Tehama-Colusa Canal Authority (TCCA) – Fish Passage Improvement Project at Red Bluff Diversion Dam

Pumping Plant and Fish Screen Project Hydraulics: Red Bluff Pumping Plant Fish Screen Hydraulic Model Study (1:42 Scale)

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Purpose

The purpose of this hydraulic model study was to document the hydraulic characteristics and performance of the Red Bluff Pumping Plant's positive barrier fish screen design for a range of Sacramento River and Tehama-Colusa Canal diversion flows. Model study data were used to enhance the fish screen performance so that it meets or exceeds performance criteria as set forth by the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (CDFG).

Introduction

This memorandum contains information on performance results of a 1:42 scale hydraulic model of the proposed Red Bluff Pumping Plant positive barrier fish screen. Reclamation's Hydraulic Investigations and Laboratory Services Group at the Technical Service Center constructed a physical model of the fish screen and pumping plant forebay in its Denver laboratory. The proposed 2,500 ft^3/sec pumping plant and 1,100-ft-long fish screen is located on the west bank of the Sacramento River approximately 1,500 ft upstream from the existing Red Bluff Diversion Dam. The fish screen is required to comply with NMFS screen performance criteria for on-river fish screens. The screen criteria require that the approach flow velocity perpendicular to the screen face not exceed 0.33 ft/sec. This approach velocity criterion is intended to prevent impingement of juvenile salmonids on the screens. Adjustable baffles are commonly used behind the fish screen to fine tune screen bays with nonuniform velocities. However, baffling cannot rectify poor screen approach conditions produced by highly nonuniform channel approach flow. Using screen baffles to adjust for poor channel approach conditions to a screen will result in significant headlosses across the screens/baffles and will result in higher pumping costs.

The physical model was used to evaluate the hydraulic performance of the fish screen structure designed by CH2M-HILL. The model was tested at several river and pumping plant flow rates. Modifications to the fish screen structure design were made to improve performance with respect to approach and sweeping velocity criteria, sediment impacts, and flow conditions in the pumping plant forebay.

Background

The Red Bluff Pumping Plant is designed to replace the Red Bluff Diversion Dam (RBDD) which is located on the Sacramento River, near the city of Red Bluff in north central California. The project provides water to the west side of the Sacramento River valley for irrigation purposes. Figure 1 is a general location map which identifies the project canals and the boundaries of the water districts served. Ineffective fish passage at RBDD has been identified as a contributing factor in the decline of the anadromous fishery resource in the upper Sacramento River basin. In 1991, Reclamation initiated the RBDD Fish Passage Program to identify and recommend alternatives which represent potential solutions for improving fish passage at RBDD. In 1992, Reclamation published an Appraisal Report which documents various alternatives to improve fish passage [1]. The scope of the Fish Passage Program was established to develop alternatives to achieve the following objectives:

- Improving fish passage while maintaining current water deliveries to the Tehama-Colusa and Corning Canals
- Maintaining existing economic benefits of RBDD
- Preventing adverse impacts in other geographical areas.

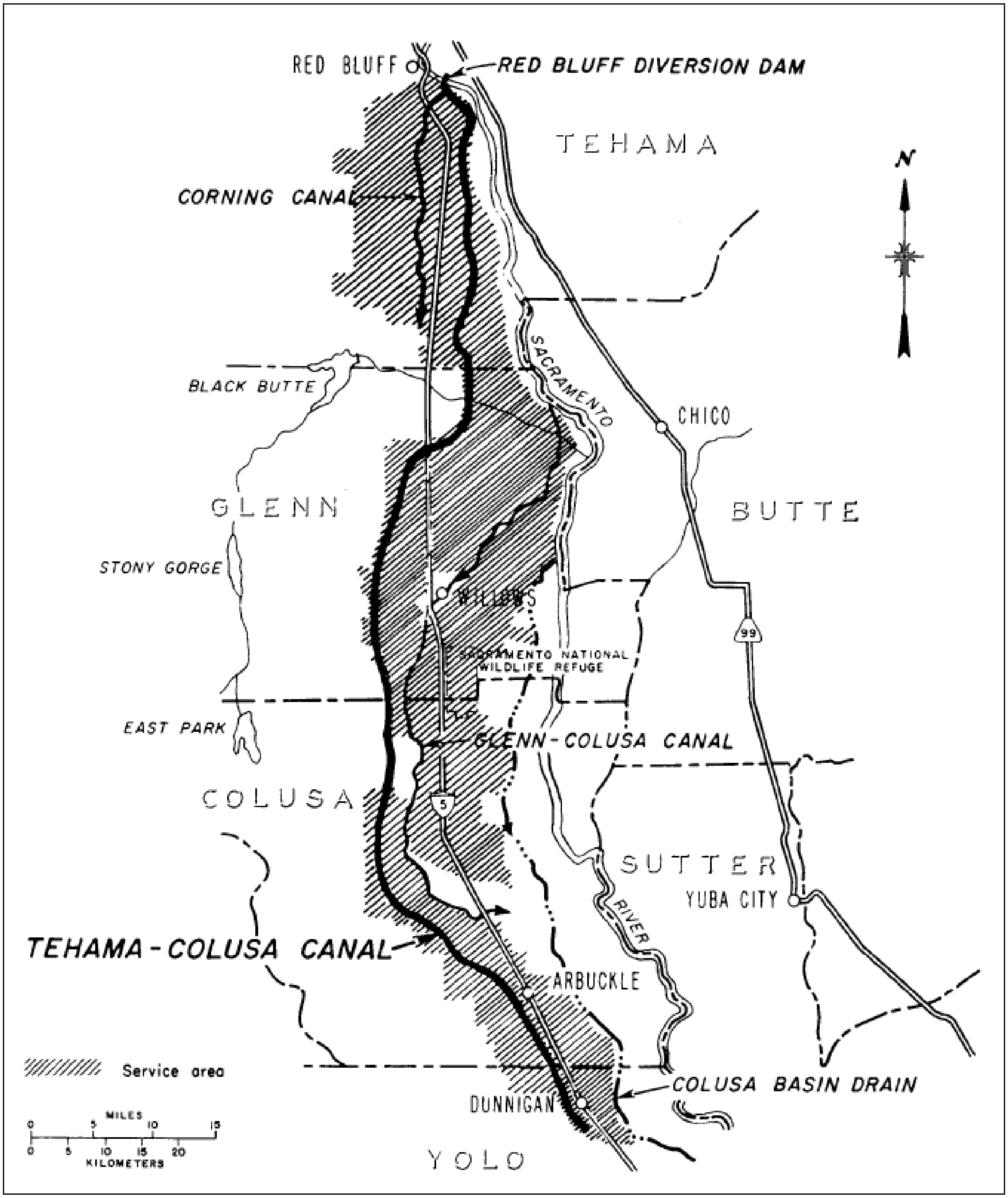

Figure 1. General location map of Red Bluff Diversion Dam and project area extents.

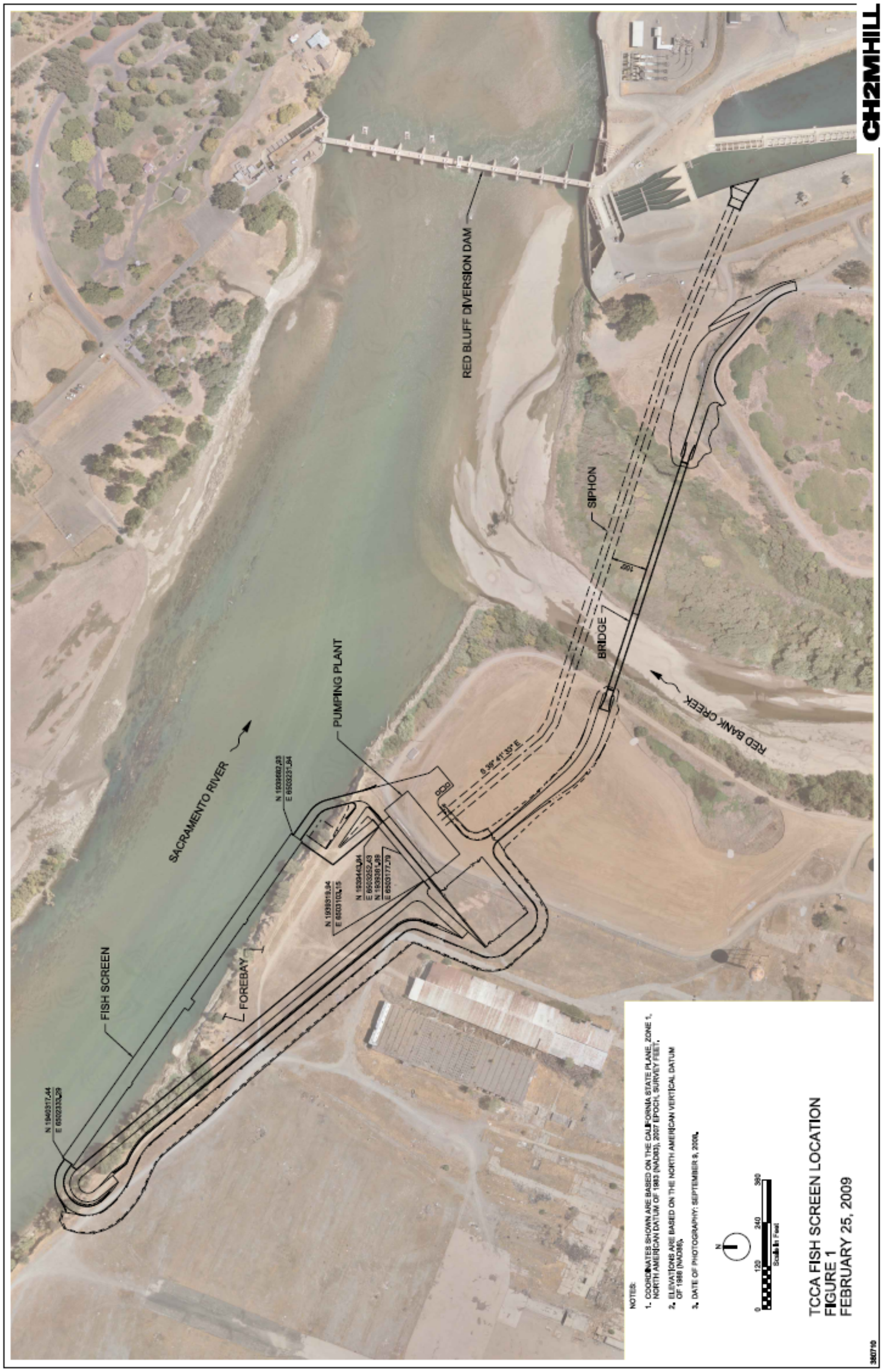

Figure 2. Aerial photograph with an overlay of the Red Bluff Pumping Plant and Fish Screen layout that was modeled.

