R-96-05

HYDRAULIC MODEL STUDY OF THE POSITIVE BARRIER FISH SCREEN AT RECLAMATION DISTRICT NO. 108 WILKINS SLOUGH PUMPING PLANT

September 1996

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Technical Service Center
Water Resources Services
Water Resources Research Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1996	Final

4. TITLE AND SUBTITLE
Hydraulic Model Study of the Positive Barrier Fish Screen at Reclamation District No. 108 Wilkins Slough Pumping Plant

5. FUNDING NUMBERS
PR

6. AUTHOR(S)
Tracy B. Vermeyen

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bureau of Reclamation
Technical Service Center
Denver CO 80225

8. PERFORMING ORGANIZATION REPORT NUMBER
R-96-05

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Bureau of Reclamation
Denver Federal Center
PO Box 25007
Denver CO 80225-0007

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DIBR

11. SUPPLEMENTARY NOTES
Hard copy available at the Technical Service Center, Denver, Colorado

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

The Bureau of Reclamation conducted hydraulic model studies to document the hydraulic characteristics and performance of the Wilkins Slough positive barrier fish screen design for a range of river and diversion flows. The studies were undertaken because winter-run chinook salmon populations in the Sacramento River are in decline and have been listed as an endangered species. The decline in salmon population has been attributed, in part, to juvenile fish mortality associated with unscreened irrigation diversions. As a result, Reclamation District No. 108 has initiated a fish screen assessment program, which includes the proposed positive barrier fish screen to be constructed at the Wilkins Slough Pumping Plant. These hydraulic model studies were requested by the Bureau of Reclamation Mid-Pacific Regional Office. Model study data were used to improve the fish screen design so that it meets or exceeds performance criteria as set forth by the National Marine Fisheries Service and the California Department of Fish and Game.

14. SUBJECT TERMS--fish protection/ hydraulic model/ velocity criteria/ endangered species/ positive barrier/ fish screen/ Sacramento River/ California/ Wilkins Slough positive barrier fish screen

15. NUMBER OF PAGES
33

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UL	UL	UL	UL

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by

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ACKNOWLEDGMENTS

Reclamation District No. 108 and their civil engineering consultant, Laugenour and Meikle, provided the engineering design drawings and topographic surveys necessary to conduct the hydraulic model study. Ron Brockman from the Bureau of Reclamation Mid-Pacific Regional Office was the team leader for this study. Ron Bachman, Project Manager, U.S. Fish and Wildlife Service, represented Fish and Wildlife interests in this project. Rick Wantuck from National Marine Fisheries Service provided technical overview related to fish screen performance criteria. Brent Mefford, Technical Specialist, provided technical assistance. Manuel Flores was responsible for model construction. Dean Connor and Jerry Fitzwater were the hydraulic technicians responsible for the data collection and equipment maintenance. Tom Hovland was the technical editor.

CONTENTS

Page

Purpose . . . 1
Introduction . . . 1
The problem . . . 1
The solution . . . 1
Conclusions . . . 2
The model . . . 3
  Similitude and model scale . . . 6
  Data collection . . . 7
  Model operation . . . 7
  Stage-discharge relationship . . . 8
  Velocity measurements . . . 8
  Velocity criteria . . . 8
  Approach conditions and screen velocity distributions . . . 9
  Sediment deposition characteristics . . . 10
  Identification of undesirable flow conditions . . . 10
Test results . . . 10
  Initial screen evaluation . . . 10
  Modification No. 1 . . . 15
  Modification No. 2 . . . 16
  Test No. 1 results . . . 17
  Test No. 2 results . . . 20
  Test No. 3 results . . . 21
  Test No. 4 results . . . 24
  Qualitative sediment deposition test results . . . 27
  Trash deflector . . . 32
Bibliography . . . 33

TABLES

Table

1 Summary of model test conditions . . . 10
2 Test No. 1 prototype velocity data collected at elevations 19.5, 22.0, and 24.5 feet . . . 19
3 Test No. 2 prototype velocity data collected at elevations 19.5, 22.0, and 24.5 feet . . . 22
4 Test No. 2 prototype velocity data collected at elevation 22.0 feet . . . 23
5 Test No. 2 prototype velocity data collected at elevation 22.0 feet . . . 23
6 Test No. 3 prototype velocity data collected at elevations 19.5, 22.0, and 24.5 feet . . . 25
7 Test No. 3 prototype velocity data collected at elevation 22.0 feet . . . 26
8 Test No. 4 prototype velocity data collected at elevation 22.0 feet . . . 26

FIGURES

Figure

1 Plan view of the Wilkins Slough positive barrier fish screen as designed by Laugenour and Meikle Civil Engineers . . . 2
2 Plan view of the Wilkins Slough positive barrier fish screen hydraulic model . . . 4
3 View of the 1:20 scale model looking upstream . . . 4
4 Photograph of a single fish screen bay . . . 5
5 Laugenour and Meikle's design drawings of the south elevation and section A-A (from fig. 1) for the Wilkins Slough positive barrier fish screen . . . 5

CONTENTS—CONTINUED

FIGURES—CONTINUED

Figure		Page
6	Sontek ADV and positioning table used to collect horizontal velocity profiles across a single screen bay	9
7	Dye streaks for test No. 1 with original upstream transition wall geometry	11
8	Dye streaks for test No. 1 with no diversion and original upstream transition wall geometry	12
9	Dye streaks for test No. 2 with original upstream transition wall geometry	13
10	Dye streaks for test No. 3 with original upstream transition wall geometry	14
11	Photograph of modified upstream transition wall	15
12	Normal approach velocity versus louver rotation—screen bays No. 7 and 15—test No. 1 flow conditions	16
13	Plot of approach velocity isovels over the Wilkins Slough positive barrier fish screen for test No. 1 flow conditions	18
14	Detailed plot of approach velocity isovels for bay No. 7	20
15	Plot of approach velocity isovels over the Wilkins Slough positive barrier fish screen for test No. 2 flow conditions	21
16	Plot of approach velocity isovels over the Wilkins Slough positive barrier fish screen for test No. 3 flow conditions	24
17	Settling velocity of sand and silt in 15 °C water and an example of the sediment scaling procedure	27
18	(a) Model and prototype grain size distributions for sediment dredged from the pumping plant forebay. (b) Comparison of grain size distributions for the model and prototype deposition in the forebay	28
19	Prototype sediment depth contours developed during the 3-day sediment deposition test	30
20	Bay No. 3 sediment deposition	30
21	Bay No. 9 sediment deposition	31
22	Bay No. 12 sediment deposition	31
23	Bay No. 15 sediment deposition	32

PURPOSE

The purpose of this hydraulic model study was to document the hydraulic characteristics and performance of a positive barrier fish screen design for a range of river and diversion flows. Model study data were used to improve the fish screen design so that it meets or exceeds performance criteria as set forth by the NMFS (National Marine Fisheries Service) and the CDFG (California Department of Fish and Game).

INTRODUCTION

Reclamation District No. 108, established in 1870, owns and operates an irrigation district encompassing about 48,000 acres of irrigated agricultural land. The District is located about 40 miles north of Sacramento, California. In 1917, the District began construction of major distribution facilities and became the first reclamation district in California to deliver irrigation water. The District's 130 water users grow a wide variety of crops including: rice, wheat, corn, safflower, sugar beets, tomatoes, beans, fruits, and nuts.

The Wilkins Slough Pumping Plant (see fig. 1), the largest of the District's seven pumped diversions, was constructed on the west bank of the Sacramento River in 1918. The pumping plant has seven 54-inch vertical pumps with the capacity to deliver 800 ft^3/s of Sacramento River water to a canal system which supplies the District's water users. An average of 150,000 acre-feet of water is pumped each year from the Sacramento River under a water rights contract with the Bureau of Reclamation (Reclamation). About 120 miles of irrigation canals are used to convey the water to District farms.

THE PROBLEM

Winter-run chinook salmon populations in the Sacramento River are in decline and have been listed as an endangered species. The decline in salmon population has been attributed, in part, to juvenile fish mortality associated with unscreened irrigation diversions. Studies have shown that unscreened irrigation diversions result in salmon mortality because juvenile salmon are pumped into irrigation canals where they cannot return to the river.

THE SOLUTION

Fishery biologists believe that screening irrigation diversions will enhance the survival rates of downstream migrating juvenile salmon. As a result, the U.S. Department of Interior, working through the Fish and Wildlife Service and Reclamation, have entered into an agreement to assist Reclamation District No. 108 in developing a positive barrier fish screen at the Wilkins Slough Pumping Plant.

Since 1993, the District has been testing electrical and acoustic fish guidance systems at Wilkins Slough Pumping Plant (see fig. 1). The fish guidance systems were designed to keep juvenile chinook salmon from being pumped out of the river. Preliminary test results indicate the electrical and acoustic systems have been only partially successful. As a result, Reclamation District No. 108 initiated a positive barrier fish screen appraisal study (Laugenour and Meikle, 1995) to develop an alternative to electrical and acoustic fish guidance systems. If future tests show the electrical barriers (acoustic barrier tests have been suspended) do not meet fish screening criteria, the District will consider the construction of a positive barrier fish screening structure at Wilkins Slough Pumping Plant.

