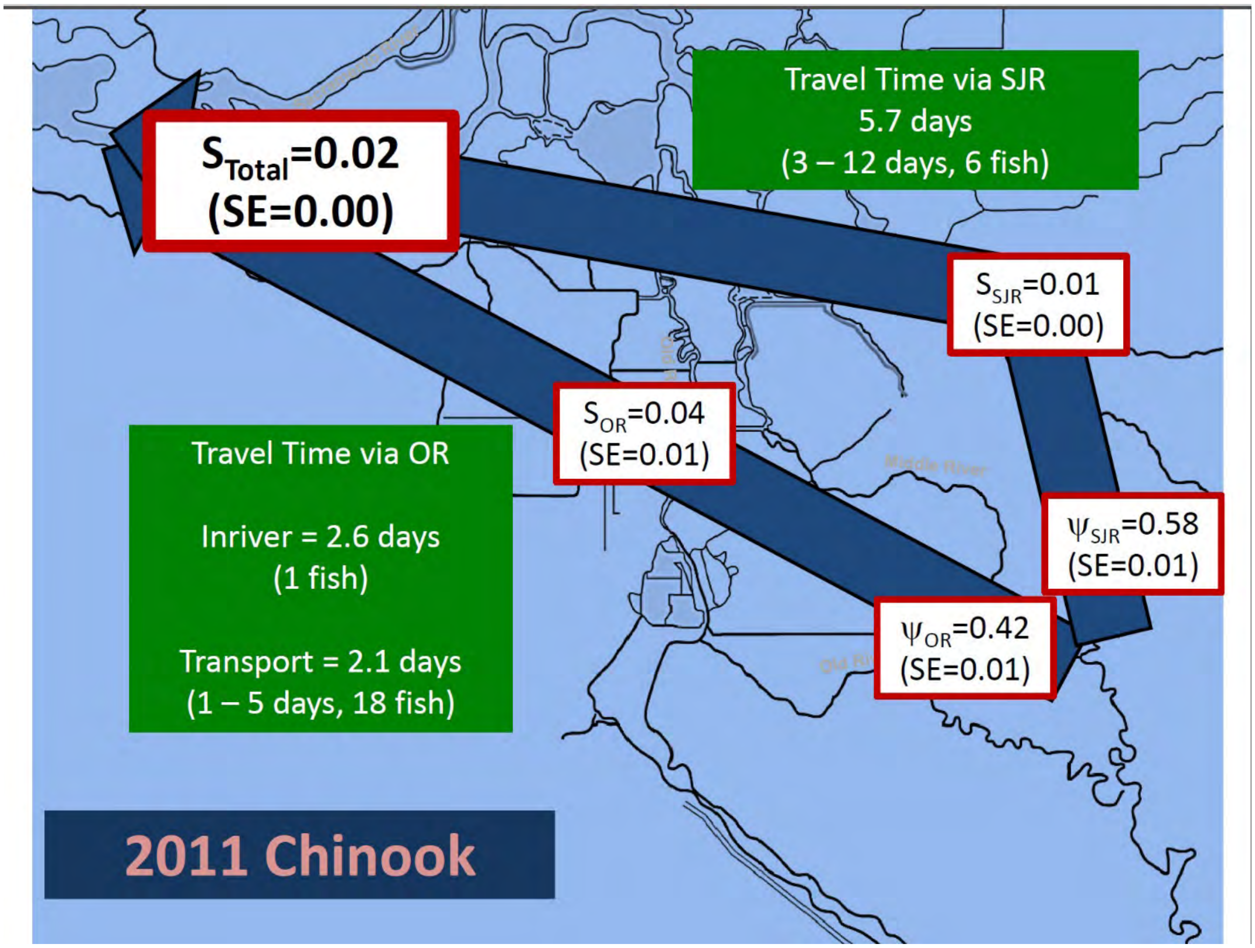


Figure 49 Comparison of entrainment rates, ψ, and survival, S, between acoustically tagged juvenile salmon taking an Old River route through the central delta versus remaining in the mainstem San Joaquin based on 6-year study data collected in 2011 (Courtesy of Rebecca Buchanan).

Figure 50. Ariel View of Columbia Cut and suggested placement of behavioral barriers. Option 1 would be placed where data was collected but may be at either too steep of an angle or be unnecessarily long. Option 2 presumably would have the same effect but be significantly small, and therefore more cost effective. White arrows indicate relative magnitude of flow and direction during positive flow conditions. The main stem San Joaquin flows are roughly four times the flow in the CCuu and the flow in Columbia Cut is about half of that.

Figure 51. Ariel View of Turner Cut and suggested placement of behavioural barriers yellow lines. The two Negative flow barriers are suggested instead of a barrier inside of TCddw, since most of the flow from TCddw enters TCds on the flood tide. White arrows indicate relative magnitude of flow on the main steam San Joaquin relative to Turner Cut. The double ended arrow in Turner Cut indicates that during the ebb tide there is both positive and negative flow at Turner Cut. The relevant sites are labeled as well.

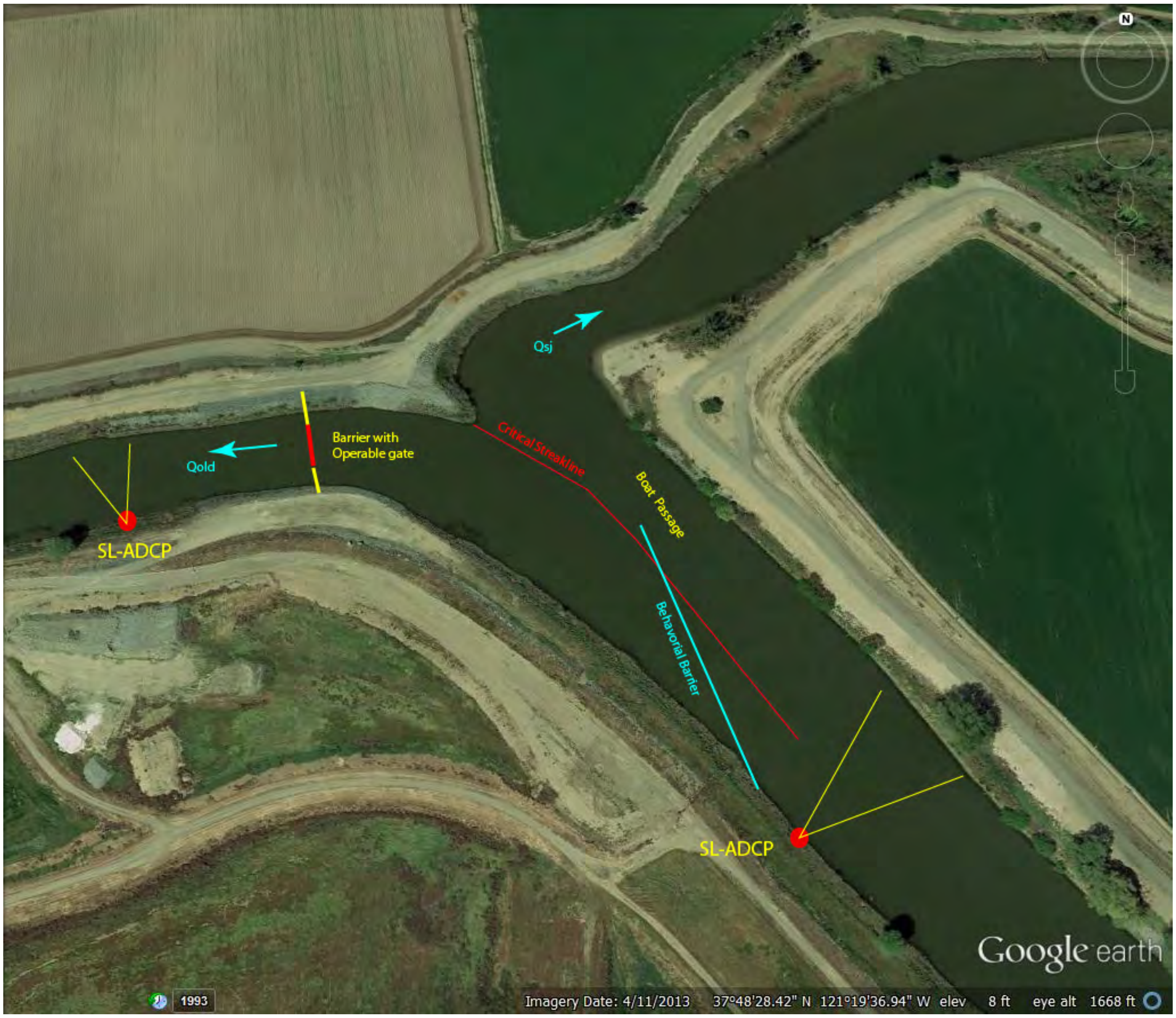
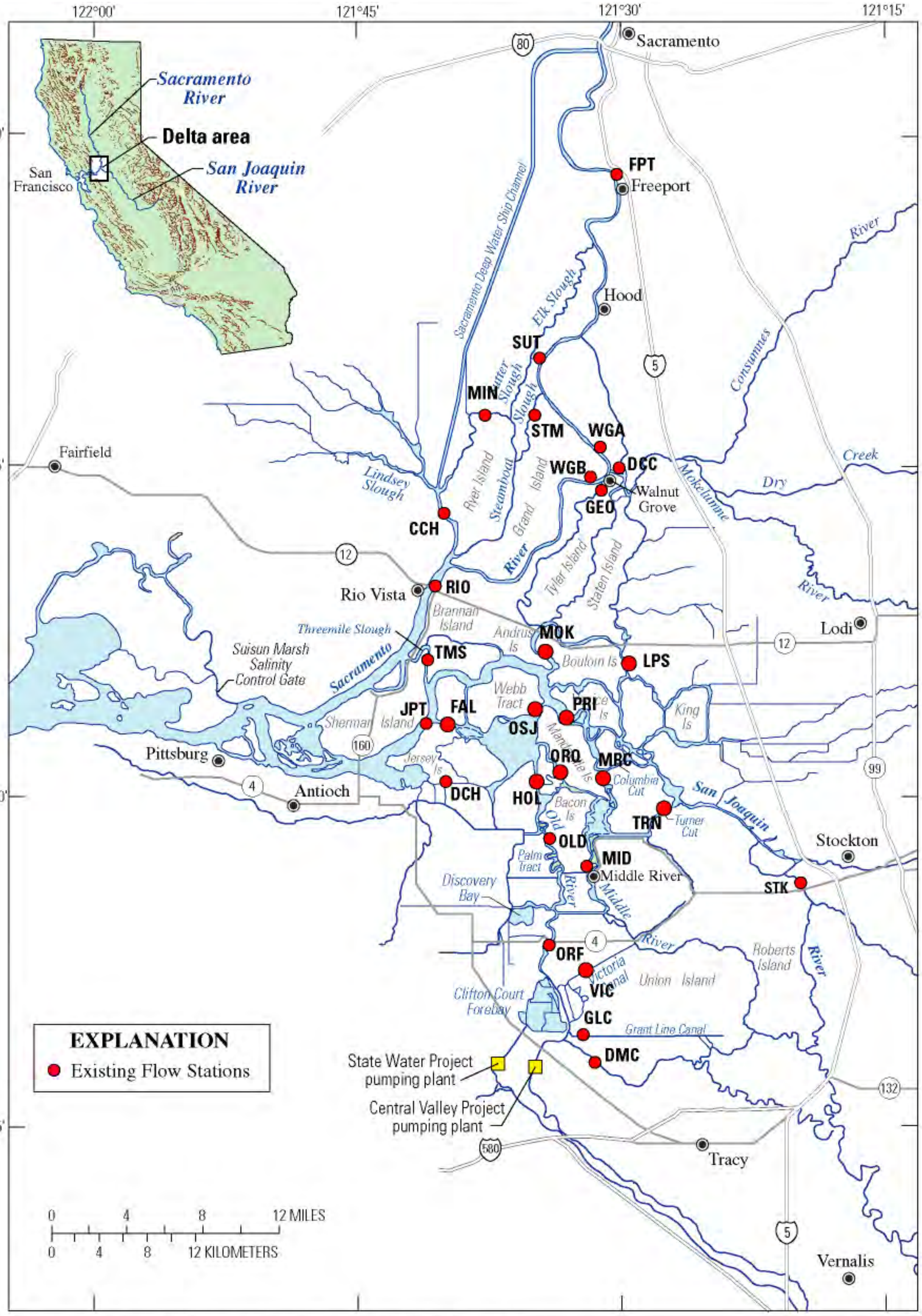


Figure 52. Schematic of combining a technologies. An operable barrier that modulates the flow so that the streakline is in an optimal position for an upstream behavioral barrier. The ration of the discharges, Qold/Qsj, collected from a pair of SL-ADCP's shown are used to control the gate position.

Figure 53. SL-ADCP deployment schematic showing two SL-ADCP's which can be used in combination with the permanent USGS flow station TRN(Q) above to understand the influence of high San Joaquin River inflows and exports on the hydrodynamics of the Turner Cut junction.

Figure 54. SL-ADCP deployment schematic showing four SL-ADCP's which can be used to understand the influence of high San Joaquin River inflows and exports on the hydrodynamics of the Columbia Cut junction.



Location of flow station sites in the Delta Area of California.

Figure 55. Location of USGS-maintained flow and water quality stations in the Sacramento/San Joaquin Delta.

Appendix Figures

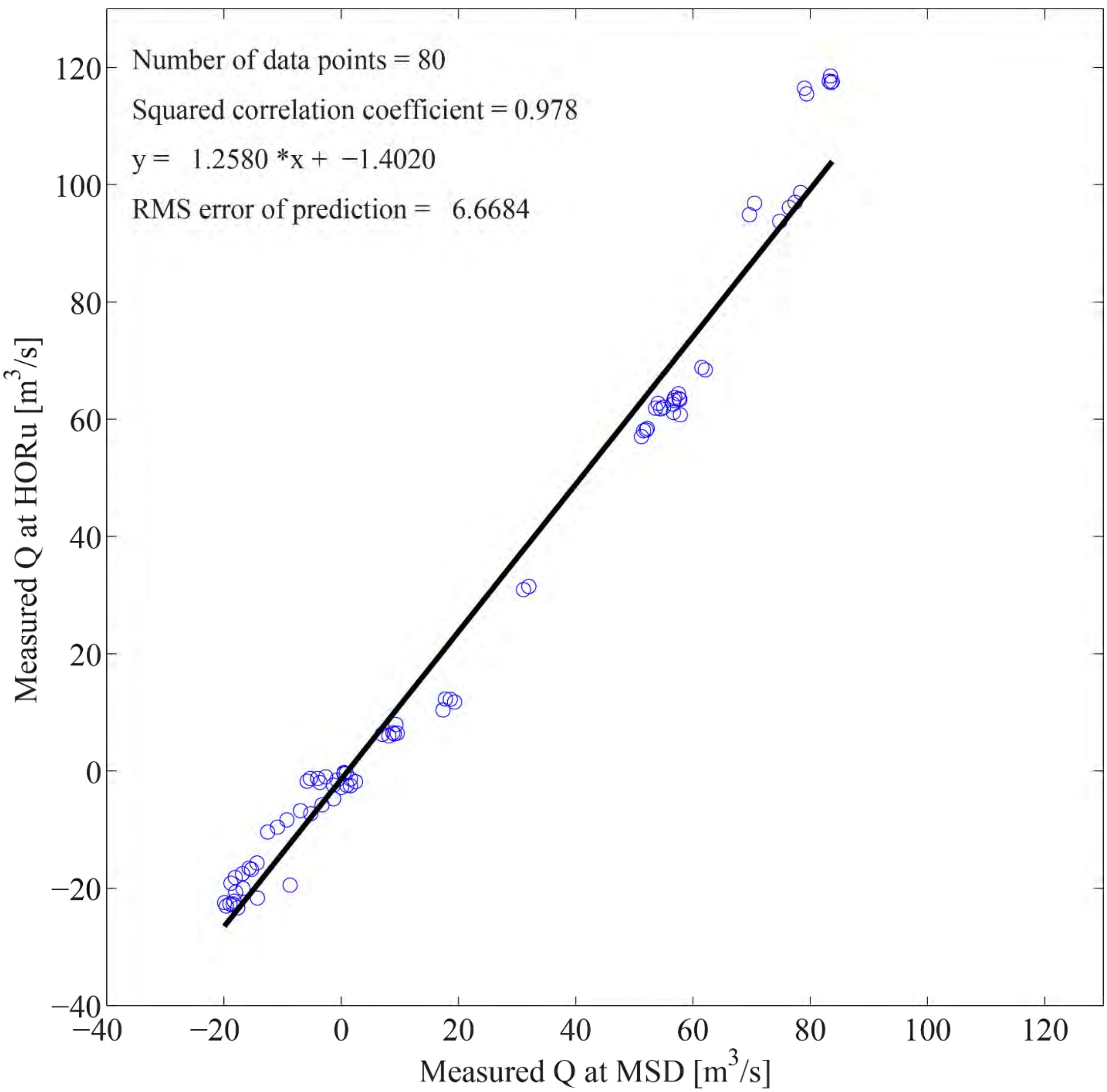


Figure A56. Linear regression of flow measured at MSD and flow measured at HORu.

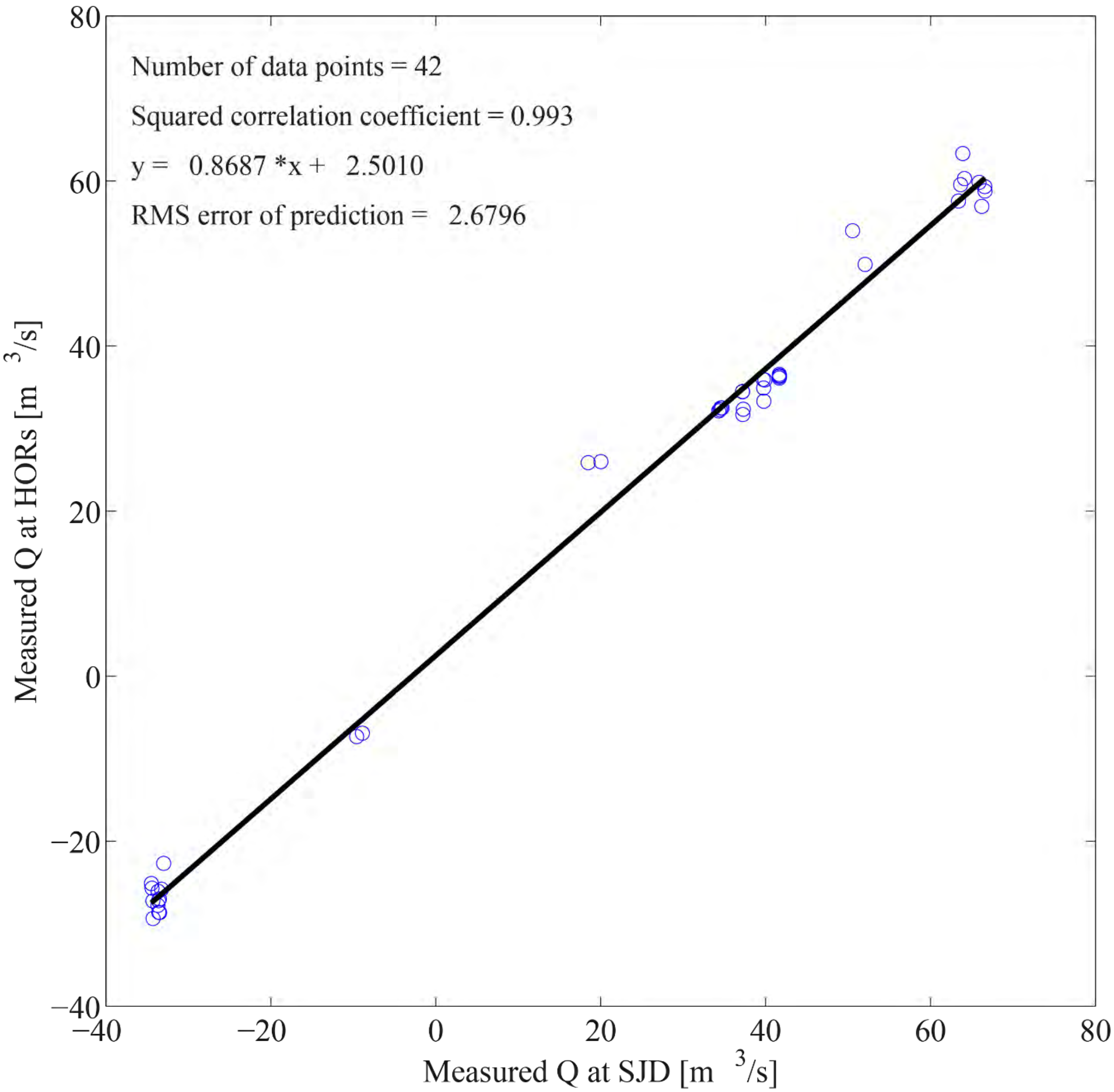


Figure A57. Linear regression of flow measured at SJD and flow measured at HORs.