Conclusions

- The Red Bluff Pumping Plant fish screen structure tested in the physical model performed adequately for a wide range of river flows and pumping rates of 1,250 and 2,500 ft^3/sec.
- For economic reasons, the fish screen location in the final design was moved 100 ft upstream from the modeled screen. However, it was decided that the minor offset did not warrant additional model testing.
- Near uniform approach velocity distributions were measured along the fish screen structure for a wide range of river and pumping plant operations.
- Near uniform velocity distributions in the model were obtained using internal baffles adjusted to 5 to 7.5 percent open area. Final baffle settings should be determined as part of a formal fish screen evaluation program.
- Sweeping velocities of 4 and 6 ft/sec were measured for river flows of 8,000 and 12,600 ft^3/sec, respectively.
- High flow in Red Bank Creek did not negatively affect the velocity distribution along the fish screen. However, high flows in Red Bank Creek did increase the river water surface elevations along the screen.
- The upstream and downstream transition walls were effective at training the river flow so that it approached and passed the structure with minimal flow disturbance.
- Flow in the approach channel to the pump sump was weakly skewed, with higher velocities along the south transition wall. The maximum channel velocity was about 1 ft/sec (prototype).
- A qualitative sediment transport test showed good sediment transport capacity in the main river channel adjacent to the fish screen structure.
- The majority of the sediment accumulated in the river channel upstream from the fish screen structure.
- Sediment deposition did not occur anywhere in a 25-ft-wide zone along the entire fish screen length.
- Fine sediment deposited between the screen and baffles and in the fish screen bays behind the baffles.

The Model

The fish screen model was constructed using preliminary design data provided by CH2M-Hill as shown in figure 2. Subsequently, changes were made to replace fish bypasses with fish refuges built into the bypass intake bays. The fish refuge concept was modeled in a laboratory flume and is documented in a separate technical memorandum [2]. Following the completion of model testing, the fish screen location was moved 100 ft upstream for economic reasons. It was decided by the design team that this minor offset did not warrant additional model testing.

The hydraulic model was constructed to a 1:42 scale in a water tight box with dimensions of 44 feet wide, 90 ft long, and 4 feet deep (figure 3). The model scale was selected to allow the construction of the fish screen and sufficient channel length to accurately reproduce the riverine hydraulics. The model included the following features:

- The Red Bluff Pumping Plant forebay and fish screen
- 3,800 ft of Sacramento River channel and floodplain
- 200 ft of Red Bank Creek and delta

Model topography (1 ft contour interval) was generated using land survey and bathymetry data collected in September 2008. The survey datums for this project were as follows:

- Horizontal Control – California State Plane, Zone 2, North American Datum of 1983 (NAD83)
- Vertical Control - North American Vertical Datum of 1988 (NAVD88)

The maximum depth in the river channel along the fish screen for the design river discharge (12,600 ft^3/sec) is 11.2 ft. The main river channel width varies from 500 ft at the first screen bay to a minimum of 335 ft about 600 ft down the fish screen structure. A wide range of river flows were modeled over the course of this study. The minimum and maximum Sacramento River flows modeled were 8,000 and 80,000 ft^3/sec, respectively.

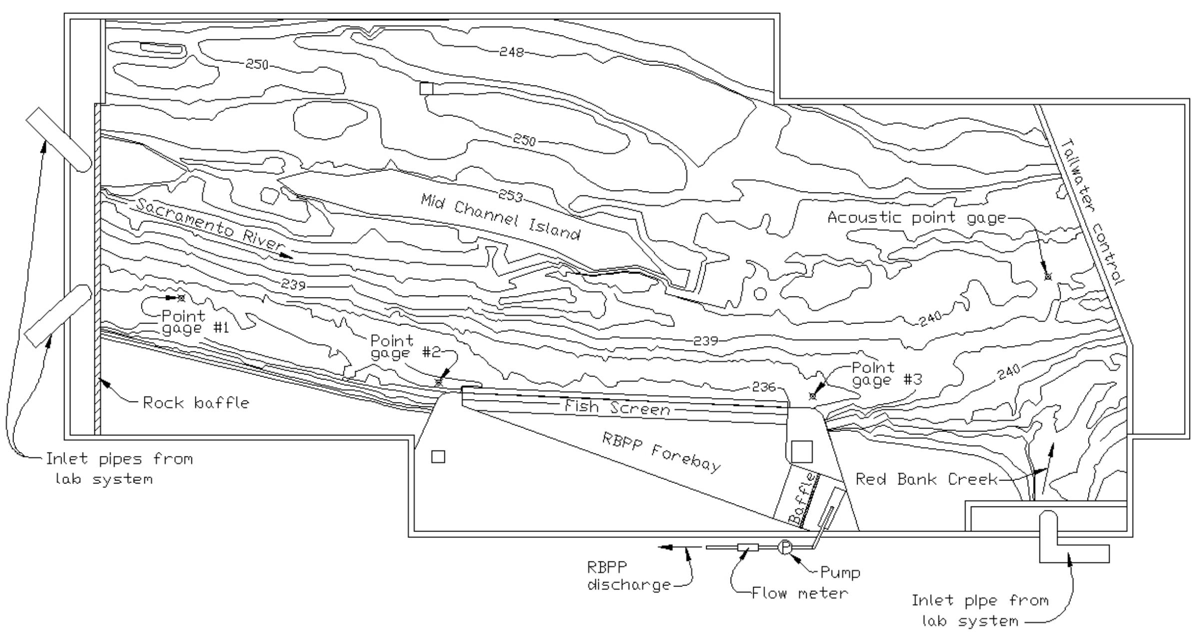

Figure 3. Plan view schematic of the Red Bluff Pumping Plant fish screen hydraulic model in Reclamation's hydraulics laboratory.

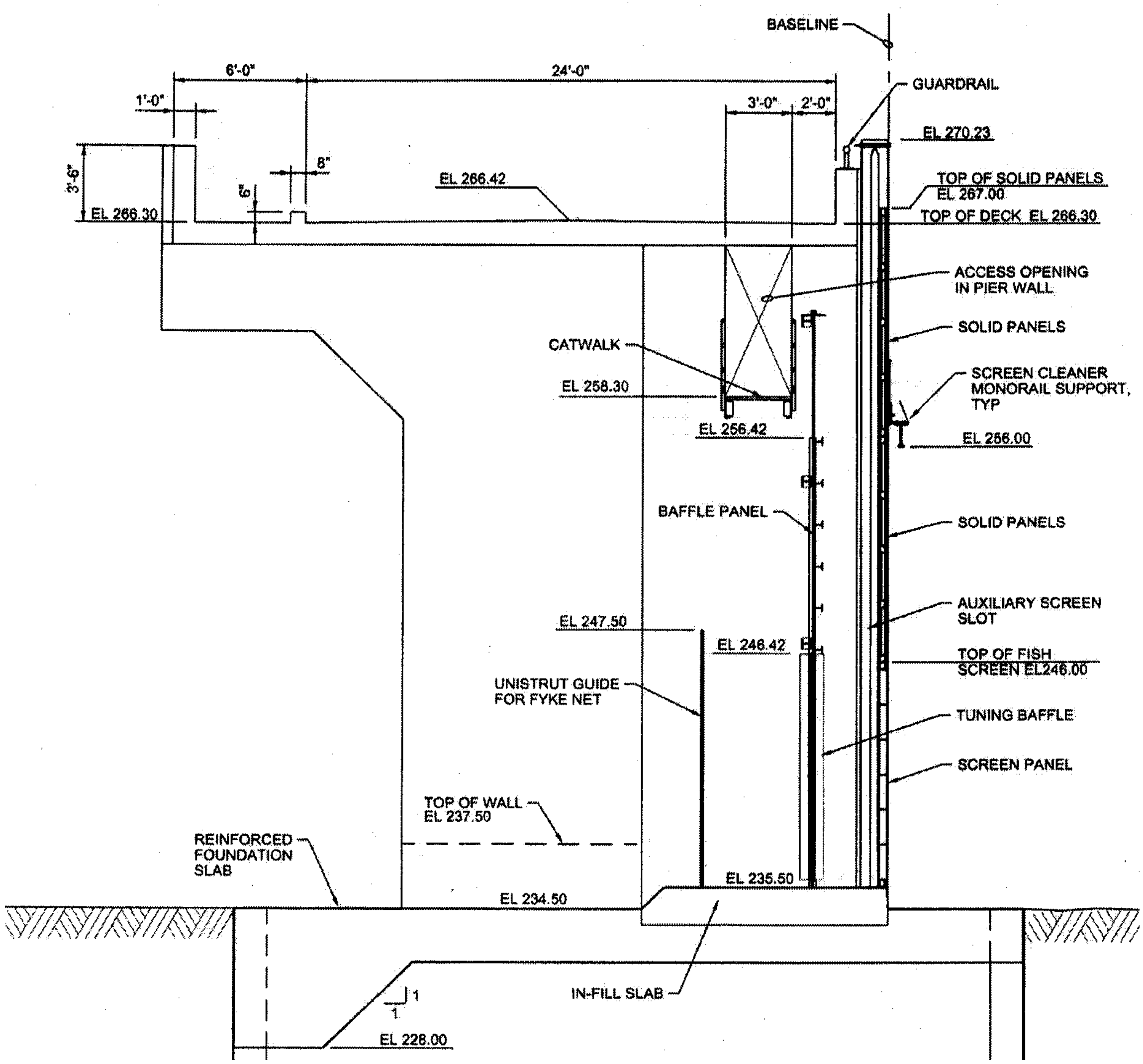

Figure 4. Section view of the Red Bluff Pumping Plant fish screen that was modeled at a 1:42 scale. All elevations and dimensions are prototype.