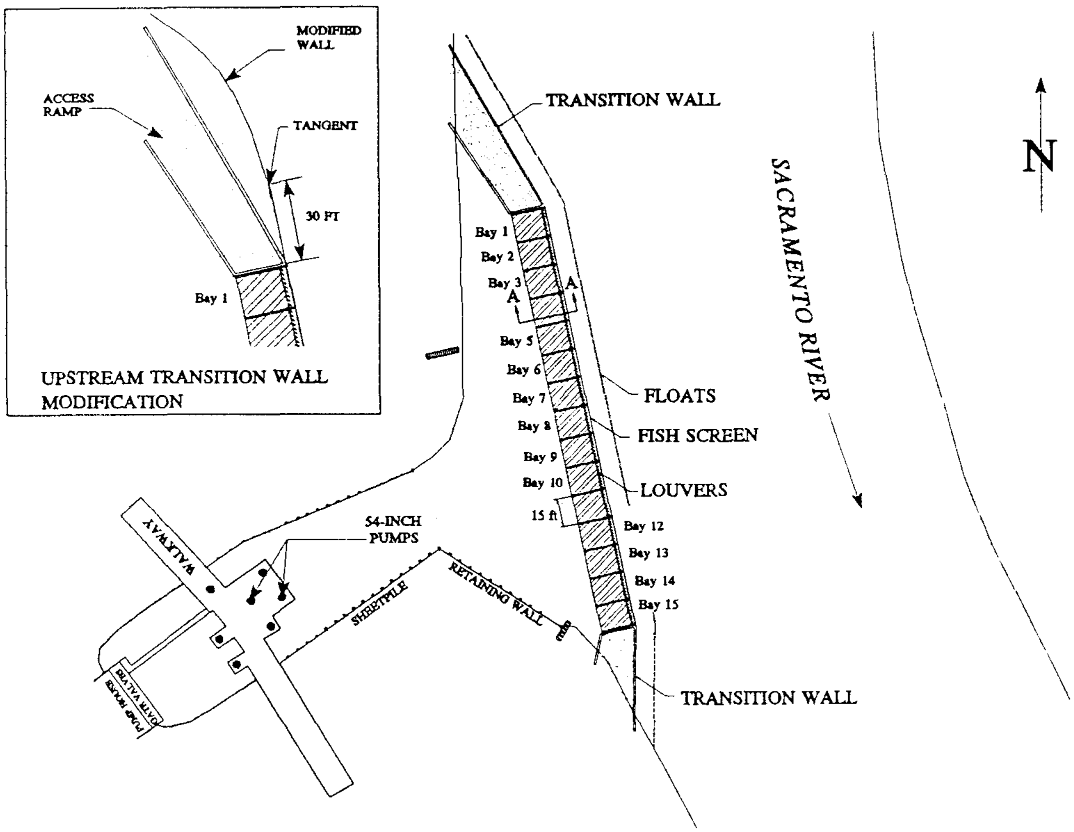


Figure 1. - Plan view of the Wilkins Slough Pumping Plant and positive barrier fish screen as designed by Laugenour and Meikle Civil Engineers. A modification to the upstream transition wall is shown in the upper left corner of the figure.

CONCLUSIONS

- The final screen design met the velocity criteria required by NMFS and CDFG for a wide range of river flows and the design discharge of 700 ft^3/s.

- For all test conditions, the last screen bay (bay No. 15) required a louver setting of 50° (40.5 percent open area) to reduce approach velocities to an acceptable level. This louver setting only applies to the louver system used in the model. A similar percent opening value should be used for prototype settings.

- Although the final screen design performed well with only 14 screen bays (bay No. 1 was blocked), the 15th screen bay is required to provide the necessary screen area to satisfy the approach velocity criteria. Velocity measurements showed that approach velocities at the first screen bay were low, but this bay is needed to begin turning the flow into the pumping plant forebay. Therefore, 15 screen bays are needed.

- A hydraulically smooth transition wall is required to introduce the river flow parallel to the fish screen. At least 30 feet of straight wall should extend upstream from the first screen bay (bay No. 1). The transition wall must be extended along the longitudinal axis of the fish screen as shown in the detail of figure 1.

- An elliptical transition from the 30-foot-long straight wall to the river bank was an effective transition in the model.

- No circulations or large-scale eddies were observed in the pumping plant forebay for diversion flows greater than 250 ft^3/s. However, during flow visualization tests with low or no diversion flow, circulations were observed.

- Small-scale eddies were observed moving along the fish screen structure, but when averaged over time, they did not modify the approach or sweeping velocities.

- Screen bay No. 15 required louvering at the flow conditions tested. Other bays may require louvering for flow conditions not tested or if as-built conditions or sedimentation changes the screen hydraulics. Model tests indicated that the screen bays located on the upstream and downstream ends of the structure are the most likely to require louvering.

- A qualitative sediment deposition test indicated that the positive barrier screen structure should not increase the amount of sediment deposited in the pumping plant forebay.

- Large quantities of sediment deposited behind the fish screen and between the louvers may prevent the louvers from being adjusted.

- No sediment was deposited along the base of the upstream transition wall, which indicates a potential for scour. The design of this transition wall should include scour protection.

THE MODEL

The physical model was constructed in a sealed box with dimensions of 44 feet long, 28 feet wide, and 4 feet deep. The model features include the Wilkins Slough positive barrier fish screen structure and about 800 feet of Sacramento River channel (figs. 2 and 3). A 1:20 scale was chosen to include, in a limited laboratory space, sufficient river channel to develop representative approach flow conditions to the fish screen. Laugenour and Meikle provided the site survey of river channel topography and the pumping plant forebay and structure.

At Wilkins Slough, the Sacramento River channel is about 220 to 250 feet wide, or about 11 feet wide in the model. The maximum depth of flow in this reach is 35 feet, which is about 21 inches deep in the model. The maximum river flow modeled was 17,500 ft^3/s at a river stage of 40 feet; the corresponding model flow was 9.8 ft^3/s. The maximum diversion flow was 700 ft^3/s, which was 0.39 ft^3/s in the model.

The prototype fish screen dimensions are 225 feet long and 10 feet high (2250 ft^2). The fish screen was modeled using an 11.25-foot-long, 6-inch-high fish screen. The structure consists of 15 screen bays that are 15 feet wide. Each model screen bay was 9 inches wide and was backed by a louver system (figs. 4 and 5). The louvers are designed to control the approach velocities. Each screen bay contains 9 louvers, and each louver is 0.9 inch wide (1.5 feet prototype). The louver width used in the model was increased from Laugenour and Meikle's design to allow nearly complete blockage of a screen bay. The 9 louvers were linked together to rotate at equal increments with the rotation of a connecting rod.

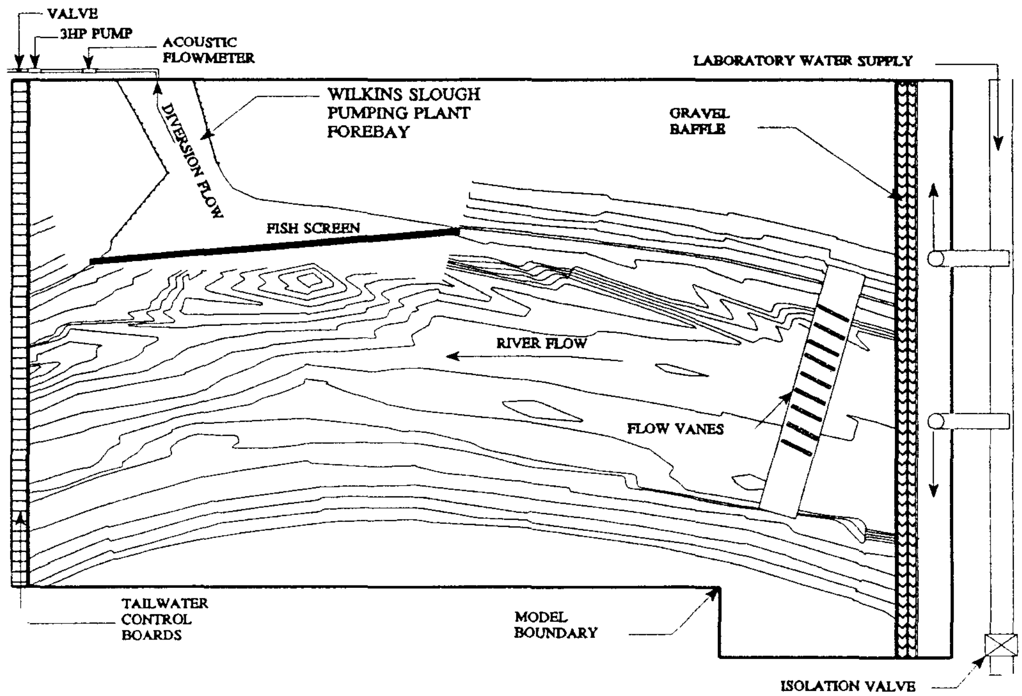


Figure 2. - Plan view of the Wilkins Slough positive barrier fish screen hydraulic model. The model was constructed at a 1:20 scale in a 44-foot-long by 28-foot-wide by 4-foot-deep watertight box.