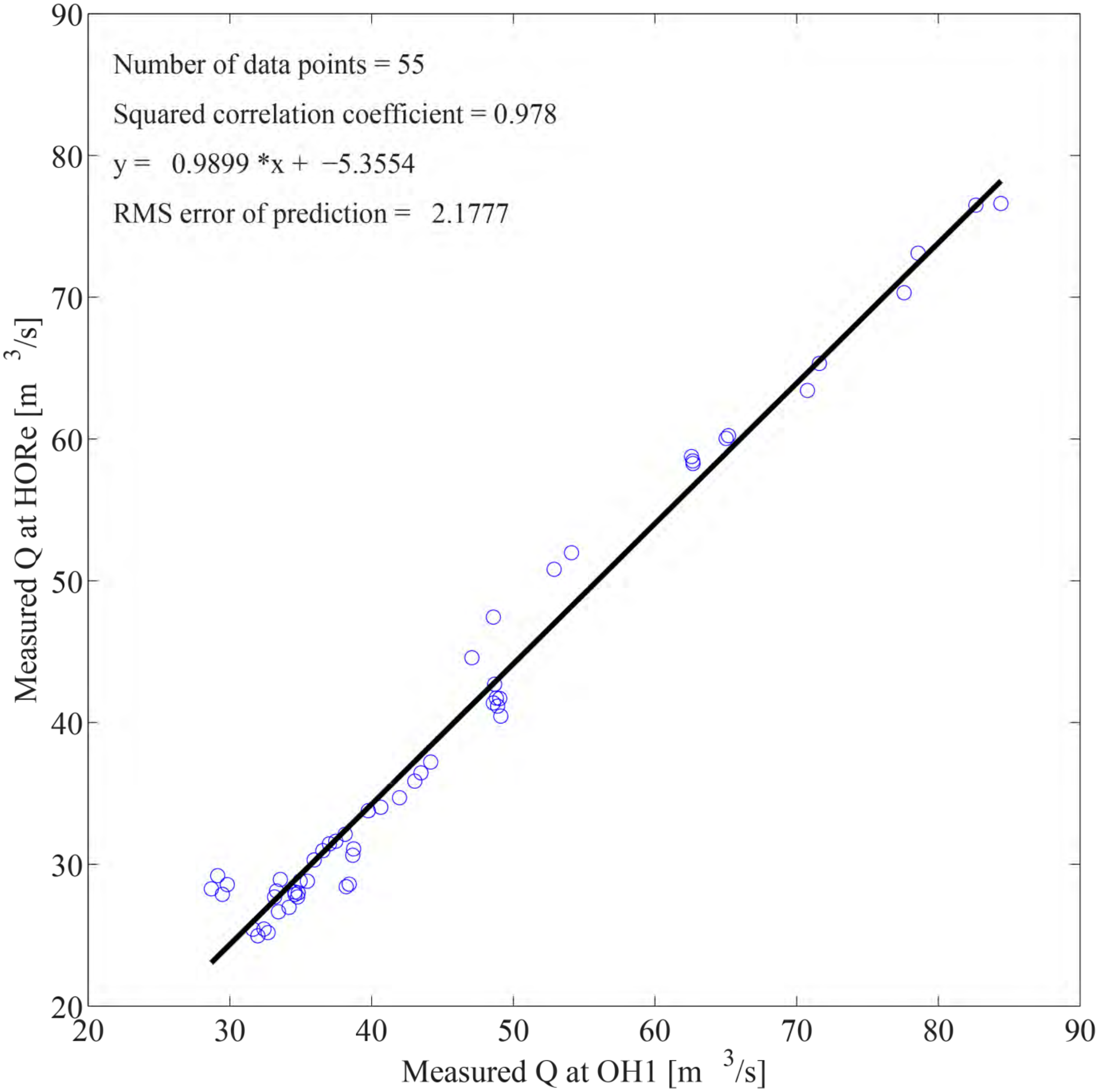


Figure A58. Linear regression of flow measured at OH1 and flow measured at HORe.

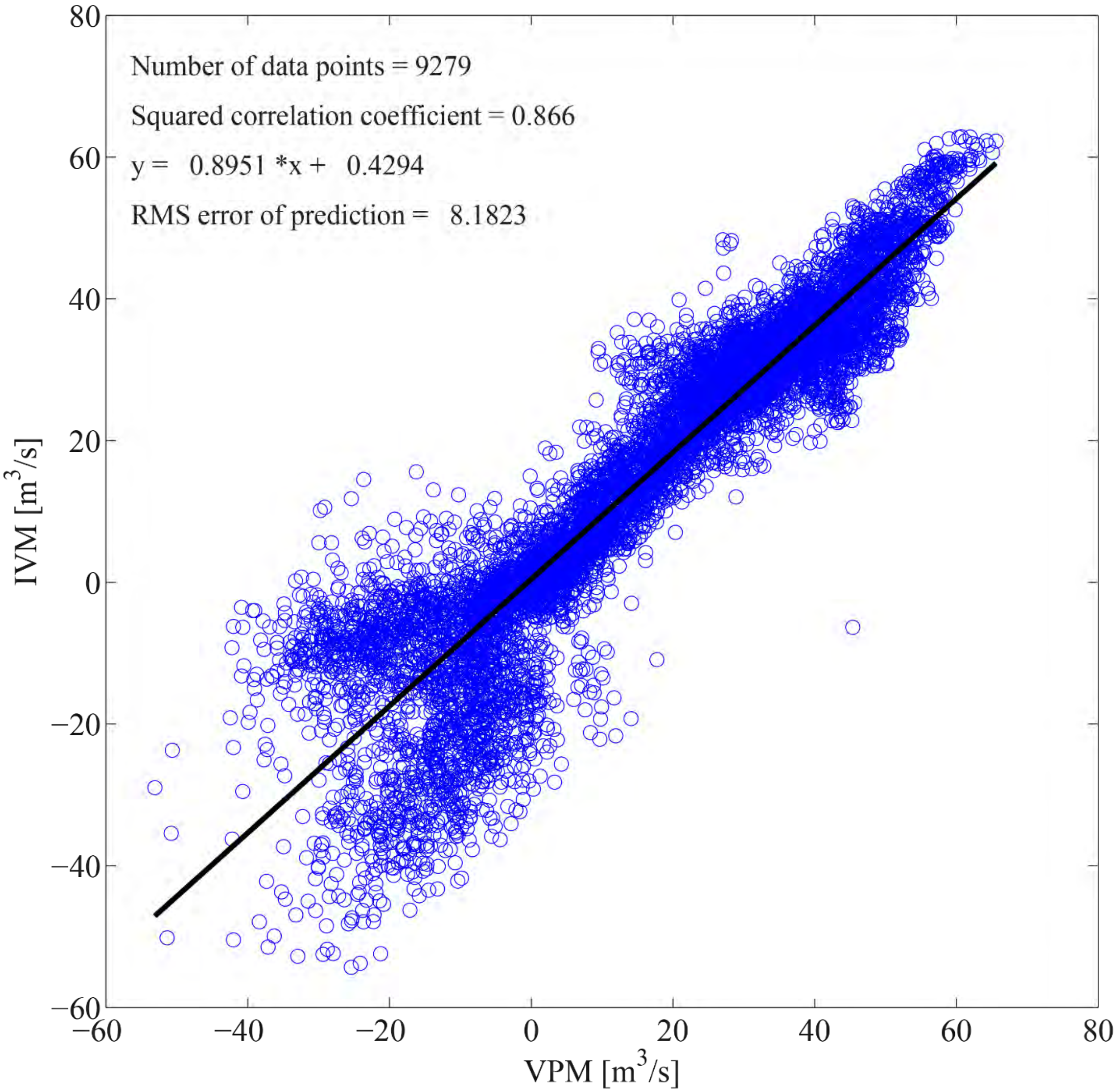


Figure A59. Linear regression of flow measured HORu using the gage regression (IVM) and the velocity profile method (VPM).

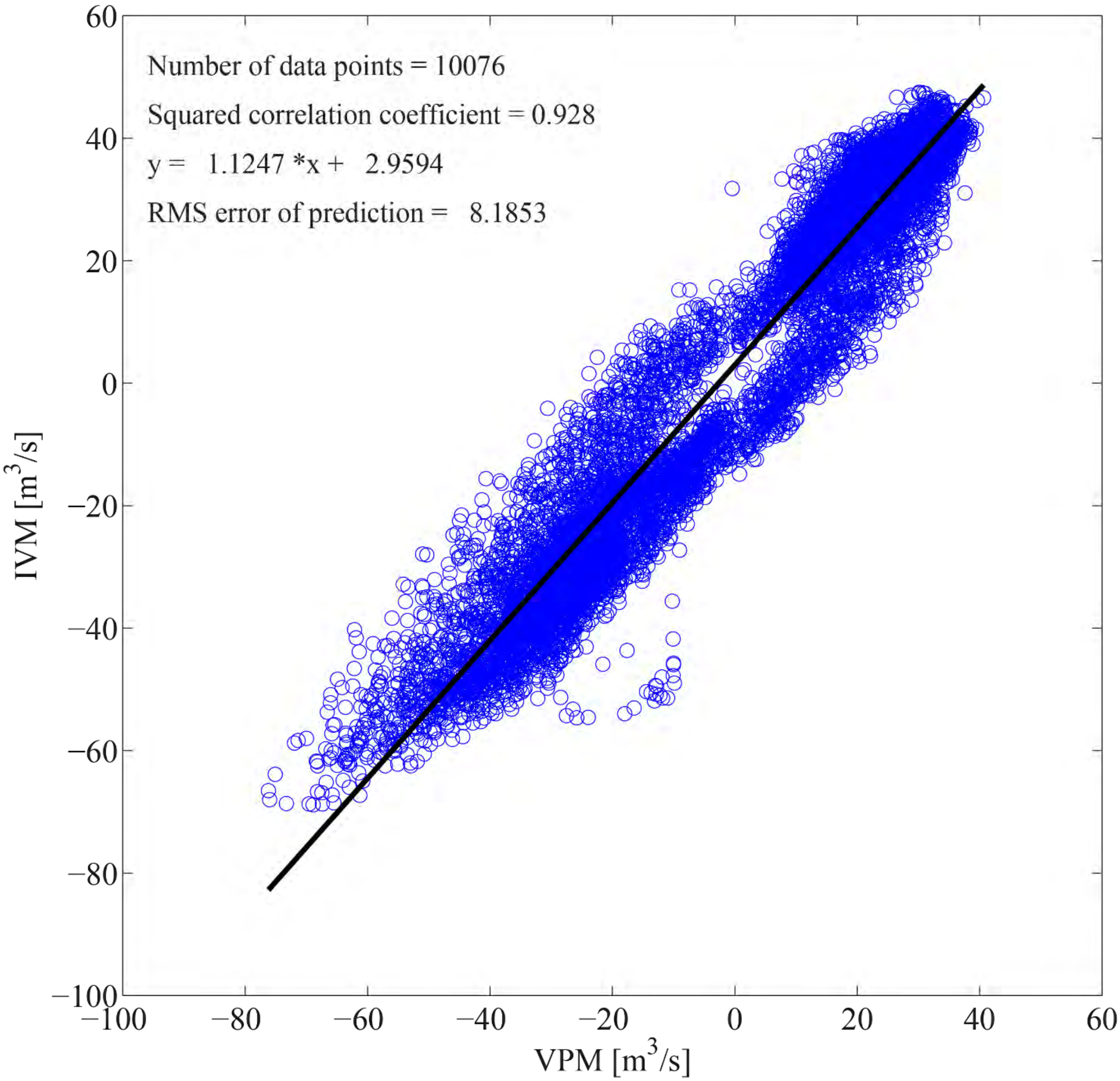


Figure A60. Linear regression of flow measured at HORs using the gage regression (IVM) and the velocity profile method (VPM).

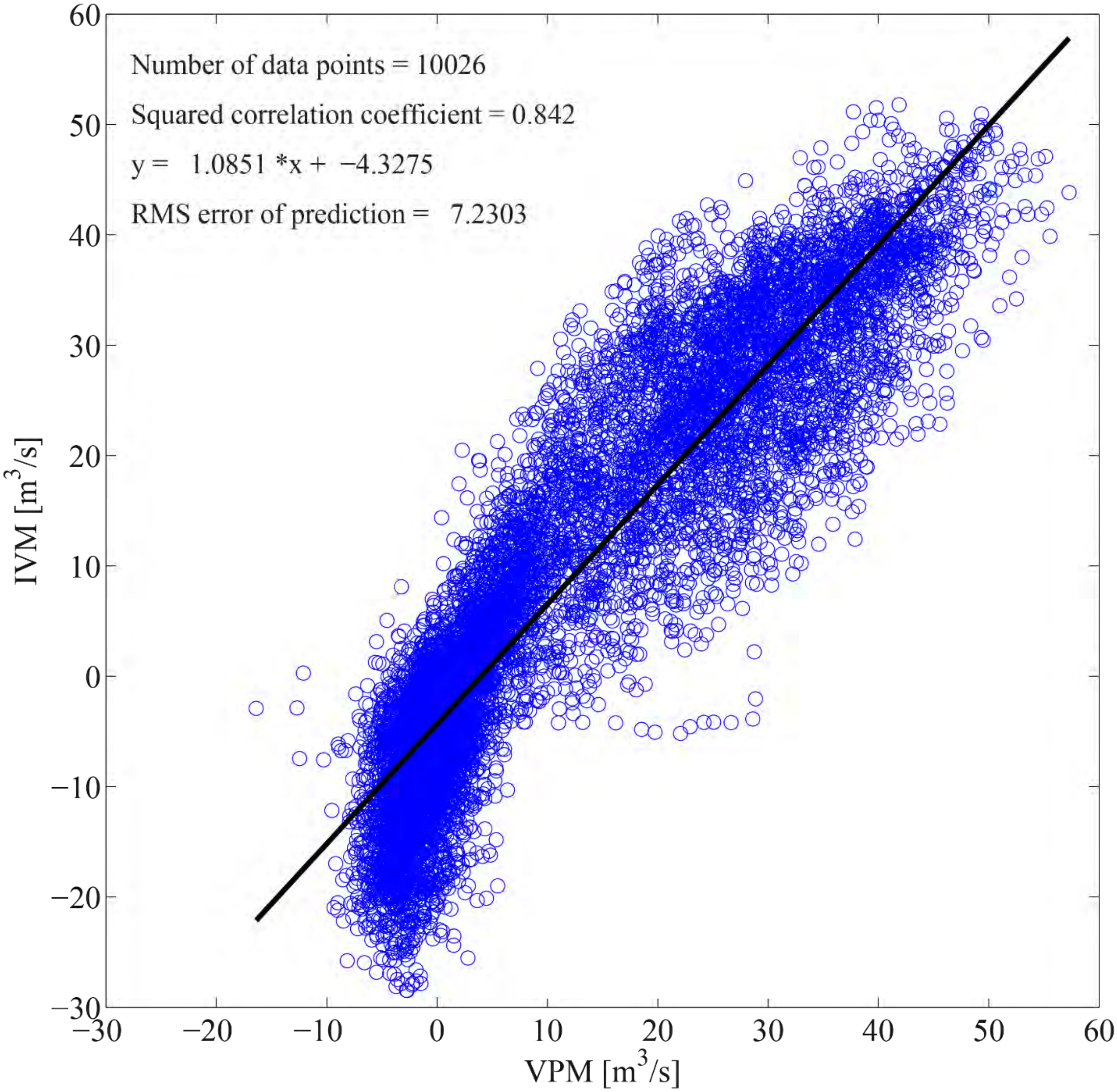


Figure A61. Linear regression of flow measured HORe using the gage regression (IVM) and the velocity profile method (VPM).

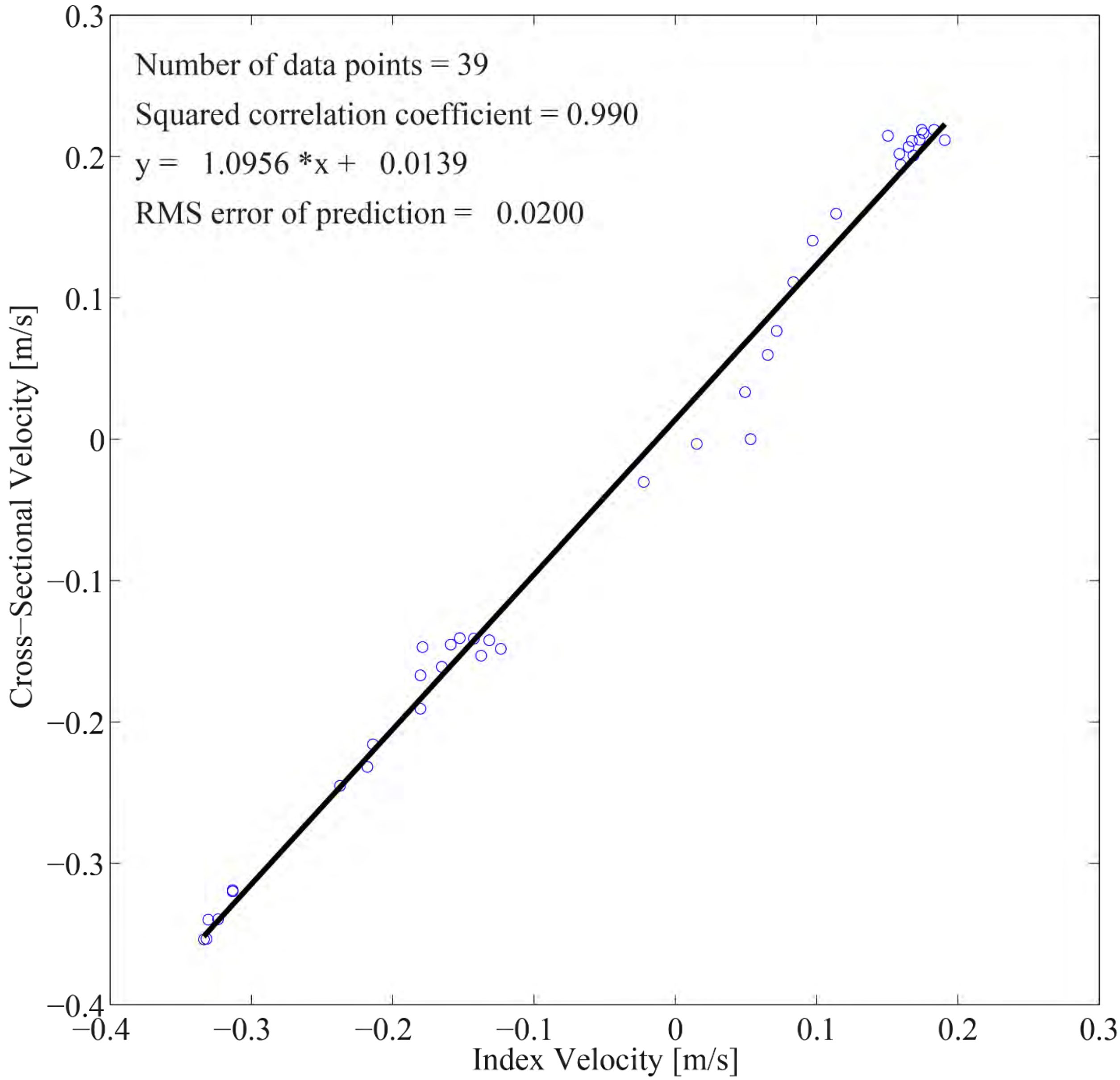


Figure A62. Linear Regression of index velocity measured at SJTC and measured cross-sectional velocity.