The prototype fish screen structure dimensions are approximately 1,100 ft long and 31.5 ft high. The model contained all 60 fish screen bays and each screen panel was 15 ft wide and 8.85 ft high (figure 4). Above each screen, solid panels extended from the screen to the top of structure (El. 267.0 ft). The screen area was selected to produce a maximum approach velocity of 0.33 ft/sec for the pumping plant's design flow of 2,500 ft^3/sec. The model screens were constructed from perforated plate with 3/16 inch diameter holes (figure 5). The perforated plate had an open area of 47 percent. This perforated plate was selected to simulate the expected head loss across the screen, not the slot width of the prototype wedge-wire screen which is 0.069 in. (1.75 mm). The prototype fish screen will have tuning baffles (adjustable vertical louvers) to adjust the flow through each screen bay. Custom made perforated plates with 5, 7.5 and 10 percent open areas were used in the model to simulate the tuning baffles (figure 5).

Figure 5. Photograph of the model fish screen material (right bay) and porosity plates (left bay) used to simulate tuning baffles.

Similitude and Model Scale

The Red Bluff Pumping Plant fish screen model was built to a 1:42 geometric scale using Froude law relationships. Froude scaling was chosen because the hydraulic performance of the model/prototype fish screens depend primarily on inertial and gravitational forces.

The following scaling relationships were used to convert model data to prototype scale:

Length	$L_R = L_P/L_M$	$(1:42)^1$	1:42
Area	$A_R = (L_R)^2$	$(1:42)^2$	1:1,764
Volume	$Vol_R = (L_R)^3$	$(1:42)^3$	1:74,088
Velocity	$V_R = (L_R)^{1/2}$	$(1:42)^{1/2}$	1:6.48
Discharge	$Q_R = (L_R)^{5/2}$	$(1:42)^{5/2}$	1:11,432
Time	$T_R = (L_R)^{1/2}$	$(1:42)^{1/2}$	1:6.48

Modeling sediment transport processes of noncohesive sediments require the simulation of tractive shear stress and turbulence because these parameters are used to describe particle motion. Shear stress and turbulence in open channel flow are related to the Reynolds number. As a result, models developed using Froude scaling require special sediment scaling to accurately simulate the sediment transport that occurs in the prototype. For this study, a fine sand mix with a D_{50} equal to 0.375 mm was used. Scaling the D_{50} particle size using critical shear stress yields a 9.1 mm particle prototype which represents the D_{15} particle size of the river bed surface material. The fine sand mix was chosen for the model so that bed load would actively transport during the simulated high flow of 80,000 ft^3/sec.

Data Collection

Velocity distributions along the fish screen and flow visualization were the two major components of the study plan. Velocities were collected using SonTek acoustic Doppler velocimeters (ADVs) to measure two-dimensional velocity vectors (in a horizontal plane). A laboratory ADV was positioned to measure sweep and approach velocity vectors near the fish screen (see figure 6). The approach velocity vector is perpendicular to the screen face and the sweep velocity vector is parallel to the screen face. Laboratory ADV velocities reported in this report have the following orientation: sweeping velocities are positive in the downstream direction and approach velocities toward the screen are negative. A SonTek FlowTracker® ADV was positioned to measure sweep and approach velocity vectors along a line parallel to the fish screen, but offset by 75 ft prototype. Velocity data were collected halfway up the screen at El 239.5 ft. Instruments were positioned laterally at the center of each screen using an instrumentation trolley (figure 7).

The purpose of the velocity data collection was to evaluate the hydraulics of the fish screen location and orientation to the river's thalweg. These data were used to adjust screen baffles to create a uniform velocity distribution over the length of the fish screen structure. Near-screen velocity measurements could not be made at a prototype distance of 3 inches (1/16 inch model) from the screen face, as required by fish screening evaluation criteria, because of acoustic interference. In addition, shallow depths in the model did not allow the evaluation of vertical velocity distribution for individual screen bays. As a result, model data are not available to determine if the proposed baffling system will have the flexibility to tune screens with vertical velocity gradients.

Water surface elevations were measured at several locations in the model using mechanical point gages and ultrasonic level sensors. The resolution of the mechanical point gages and MassaSonic™ ultrasonic level sensors (M-5000/220) were both about 0.042 ft prototype. Model flows were measured using laboratory-calibrated Venturi meters and the pumping plant discharge was measured using an Omega® inline propeller meter.

Figure 6. Photograph of Sontek velocimeters used to measure 2D velocity vectors in the river (FlowTracker in foreground) and along the fish screen (laboratory ADV in background). The grey cylindrical probe in the upper right of the photo is an ultrasonic level sensor.

Figure 7. Photograph of the instrumentation traversing trolley. This trolley was used to accurately position the ADV probes at stations along the fish screen structure. The laboratory ADV was carefully adjusted to maintain the probe's sampling volume a consistent 2 cm distance from the screen material.

Model Test Results

A full list of conditions during model test runs is provided in the Appendix. The first set of 10 model runs were performed to evaluate and calibrate instrumentation that were used to measure flow, water surface profiles, and near-screen velocities. The model's tailwater control boards were adjusted to match water surface elevations collected by CH2M-HILL in 2008 and 2009 [3]. A portable acoustic flowmeter was installed to confirm the calibration of the inline flowmeter used to measure Red Bluff Pumping Plant discharge. The laboratory ADV was tested to make sure it would adequately measure near-screen approach and sweeping velocity vectors. The ADV was positioned at the center of each bay and a boundary distance measurement was collected. Boundary distance is the distance from the ADV sampling volume to the screen surface. These measurements were made to adjust the instrumentation trolley to assure uniformity in the boundary distance. Figure 8 shows these boundary distance measurements and the average distance for 64 lateral locations was 2.0 $cm|_{model}$ or 2.75 $ft|_{prototype}$. For boundary distances less than 2 cm, acoustic interference biased the near-screen velocities.

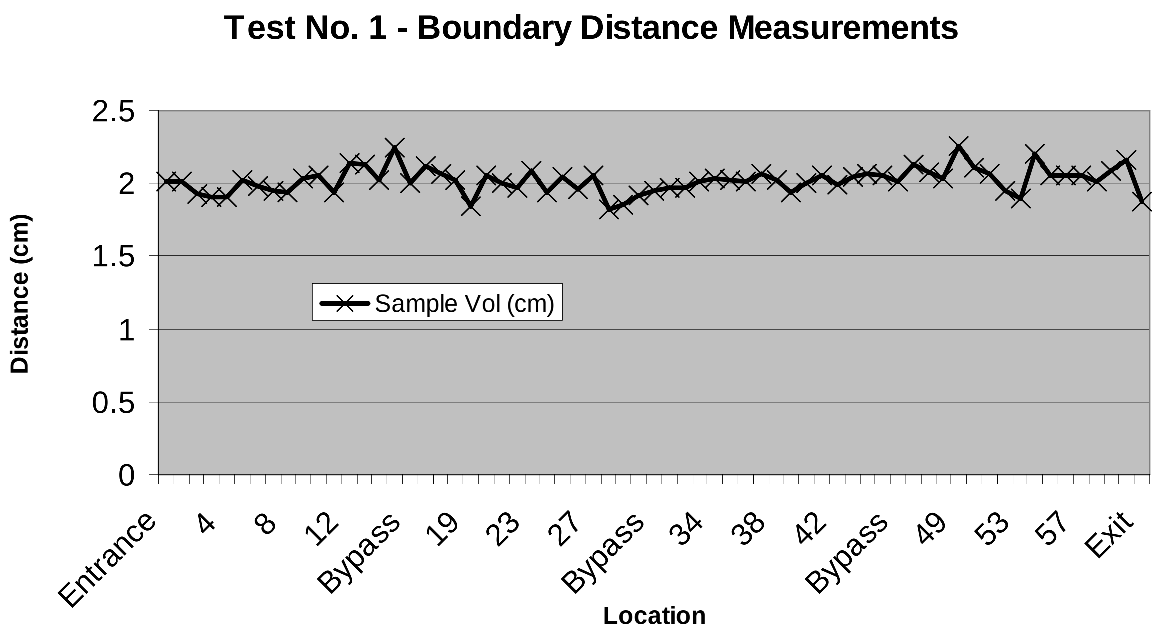

Figure 8. Plot of boundary distances measured along the 60 fish screen bays and bypass bays. A 2 cm boundary distance was the minimum distance that unbiased velocities could be measured.

Fish Screen Approach Velocities - Several model runs were conducted to evaluate and record sweeping (parallel to the screen) and approach (perpendicular to the screen) velocities at several flow and pumping rates. Laboratory ADV velocities reported in figures 9, 10 and 12 have the following orientation: sweeping velocities are positive in the downstream direction, and approach velocities toward the screen are negative. Initial velocity measurements showed for a wide range of river flows and pumping rates, that most of the flow was passing through the upstream screens (bays 1-45) and water was flowing out of the pumping plant forebay on the downstream screens (bays 52-60). A nonuniform sweeping velocity distribution was observed downstream of bay 45 and sweep velocities rapidly dropped to below 2 ft/sec at bay 60. This condition was worse for a no pumping condition. Figure 9 contains a plot of ADV approach and sweeping velocities collected for the design river flow of 12,600 ft^3/sec and with maximum pumping (2,500 ft^3/sec) and no pumping. These data indicate nonuniform velocities along the lower 20 bays of the fish screen structure.