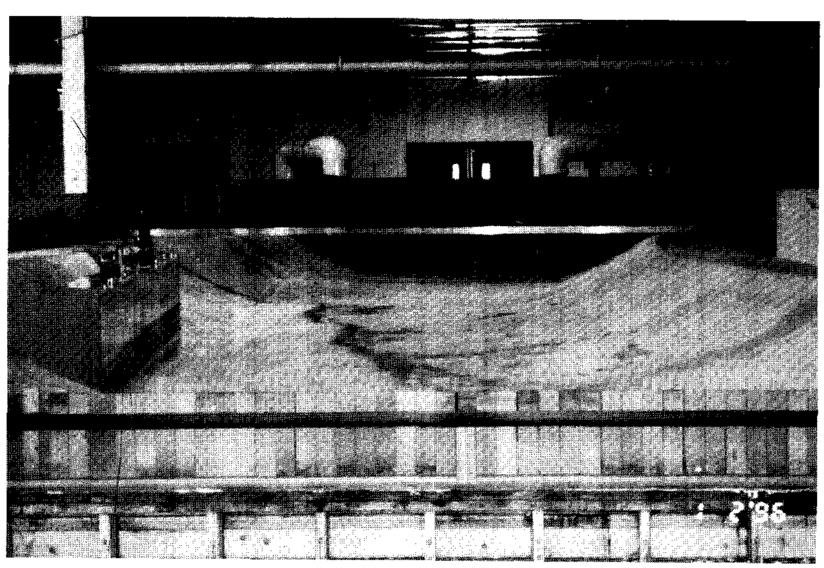


Figure 3. - View of the 1:20 scale model looking upstream. The fish screen is located on the left side of the photograph.

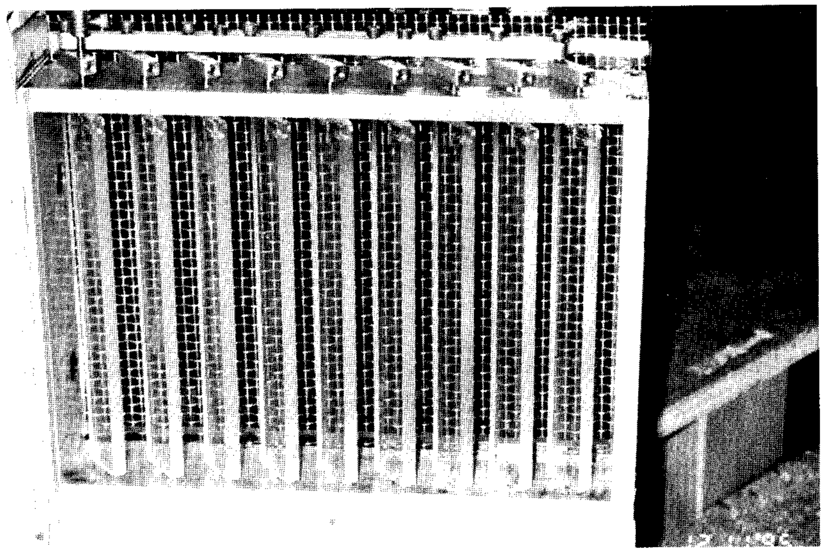


Figure 4. - Photograph of a single fish screen bay. Features shown are the plexiglas louvers, mechanical linkage system, and the screen material.

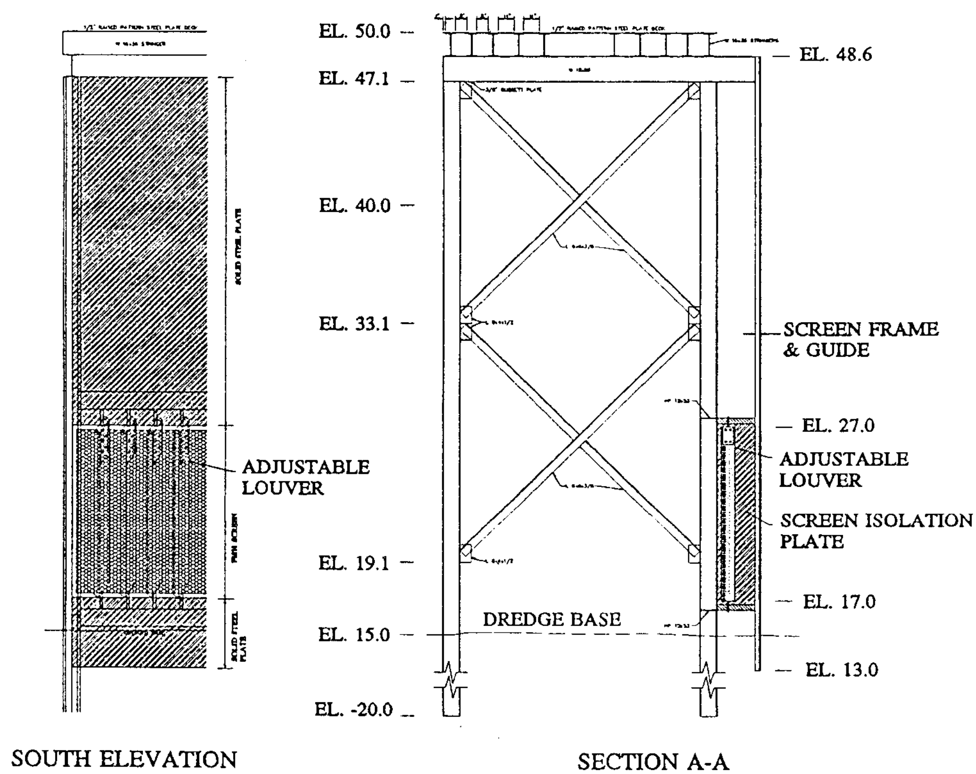


Figure 5. - Laugenour and Meikle's design drawings of the south elevation and section A-A (from fig. 1) for the Wilkins Slough positive barrier fish screen.

Screen material used in the model was stainless steel square mesh wire cloth (6 mesh) with a 1/8-inch opening, 18-gauge wire, and a 52-percent open area. The prototype screen was specified as stainless steel square wire cloth (5 mesh) with a 5/32-inch opening, 17-gauge wire, and a 53-percent open area. The use of screen material with similar percent open area or porosity is important to accurate modeling. Figure 4 shows details of the screen design.

The prototype screen design included a screen cleaner, but this feature was not included as part of the model study.

Similitude and Model Scale

The Wilkins Slough model was designed to a 1:20 geometric scale using Froude law relationships. The Froude number was chosen because the hydraulic performance of the model/prototype structures depend primarily on inertial and gravitational forces. The Froude number is defined as the ratio of inertial to gravitational forces and is expressed as:

$$F_r = \frac{v}{\sqrt{gL}}$$

where:

V = characteristic velocity
g = gravitational constant
L = characteristic length

In addition to inertial and gravitational forces, viscous forces also affect the fluid flow. In the prototype, Reynolds numbers ($\mathbb{R}$) are in the turbulent regime ($\mathbb{R}$>2000). Consequently, viscous forces are small compared to the inertial forces. Similar conditions are generated in the model by selecting a model scale that produces Reynolds numbers which are also in the turbulent regime. The Reynolds number (the ratio of inertial to viscous forces) is defined as:

$\mathbb{R} = 4VR/(\nu)$

where:

ν = kinematic viscosity, ft^2/s
V = average channel velocity, ft/s
R = hydraulic radius of channel, ft

The model scale ratio of 1:20 was selected so that the Reynolds number criterion was met and the model would operate in the turbulent flow regime.

The following scaling relations are used to convert model and prototype variables:

Length ratio	$L_r = L_p/L_m$		= 1:20
Area ratio	$A_r = L_r^2$	$= (1:20)^2$	= 1:400
Velocity ratio	$V_r = L_r^{1/2}$	$= (1:20)^{1/2}$	= 1:4.47
Discharge ratio	$Q_r = L_r^{5/2}$	$= (1:20)^{5/2}$	= 1:1,788.9
Time ratio	$T_r = L_r^{1/2}$	$= (1:20)^{1/2}$	= 1:4.47

Models involving erosion, transport, and deposition of noncohesive sediments must simulate tractive shear stress (τ_o) and turbulence because these parameters impart the forces required to move the particle and keep it in suspension. The shear stress and turbulence are a function of Reynolds number. As a result, a model operated using Froude scaling does not accurately simulate the sediment erosion and transport processes. To overcome this limitation, sediment sizes are scaled with respect to their settling velocities to compensate for a reduced Reynolds number in the model.

Data Collection

Velocity data collection and flow visualization were the two major tasks to be completed in the hydraulic model study. A detailed description of the data collection tasks follows:

- Field measurements of the approaching flow conditions to the Wilkins Slough Pumping Plant were collected so that similar conditions could be developed in the model using baffles and deflector vanes. The flow fields in the Sacramento River were measured with an acoustic Doppler current profiler.

- Flow visualization techniques were used to identify streamlines and flow patterns in the model, such as flow separation zones and eddies.