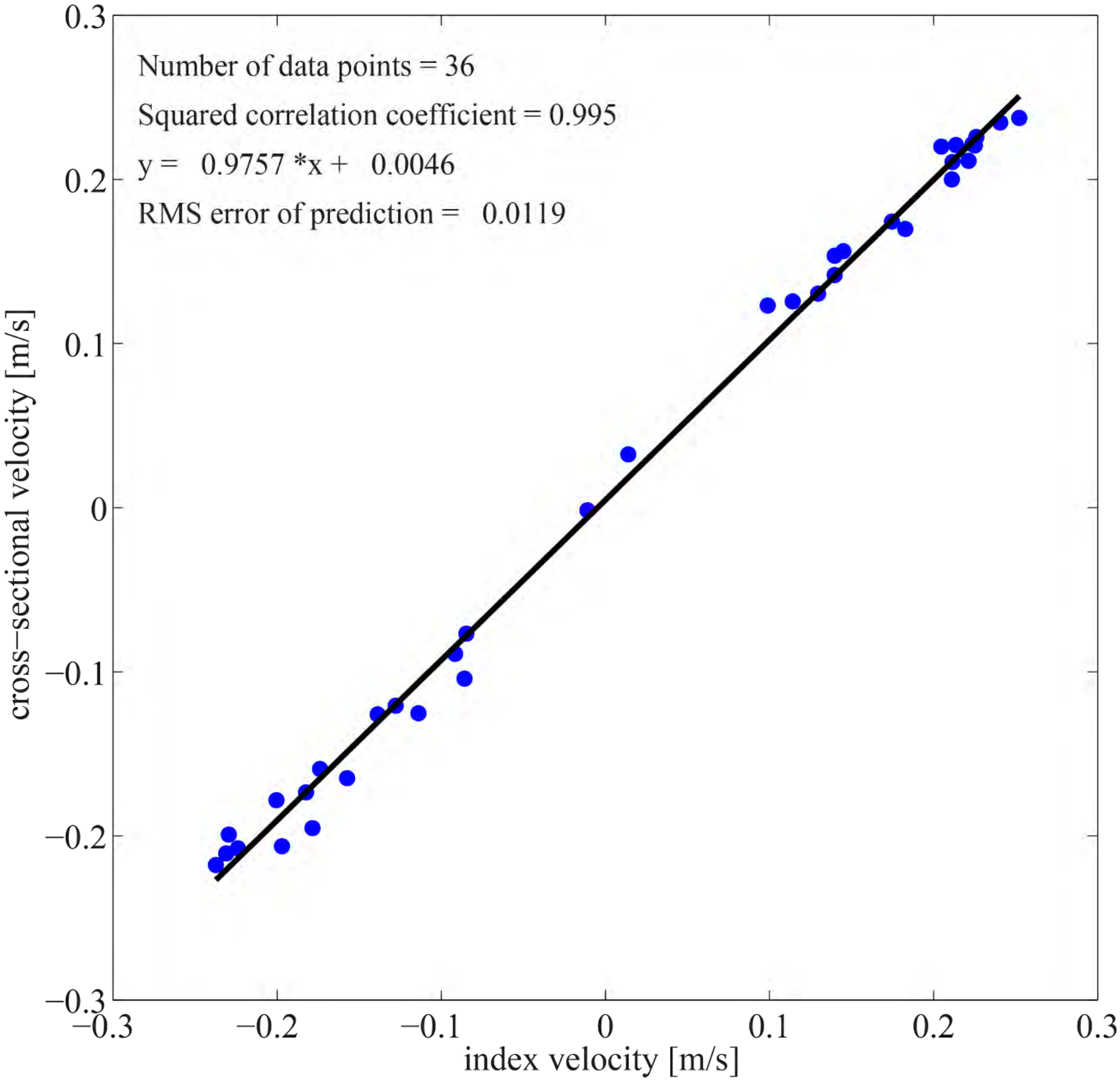


Figure A63. Linear Regression of index velocity measured at CCdd and measured cross-sectional velocity.

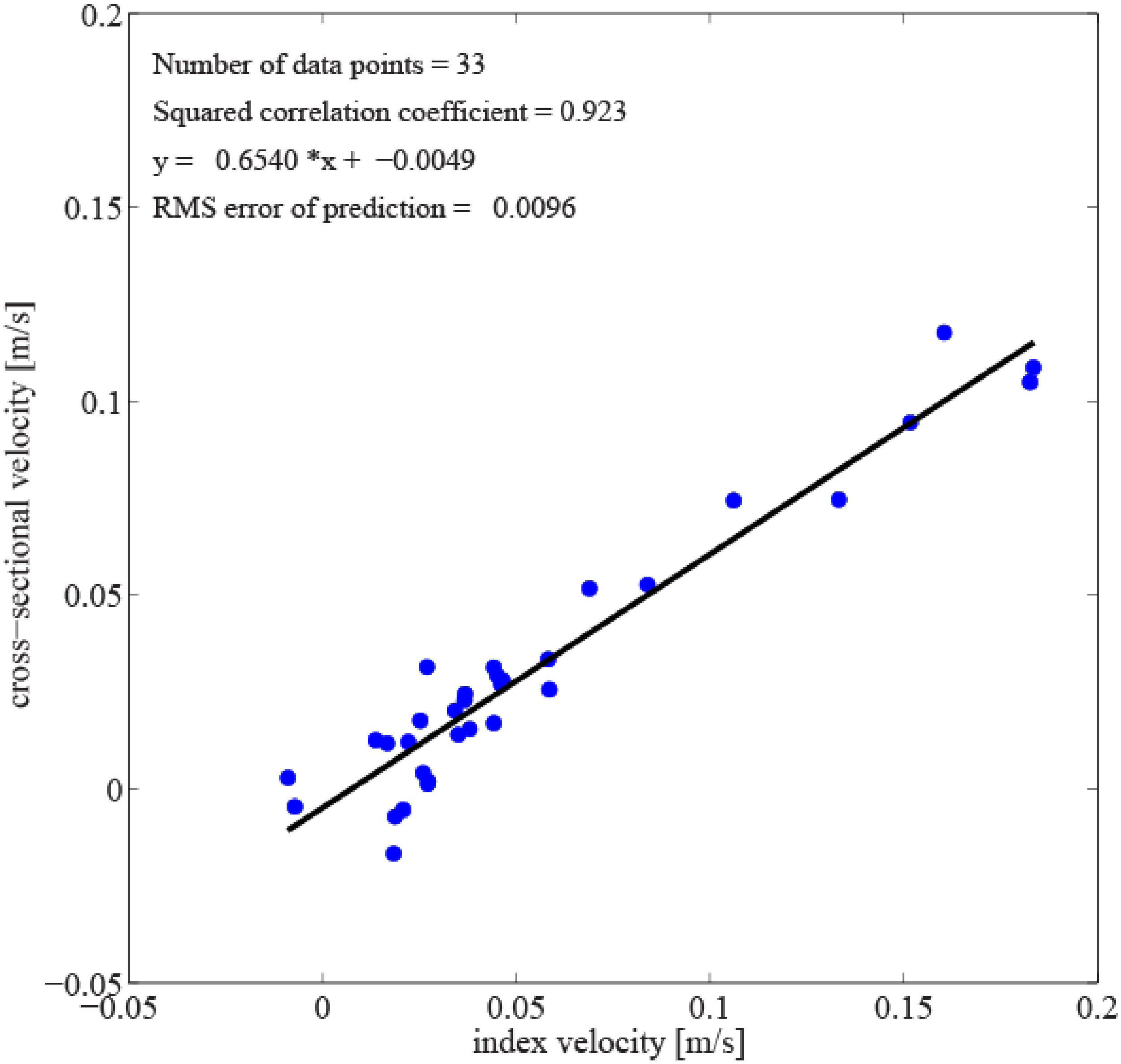


Figure A64. Linear Regression of index velocity measured at CCds and measured cross-sectional velocity.

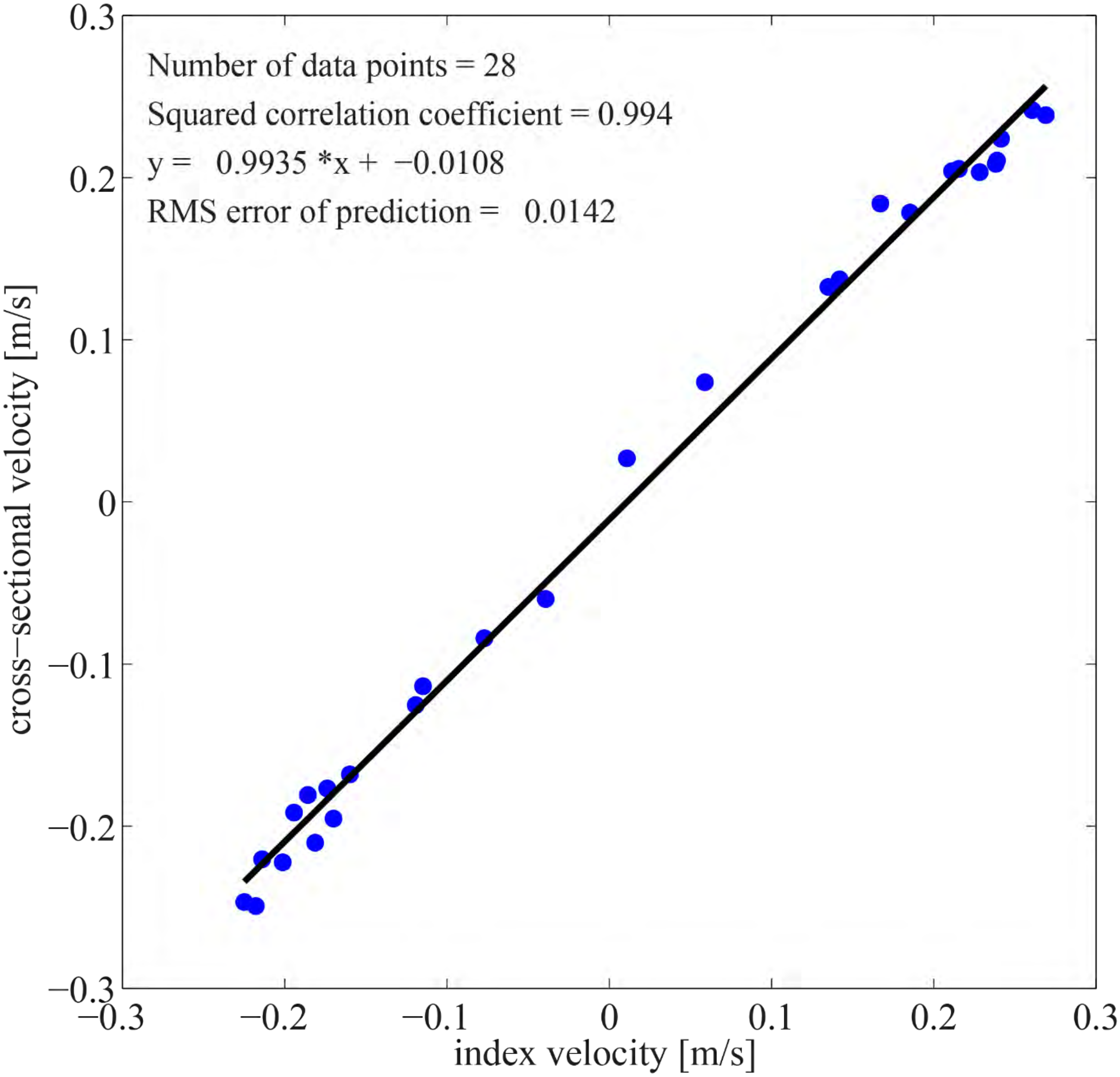


Figure A65. Linear Regression of index velocity measured at CCdu and measured cross-sectional velocity.

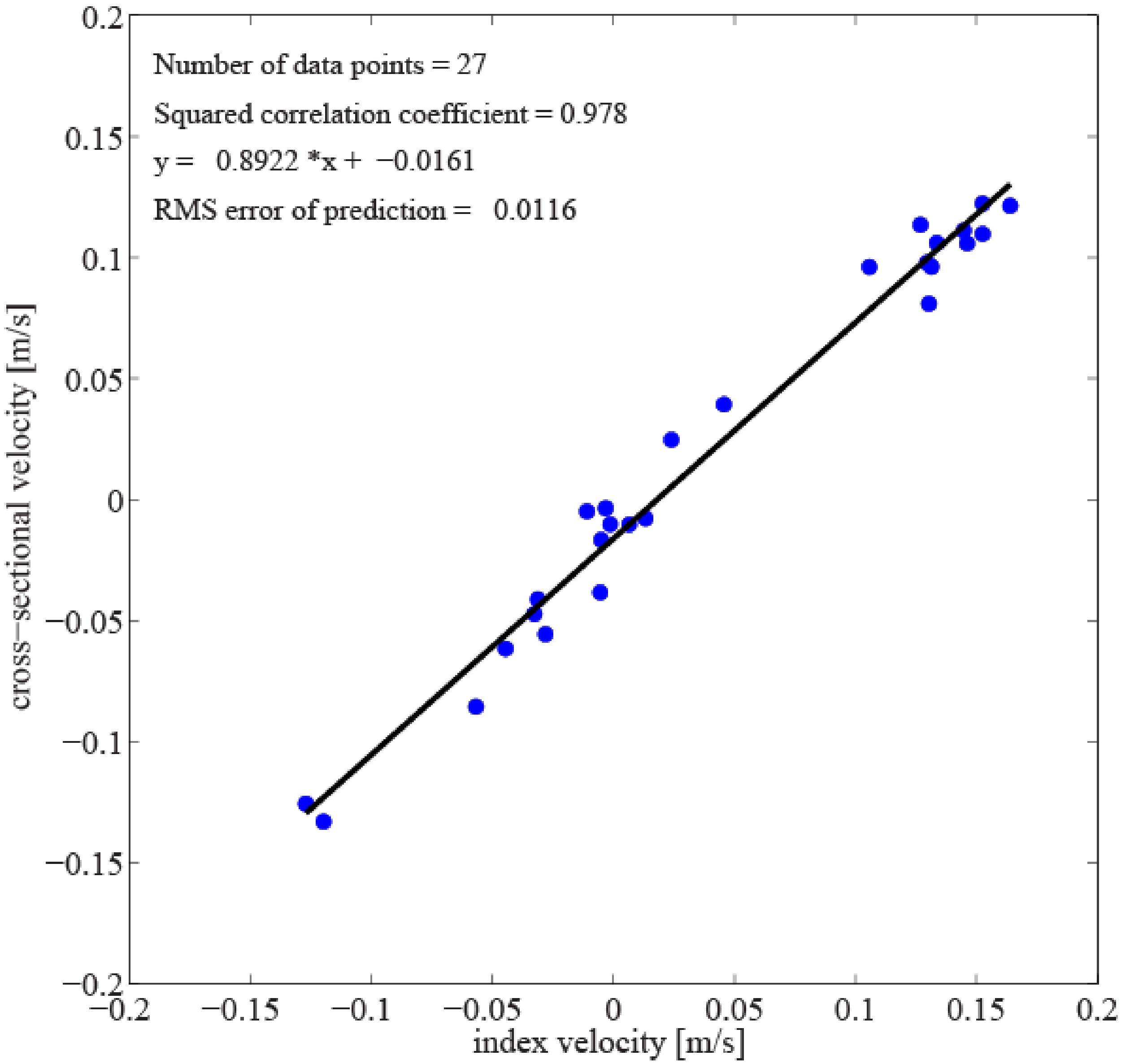


Figure A66. Linear Regression of index velocity measured at CCe and measured cross-sectional velocity.

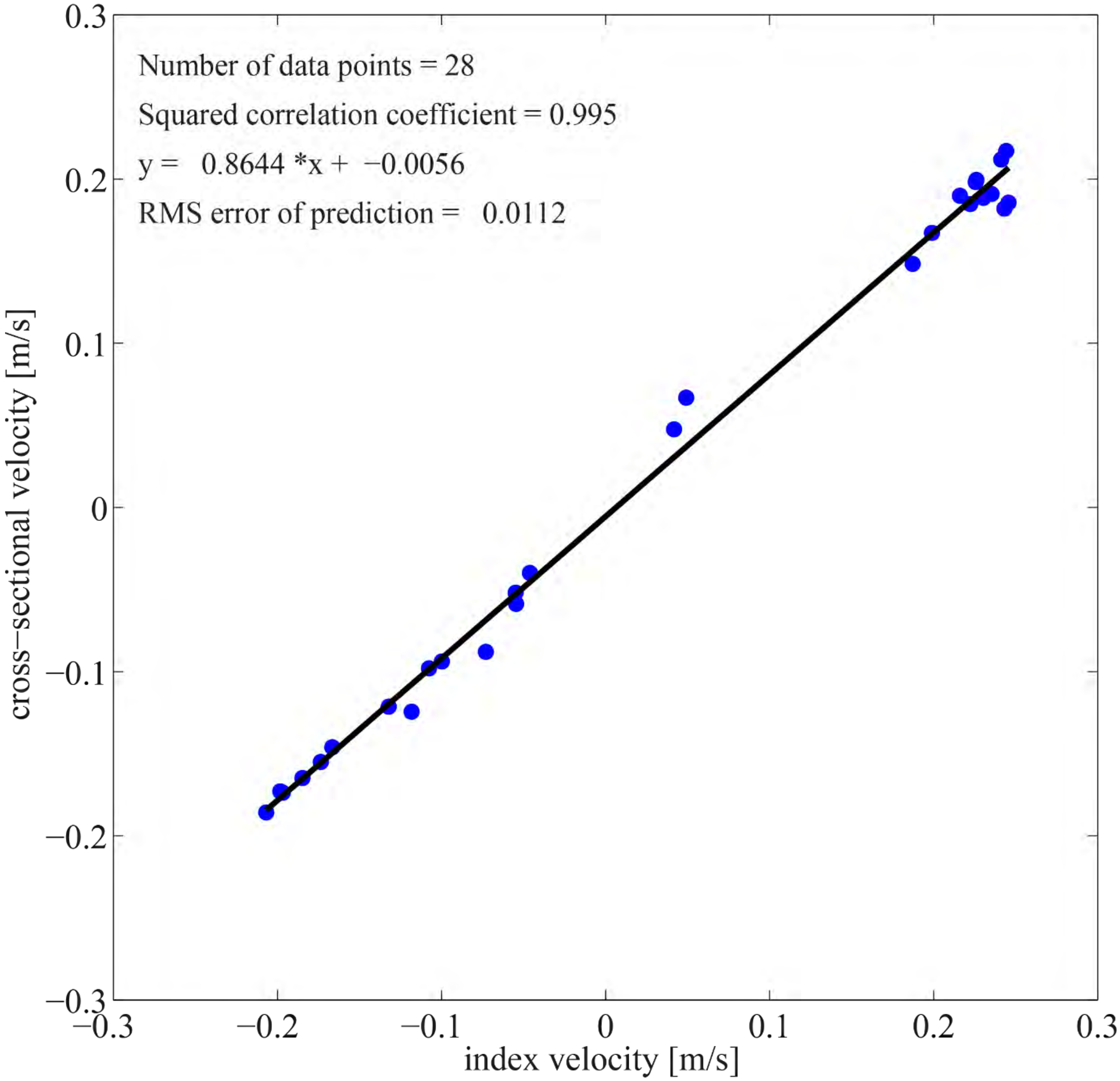


Figure A67. Linear Regression of index velocity measured at CCud and measured cross-sectional velocity.