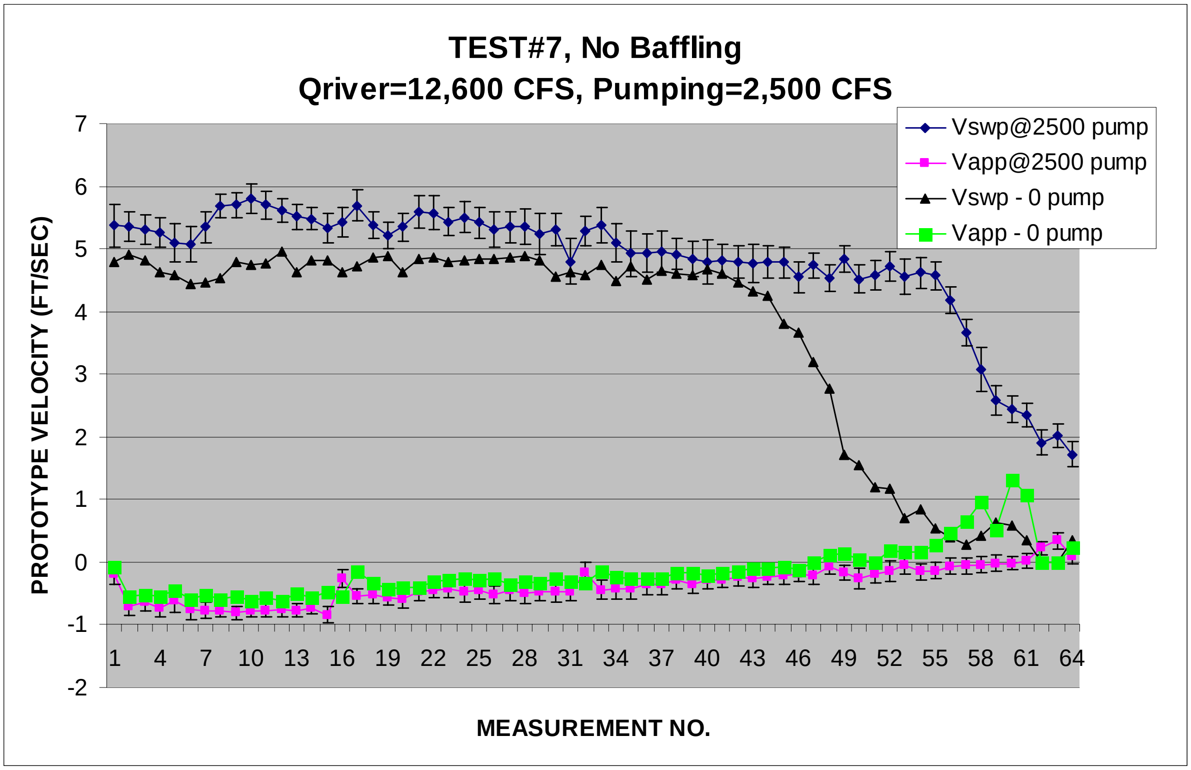

Figure 9. A comparison of near screen velocities (approach and sweep) for the design flows and no pumping condition. The error bars on the 2,500 ft^3/sec pumping rate data points represent the turbulence for each velocity component. Note: Measurement No. on the x-axis correspond to fish screen bays from upstream to downstream and include measurements at 3 bypass panels.

Fish Screen Baffling - The next round of model runs were used to fine tune the baffles that were placed in each fish screen bay to improve velocity uniformity along the screen. Several tests were conducted at various flow and pumping rates. Dye tests were conducted and bay baffling was adjusted until an acceptable baffling arrangement was achieved. The results of these tests showed that when bays 1-30 are baffled to 5% open and bays 31-60 are baffled to 7.5% open, there was near uniform approach velocity distribution along the entire fish screen. Figure 10 is a plot of ADV approach and sweeping velocities collected for the design river flow of 12,600 ft^3/sec and maximum pumping (2,500 ft^3/sec) after baffling.

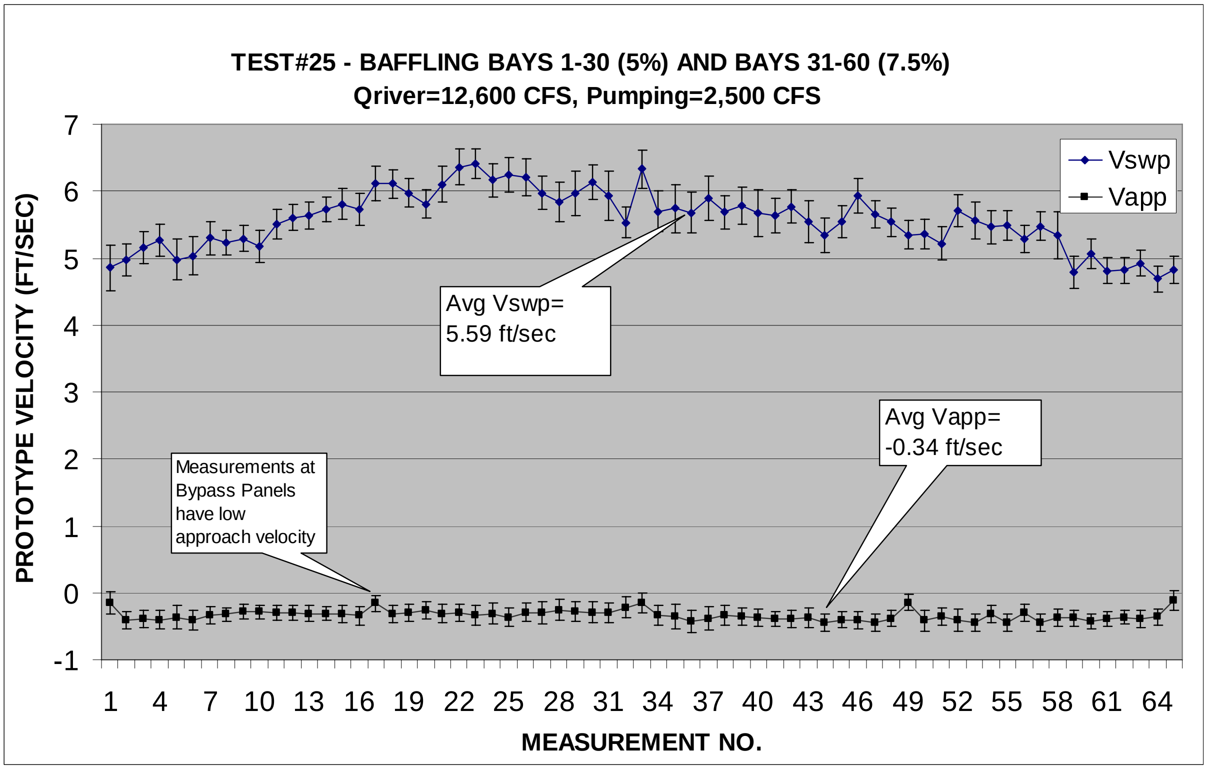

Figure 10. Approach and sweeping velocity components for fish screen design flows. These data show the improved uniformity in the near screen velocity field attributed to baffling each screen bay.

River Channel Modifications - A few model runs were made to determine if river channel modifications were needed to provide acceptable near-screen sweeping and approach velocities. Several flow and pumping rates were tested with and without the downstream channel modifications (figure 11). The results of these tests showed that baffling, not channel modification, was the key factor in producing an acceptable near-screen velocity distribution.

Winter Operation - Two model tests were conducted to document flow conditions during a no pumping or blocked screen event. All fish screen bays were blocked with aluminum plates and the pumping plant flow was shut off. These tests were performed to simulate winter operations when screen bays would be blocked to prevent sediment accumulation in the pumping plant forebay. One model run was conducted with a channel modification that extended the existing mid channel island about 600 ft downstream to prevent the flow from following the thalweg which directs the river flow toward the left bank (figure 11). Figure 12 shows the uniform sweeping velocities for the existing river channel and the modified river channel. The very low approach velocities were expected considering all flow was blocked from entering the pumping plant forebay.

Figure 11. Photograph looking upstream at the channel modification used to simulate a 600 ft extension to an existing mid channel island. The river flow is 12,600 ft^3/sec.