- The velocity fields approaching, passing, and exiting the fish screen were documented at three river discharges selected to bound the range of typical river conditions during the irrigation season. The diversion flow rate was varied for some tests.

- Approach and sweeping velocity components were measured along the screen using an acoustic Doppler velocimeter. Velocity measurements were collected in sufficient detail to identify the velocity distribution for each screen bay.

- Adjustments to the louver positions were modeled to optimize the screen performance with respect to the velocity criteria and to provide a uniform velocity distribution across each screen bay.

- Modifications to the fish screen orientation and intake configuration were modeled to optimize the screen design because the performance criteria (approach conditions and screen velocity distributions) could not be easily met with the initial design.

- Sediment dredged from the pumping plant forebay was analyzed to determine a representative grain size distribution for material deposited in the forebay.

- Qualitative assessments of sedimentation and debris passage were performed on the finalized screen structure design.

Model Operation

A 100-horsepower variable speed pump supplied water to the model. Venturi meters in the water supply system measured the flow rate into the model. Accurate flow measurements (to within ±0.5 percent) were made over a wide range of discharges using two venturi meters (8- and 12-inch). A gravel baffle was used to evenly distribute model inflows. The river stage for a given river discharge was set using tailwater control boards located at the end of the model (fig. 2). River stage was measured in the pumping plant forebay to the nearest 0.001 foot using a point gauge. A 3-horsepower pump connected to a 3-inch-diameter pipe was used to draw the diversion flows from the pumping plant forebay. A rectangular orifice (33 inches long and 1 inch high) was used to create a uniform velocity distribution across the truncated pumping plant forebay. A strap-on acoustic flowmeter and control valve were used to set the diversion discharge.

Stage-Discharge Relationship

Stage and discharge information for the USGS (U.S. Geological Survey) gaging station below Wilkins Slough near Grimes, California (USGS ID 11390500), was provided by Laugenour and Meikle. Previous surveys by Laugenour and Meikle had determined that the stage at the Wilkins Slough Pumping Plant is normally 0.3 foot higher than the stage measured at the USGS gaging station. As a result, a site specific stage-discharge relationship was developed. This stage-discharge relationship was scaled and used to set up the model for various test conditions.

Velocity Measurements

Velocity measurements were collected using an ADV (acoustic Doppler velocimeter). An ADV uses remote sensing techniques to measure simultaneously three components (V_x, V_y, and V_z) of water velocity from a single sampling volume. The sampling volume is located 2 inches from the probe head and is cylindrical in shape with a 0.08-inch diameter and a 0.24-inch length. Consequently, the flow field surrounding the measurement volume is minimally impacted by the presence of the probe. Velocity data were sampled at an output rate of 5 hertz (5 samples per second). The ADV's horizontal velocity range is ±8 ft/s. Probe operation and data storage were controlled using a personal computer.

Horizontal velocity profiles were collected by mounting the ADV probe to a single-axis positioning table (fig. 6). The probe was traversed across each fish screen bay at a constant speed using a stepper motor. The speed of the probe traverse was added to or subtracted from the sweeping velocity if the probe was moving upstream or downstream, respectively. The velocity probe collected data at about 0.2 to 0.3 inch from the screen surface, representing a prototype distance of 4 to 6 inches.

Initially, velocity traverses were collected by starting at the upstream end of each screen bay and making four passes in front of the screen at a constant elevation. However, a statistical analysis of the velocity data showed that two traverses were sufficient to calculate statistically equivalent average velocities. Average velocity measurements were taken as the average value of about 300 individual ADV measurements.

Velocity Criteria

NMFS and CDFG have established specific velocity criteria associated with the design of positive barrier fish screen structures in the State of California. These criteria have been developed from extensive biological studies to determine the swimming speed and endurance limits for various fish species. Currently, CDFG requires a maximum screen approach velocity of 0.33 ft/s with a sweeping to approach velocity component ratio of at least 2:1. In addition to this requirement, a maximum screen exposure time of not more than 60 seconds is required. This requirement indicates that a maximum length of structure exists beyond

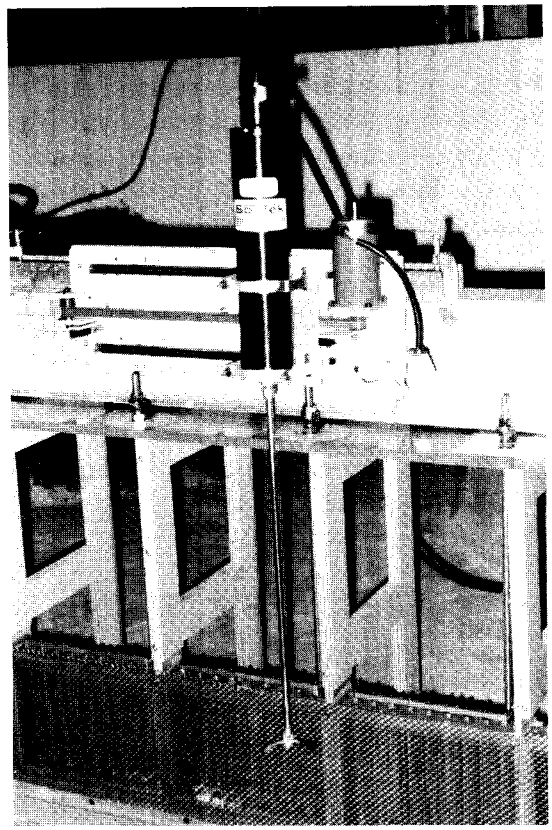


Figure 6. - Sontek ADV and positioning table used to collect horizontal velocity profiles across a single screen bay.

which a fish bypass system will be required. Thus, the effective area or screen size and the number of bypasses required are determined from these criteria. The final requirement of the resource agencies is that continuous cleaning be performed to minimize the influence of debris fouling on screen velocity magnitudes and distributions.

For Wilkins Slough, with a design discharge of 700 ft^3/s and a maximum approach velocity of 0.33 ft/s, the minimum screen surface area is 2121 ft^2. Therefore, the 2250-ft^2 screen is 6 percent larger than required by the design criteria.

Approach Conditions and Screen Velocity Distributions

Attaining adequate approach conditions to a fish screen structure is critical in achieving approach and sweeping velocities which meet resource agency criteria over the full range of hydraulic conditions expected. Although little control over approach flow direction exists for this riverbank structure, the near-screen hydraulic conditions can be varied by adjusting the screen orientation with respect to the approach flow. Thus, it is important to adequately simulate the hydraulic conditions approaching the screen structure. Minor improvements to the hydraulics can be made using louvers to control approach velocities and their distribution. In addition, flow visualization techniques were used to identify the locations for trash deflectors.

Sediment Deposition Characteristics

The model study was used to provide qualitative data on sediment deposition and trash and debris passage related to the screen structure. Laugenour and Meikle will use problem areas identified by the model to improve the final screen design. Hence, an understanding of these depositional characteristics will allow the impacts, which may degrade screen performance, to be minimized in the final screen design.

Identification of Undesirable Flow Conditions

The influence of the screen structure on the flow field can generate undesirable flow conditions, like eddies. Typically, the upstream and downstream transitions to a screen structure are the locations where changes in the flow boundary result in eddies or slack water zones. These flow conditions affect screen performance and provide predator habitat. The model study was used to identify these types of undesirable flow conditions and provide recommendations for improvements.

TEST RESULTS

Initial Screen Evaluation

The Wilkins Slough positive barrier fish screen design was initially evaluated using flow visualization and near-screen point velocity measurements. Three river flows and pumped diversions were tested (table 1). A fourth test was added during evaluation of final screen design. The range of river flows to be tested was determined using USGS discharge records and information provided by Laugenour and Meikle. Test No. 1 represents normal river flow and design flow for the positive barrier screen. Test No. 2 represents high river flow and design flow. Test No. 3 represents low river flow and design flow. Test No. 4 represents normal river flow and maximum pumping capacity of Wilkins Slough Pumping Plant.

Table 1. - Summary of model test conditions.

Test No.	River Stage (ft)	River Flow (ft^3/s)	Diversion Flow (ft^3/s)
1	30.91	8,000	700
2	40.19	17,500	700
3	26.03	4,000	700
4	30.91	8,000	900

For tests No. 1 through 3, flow visualization and velocity measurements revealed some shortcomings with the fish screen design. Bays No. 1 and 2 (the two most upstream screen bays) experienced significant outflows. This outflow was generated by flow separation resulting from the sharp transition between the screen structure and the upstream transition wall. Velocity measurements showed that the highest flows were entering the forebay through bays No. 13 through 15 at the downstream end of the screen structure. Figures 7, 8, 9, and 10 show dye streaks for tests No. 1 through 3.

Flow visualization tests for test No. 1 with no diversion flow showed that flow enters the forebay through bays No. 4 through 11 and flow exits through bays No. 1 through 3 and bays No. 12 through 15 (see fig. 8).