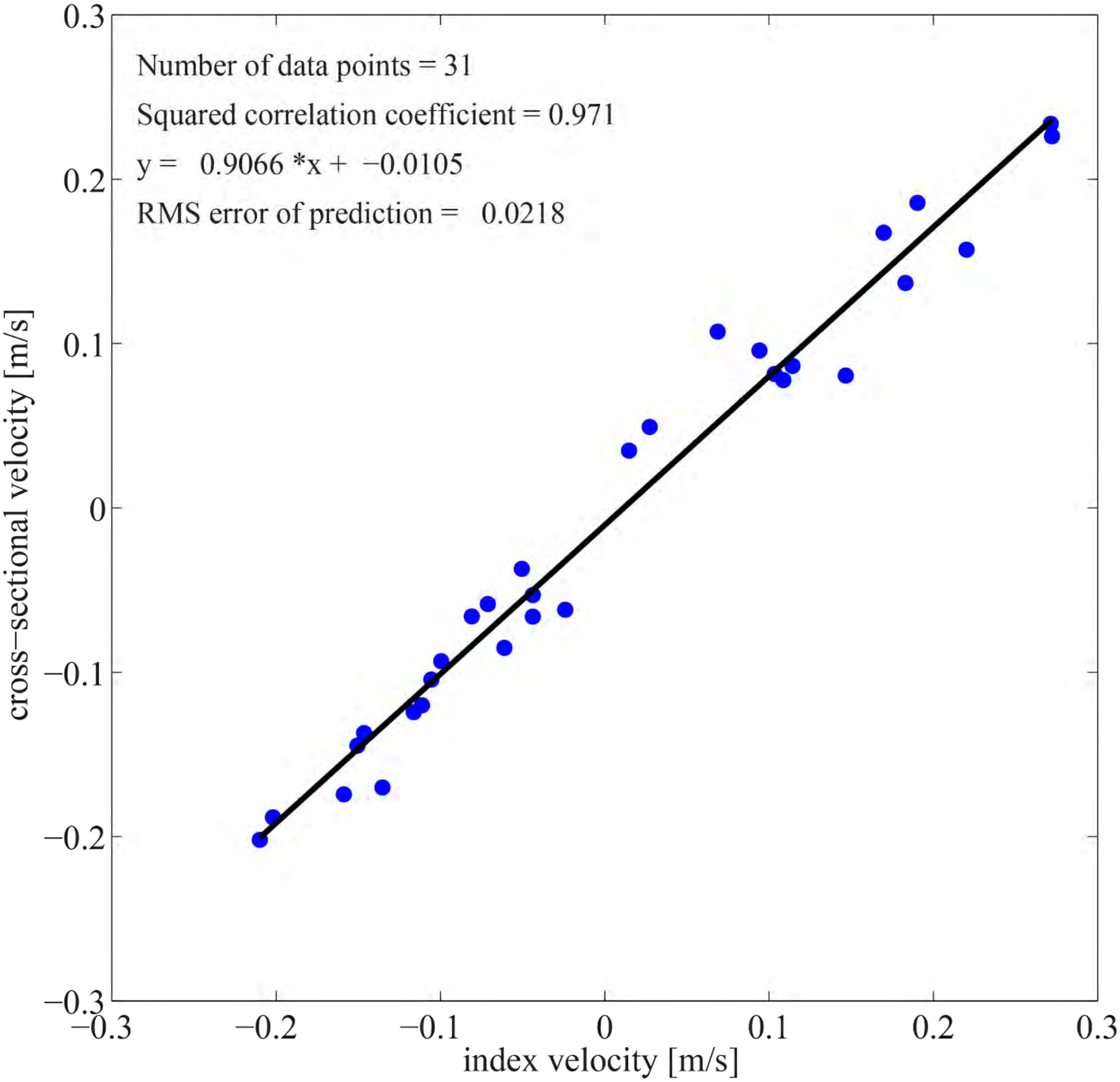


Figure A68. Linear Regression of index velocity measured at CCus and measured cross-sectional velocity.

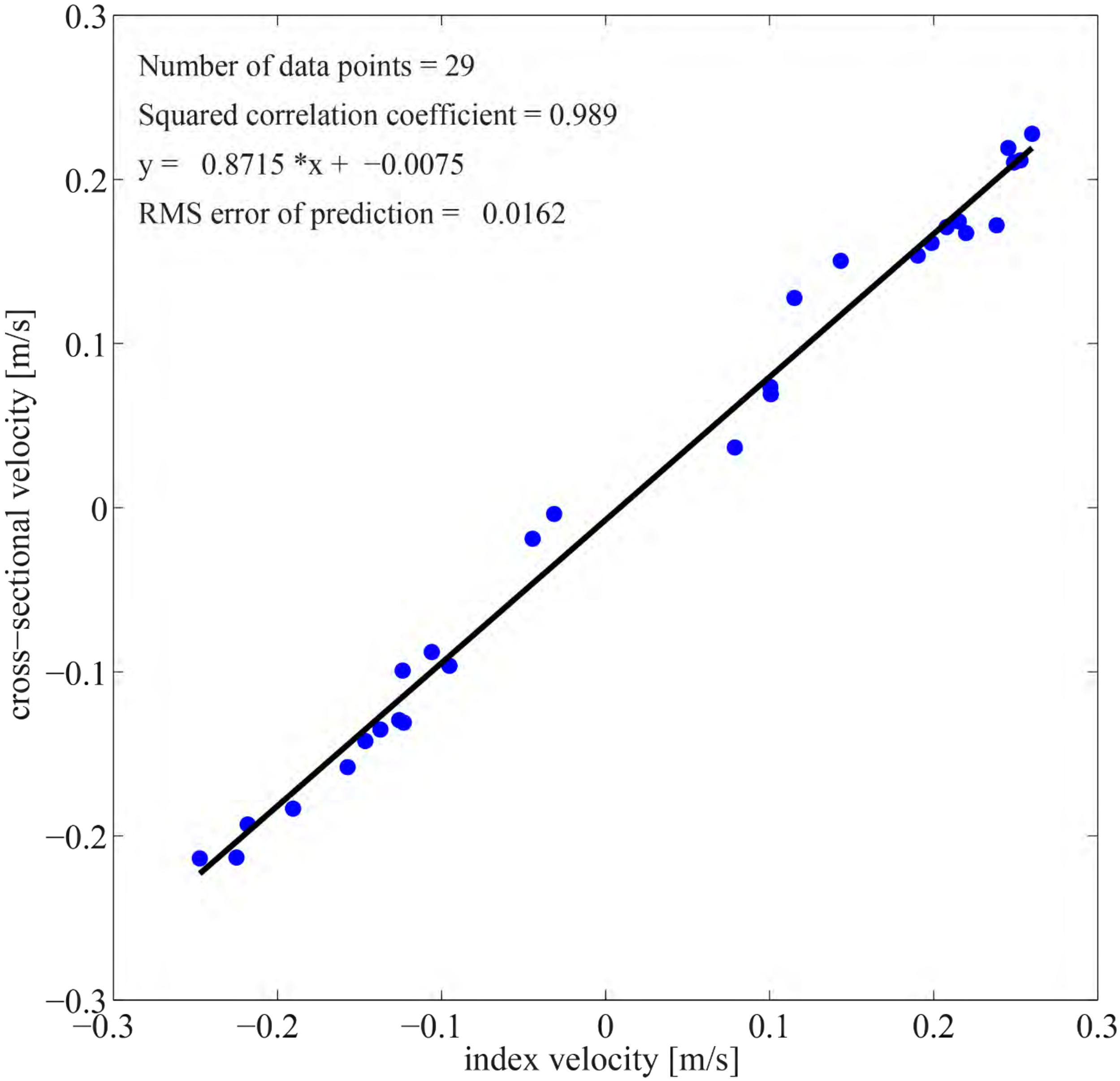


Figure A69. Linear Regression of index velocity measured at CCuu and measured cross-sectional velocity.

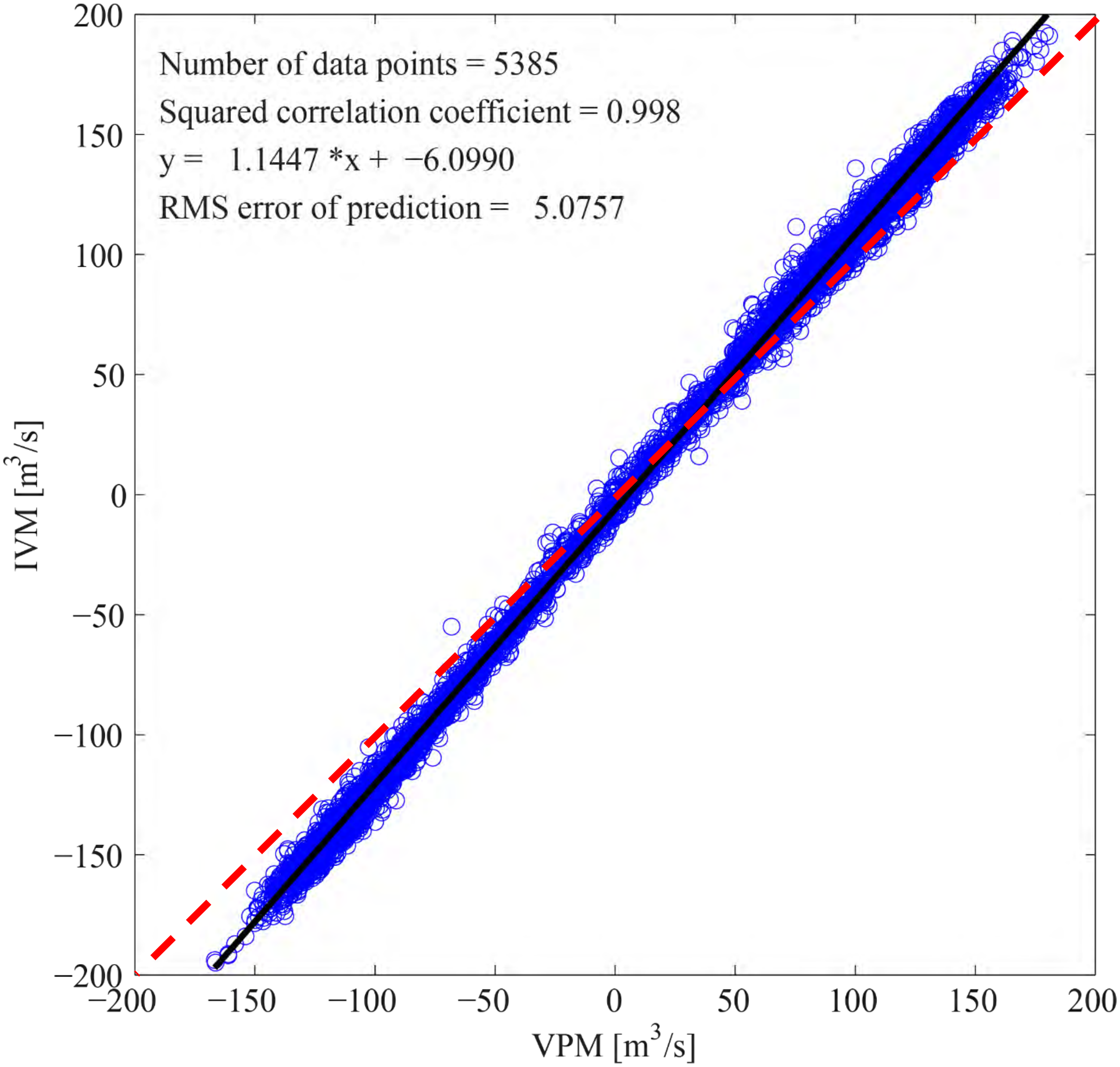


Figure A70. Linear regression of flow measured CCdd using the gage regression (IVM) and the velocity profile method (VPM). Dashed red line indicates 1:1 correlation.

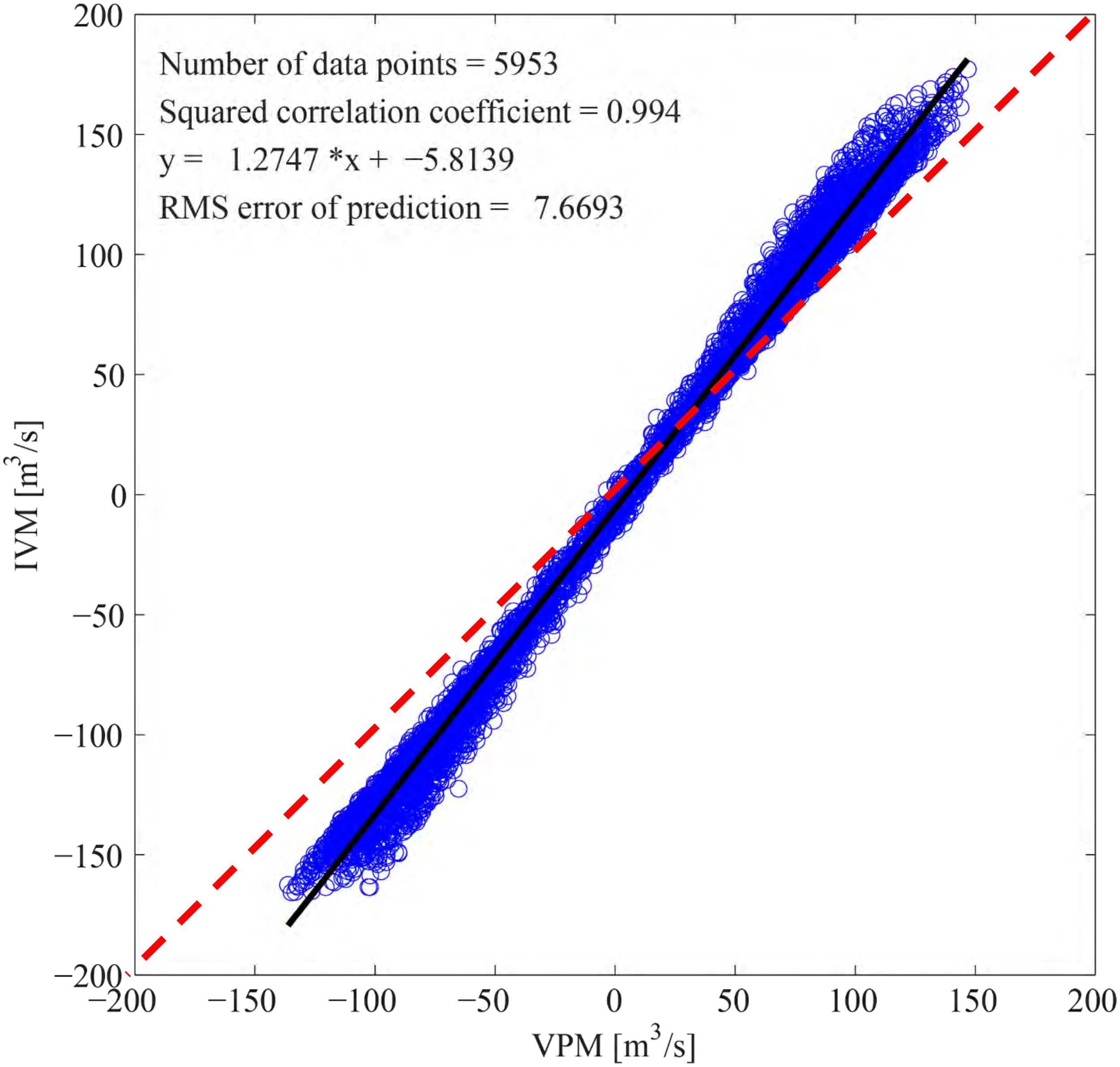


Figure A71. Linear regression of flow measured CCdu using the gage regression (IVM) and the velocity profile method (VPM). Dashed red line indicates 1:1 correlation.

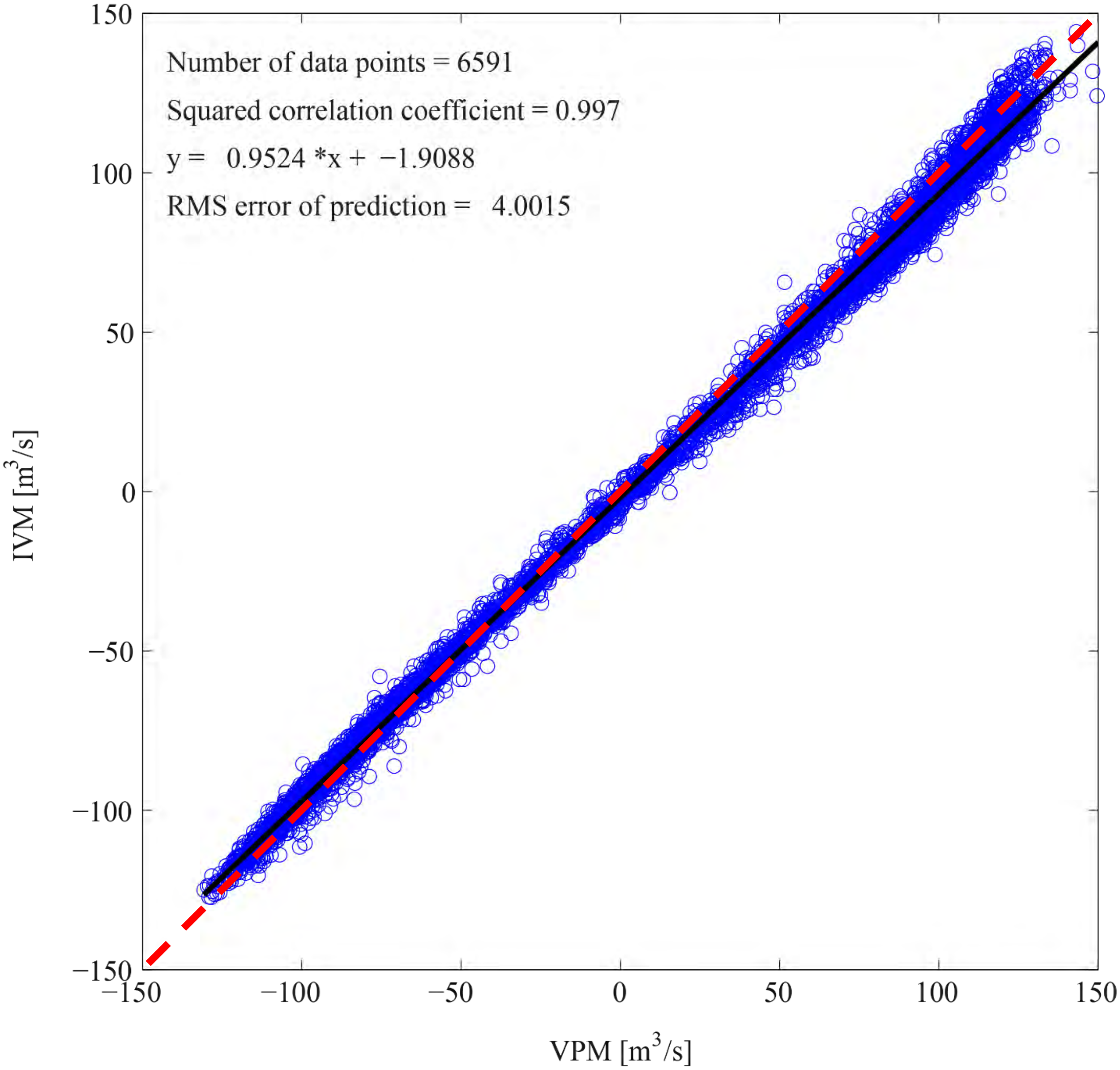


Figure A72. Linear regression of flow measured CCud using the gage regression (IVM) and the velocity profile method (VPM). Dashed red line indicates 1:1 correlation.

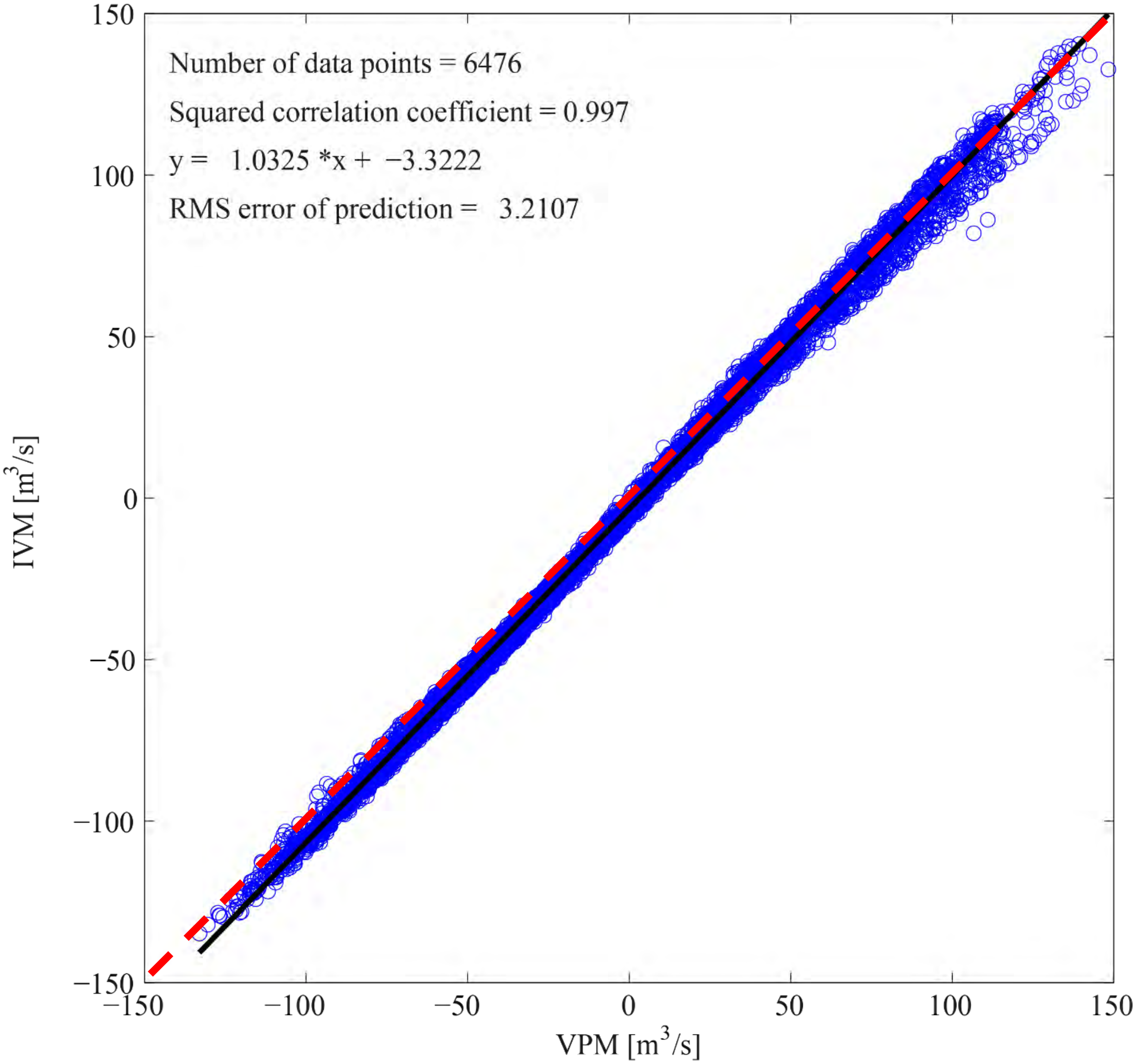


Figure A73. Linear regression of flow measured CCus using the gage regression (IVM) and the velocity profile method (VPM). Dashed red line indicates 1:1 correlation.