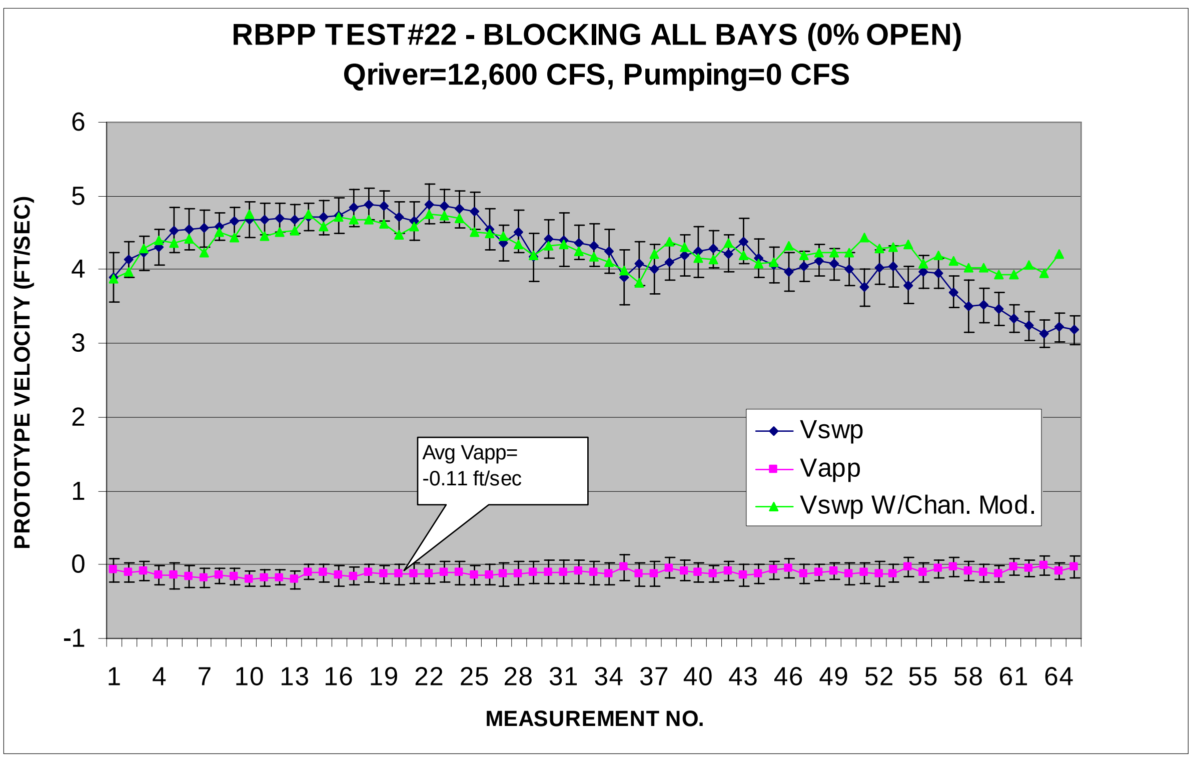

Figure 12. Near screen velocity distribution with all screen bays blocked and a river flow of 12,600 ft^3/sec. The second set of sweeping velocities (without error bars) were measured with a modified river channel.

Pump Sump Approach Channel Velocity Distribution - Four model runs were conducted to collect information on velocity distribution of flow entering the pumping plant sump. Approach velocity data were needed to set the boundary conditions for a 1:12 hydraulic model of the pumping plant [4]. The original design included a rounded forebay transition wall at the downstream end of the fish screen. This transition wall was modified based on a February 13, 2009 request from CH2M-HILL's design team. Model runs on the angled transition wall (with an 80 degree angle) showed a moderate flow separation which created skewed approach velocities to the pump intakes. Velocities were collected using a SonTek FlowTracker at 0.2, 0.6, and 0.8 times the water depth at a cross section located about 20 ft downstream from the break in the transition wall. Figure 13 shows the 2D velocity distribution collected in the 196-ft-wide rectangular channel leading to the pump sump. These velocity data show higher velocities along the right (southerly) wall with the maximum velocity of about 1 ft/sec for this worst-case scenario with a low forebay water surface elevation and maximum pumping rate. In general, transverse velocity vectors were much smaller than the approach velocities. The highest transverse velocities were in the vicinity of the transition wall (within 40 ft) and they varied from 0.02 to -0.12 ft/sec.

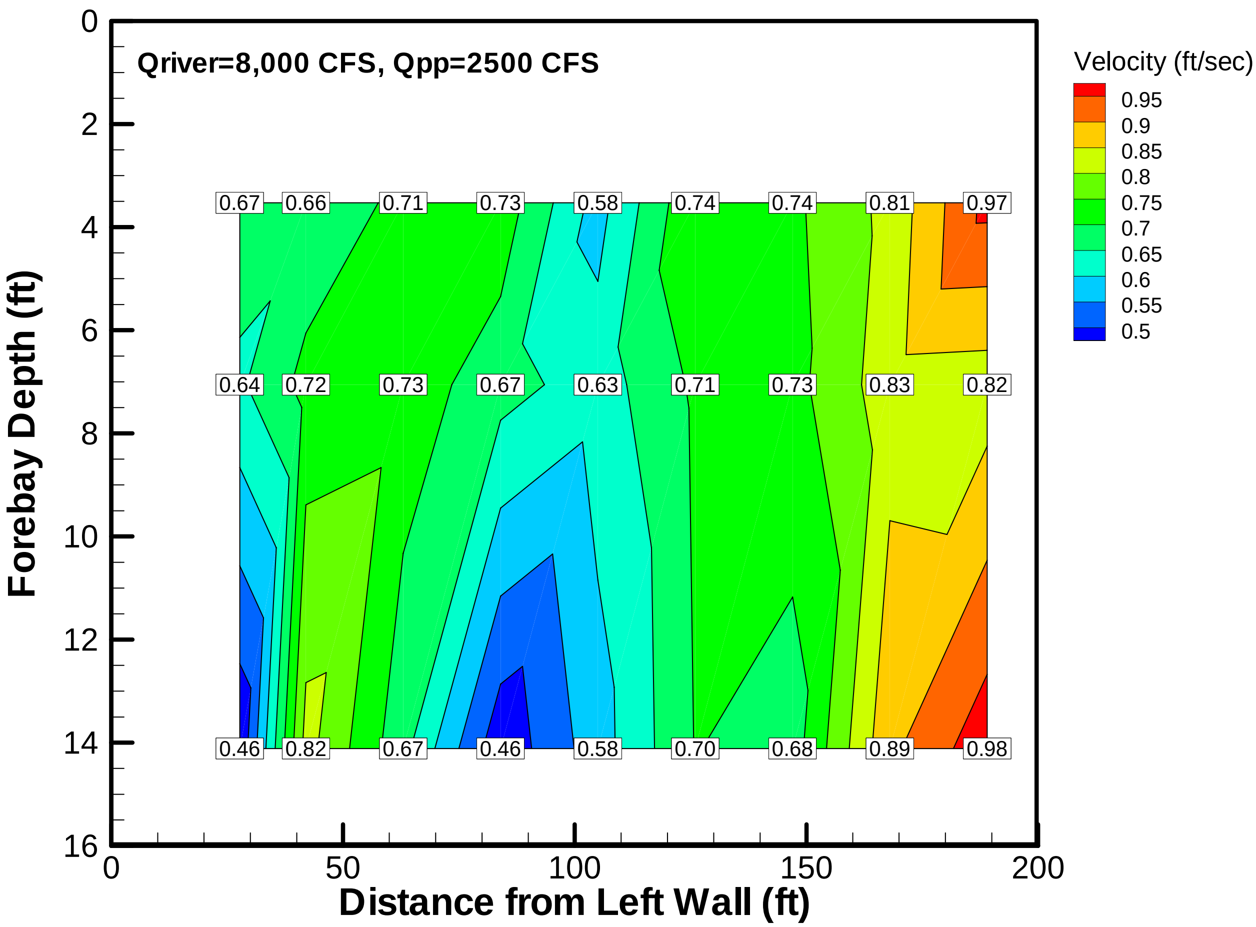

Figure 13. Contour plot of approach channel velocities toward the pump sump (looking downstream). The numbers on the plot are the measured velocity magnitude in ft/sec (prototype).

Water Surface Profiles - A series of model runs were performed to collect water surface profile data for the calibration/verification of 1D and 2D numerical models developed by TSC modelers [5] and [6]. All fish screen bays were blocked and a range of river flows were tested. The Red Bluff Pumping Plant flow was zero for all tests. These tests did not include velocity measurements along the fish screen. Figure 14 presents a comparison of water surface elevations from the hydraulic model and CH2M-HILL's field measurements at the upstream Mill Site location [1]. The upstream Mill Site location corresponds with the water surface point gage #1 in the hydraulic model. These model data confirmed that the hydraulic model was accurately reproducing prototype water surface elevations for flows up to 29,000 ft^3/sec. This close agreement is confirmation that the bed roughness in the physical model was similar to the prototype condition for flows less than 30,000 ft^3/sec.

Water surface elevation data were provided to TSC river modelers to calibrate their 2D SRH-2D computer model. The largest difference between the physical model and the SRH-2D model at the upstream Mill Site was 0.37 ft for a river flow of 8,000 ft^3/sec, and was 0.15 ft for a 20,000 ft^3/sec river flow (ref. Table 3 in [6])

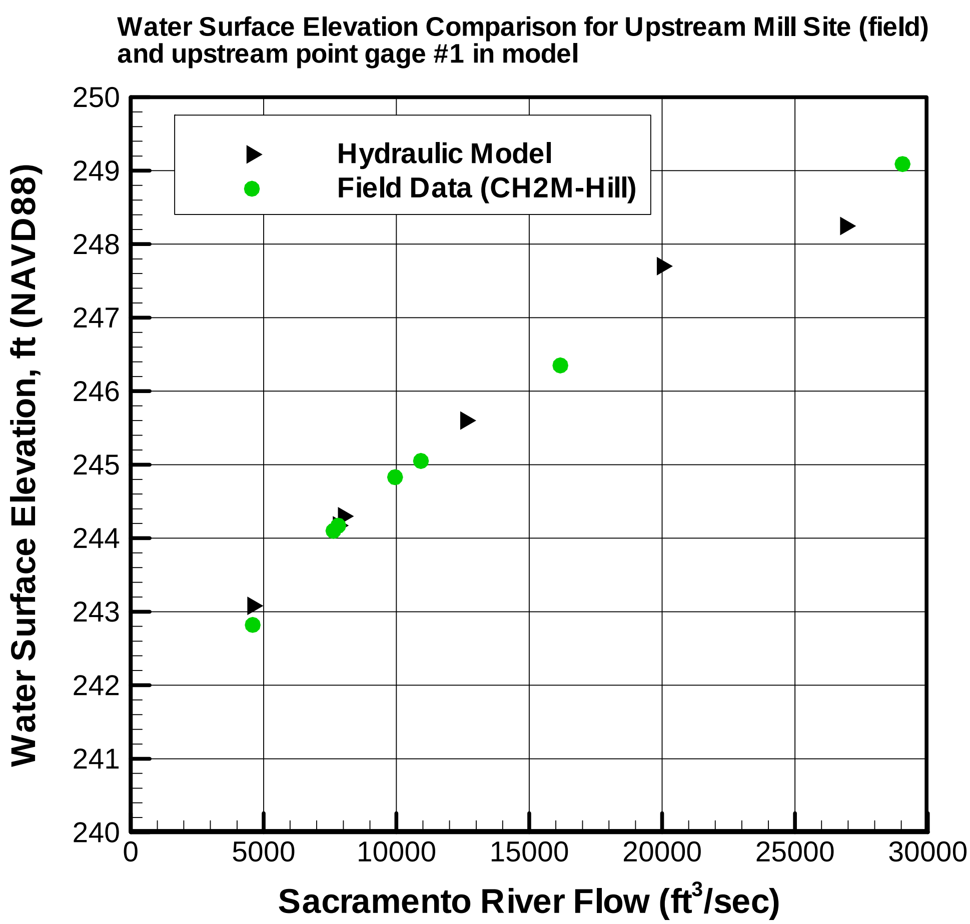

Figure 14. Water surface elevation comparison for the upstream Mill Site and point gage #1 in the hydraulic model. These data indicate close agreement between the model and prototype channel roughness.