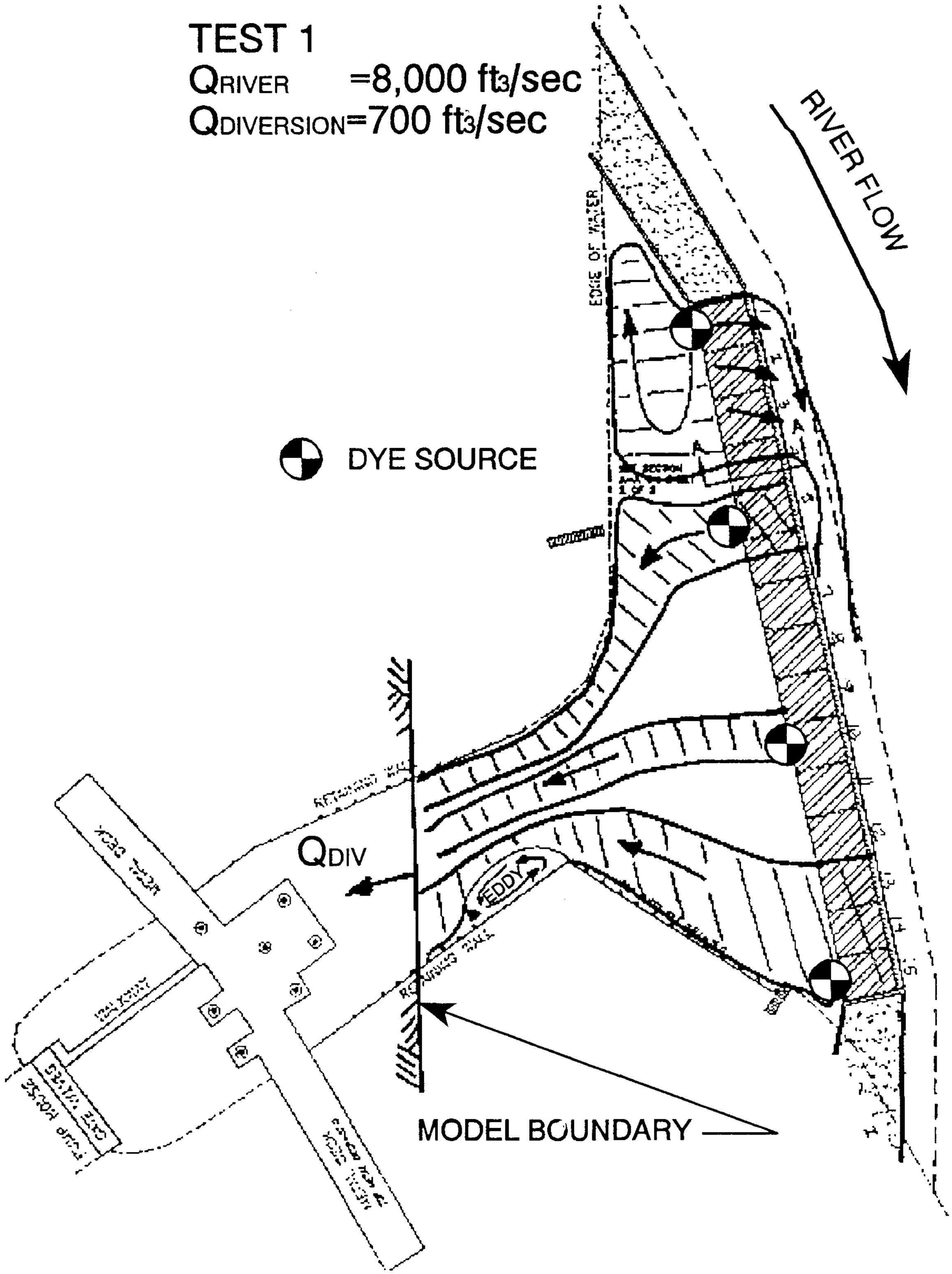


Figure 7. - Dye streaks for test No. 1 with original upstream transition wall geometry.

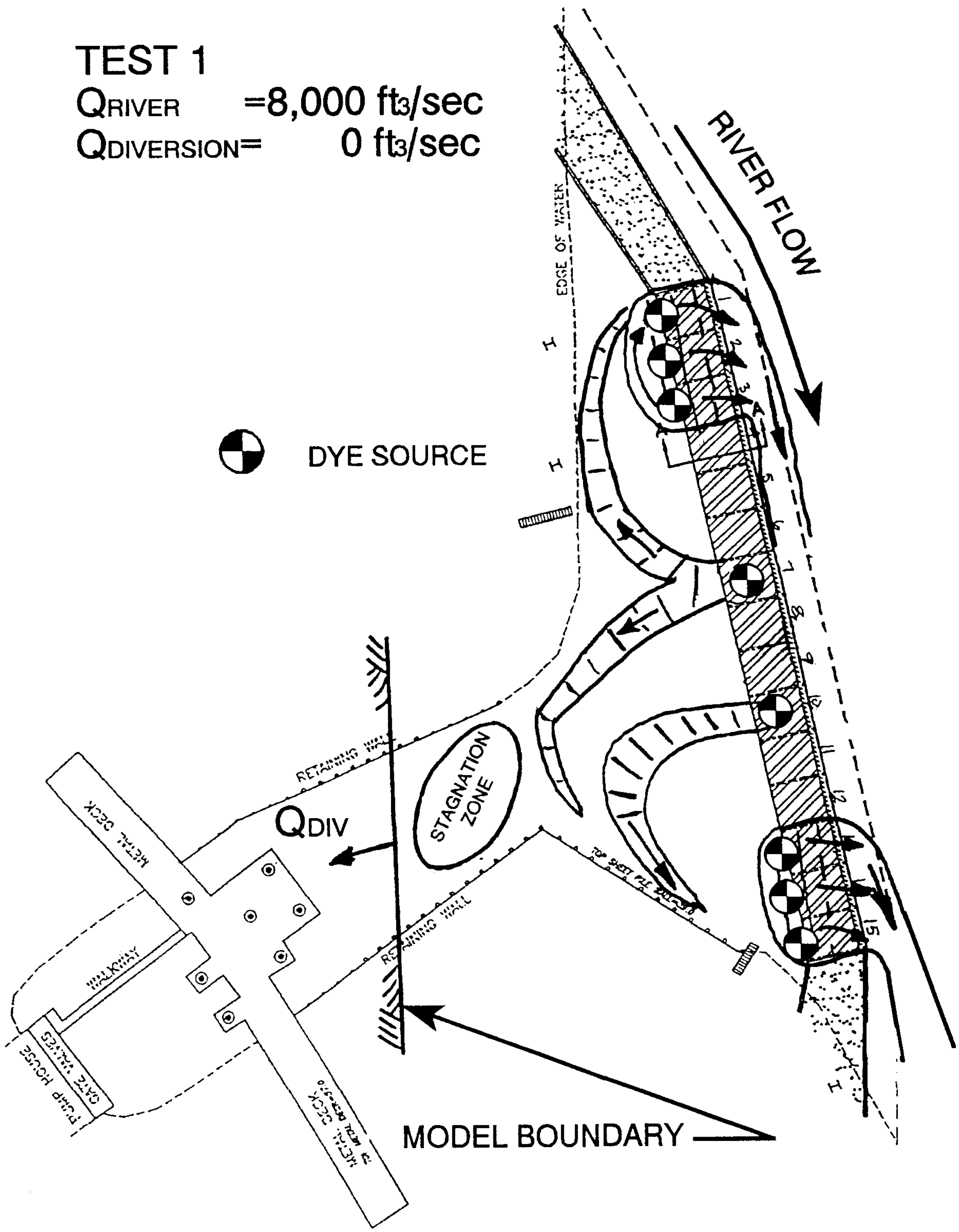


Figure 8. - Dye streaks for test No. 1 with no diversion and original upstream transition wall geometry.