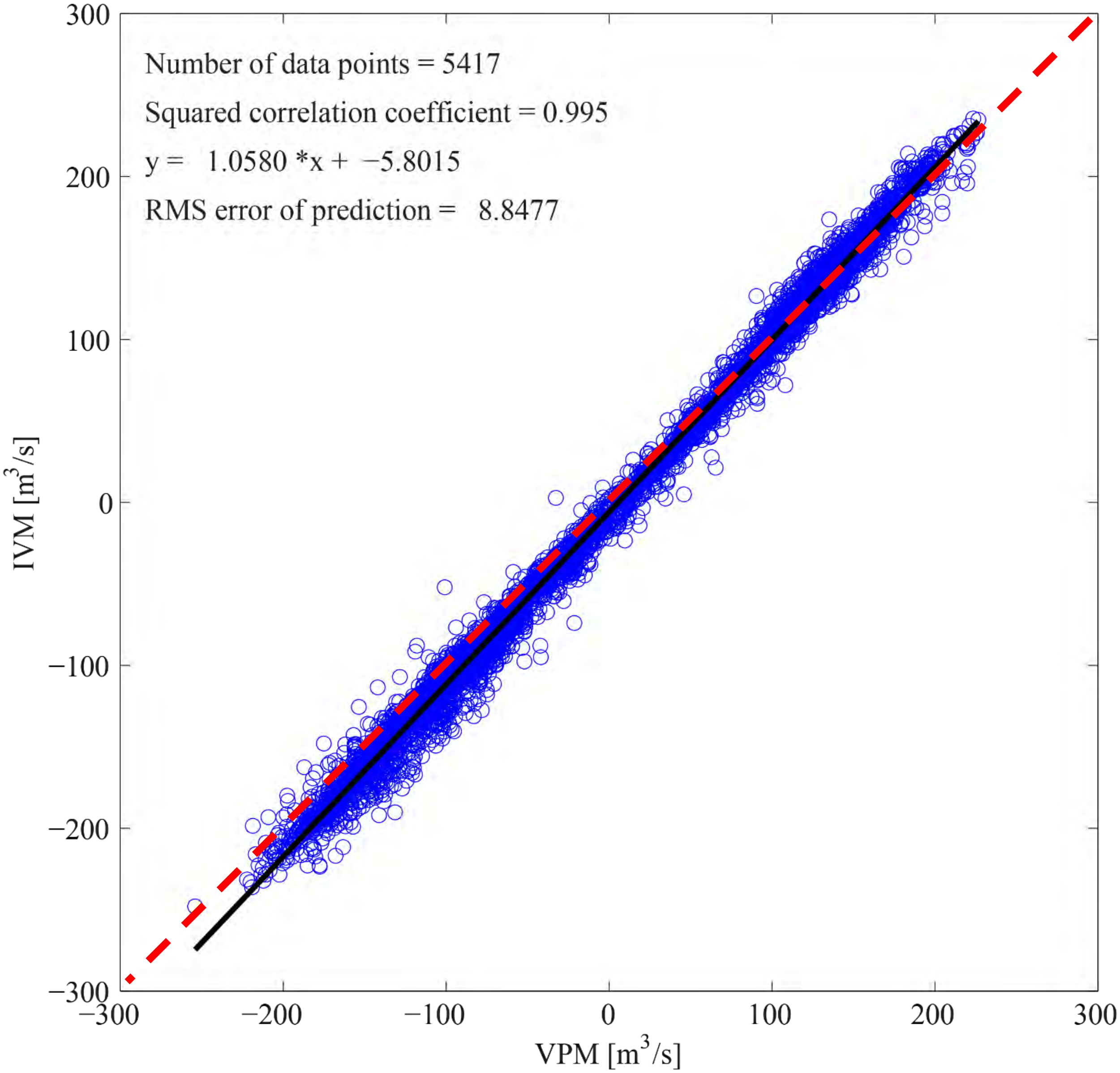


Figure A74. Linear regression of flow measured CCuu using the gage regression (IVM) and the velocity profile method (VPM). Dashed red line indicates 1:1 correlation.

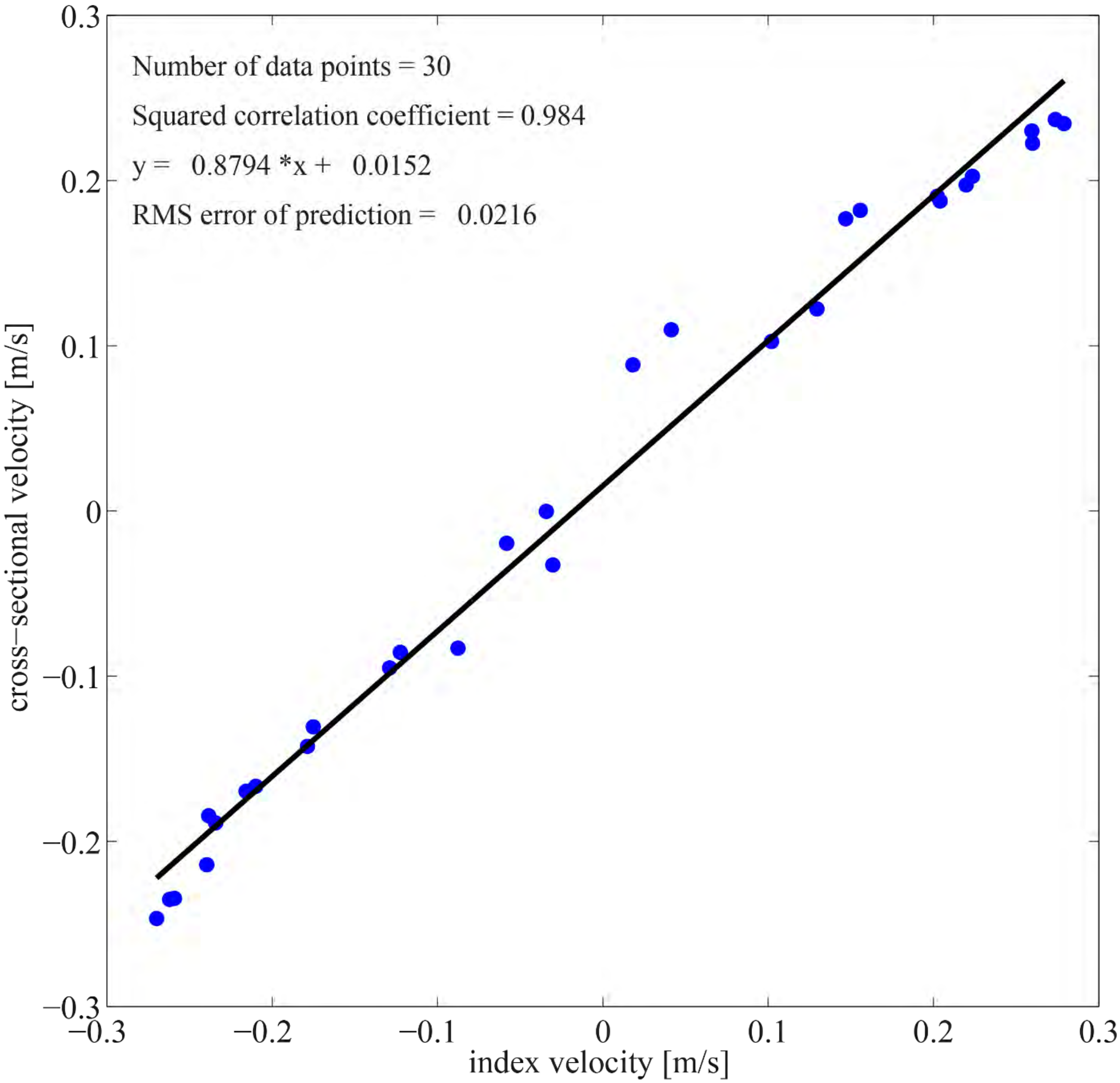


Figure A75. Linear Regression of index velocity measured at TCdde and measured cross-sectional velocity.

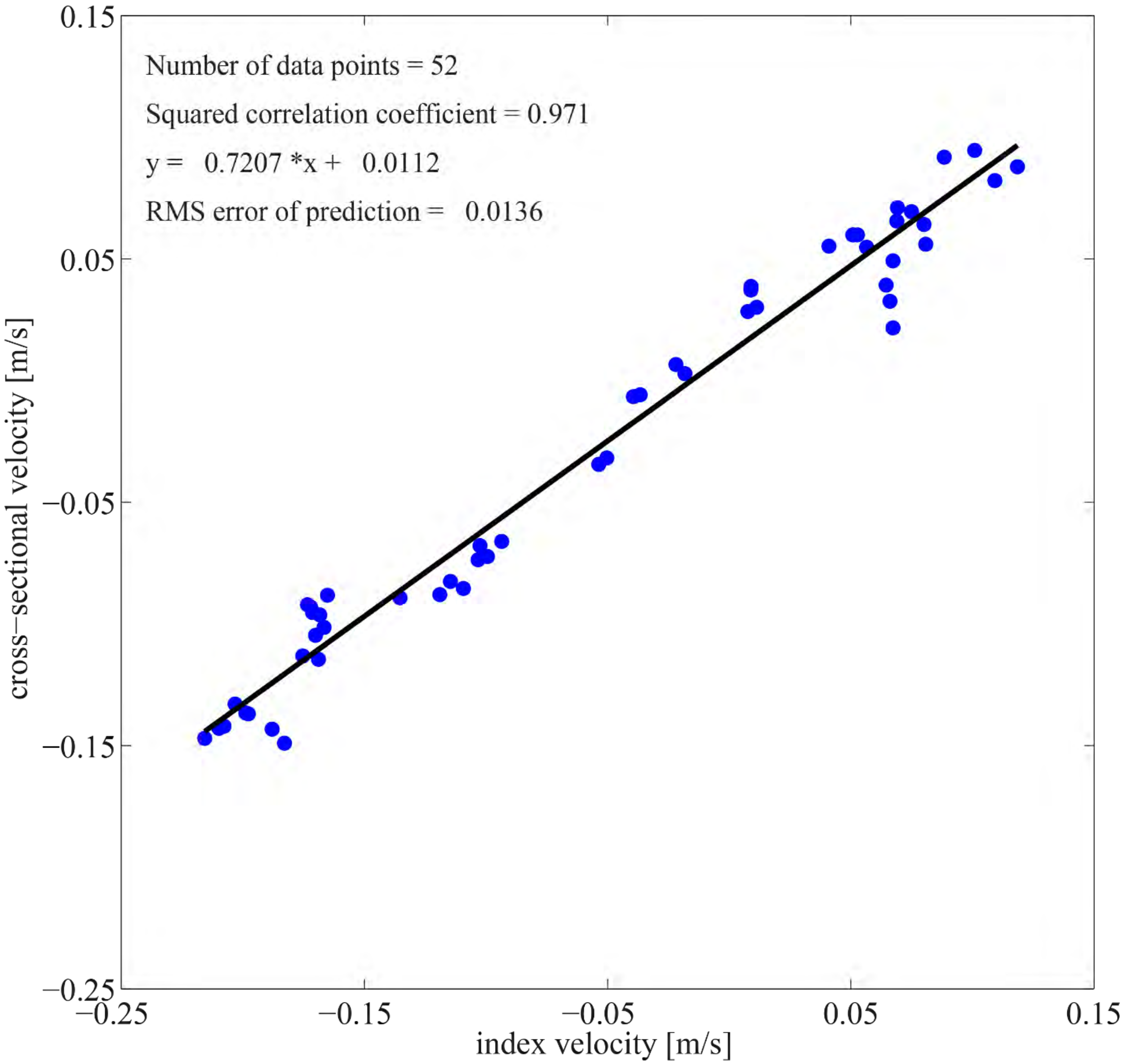


Figure A76. Linear Regression of index velocity measured at TCddw and measured cross-sectional velocity.

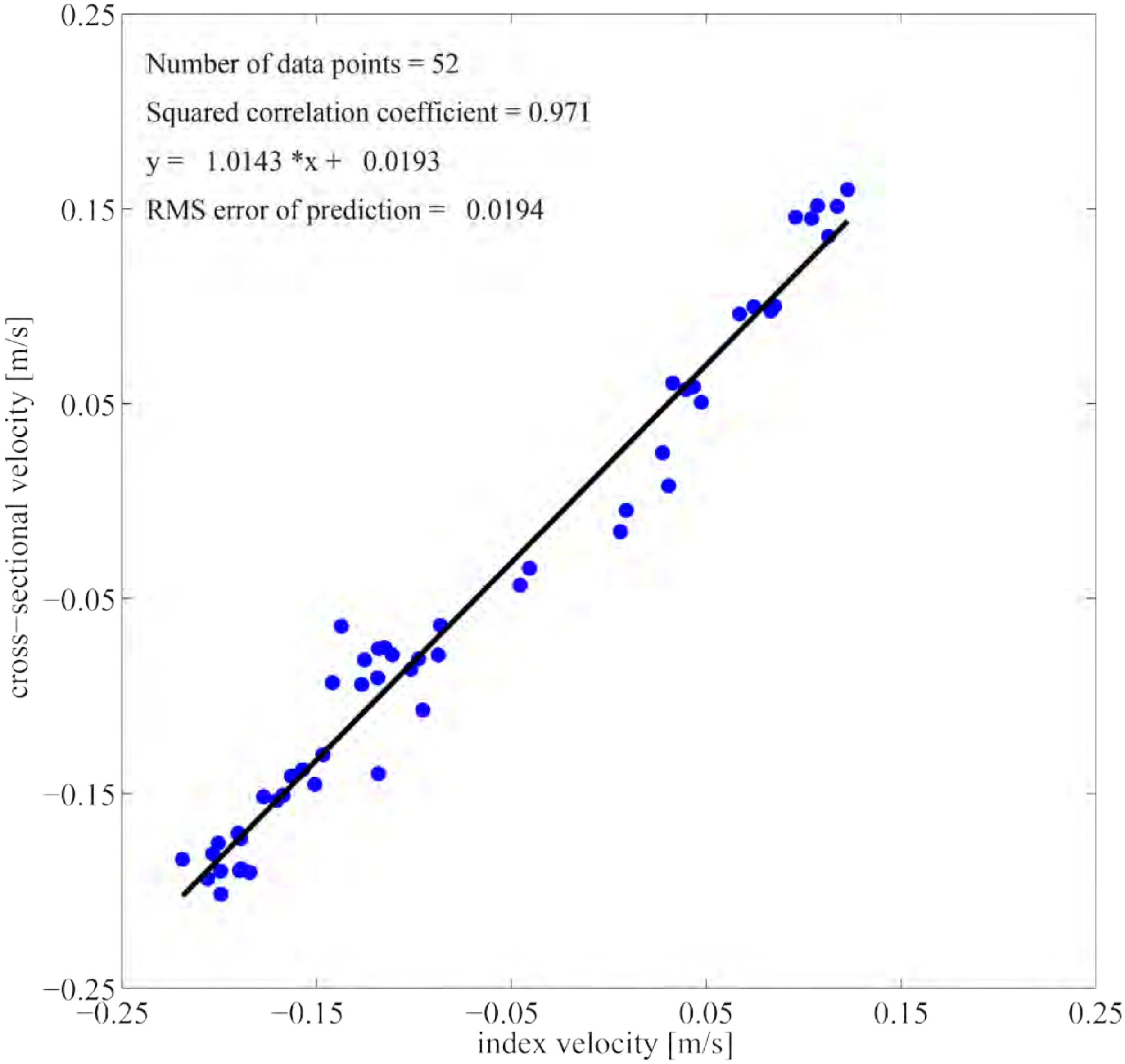


Figure A77. Linear Regression of index velocity measured at TCds and measured cross-sectional velocity.

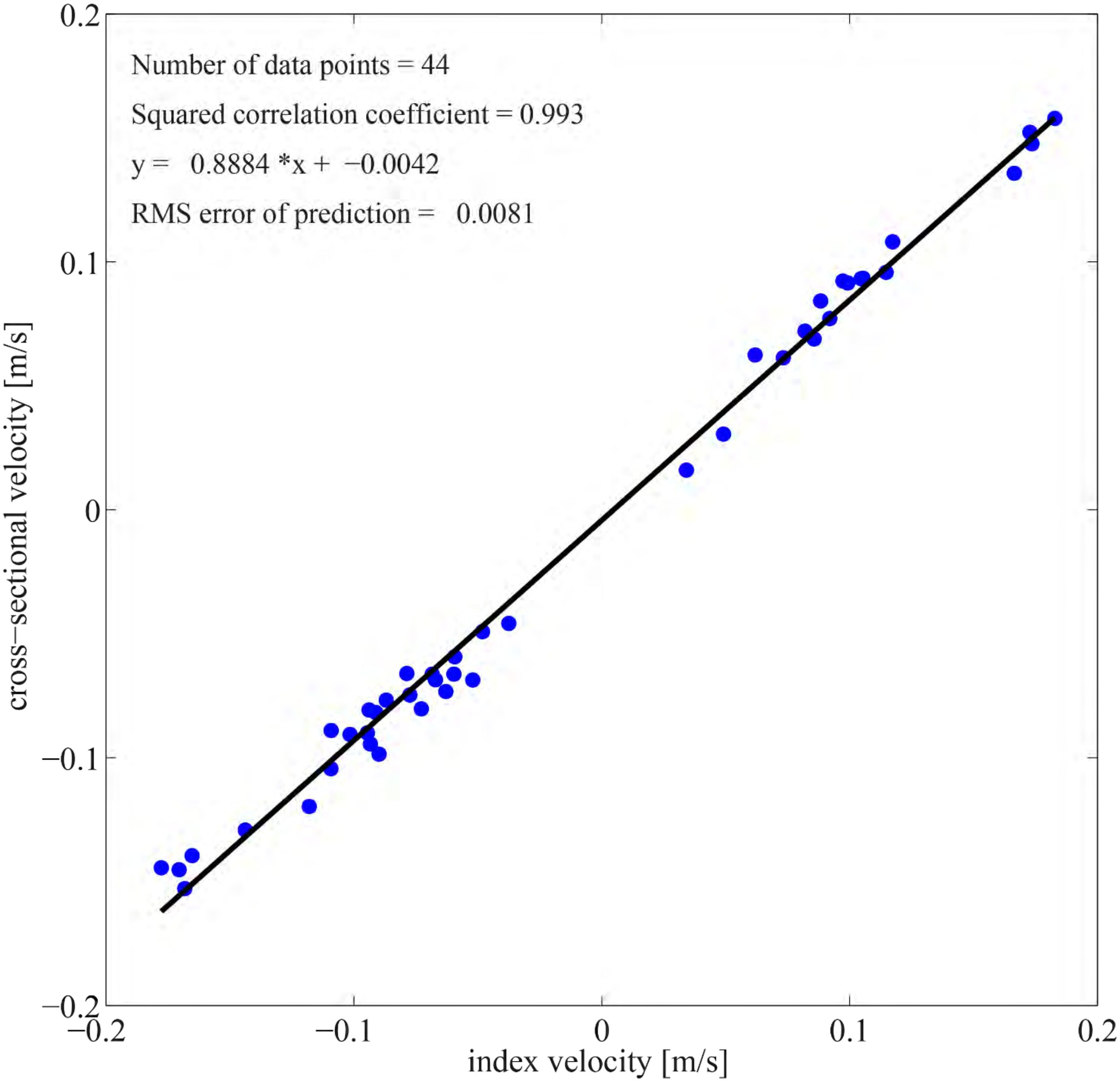


Figure A78. Linear Regression of index velocity measured at TCus and measured cross-sectional velocity.