Red Bank Creek Tests - A series of model runs were made to determine if large inflows from Red Bank Creek (RBC) and a built-up RBC delta would negatively impact near-screen velocities along the fish screen and create undesirable changes to the Sacramento River water surface profiles. RBC flood flows of 18,900 and 23,200 ft^3/sec were modeled in combination with river flows of 8,000, 12,600 and 25,000 ft^3/sec. In general, RBC flows reduced the sweep velocities by 1 ft/sec and the approach velocities by less than 0.1 ft/sec. Table 1 summarizes the water surface profile data for the RBC flood flow tests. In general, these test conditions created higher water surface elevations throughout the model. For example, there was a 1.9 ft increase in stage at the upstream Mill Site for a RBC flow of 18,900 ft^3/sec and a river flow of 8,000 ft^3/sec (Test RBC4).

Three model runs were made with sand bags placed in the model to create an elevated RBC delta. This test was used to evaluate the approach velocities on the lower portion of the fish screen with this downstream channel constriction. Figure 15 shows the approach and sweep velocities for a river flow of 12,600 ft^3/sec and a pumping rate of 2,500 ft^3/sec. The constricted river channel created backwater that reduced the average sweep velocity from 5.6 to 4.0 ft/sec when compared to baseline measurements for the same flow conditions. Similarly, with an elevated delta the average approach velocity was reduced from 0.34 to 0.27 ft/sec, and the water surface elevation at the upstream Mill site was increased by 0.8 ft.

Table 1. Summary of Red Bank Creek (RBC) flood flow tests and with an elevated RBC delta.

Test	Q_{RIVER} (ft^3/sec)	Q_{RBPP} (ft^3/sec)	Q_{RBC} (ft^3/sec)	WSEL at Upstream Mill Site (ft)	WSEL at Upstream work point (ft)	WSEL at Downstream work point (ft)
RBC1	25,000	2,500	18,900	249.30	248.56	248.80
RBC2	25,000	2,500	23,200	249.34	249.28	248.69
RBC3	12,600	2,500	18,900	247.07	247.10	246.67
RBC4	8,000	2,500	18,900	246.23	246.22	245.92
RBC5*	8,000	1,250	0	244.93	244.96	244.49
RBC6*	25,000	2,500	0	243.75	243.61	242.98
RBC7*	12,600	2,500	0	246.06	246.17	245.66

* built up RBC delta in model

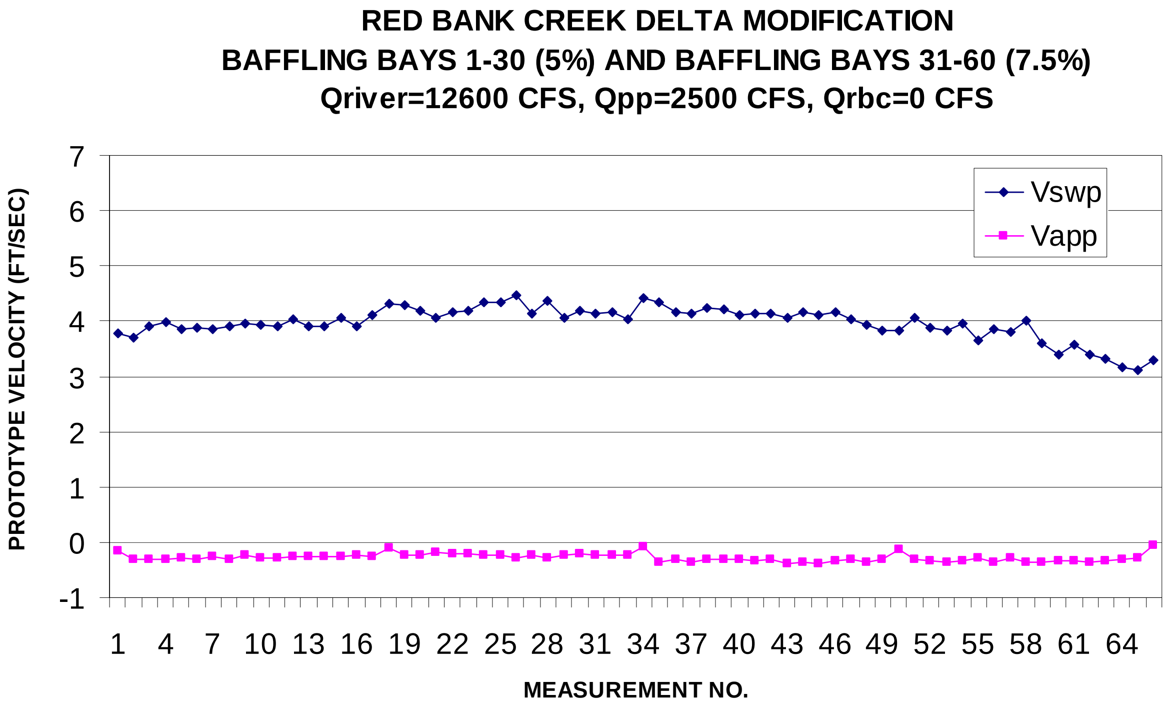

Figure 15. Plot of near-screen sweep and approach velocities for the RBC delta modification test. These data show good uniformity along the screen. The constricted river channel created backwater that reduced the average sweep velocity from 5.6 to 4.0 ft/sec when compared to baseline measurements for the same flow conditions. Similarly, the average approach velocity was reduced from 0.34 to 0.27 ft/sec. The built up delta increased the water surface elevation at the upstream Mill site by 0.8 ft.

Sediment Transport - The final model run was a test to evaluate the sediment transport characteristics along the Red Bluff Pumping Plant fish screen structure. The test was run at a river discharge of 80,000 ft^3/sec with no pumping. However, fish screens were not blockedduring this test. Fine sand was introduced to the main river channel only, because sediment transport past the screen structure was the primary interest. Sediment was added to the model at the rate of 0.25 ft^3/hr which is equivalent to about 105 yd^3/hr prototype. The model was operated for 7.5 hours a day for 8 days for a total of 60 hours (388 hrs prototype). The total volume of sediment added to the model was 48,700 $yd^3{}_{prototype}$. At the start of each day the model was filled slowly using the Red Bank Creek inlet to minimize erosion during start up. Similarly, at the end of the day the model flow was slowly turned off. It took several days for the sediment deposits to develop and reach equilibrium. The bulk of the sediment deposition occurred upstream from the fish screen.

Figures 16 and 17 are photographs of the model at the conclusion of the sediment test. Figure 16 shows the extent of sand dunes which formed along the south (right) bank of the Sacramento River upstream from the fish screen structure. Figure 17 shows the downstream extent of sediment deposition which was about half way down the screen (near Bay 32). In both photographs, no sediment was deposited within 25 ft of the fish screens. Observation during the sediment test revealed that sediment moving near the screen was transported moved away from the screen by secondary currents. On the last day of testing the pumping plant was set to maximum pumping which caused the clear zone along the screen to contract in the middle section of screen (bays 25 to 35). However, when the pumping plant was off, the clear zone expanded again.

At the conclusion of the 8-day sediment test, a Leica HDS6000 high-speed laser scanner was used to survey the model to gather data needed to calculate the volume of sediment deposited in model. Figure 18 shows the combination of the laser survey data with the original survey data. The laser data were imported into AutoCAD® and a series of cross sections were analyzed to compute the volume of sand deposited in the model. The estimated volume of sediment was 18,900 yd^3 prototype. This volume only includes sediment deposits that were more than 0.9 ft thick (¼ inch in the model) because ¼ in. was the resolution of the laser scanner.

After the sediment test, examination of the fish screen structure revealed fine sediment accumulation between the screen and baffles and in each fish screen bay. Sediment deposits in a given bay were similar to all other bays. Figure 19 is a photograph of the sediment deposition in bays 48 through 51.