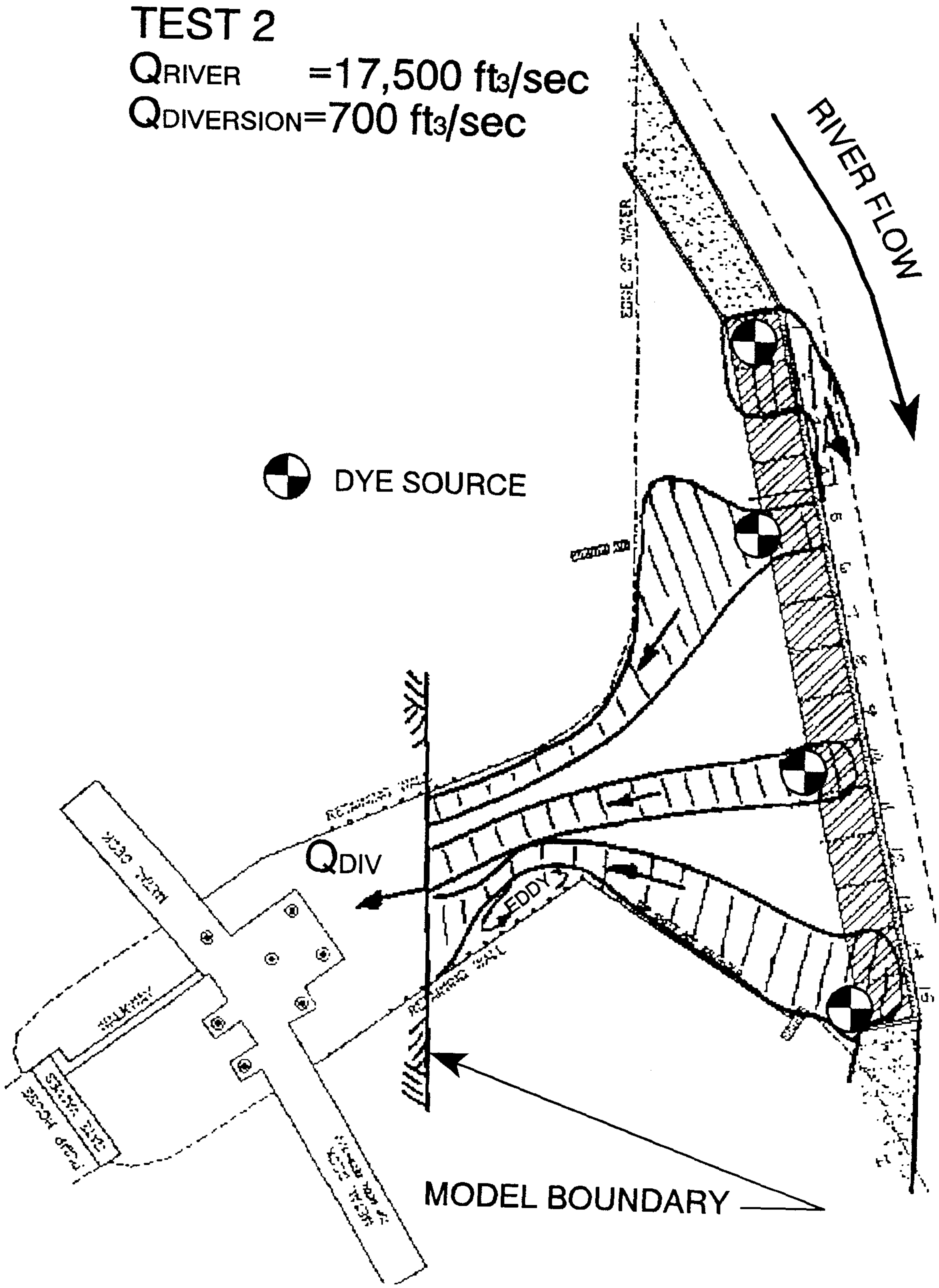


Figure 9. - Dye streaks for test No. 2 with original upstream transition wall geometry.

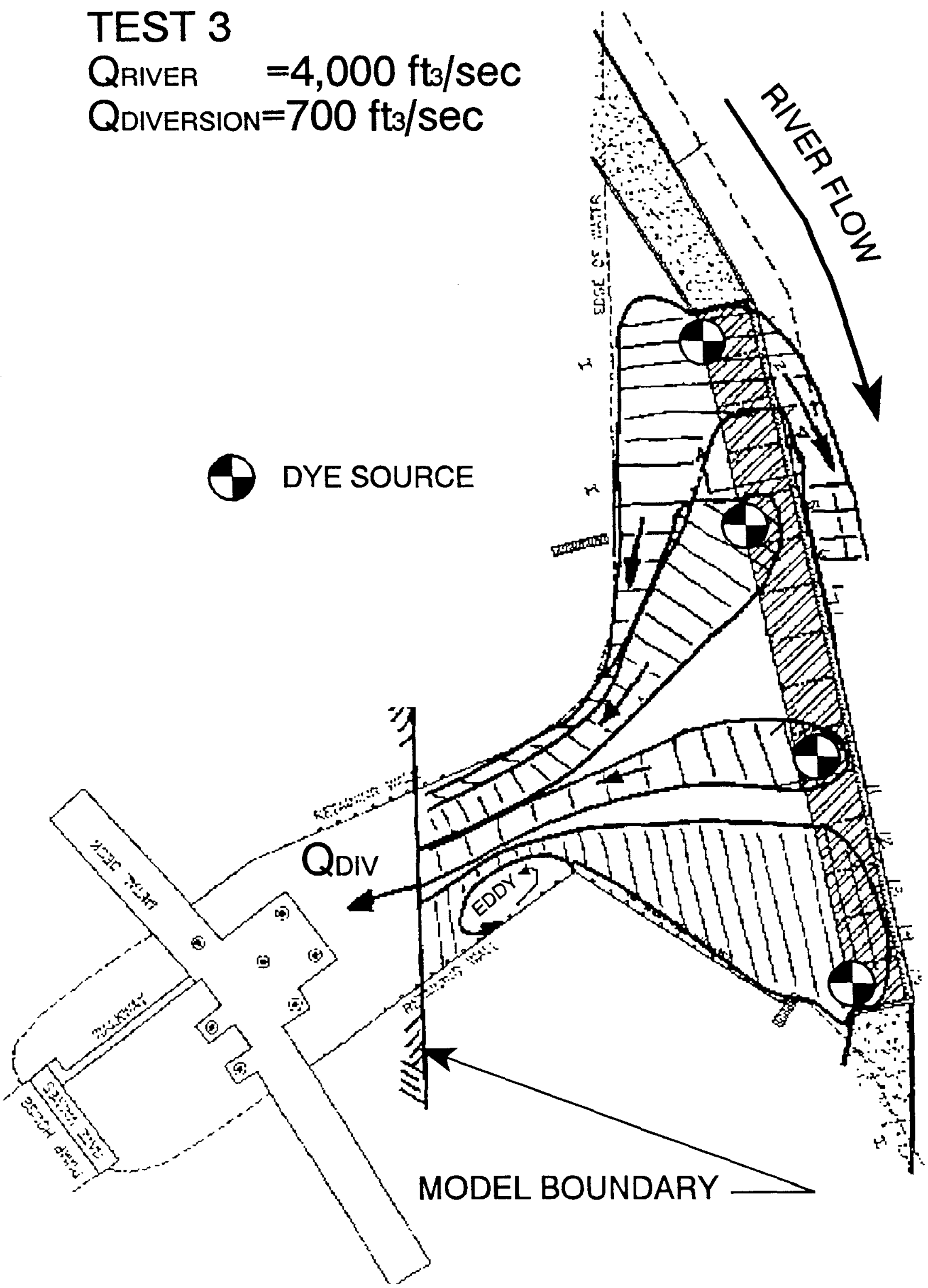


Figure 10. - Dye streaks for test No. 3 with original upstream transition wall geometry.

Modification No. 1

The first screen modification was made to the upstream transition wall to provide a hydraulically efficient transition between the sheet pile wall and the screen structure. The transition was modified by extending the face of the screen structure 30 feet upstream. An elliptical shaped transition wall which was tangent to the screen extension was used to transition from the screen face extension into the river bank (see fig. 11).

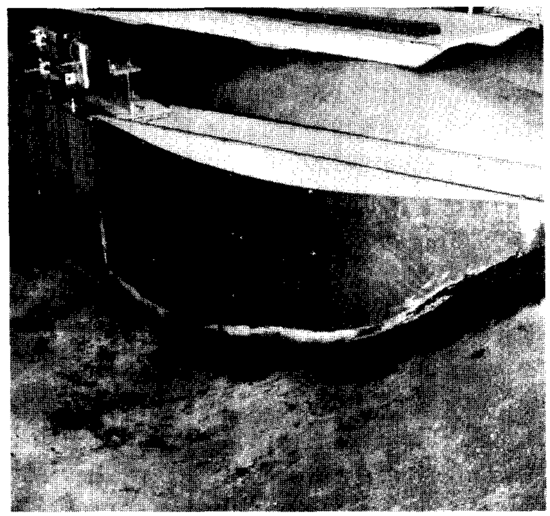


Figure 11. - Photograph of modified upstream transition wall.

This modified transition was evaluated using flow visualization and near-screen velocity measurements. The flow visualization tests indicated a major improvement in the approach conditions to the fish screen. However, velocity measurements at bay No. 15, collected for 3 test conditions (tests No. 1 through 3), indicated that the approach velocities were larger than the 0.33-ft/s velocity criteria. The high velocities at bay No. 15 were caused by a combination of a rise in the river channel and encroachment of the levee toe. These changes in the channel geometry caused a greater differential head across the screen, hence a higher approach velocity through bay No. 15. The influence of the channel bed and levee toe on the approach flow can be reduced if the material is excavated during screen construction.

The modified transition introduced the flow parallel to the fish screen, which eliminated the outflow from screen bays No. 1 and 2. However, flow visualization and velocity measurements showed a very low approach velocity at bay No. 1. Low velocities at bay No. 1 resulted from the effects of the upstream transition wall. Because the wall introduced the flow parallel to the screen, it took a period of time for flow along the screen structure to change direction so it could flow into the screen.

Modification No. 2

The second screen modification was made to correct minor deficiencies identified while evaluating the first modification. Modification No. 1 evaluations showed that the approach velocity criteria were met for all bays except bay No. 15. Therefore, a decision was made to use the louvers to reduce the approach velocities through bay No. 15 rather than attempt to make additional structural modifications. One task was to determine the louver position which would reduce the approach velocities at bay No. 15 to below 0.33 ft/s.