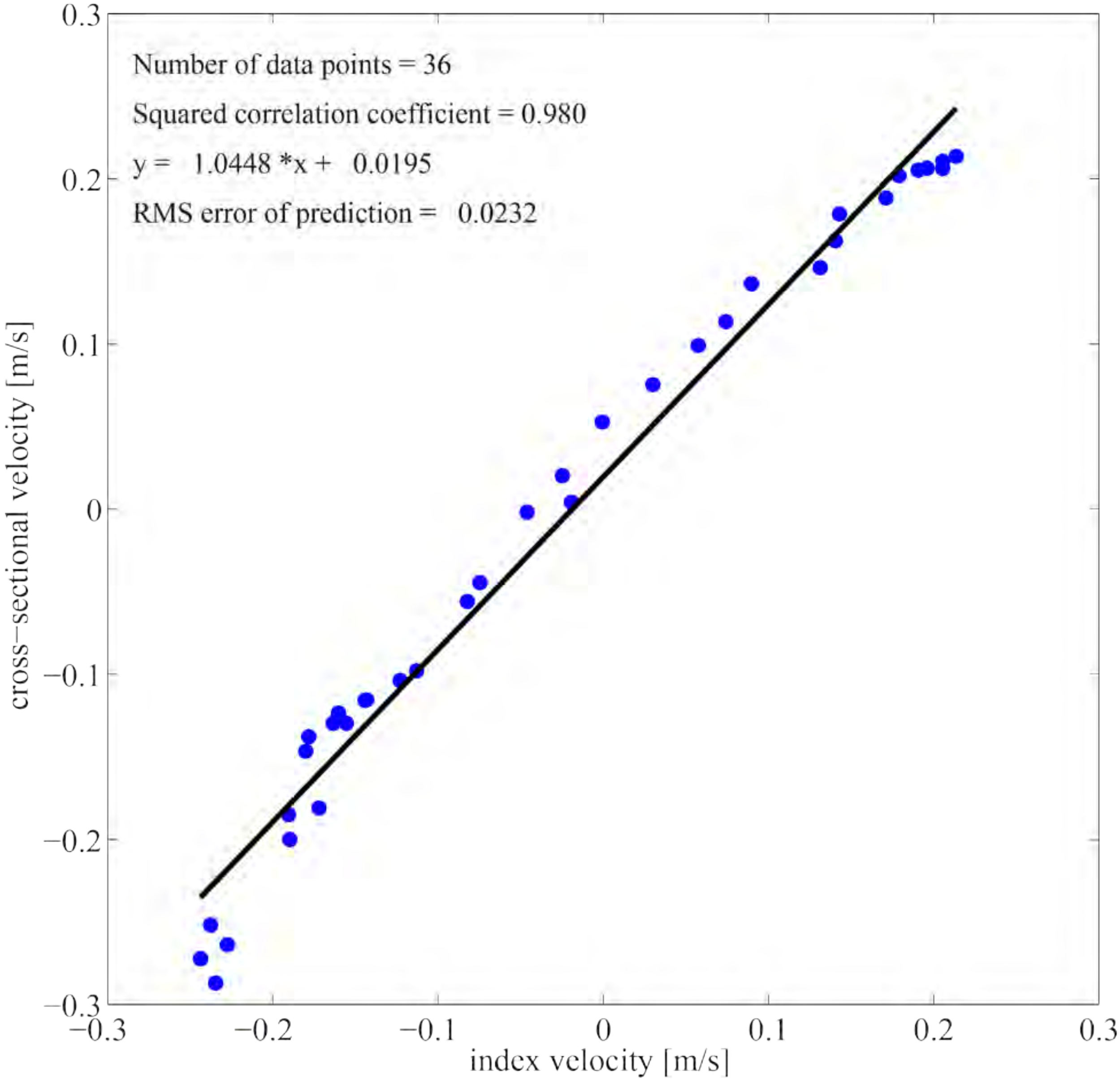


Figure A79. Linear Regression of index velocity measured at TCuu and measured cross-sectional velocity.

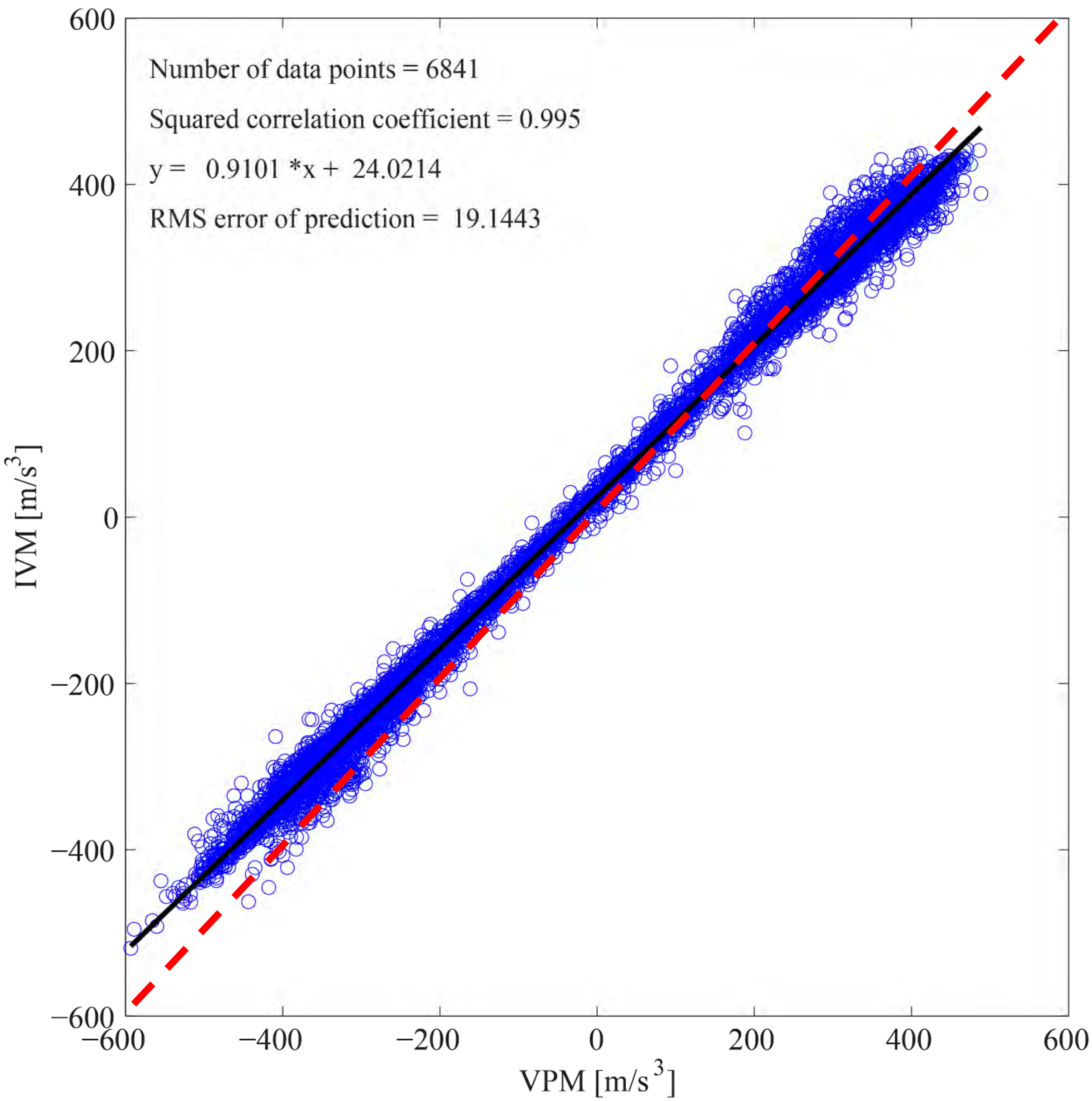


Figure A80. Linear regression of discharge estimated TCdde using the velocity profile method (VPM) as a predictor of the index velocity method (VPM). Dashed red line indicates 1:1 correlation.

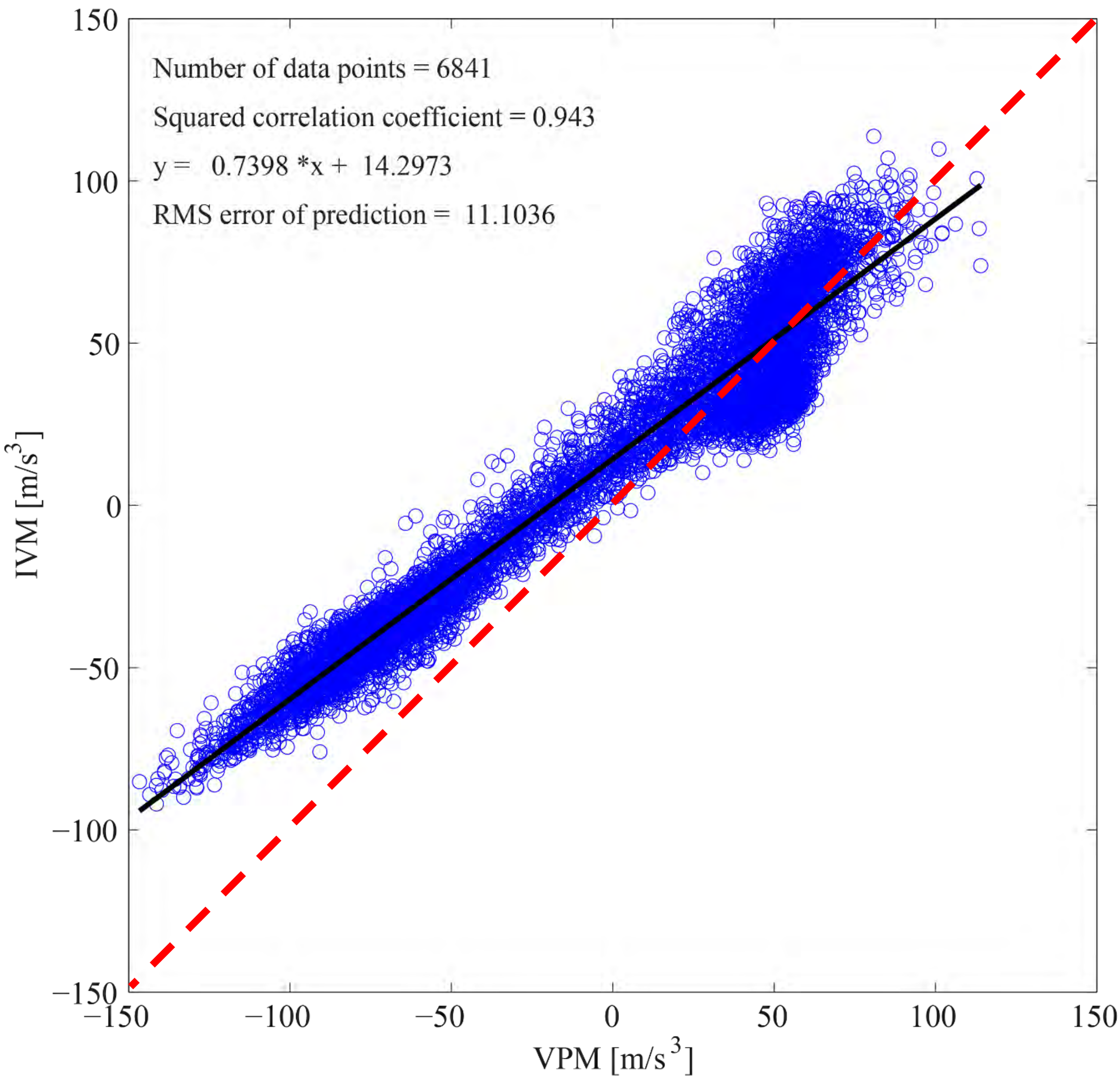


Figure A81. Linear regression of flow measured TCddw using the index velocity method (IVM) and the velocity profile method (VPM).

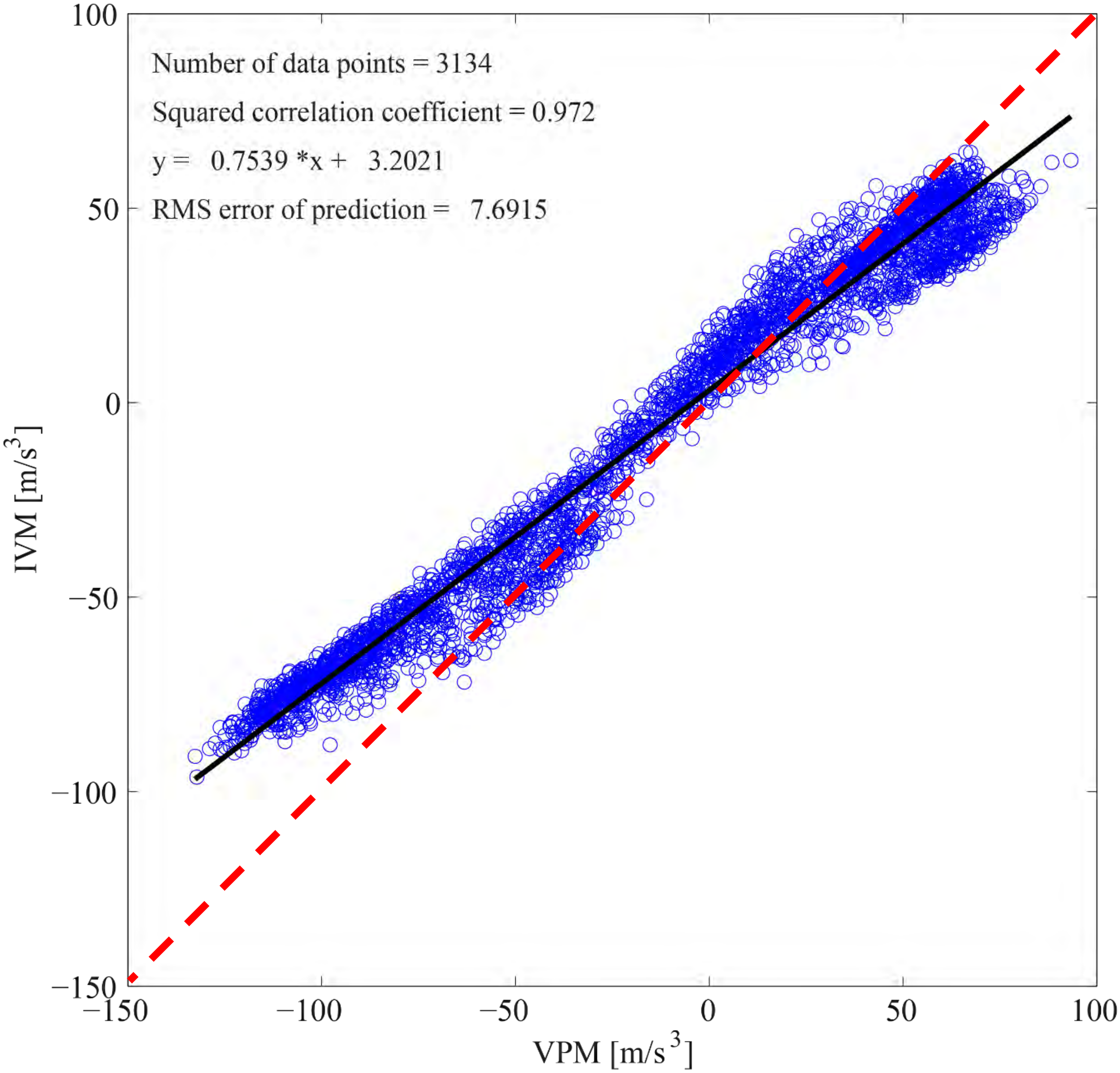


Figure A82. Linear regression of flow measured TCds using the index velocity method (IVM) and the velocity profile method (VPM).

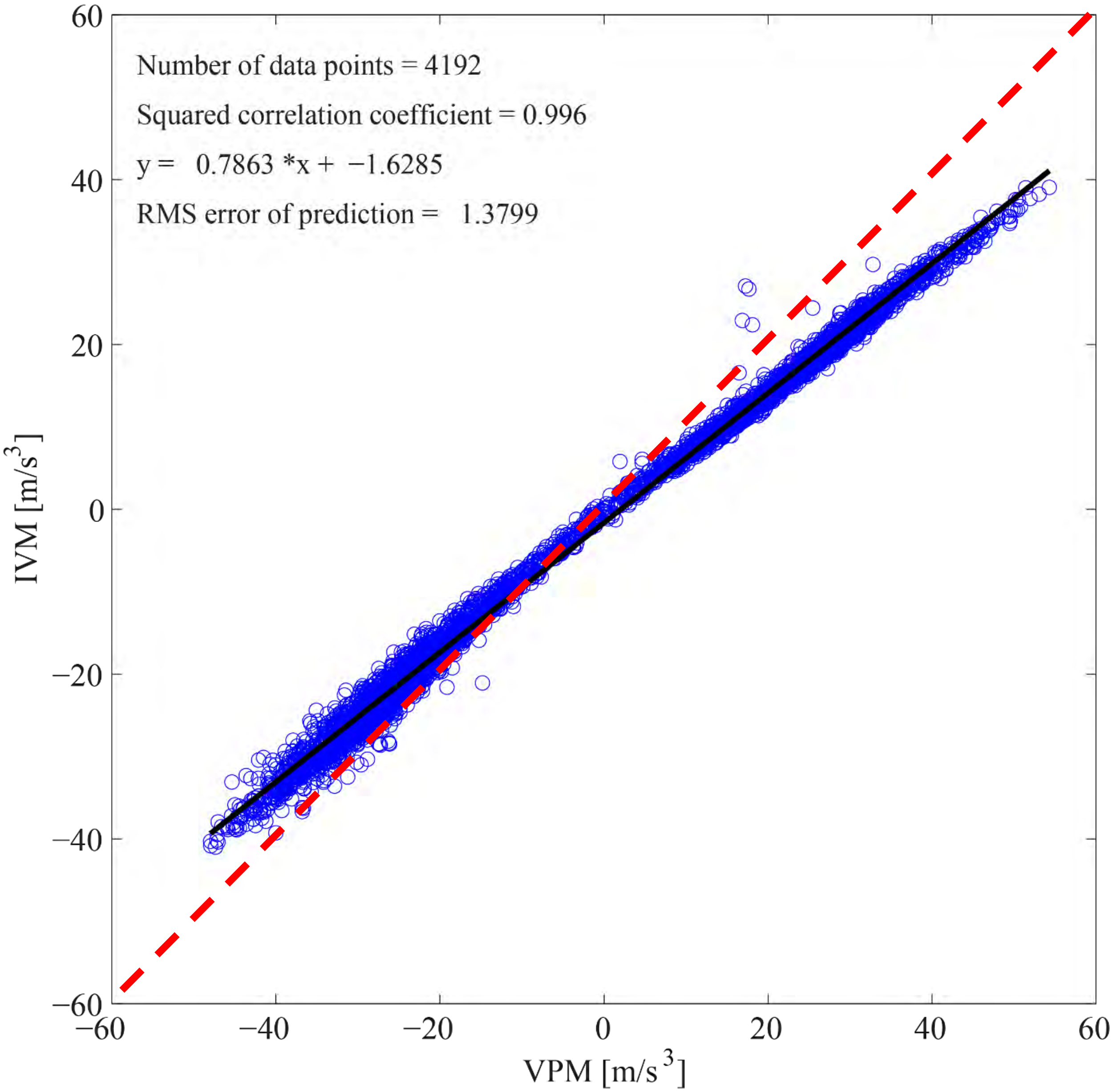


Figure A83. Linear regression of flow measured TCus using the index velocity method (IVM) and the velocity profile method (VPM).