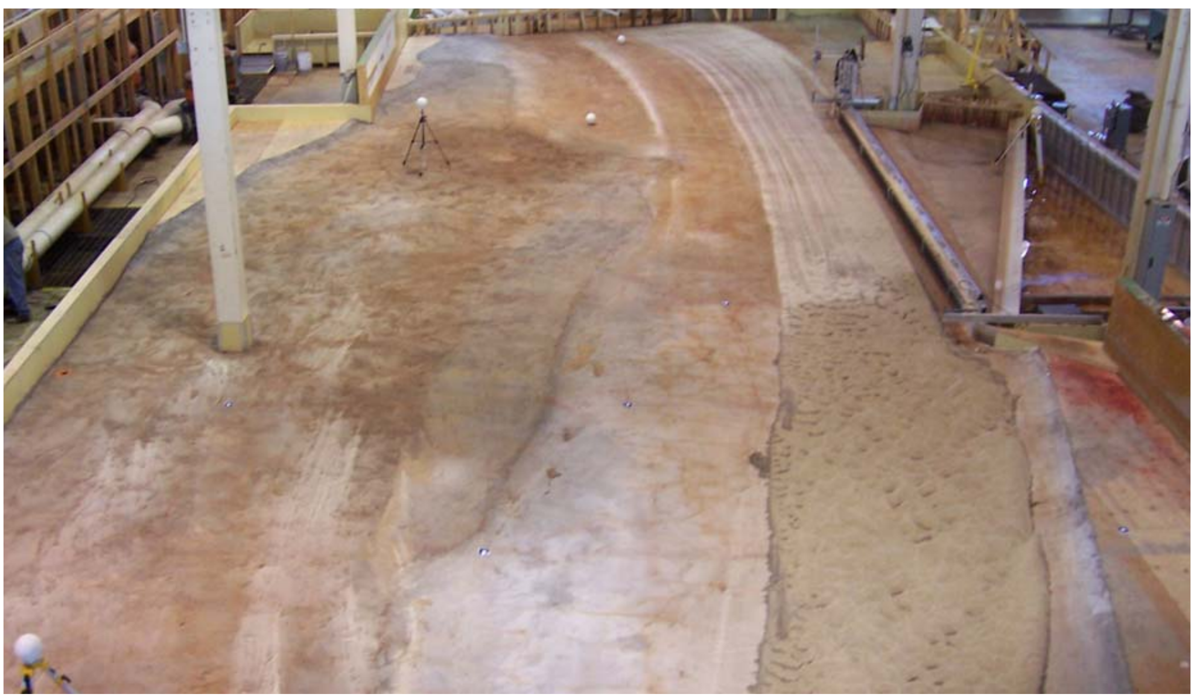

Figure 16. Photograph of the Red Bluff Fish Screen model after the completion of the sediment transport test. The darker sediment areas in the picture are the thicker deposits and the light sediment is the material that was being transported through the model and into the tail box. The tripods and spheres in the model are survey markers used during the laser scanner survey.

Figure 17. Photograph of the upper half of the fish screen structure (looking upstream) and sediment deposits. Note the 25-ft-wide sediment-free zone along the screen structure.

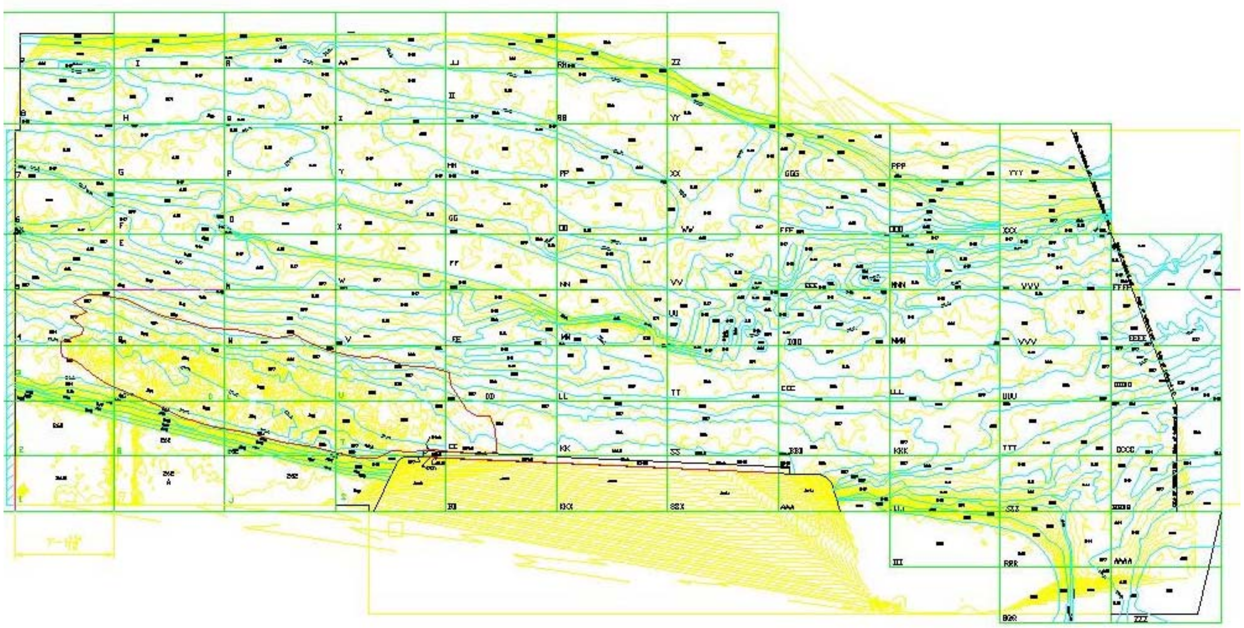

Figure 18. Plan view of the original model topography (blue contours) and the post sediment test topography (yellow contours). The rectangular grid represents the 4ft by 8 ft plywood sheets used to construct the model topography. The area enclosed by the purple polyline contained about 6.9 $ft^3{}_{model}$ (18,900 $yd^3{}_{prototype}$) of sediment.

Figure 19. Photograph of sediment deposited in bays 48 through 51. Bays 49 and 50 have their baffle plates removed. The clear areas behind the baffle plates were caused by the water flowing through the baffle orifices.

References

[1] Bureau of Reclamation. 1992. Appraisal report: Red Bluff diversion dam fish passage program. United States Dept. of the Interior, Bureau of Reclamation, Mid-Pacific Region, Sacramento.

[2] Lentz, D., Draft Technical Memorandum, Tehama-Colusa Canal Authority (TCCA) - Red Bluff Pumping Plant and Fish Screen Project Hydraulics: Fish Refuge Physical Modeling (1:1 Scale), June 30, 2009.

[3] Ken Iceman and Brad Memeo, CH2M-HILL Technical Memorandum, TCCA Fish Passage Improvement Project at Red Bluff Diversion Dam Hydrology: Flow-duration Data, Flood Frequency Data, and Project Design Flows, March 25, 2009

[4] Frizell, K.Warren, Draft Technical Memorandum, Tehama-Colusa Canal Authority (TCCA) - Red Bluff Pumping Plant and Fish Screen Project Hydraulics: Pump Sump and Afterbay Physical and Numerical Modeling, July 24, 2009.

[5] Russell, K., Draft Technical Memorandum - Tehama-Colusa Canal Authority (TCCA) - Red Bluff Pumping Plant and Fish Screen Project Hydraulics: Low Flow Water Surface Profiles Upstream of Red Bluff Diversion Dam from 1-D HEC-RAS Model, January 21, 2009

[6] Russell, K., Draft Technical Memorandum, Tehama-Colusa Canal Authority (TCCA) - Red Bluff Pumping Plant and Fish Screen Project Hydraulics: Low Flow Water Surface Profiles Upstream of Red Bluff Diversion Dam from 2-D SRH-2D Model, March 17, 2009.

Appendix

Model Testing Summary

Table A1: Model testing summary

Test No.	Date 2009	River Flowrate (ft^3/sec)	RBPP Flowrate (ft^3/sec)	Red Bank Creek Flowrate (ft^3/sec)	Comments
1	January 14	12,600	2,550	0	Model setup - velocity measurement equipment.
2	January 16	7,800	0	0	Low flow water surface evaluation and point gage calibration and ADV seeding.
3	January 16	7,800	2,500	0	Low flow w/max pumping.
4	January 26	7,800	2,500	0	Evaluate the need to add seed material for velocity measurements.
5	January 26	7,800	0	0	Screen velocity measurements for low flow/no pumping.
6	January 27	12,600	0	0	Normal flow w/NO pumping.
7	January 28	12,600	2,400	0	Normal flow w/high pumping.
8	January 29	20,000	2,500	0	High flow w/max pumping.
9	January 29	20,000	0	0	High flow w/NO pumping.
10	February 2	12,600	2,500	0	Normal flow w/max pumping. Velocity measurements were taken at bay 57 only. Introduction of channel modifications (sandbags) & baffling (aluminum punch plate) in screen bays 1-15.
11	February 2	12,600	2,500	0	Normal flow w/max pumping. Channel modifications, double baffling in screen bays 1-15, & single baffling in screen bays 16-30.
12	February 2	12,600	2,500	0	Normal flow w/max pumping. DS channel modifications only. Double baffling in screen bays 1-30.
13	February 2	12,600	2,500	0	Normal flow w/max pumping. DS channel modifications only. Double baffling in screen bays 1-45.
14	February 3	12,600	2,500	0	Normal flow w/max pumping. Channel modifications, double (small & large hole) baffling in screen bays 1-15 & double (large hole) baffling in screen bays 16-45.

15	February 3	12,600	2,500	0	Normal flow w/max pumping. Channel modifications, double (small hole) baffling in screen bays 1-15 & double (large hole) baffling in screen bays 16-45.
16	February 6	12,600	2,500	0	Normal flow w/max pumping. DS channel modifications only. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
17	February 6	12,600	0	0	Normal flow w/NO pumping. DS channel modifications only. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
18	February 9	8,000	2,500	0	Low flow w/max pumping. DS channel modifications only. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
19	February 9	8,000	0	0	Low flow w/NO pumping. DS channel modifications only. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
20	February 9	25,000	2,500	0	High flow w/max pumping. DS channel modifications only. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
21	February 10	12,600	0	0	Normal flow w/NO pumping. DS channel modifications only. Blocked all bays (0% open).
22	February 10	12,600	0	0	Normal flow w/NO pumping. NO channel modifications. Blocked all bays (0% open).
23	February 10	12,600	1,250	0	Normal flow w/low pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
24	February 10	12,600	1,250	0	Normal flow w/low pumping. DS channel modifications only. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
25	February 12	12,600	2,500	0	Normal flow w/max pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
26	February 13	25,000	2,500	0	High flow w/max pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.