Modification No. 1 evaluations showed that approach velocities measured at bay No. 1 were nearly zero and outflow was observed, indicating that bay No. 1 was ineffective. So rather than reconstruct the upstream transition wall, the modification No. 2 evaluations were performed with bay No. 1 covered to simulate an additional 15-foot extension to the upstream transition wall. However, this modification does not suggest that bay No. 1 is not required in the final screen design. The performance of bay No. 2 can be considered to be indicative of what can be expected at bay No. 1 if 45 feet of straight approach were incorporated into the upstream transition wall design.

For test No. 1 flow conditions, velocity measurements were collected at bays No. 7 and 15 for a complete range of louver positions. Figure 12 shows the relationship between the normalized approach velocities and the louver rotation (note: a normalized approach velocity less than or equal to 1 meets the velocity criteria). Velocities measured at bay No. 15 showed that for louver positions between 0 and ±40°, the approach velocities were greater than 0.33 ft/s. As a result, bay No. 15 louvers were set at 50° rotation in the downstream direction to ensure velocity criteria compliance. The data plotted for bay No. 7 are included as a guide to setting louver position for the other screen bays, if necessary.

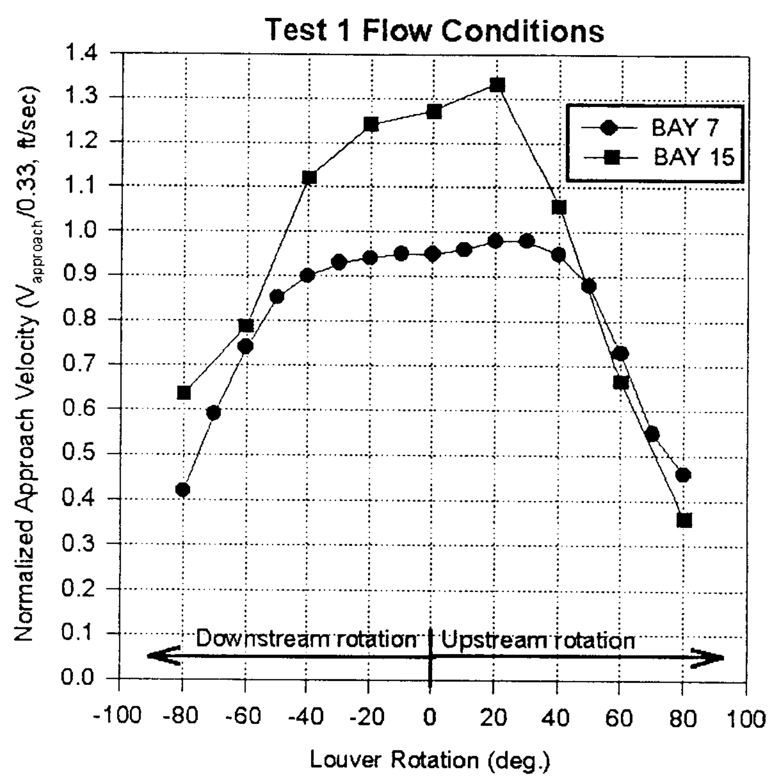


Figure 12. - Normal approach velocity versus louver rotation—screen bays No. 7 and 15—test No. 1 flow conditions.

A detailed investigation of the near-screen approach velocity distribution was conducted for this screen configuration. The base of the 10-foot high screen was set at elevation 17 feet. Horizontal velocity profiles were measured at elevations 19.5, 22, and 24.5 feet. The near-screen velocity profiles were used to determine the average sweeping and approach velocity for each screen bay at the three elevations. Velocity data were also used to determine the approach velocity distribution for the entire fish screen.

Field observations of transient, small-scale eddies originating in a shear zone upstream from the proposed fish screen structure were also observed in the model for tests No. 1 and 2. These eddies were swept past the fish screen structure and had no measurable impact on the average sweeping and approach velocities. Eddies were not observed during test No. 3 because of the low river flows.

Large-scale eddies were observed in the field at the existing electrical barrier structure. These eddies were not observed during flow visualization of tests No. 1 through 3. However, eddies or circulations did form when small or zero diversion flows existed. These circulations consisted of outflow through the first three and last three screen bays and inflow in the middle screen bays. More details on circulations and measured approach velocities are contained in the following sections.

The final configuration of the positive barrier fish screen consisted of bay No. 1 being blocked and bay No. 15 louvers rotated 50° in the downstream direction. An exception to this configuration was implemented for test No. 4, which was conducted with bay No. 1 open and bay No. 15 louvers rotated 50° downstream.

Test No. 1 Results

The approach velocity distribution for bays No. 2 through 15 is shown in the form of isovels (velocity contours) on figure 13. Figure 13 shows that the approach velocities are less than or equal to 0.33 ft/s over the entire screen area and are uniformly distributed. The average approach and sweeping velocities over the entire screen were 0.23 and 2.58 ft/s, respectively. The average angle of attack on the screen was 5.24°. Average velocity data for each screen bay are reported in table 2.

The velocity drops to 0.165 ft/s in a section of screen from a distance of 165 to 195 feet (bays No. 11 and 12). This reduced velocity zone is most likely attributed to a 2- to 3-foot rise in the river bed near bay No. 11. Another contributing factor is secondary currents which form in a river bend. Secondary currents flow toward the inside of the river bend and may decrease approach velocities along portions of the screen structure. This reduced velocity zone was also measured in tests No. 2 and 4. Test No. 3 velocity measurements did not show this low approach velocity region, which would be expected for a low river flow.

CDFG velocity criteria specify that near-screen velocities be measured 3 inches from the screen face. However, attempts to measure velocities at that distance in the model (0.15 inch) produced erratic results. The erratic results were caused by interference between the screen surface and the probe's sampling volume. On average, the velocities were measured at a prototype distance of 5.4 inches (model distance was 0.27 inch), which explains why the average approach velocities were lower than the expected design value of 0.33 ft/s. Measurements collected closer to the screen would approach the design value of 0.33 ft/s. Another reason for a reduced velocity is that velocity measurements were not collected to

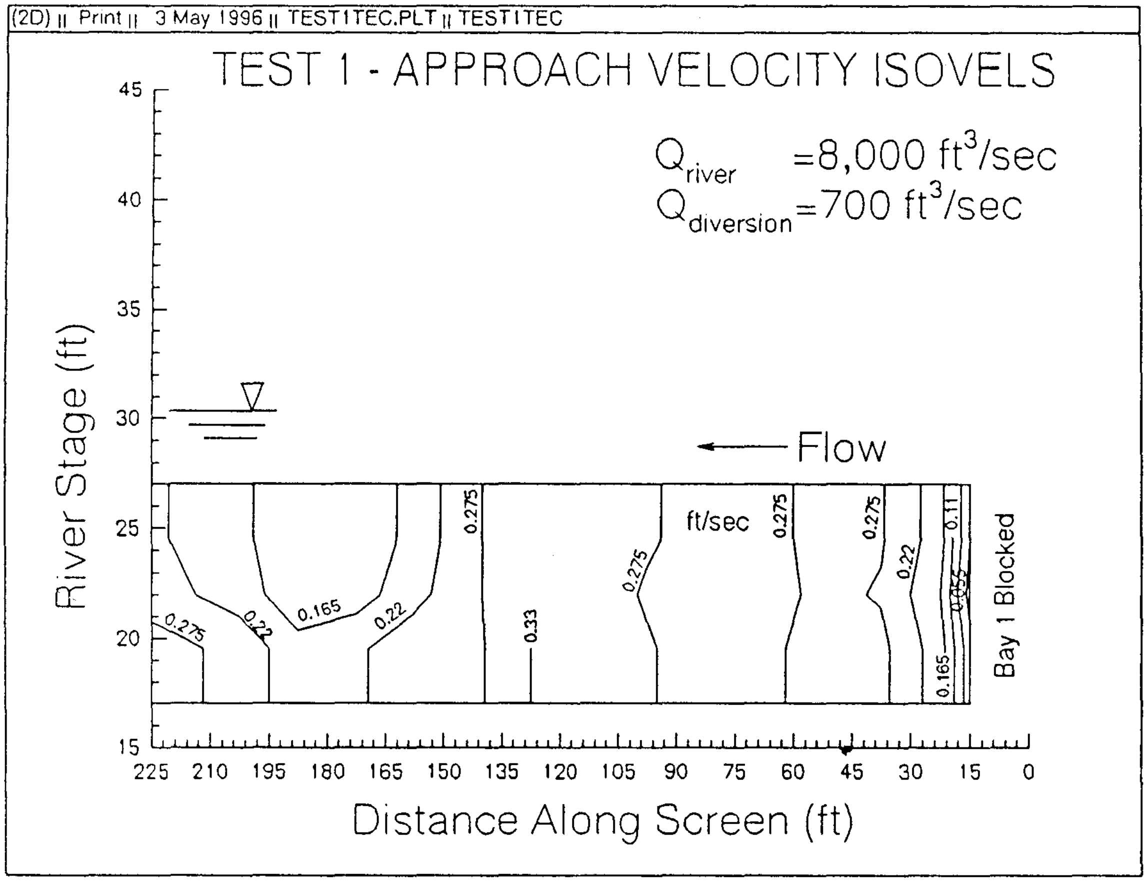


Figure 13. - Plot of approach velocity isovels over the Wilkins Slough positive barrier fish screen for test No. 1 flow conditions. Note that bay No. 1 was blocked and bay No. 15 was louvered 50° downstream.

determine the amount of flow entering the entire control volume encompassing the fish screen. For example, velocities measured 6 inches in front of the screen face cover 90 percent of the control volume's surface area. The other 10 percent of the surface area is comprised of the top, bottom, and sides of the control volume.