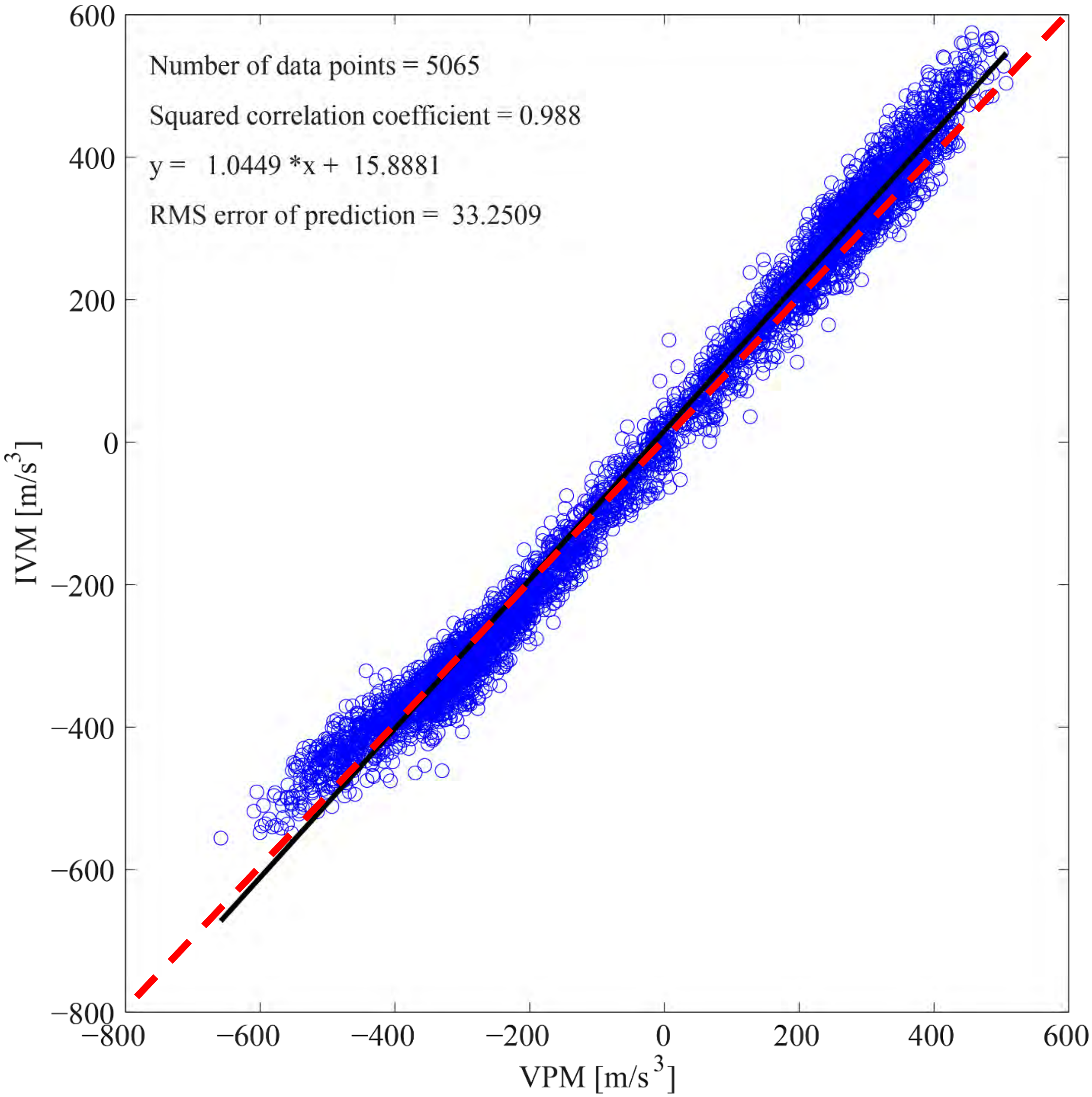


Figure A84. Linear regression of flow measured TCuu using the index velocity method (IVM) and the velocity profile method (VPM).

APPENDIX E

Modeling Physical Barriers

Modeling Physical Barriers (Gates) as Engineering Solutions to Satisfy NMFS BiOp RPA Action IV.1.3

October, 2014

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Bay Delta Office

Department of Water Resources

1. Introduction

This report provides detailed modeling information on the potential impact on flow, water quality and water level throughout the Delta of physical barriers (gates) as engineering solutions to deter fish from entering the Delta. The modeling was performed to provide information to support decision making for engineering solutions to satisfy the NMFS BiOp RPA Action IV.1.3 (Action). The Action objective is to prevent emigrating Salmonids from entering into the Interior and Southern Delta, and to reduce exposure to the CVP and SWP export facilities. Delta Simulation Model 2 (DSM2) was used to simulate gates on the Delta channels: Georgiana Slough, Head of Old River, Turner Cut and Columbia Cut. The modeling results have been evaluated for impact analysis of flow, water quality, and water level throughout the Delta.

2. The Simulation Model

DSM2 is a one-dimensional hydrodynamic and water quality model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento-San Joaquin Delta. DSM2 represents the best available planning model for Delta tidal hydraulic and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental impacts caused by future facilities and operations.

DSM2 consists of three modules: HYDRO, QUAL, and PTM. HYDRO simulates flow, velocities and water level and provides the flow input for QUAL and PTM. DSM2-HYDRO outputs are used to predict changes in flow rates, water level, and their effects on Delta channels as a result of future facilities and operations.

QUAL module simulates fate and transport of conservative and non-conservative water quality constituents, including salts, given a flow field simulated by HYDRO. Outputs are used to estimate changes in salinity and their effects on Delta channels as a result of future facilities and operations.

The DSM2-PTM module, not used in this modeling analysis, simulates pseudo 3-D transport of neutrally buoyant particles based on the flow field simulated by HYDRO. It simulates the transport and fate of individual particles traveling throughout the Delta. PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae. Additional information on DSM2 can be found on the DWR Modeling Support Branch website at http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm

3. Methodology

There were several scenarios investigated during this analysis ranging from full flow blockage to partial flow blockage at four key junctions in the Delta (Figure 1). An additional key junction, Threemile Slough, for which prior analysis had been conducted and is discussed in this report, is not shown on the Figure 1. The purpose of the flow blockage is to simulate a gate blocking a junction to divert emigrating Salmonids from entering into the Delta channels and to keep them in the Sacramento River or San Joaquin River for their passage to the Ocean. The 16-year (Water Year 1976 – Water Year 1991) DSM2 model was used to simulate these scenarios. The 16-year DSM2 model simulations have also been used for the Bay Delta Conservation Plan (BDCP) Draft EIR/S, South Delta Improvements Program (SDIP). Franks Tract Project, Storage Investigations and Operations Criteria and Plan (OCAP). The DSM2 model simulation of Existing Conditions for the BDCP Draft EIR/EIS was used as a baseline. The modeled or simulated flow, water quality, and water level were then compared with the baseline and the incremental changes were evaluated for impacts on various Delta locations.

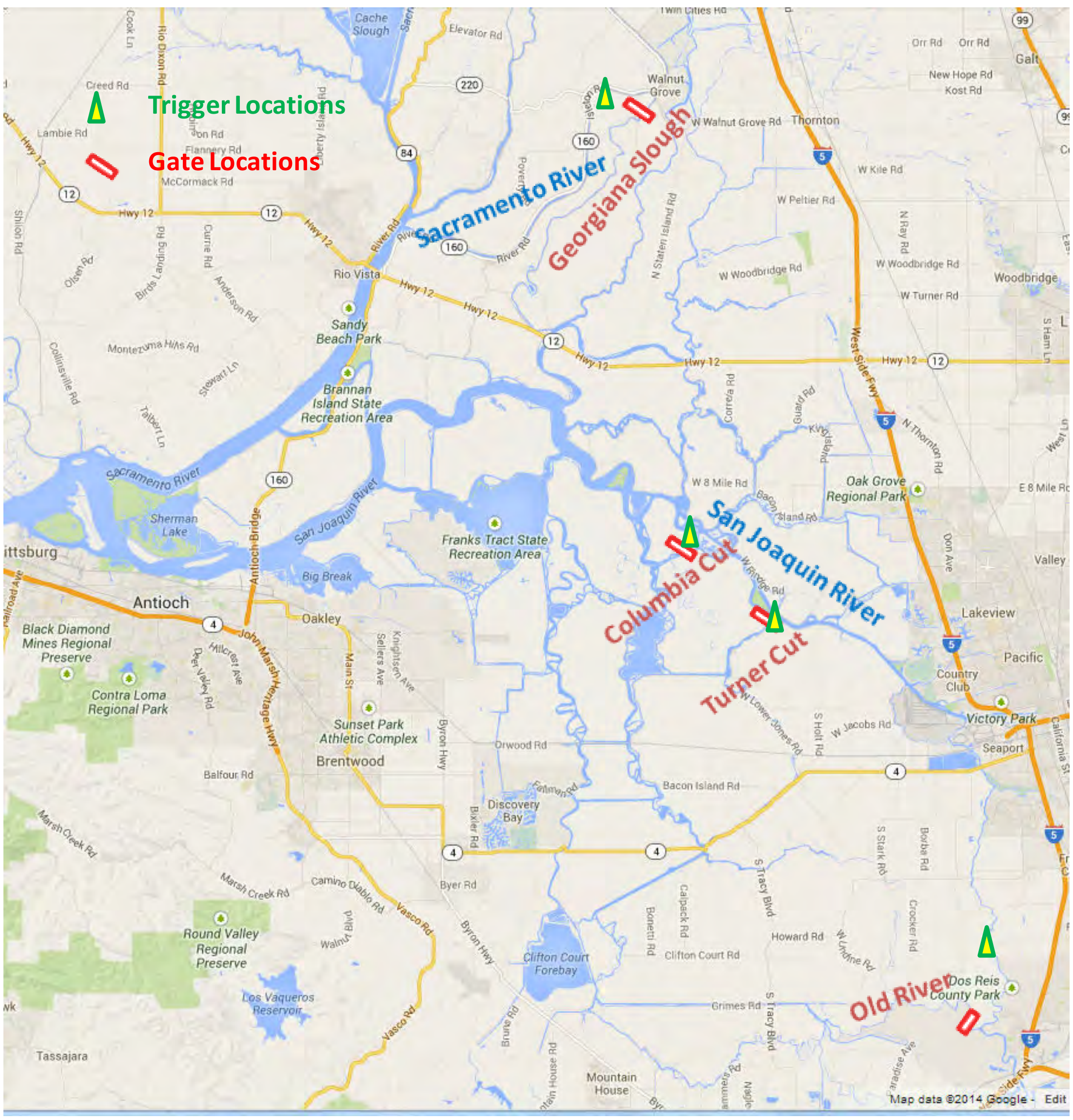

Figure 1: Gate locations in the Delta channels.

3.1. Description of Existing Condition

The Existing Conditions model simulation was developed assuming Year 2009 level of development and regulatory conditions. The Existing Conditions assumptions included existing facilities and ongoing programs that existed as of February 13, 2009 (publication date of the BDCP Public EIR/EIS Notice of Preparation and Notice of Intent) could affect or could be affected by implementation of the Alternatives. The Existing Conditions assumptions also included assumptions related to the State Water Project (SWP) and Central Valley Project (CVP), ongoing policies by governmental and non-profit entities, and assumptions related to annual actions that vary every year. One exception to this was the NMFS Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (BiOp), released in June 2009, was included in the development of the Existing Conditions simulation (BDCP Public EIR/EIS, 2013).

3.2. Description of Modeling Scenarios

The modeling scenarios were developed by adding a gate, or a combination of gates, to the Existing Conditions model simulation. The scenarios were divided into three categories: Full flow blockage to Delta Channels, Partial Flow Blockage to Delta Channels, and Flow Blockage used in other Projects. The gates in these scenarios were operated either by Flow trigger or Velocity trigger option to restrict flow to the Delta channels. The scenarios which included Georgiana Slough or Head of Old River gate had gate operation trigger location either in the Delta channels or in the Rivers. The scenarios which included Turner Cut and Columbia Cut gate had trigger location only in the Delta channels. These channels are located in Central Delta and are influenced by the tide. It was assumed that the impact from trigger location in the Rivers for these gates would be similar to that of the channels. Table 1 lists the categories with gate locations and operations for each of the scenarios.

Table 1: Modeling scenarios of gate location and operation

Category	Location of Gate	Gate Operation Trigger	Trigger Location
Full Flow Blockage to Delta Channels	Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut (Four Gates)	Closed on positive flow in channel & opened on reverse flow	Flow in Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut
	Georgiana Slough	Closed on positive flow in channel & opened on reverse flow	Flow in Georgiana Slough
	Head of Old River	Closed on positive flow in channel & opened on reverse flow	Flow in Head of Old River
	Turner Cut	Closed on positive flow in channel & opened on reverse flow	Flow in Turner Cut
	Columbia Cut	Closed on positive flow in channel & opened on reverse	Flow in Columbia Cut

Category	Location of Gate	Gate Operation Trigger	Trigger Location
		flow	
	Head of Old River, Turner Cut & Columbia Cut (Three Gates)	Closed on positive flow in channel & opened on reverse flow	Flow in Head of Old River, Turner Cut & Columbia Cut
	Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut (Four Gates)	Closed on ebb & opened on flood	Flow in Sacramento River, San Joaquin River, Turner Cut & Columbia Cut
	Georgiana Slough	Closed on ebb & opened on flood	Flow in Sacramento River
	Head of Old River	Closed on ebb & opened on flood	Flow in San Joaquin River
	Head of Old River, Turner Cut & Columbia Cut (Three Gates)	Closed on ebb & opened on flood	Flow in San Joaquin River, Turner Cut & Columbia Cut
Partial Flow Blockage to Delta Channels	Georgiana Slough	Partial closed on ebb to block 50% net flow & opened on flood	Flow in Sacramento River
	Head of Old River	Partial closed on ebb to block 50% net flow & opened on flood	Flow in San Joaquin River
	Georgiana Slough	Closed on high velocity & Opened on low velocity	Velocity in Sacramento River
	Georgiana Slough	Partial closed on high velocity to block 50% net flow & opened on low velocity	Velocity in Sacramento River
	Head of Old River	Closed on high velocity & Opened on low velocity	Velocity in San Joaquin River
	Head of Old River	Partial closed on high velocity to block 50% net flow & opened on low velocity	Velocity in San Joaquin River
Flow Blockage used in other Projects	Threemile Slough (Franks Tract Project)	Franks Tract Project proposed operation, Seasonal operation for Fish and Water Quality	Flow in Sacramento and San Joaquin River or EC in Jersey Point

3.2.1. Full Flow Blockage to Delta Channels:

The gates were modeled to restrict flow from entering into the junctions. The gates at one, or a combination of sites, were modeled in this category. The gates' operations were triggered by either flow in the Delta channels where the gates were placed, or flow in the Rivers. The gates with trigger location in Delta channels were closed on the positive flows in the channels and were opened on reverse flow in the channels. The gates with trigger location in the Sacramento or San Joaquin River are described below as flow trigger.

3.2.1.1. Flow Trigger:

The gates were closed on the ebb tide when the water flowed towards the Ocean from the Rivers. The gates were opened on the flood tide when the water flowed from the Ocean towards the Rivers. The gate operation at Georgiana Slough was used to illustrate the flow trigger method. The trigger was based on the flow in the Sacramento River downstream of the gate. When the flow direction at the Sacramento River at the trigger location was towards the Ocean, the Georgiana Slough gate was closed. The gate was opened during reverse flow periods. Figure 2 illustrates the gate closure in response to the flow trigger. The gate operation at the Head of Old River was based on the flow in the San Joaquin River downstream of the gate. The gate operation scenario was similar to the Georgiana Slough gate.

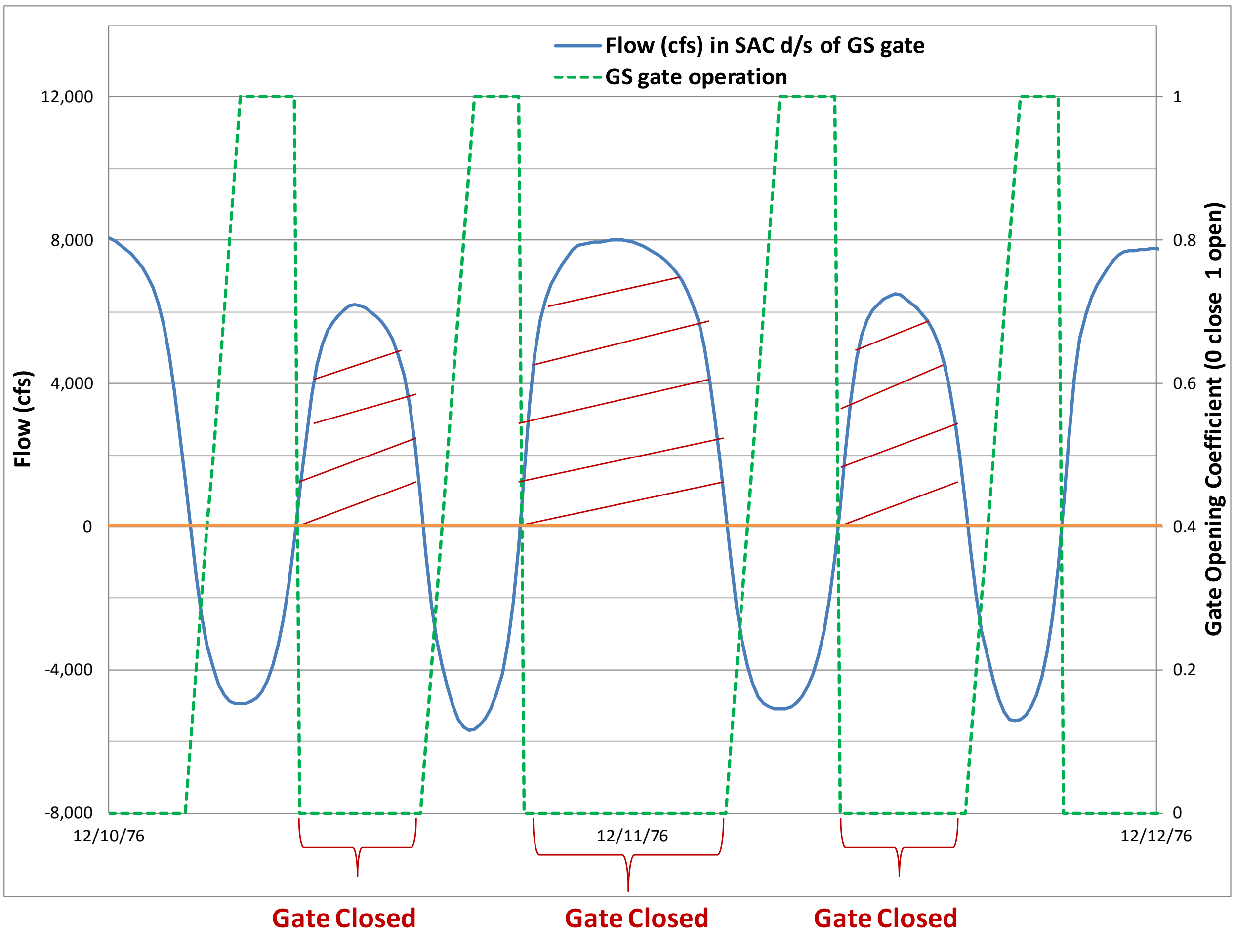

Figure 2: Flow triggered gate operation (open/close)

3.2.2. Partial Flow Blockage to Delta Channels:

The gates were modeled to restrict partial flow from entering into the junctions. The gates were placed in the junctions on Delta channels. In this category, flow was not fully blocked to enter into the channels from the Rivers during the ebb tide. The gates operations were triggered by either flow in the Rivers, or velocity in the Rivers. These triggers were described below.

3.2.2.1. Flow Trigger:

During the ebb tide, the size of the gate was modified to attain an average flow blockage of about 50% over the 16-year model simulation period. The scenario was analyzed to evaluate incremental changes in water quality and water level. The gates were closed on the ebb tide when the water flowed towards the Ocean from the Sacramento or San Joaquin River. The gates were opened on the flood tide when the water flowed from the Ocean towards the Rivers. Figure 2 illustrates the flow trigger scenario for Georgiana Slough. The Head of Old River gate had similar operations.