27	February 13	25,000	1,250	0	High flow w/low pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
28	February 18	12,600	2,500	0	Normal flow w/max pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Approach Velocity measurements were taken near the pump sump at several stations and depths.
29	February 18	12,600	1,250	0	Normal flow w/low pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Approach Velocity measurements were taken near the pump sump at several stations and depths.
N/A	February 19	0	0	0	The model was resurveyed as a check against the original survey. Results showed good agreement with earlier surveys.
30	February 19	8,000	2,500	0	Low flow w/max pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Approach Velocity measurements were taken near the pump sump at several stations and depths.
31	February 19	8,000	1,250	0	Low flow w/low pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Approach Velocity measurements were taken near the pump sump at several stations and depths.
32	February 19	8,000	0	0	Low flow w/NO pumping. NO channel modifications. Blocked all bays (0% open). WS Elevation measurements, no velocity data collected
33	February 19	7,810	0	0	Low flow w/NO pumping. NO channel modifications. Blocked all bays (0% open). WS Elevation measurements, no velocity data collected
34	February 19	4,590	0	0	Low flow w/NO pumping. NO channel modifications. Blocked all bays (0% open). WS Elevation measurements, no velocity data collected
35	February 19	20,000	0	0	High flow w/NO pumping. NO channel modifications. Blocked all bays (0% open). WS Elevation measurements, no velocity data collected

36	February 19	26,900	0	0	High flow w/NO pumping. NO channel modifications. Blocked all bays (0% open). WS Elevation measurements, no velocity data collected
37	February 20	8,000	1,250	0	Low flow w/low pumping. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
RBC 1	February 20	25,000	2,500	18,900	High flow, max pumping, and flash flood conditions at Red Bank Creek. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
RBC 2	February 20	25,000	2,500	23,200	High flow, max pumping, and flash flood conditions at Red Bank Creek. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
RBC 3	February 23	12,600	2,500	18,900	Normal flow, max pumping, and flash flood conditions at Red Bank Creek. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
RBC 4	February 23	8,000	2,500	18,900	Low flow, max pumping, and flash flood conditions at Red Bank Creek. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
RBC 5	February 23	8,000	1,250	0	Low flow w/low pumping. Sandbags were placed on the Red Bank Creek flow discharge line, in order to simulate a sediment delta. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
RBC 6	February 23	25,000	2,500	0	High flow w/max pumping. Sandbags were placed on the Red Bank Creek flow discharge line, in order to simulate a sediment delta. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.
RBC 7	February 24	12,600	2,500	0	Low flow w/max pumping. Sandbags were placed on the Red Bank Creek flow discharge line, in order to simulate a sediment delta. NO channel modifications. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60.

38	March 3	12,600	1,250	0	Normal flow w/low pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Evaluation u/s and d/s river bank transition wall modifications.
39	March 3	25,000	1,250	0	High flow w/low pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Evaluation u/s and d/s river bank transition wall modifications.
40	March 3	8,000	1,250	0	Low flow w/low pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Evaluation u/s and d/s river bank transition wall modifications.
41	March 10	12,600	2,500	0	Normal flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Evaluation u/s and d/s river bank transition wall modifications.
42	March 12	12,600	2,500	0	Normal flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, added sediment trap in tailbox. check WS elevations after modification
43	March 13	25,000	2,500	0	High flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, added sediment trap in tailbox, check WS elevations after modification
44A	March 13	46,619	2,500	0	High flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, Modified sediment trap in tailbox, check WS elevations after modification
44B	March 13	80,000	2,500	0	Flood flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, selected 80,000 ft^3/sec as test discharge
45	March 13	80,000	0	0	Flood flow, NO pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, modification to sediment trap in tailbox, checked WS elevations after modification
46	March 16	12,600	2,500	0	Normal flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, Test modified sediment trap in tailbox, check WS elevations after modification -OK

47	March 16	8,000	2,500	0	Low flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, Test modified sediment trap in tailbox, check WS elevations after modification-OK
48	March 16	25,000	2,500	0	High flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, Test modified sediment trap in tailbox, check WS elevations after modification –OK
49	March 16	50,000	0	0	High flow, NO pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, Test modified sediment trap in tailbox, check WS elevations after modification –Low
50	March 16	25,000	2,500	0	High flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Prepare model for sediment test, Test modified sediment trap in tailbox, check WS elevations after modification –OK
Sed-Day 1	April 28	80,000	0	0	Flood flow, NO pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. BEGIN Sediment Test
Sed-Day 8	May 7	80,000	0/2500	0	Flood flow, NO and max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. END Sediment Test
50	June 5	80,000	2,500	0	Flood flow, max pumping. Baffling (5% open) in screen bays 1-30 & baffling (7.5% open) in screen bays 31-60. Measure 3-D velocity field along screen after sediment test.

PEER REVIEW DOCUMENTATION
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Project and Document Information

Project Name: Tehama-Colusa Canal Authority (TCCA) – Fish Passage Improvement Project at Red Bluff Diversion Dam

WOID: RBTLT

Document Title: Pumping Plant and Fish Screen Project Hydraulics: Red Bluff Pumping Plant Fish Screen Hydraulic Model Study (1:42 Scale)

Document Author(s)/Preparer(s): Tracy B. Vermeyen, P.E. Hydraulic Engineer

Peer Reviewer(s): Connie DeMoyer, P.E. Hydraulic Engineer

Note: External technical review comments were submitted by Robert Gatton, CH2M-Hill and Steve Thomas, National Marine Fisheries Service.

Review Certification

Peer Reviewer: I have reviewed the above document and believe it to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer: Connie DeMoyer Date reviewed: 8/31/09
(Signature)

Preparer: I believe that this document has been reviewed and approved in accordance with Reclamation policy, and is complete and ready for distribution.

Lead Author: Tracy B. Vermeyen Date: 9/2/2009
(Signature)

Quality Review Form (QRF)

Client/Project: TCCA Fish Passage Improvement Project		
Project No.: 380710.FD.PM.RV	F	Fatal flaw - must be revised
Phase: July 29, 2009 Physical Hydraulic Model TM	S	Serious problem, needs to be addressed, could escalate to 'F'
Date: September 2, 2009	C	Coordination problem - resolve
Notes: Return QC comments to Joe Green-Heffern/SAC and the applicable Project Technology Lead Engineer by email	N	Note to originator, change not necessary, could result in better future work product

Reference Page or Sheet No.	Reviewer	Review Comment	Comment Type	Responder	Response	Follow-up Item No.
General	**Gatton**	This is a very well written draft that clearly summarizes many months of work. I agree with Tracy's approach of a bit of editorial clean up and final peer review after he returns.	**C**	**TVermeyen**	Thank you	
Page 2	**Gatton**	Minor terminology correction. It is Red Bluff Diversion Dam not Tehama Colusa. Also NMFS does not go by NOAA Fisheries any more. It should read " NMFS and CDFG"	**C**	**TVermeyen**	Change completed 8/17/2009	
Page 5	**Gatton**	In general I like the bulleted "Conclusions" but I have a hard time with bullet No.3. For a project with a TDH of 12.5 feet we are not too excited about 5 to 7.5 % porosity. These porosities may have been determined from lab measurements which are not likely to replicate the field profiles. We expect to have roughly 5 % in bay 1 and 98% in bay 60 with the intervening bays evenly spaced between. This is an issue of major concern to NMFS and CDFG and a better prediction is needed.	**F**	**TVermeyen**	The model baffling results could be used for an initial setting the prototype baffles. We concur that these baffle settings will be changed during field evaluation. We are reporting that the model results indicate that baffling will be necessary to create a uniform velocity distribution along the screen and that channel modifications are not necessary.	
Page 6	**Gatton**	First paragraph add a sentence of two explaining that the final design has for cost reasons moved 100 feet upstream but it is TSC's opinion that this does not affect the results of the model.	**S**	**TVermeyen**	Change completed 8/17/2009	
Page 12	**Gatton**	Figure 9 point out that + is downstream and away from the screen. The negative approach velocities are a bit confusing. Also from a terminology point of view we refer to them as "blowout bays" not "3 bypass panels".	**C**	**TVermeyen**	Added two sentences on pages 9 and 11 describing the 2-D velocity vector orientation. Change completed 8/17/2009	
Page 12	**Gatton**	On the paragraph "Fish Screen Baffling" I have the same comment as on page 5 above.	**F**	**TVermeyen**	See page 5 response.	
Page 13	**Gatton**	Figure 10 has the same comments as Figure 9.	**C**	**TVermeyen**	Added two sentences on pages 9 and 11 describing the velocity vector orientation. Change completed 8/17/2009	
Page 5	**Thomas**	Velocities in the approach channel are refered to as "approach velocity" which can be confused with velocities normal to the fish screen. Please consider replacing "approach velocity" with "approach channel velocity."	**C**	**TVermeyen**	Change completed 8/17/2009	
Page 12 **Page 5**	**Thomas**	Baffled approach velocities look really good, but the scale of the modle didn't allow investigating vertical distribution of flow. Studies at SMWC and RD108-Poundstone showed tendencies for higher Va near screen bottoms, although GCID was fairly uniform. The report should state that the proposed baffling system may not provide sufficient flexibility to attain acceptable uniformity of flow and that additional baffles may be required. Alternativley, a split baffle system that allows for adjusting porosity at two levels would provide additional flexibility. This should be noted in the conclusions as well.	**S**	**TVermeyen**	Added two sentences on page 9 to address this comment. Change completed 8/17/2009.	