3.2.2.2. Velocity Trigger:

The gate operation was triggered by velocity in the Rivers. The gate at a junction of a River and channel operated based on velocity in the River downstream of the junction. The velocity in the Delta followed the tidal cycle and has two high and two low velocities in every 6 hours. When the velocity changed from high to low, the gate was closed, and when the velocity changed from low to high, the gate was opened. Figure 3 illustrates the gate closure in response to the velocity trigger. The gate at Georgiana Slough operated based on a velocity trigger in the Sacramento River downstream of the junction. Another scenario which blocked about 50% of the flow during the gate closure period (Figure 3) was simulated. This modeling scenario was developed by modifying the size of the gate. The gate at the Head of Old River was operated on a similar velocity trigger formulation, but it was based on the velocity in the San Joaquin River downstream of the junction.

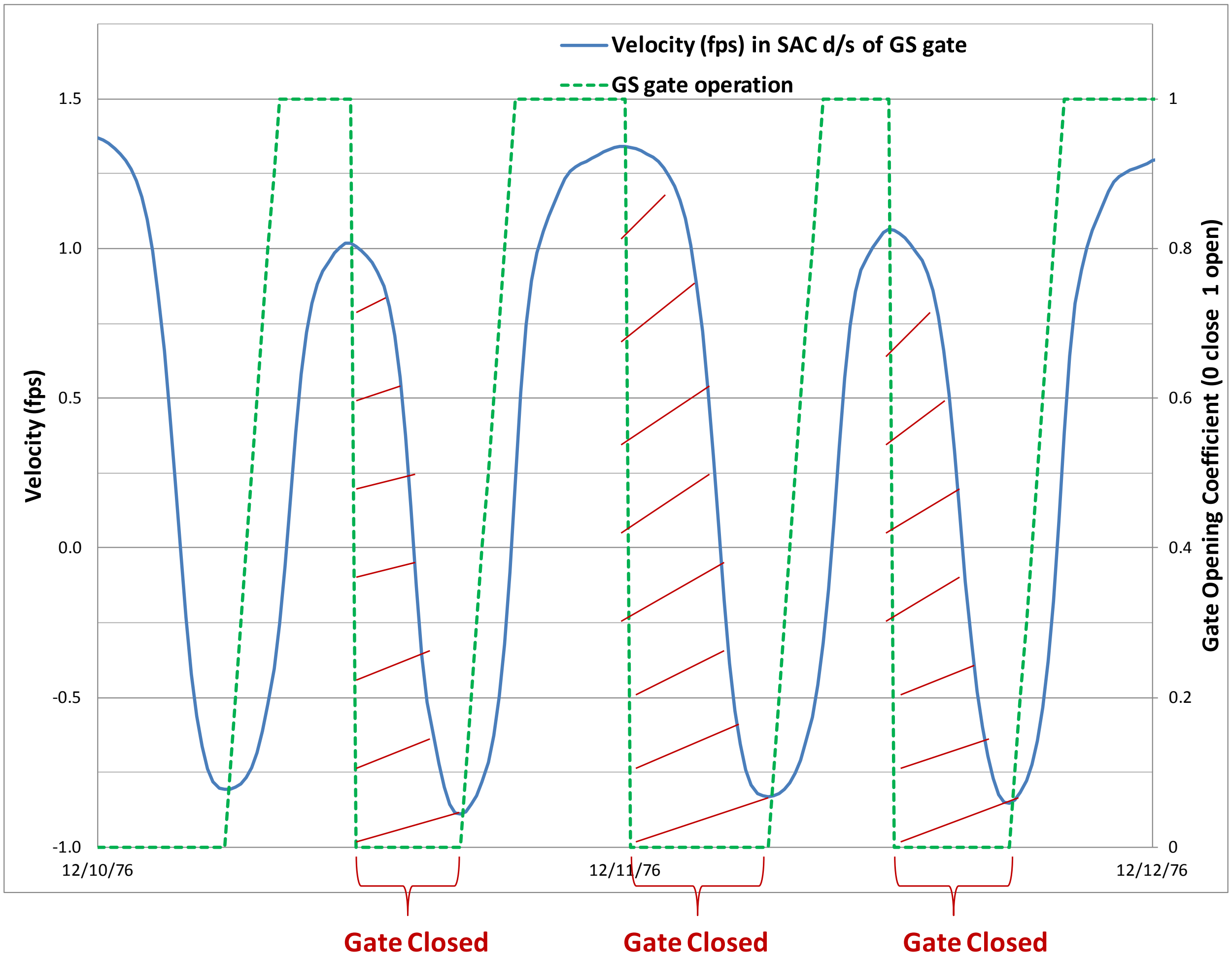

Figure 3: Velocity triggered gate operation (open/close)

3.2.3. Flow Blockage used in other Projects:

As noted under 3. Methodology, prior gate modeling analysis had already been conducted for Threemile Slough (Franks Tract Project). The Franks Tract Project objectives were different than the objective of NMFS BiOp RPA Action IV.1.3 but one of the objectives was to protect sensitive fish species and reduce seawater intrusion through modifications of flow conditions in the western Delta. The proposed Franks Tract Project includes a tidally operated gate located in the Threemile Slough. The Franks Tract DSM2 model was re-ran for this study analysis to simulate the proposed gate operations. The modeling results were analyzed for any impacts on the Delta.

4. Model Results:

The DSM2 model was simulated for 16 years for Existing Conditions and all scenarios listed in Table 1. The model results were in 15 minutes intervals and were processed to generate monthly average flow, monthly average EC (used for salinity), and daily minimum water level. The percentage of time that the gates were closed throughout the simulation period is reported in Table 2 for all scenarios.

Table 2: Gate closure frequency

Category	Location of Gate	Gate Operation Trigger	Trigger Location	Percent of time gate was closed
Full Flow Blockage to Delta Channels	Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut (Four Gates)	Closed on positive flows in channel & opened on reverse flows	Flow in Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut	99, 99, 51 & 50
	Georgiana Slough	Closed on positive flows in channel & opened on reverse flows	Flow in Georgiana Slough	99
	Head of Old River	Closed on positive flows in channel & opened on reverse flows	Flow in Head of Old River	99
	Turner Cut	Closed on positive flows in channel & opened on reverse flows	Flow in Turner Cut	51
	Columbia Cut	Closed on positive flows in channel & opened on reverse flows	Flow in Columbia Cut	50
	Head of Old River, Turner Cut & Columbia Cut (Three Gates)	Closed on positive flows in channel & opened on reverse flows	Flow in Head of Old River, Turner Cut & Columbia Cut	99, 51 & 50
	Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut (Four Gates)	Closed on ebb & opened on flood	Flow in Sacramento River, San Joaquin River, Turner Cut & Columbia Cut	80, 80, 51 & 50
	Georgiana Slough	Closed on ebb & opened on flood	Flow in Sacramento River	80
	Head of Old River	Closed on ebb & opened on flood	Flow in San Joaquin River	80
	Head of Old River, Turner Cut & Columbia Cut (Three Gates)	Closed on ebb & opened on flood	Flow in San Joaquin River, Turner Cut & Columbia Cut	80, 51 & 50
Partial Flow Blockage to Delta	Georgiana Slough	Partial closed on ebb to block 50% net flow & opened on flood	Flow in Sacramento River	80
	Head of Old River	Partial closed on ebb to	Flow in San Joaquin	80

Category	Location of Gate	Gate Operation Trigger	Trigger Location	Percent of time gate was closed
Channels		block 50% net flow & opened on flood	River	
	Georgiana Slough	Closed on high velocity & Opened on low velocity	Velocity in Sacramento River	46
	Georgiana Slough	Partial closed on high velocity to block 50% net flow & opened on low velocity	Velocity in Sacramento River	46
	Head of Old River	Closed on high velocity & Opened on low velocity	Velocity in San Joaquin River	45
	Head of Old River	Partial closed on high velocity to block 50% net flow & opened on low velocity	Velocity in San Joaquin River	45
Flow Blockage used in other Projects	Threemile Slough (Franks Tract Project)	Franks Tract Project proposed operation, Seasonal operation for Fish and Water Quality	Flow in Sacramento and San Joaquin River or EC in Jersey Point	12

The modeled flow for the scenarios was compared with Existing Conditions at downstream locations of the gate in Georgiana Slough, Head of Old River, Columbia Cut and Turner Cut. The modeled EC was compared at Sacramento River at Emmaton (Emmaton), San Joaquin River at Jersey Point (Jersey Point), Clifton Court Forebay (Clifton Court), and Old River at Tracy Road (Tracy Road). The modeled water level (stage) was compared at Old River at Tracy Road, San Joaquin River at Brandt Bridge (Brandt Bridge), and San Joaquin River at Prisoners Point (Prisoners Point) (Figure 4). The processed values are presented in Figures 5 through 71.

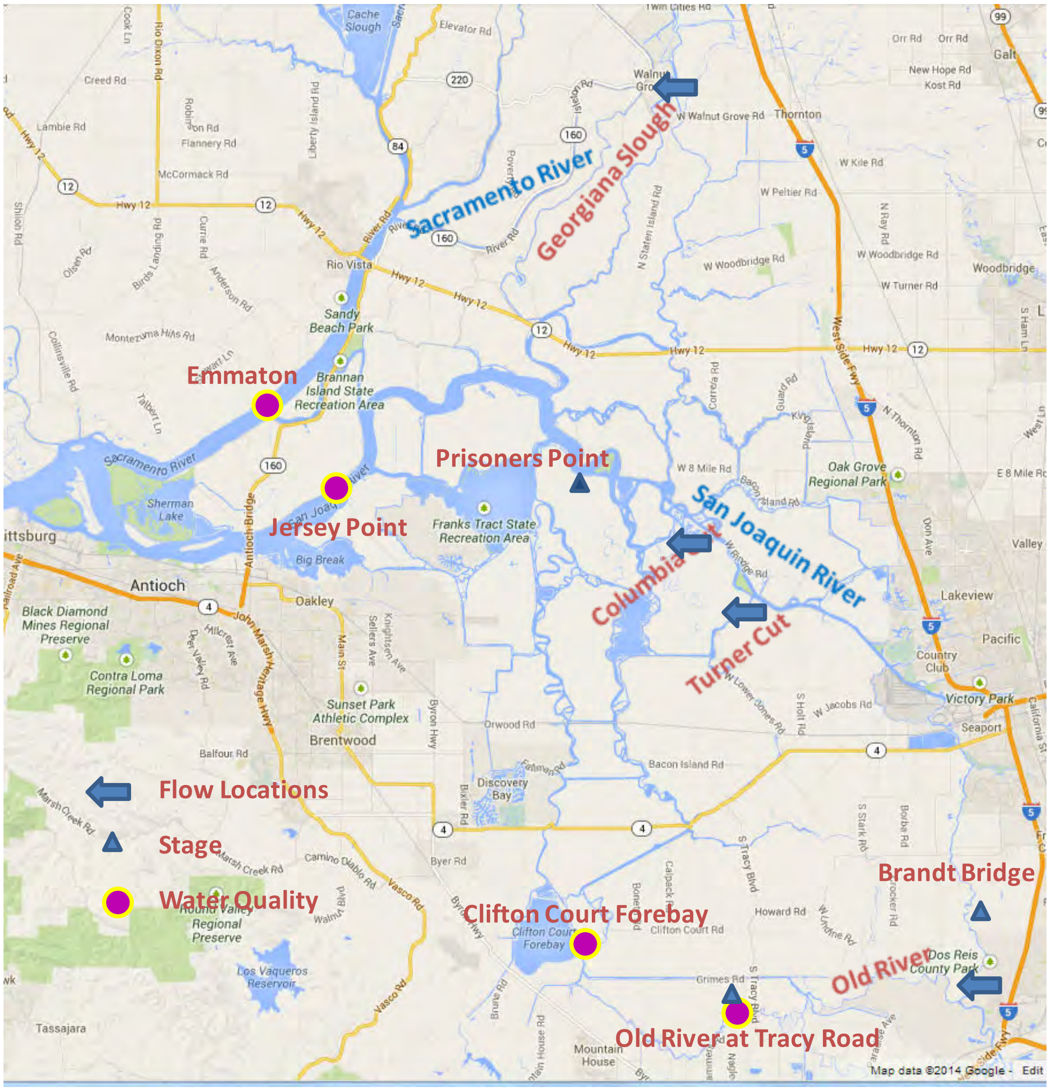

Figure 4: Model output Locations

4.1. Full Flow Blockage to Delta Channels:

The gates at Georgiana Slough and Head of Old River were closed for 99% of the time for the flow in the Delta channels trigger scenarios; therefore, little to no flow was going through these channels. The gates at Georgiana Slough and the Head of Old River were closed 80% of the time (Table 2) for the flow in the Rivers trigger scenarios. The gates were closed less frequently than the previous scenarios; therefore, little flow went through these channels. The gates at Columbia Cut and Turner Cut were closed or opened 50% of the time. Figure 5 through Figure 20 showed monthly average flow in the Delta channels downstream of the gates. A positive flow direction in Columbia and Turner Cut refers to flow towards the San Joaquin River, and a negative flow direction refers to flow from the San Joaquin River into the Cuts.

Figure 21 through Figure 36 showed monthly average EC comparison bar plots. The Georgiana Slough gate and Four Gates scenarios (see Table 1) blocked better quality Sacramento River flow from entering into the Interior and Southern Delta, and allowed more water to flow through the Sacramento River. This flow pattern had an impact on water quality. EC at Clifton Court and Jersey Point increased, and EC at Emmaton decreased. The Head of Old River gate and Three Gates scenarios (see Table 1) had no impact on EC at Emmaton, Jersey Point, or Clifton Court.

The Delta Cross Channel (DCC) gates were fully closed from February 1st through May 20th in accordance with the State Water Resources Control Board Decision 1641 (Bureau of Reclamation). The DCC gates were closed for a total of 14 days from May 21st through June 15th. During those months, the model showed that the Head of Old River gate and Three Gates scenarios deteriorated EC at Tracy Road, but improved or had no impacts on EC for all other months. The Four Gates scenario increased EC at Tracy Road. The Georgiana Slough gate had no impact on EC at Tracy Road. The Columbia Cut gate and Turner Cut gate scenarios had no impact on EC at these locations. Therefore, no further modeling of partial flow blockage scenarios for Columbia Cut and Turner Cut gates were necessary.

Daily minimum water levels at the South Delta locations were evaluated (Figure 37 to Figure 48). The Head of Old River gate dropped the water level by 1 foot or more during most years of the 16 year simulation period. The Head of Old River gate restricted San Joaquin flows from entering Old River and left more water in the San Joaquin River. As a consequence, the water level at Brandt Bridge increased by 1 foot or more 40% of the time. The water level at Prisoners Point, which is 45 miles downstream from the gate site, did not change. All of the other gate scenarios did not have an impact on water level in the South Delta.

4.2. Partial Flow Blockage to Delta Channels:

For the flow trigger scenarios, with the 50% flow blockage on the ebb tide, more Sacramento River water went into Georgiana Slough, and more San Joaquin River water went into Old River (Figure 17 to Figure 20).

For the velocity trigger scenarios, the gates were closed 46% of the time in Georgiana Slough, and 45% of the time at Head of Old River (Table 2). As expected, flow was less restricted to these channels (Figure 49 to Figure 52).

EC at Clifton Court and Jersey Point increased in response to the Georgiana Slough gate operations. EC at Emmaton decreased, and there was no impact at Tracy Road. The velocity trigger scenarios had a smaller impact on EC (Figure 53 to Figure 56) than the flow trigger scenarios (Figure 33 to Figure 36).

The combined effects of the DCC gate and the Head of Old River gate closures deteriorated EC from February to May at Tracy Road. There were no impacts to EC at Emmaton, Jersey Point, and Clifton Court.

The Georgiana Slough gate didn't have an impact on water level in the South Delta. The impacts on water level in the South Delta channels, due to the Head of Old River gate, were similar in trends as compared with the previous scenarios, but the magnitudes of changes were smaller. The velocity trigger scenarios had a smaller impact on water level (Figure 57 to Figure 59) than the flow trigger scenarios (Figure 46 to Figure 48).

4.3. Flow Blockage used in other Projects:

The Franks Tract Project proposed gate at Threemile Slough was operated seasonally for water quality and fishery benefits. The gate improved water quality in Clifton Court and Jersey Point, and had no impact on water quality in Emmaton and Tracy Road. The gate had no impact on water level in the South Delta (Figure 60 to Figure 67).

5. Conclusion:

The impacts of the Georgiana Slough, Head of Old River, Turner Cut and Columbia Cut gates on water quality and water level varied. Figure 68 through Figure 71 represented incremental changes in water quality throughout the Delta for each of the gates. The figures also showed relative impacts among the four different gates. Table 3 summarizes the impacts on water quality for all scenarios.

Table 3: Impacts of modeling scenarios on water quality

			Impact on Water Quality (EC)			
Category	Location of Gate	Gate Operation Trigger	Clifton Court	Emmaton	Jersey Point	Tracy Road
Full Flow Blockage to Delta Channels	Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut (Four Gates)	Closed on positive flow in channel & opened on reverse flow	Deteriorated	Improved	Deteriorated	Deteriorated*
	Georgiana Slough	Closed on positive flow in channel & opened on	Deteriorated	Improved	Deteriorated	No/Minimal

			Impact on Water Quality (EC)			
Category	Location of Gate	Gate Operation Trigger	Clifton Court	Emmaton	Jersey Point	Tracy Road
		reverse flow				
	Head of Old River	Closed on positive flow in channel & opened on reverse flow	No/minimal	No	No	Deteriorated*
	Turner Cut	Closed on positive flow in channel & opened on reverse flow	No	No	No	No
	Columbia Cut	Closed on positive flow in channel & opened on reverse flow	No	No	No	No
	Head of Old River, Turner Cut & Columbia Cut (Three Gates)	Closed on positive flow in channel & opened on reverse flow	No/minimal	No	No	Deteriorated*
	Georgiana Slough, Head of Old River, Turner Cut & Columbia Cut (Four Gates)	Closed on ebb & opened on flood	Deteriorated	Improved	Deteriorated	Deteriorated*
	Georgiana Slough	Closed on ebb & opened on flood	Deteriorated	Improved	Deteriorated	No/Minimal
	Head of Old River	Closed on ebb & opened on flood	No	No	No	Deteriorated*
	Head of Old River, Turner Cut & Columbia Cut (Three Gates)	Closed on ebb & opened on flood	No/Minimal	No	No	Deteriorated*
Partial	Georgiana	Partial closed	Deteriorated	Improved	Deteriorated	No/Minimal

			Impact on Water Quality (EC)			
Category	Location of Gate	Gate Operation Trigger	Clifton Court	Emmaton	Jersey Point	Tracy Road
Flow Blockage to Delta Channels	Slough	on ebb to block 50% net flow & opened on flood				
	Head of Old River	Partial closed on ebb to block 50% net flow & opened on flood	No	No	No	Minimal*
	Georgiana Slough	Closed on high velocity & Opened on low velocity	Deteriorated	Improved	Deteriorated	No/Minimal
	Georgiana Slough	Partial closed on high velocity to block 50% net flow & opened on low velocity	Deteriorated	Improved	Deteriorated	No/Minimal
	Head of Old River	Closed on high velocity & Opened on low velocity	No	No	No	Minimal*
	Head of Old River	Partial closed on high velocity to block 50% net flow & opened on low velocity	No	No	No	Minimal*
Flow Blockage used in other Projects	Threemile Slough (Franks Tract Project)	Franks Tract Project proposed operation, Seasonal operation for Fish and Water Quality	Improved	No	Improved	No

* EC deteriorated at Tracy Road when both DCC and Head of Old River gates were closed.

The modeling analysis conclusions are:

- The impacts on water quality and water level decreased as gate closure time decreased.

- The Georgiana Slough Gate deteriorated water quality in the Central and South Delta, as well as in the SWP & CVP export facilities.
- The Georgiana Slough Gate improved water quality at Emmaton.
- The Head of Old River Gate deteriorated water quality locally, and caused lower water level in the South Delta.
- The Columbia and Turner Cut Gates had no impact on water quality or water level.

6. References:

1) Bay Delta Conservation Plan. November 2013. Public Draft EIR/EIS. Appendix 3D: Defining Existing Conditions, No Action Alternative, No Project Alternative, and Cumulative Impact Conditions.
2) Bureau of Reclamation. Delta Cross Channel Gates. Available: < http://www.usbr.gov/mp/cvo/vungvari/xcgtxt.html >. Accessed: September 18, 2014.