A test was conducted where horizontal velocity profiles were collected every foot from elevation 17 to elevation 27. The approach velocity distribution for bay No. 7 is presented as an isovel plot on figure 14. Bay No. 7 was selected for analysis because its approach velocities were typical for the majority of the screen bays. The isovel plot shows a few small areas where the velocities were measured to be at least 0.33 ft/s. However, average approach velocities along each of the 11 horizontal traverses never exceeded 0.33 ft/s.

A flow visualization test was conducted with a pumping plant discharge equal to 0 ft^3/s. For these flow conditions, dye streaks indicated outflow through bays No. 1 through 3 and bays No. 12 through 15. Inflows were observed in bays No. 4 through 11. No near-screen velocity measurements were collected for this test.

Table 2. - Test No. 1 prototype velocity data collected at elevations 19.5, 22.0, and 24.5 feet. This laboratory test was for modification No. 2 with bay No. 1 blocked and bay No. 15 louvered 50° downstream.

Screen Bay No.	V_x-Avg (vertical) (ft/s)	V_y-Avg (sweeping) (ft/s)	V_z-Avg (approach) (ft/s)	Magnitude (ft/s)	Attack angle w/screen face (degrees)
		Elevation 19.5			
1	0.14	2.26	0.02	2.26	0.61
2	0.19	2.50	0.19	2.51	4.31
3	0.07	2.53	0.29	2.55	6.44
4	0.04	2.63	0.30	2.65	6.52
5	0.01	2.63	0.26	2.65	5.62
6	0.03	2.65	0.25	2.67	5.46
7	0.03	2.57	0.28	2.59	6.25
8	-0.02	2.53	0.32	2.55	7.23
9	-0.14	2.44	0.33	2.46	7.62
10	-0.17	2.52	0.26	2.54	5.94
11	-0.07	2.48	0.26	2.50	6.06
12	-0.09	2.55	0.21	2.56	4.73
13	-0.04	2.33	0.19	2.33	4.55
14	-0.04	2.49	0.25	2.51	5.76
15/50°	-0.08	2.28	0.31	2.30	7.82
		Elevation 22.0			
1	0.15	2.70	-0.02	2.70	-0.36
2	0.16	2.78	0.17	2.78	3.44
3	0.08	2.72	0.27	2.73	5.68
4	0.05	2.83	0.29	2.84	5.90
5	0.02	2.76	0.25	2.77	5.25
6	0.06	2.88	0.25	2.89	5.04
7	0.06	2.84	0.27	2.85	5.50
8	0.00	2.67	0.30	2.68	6.41
9	-0.06	2.48	0.30	2.50	6.96
10	-0.05	2.72	0.27	2.73	5.73
11	-0.01	2.87	0.20	2.88	4.01
12	-0.01	2.88	0.14	2.89	2.81
13	-0.01	2.76	0.12	2.77	2.41
14	0.02	2.76	0.20	2.77	4.07
15/50°	-0.02	2.53	0.24	2.54	5.51
		Elevation 24.5			
1	0.10	2.55	0.00	2.55	0.10
2	0.18	2.67	0.19	2.68	4.12
3	0.15	2.57	0.28	2.58	6.15
4	0.15	2.61	0.28	2.62	6.11
5	0.08	2.57	0.27	2.59	5.89
6	0.12	2.65	0.26	2.66	5.55
7	0.14	2.62	0.28	2.63	6.08
8	0.10	2.55	0.30	2.57	6.73
9	0.04	2.48	0.30	2.50	6.92
10	0.07	2.62	0.27	2.64	5.94
11	0.03	2.95	0.18	2.96	3.49
12	0.00	2.98	0.13	2.99	2.52
13	0.02	3.00	0.12	3.01	2.31
14	0.04	2.93	0.18	2.94	3.48
15/50°	0.02	2.74	0.23	2.75	4.83

Note: A positive V_x is downward, a positive V_y is downstream, and a positive V_z is into the fish screen.

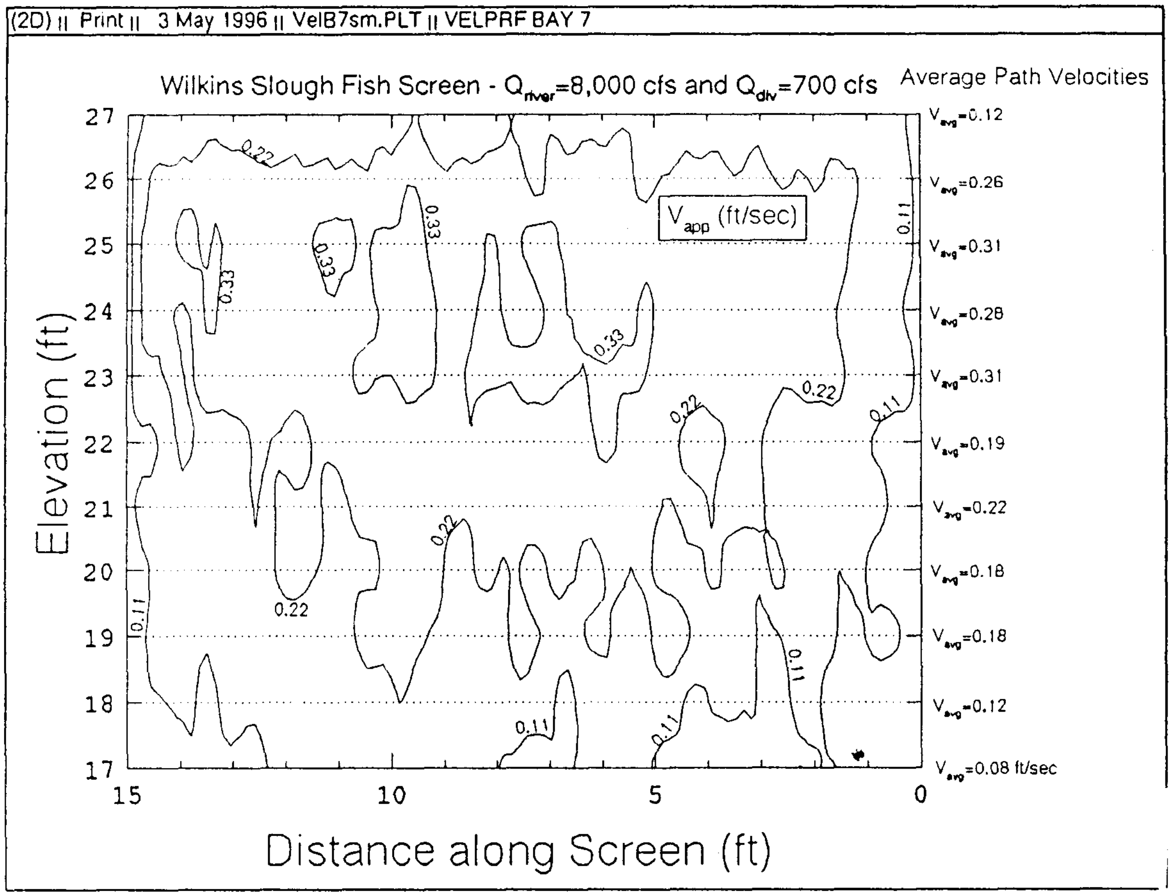


Figure 14. - Detailed plot of approach velocity isovels for bay No. 7. Horizontal velocity transects were collected at 1-foot increments for test No. 1 flow conditions. Average velocities for each transect are shown on the right side of the plot (flow was from right to left).

Test No. 2 Results

On average, the approach velocities were measured at a prototype distance of 5.4 inches (model distance was 0.27 inch) from the screen face. Figure 15 shows the isovel plot for bays No. 2 through 15; bay No. 1 was blocked. The average approach and sweeping velocities over the entire screen were 0.23 and 3.50 ft/s, respectively. The average angle of attack on the screen was 3.74°. Average velocity data for each screen bay are reported in table 3. Velocities of 0.33 ft/s were measured in two areas (bay No. 4 and bays No. 8 and 9) for test No. 2 flow conditions. As in test No. 1, an area of low velocity was measured near bays No. 12 and 13. The approach velocities were even smaller than those measured in test No. 1, which was expected because secondary currents would be more pronounced for higher river flows.

A low diversion flow test was conducted with the pumping plant discharge equal to 250 ft^3/s. For these flow conditions, approach velocities ranged from a minimum of 0.10 ft/s at bay No. 2 to a maximum of 0.23 ft/s at bay No. 4. Outflow was measured at bays No. 12 through 15. A complete list of the near-screen velocities is contained in table 4.

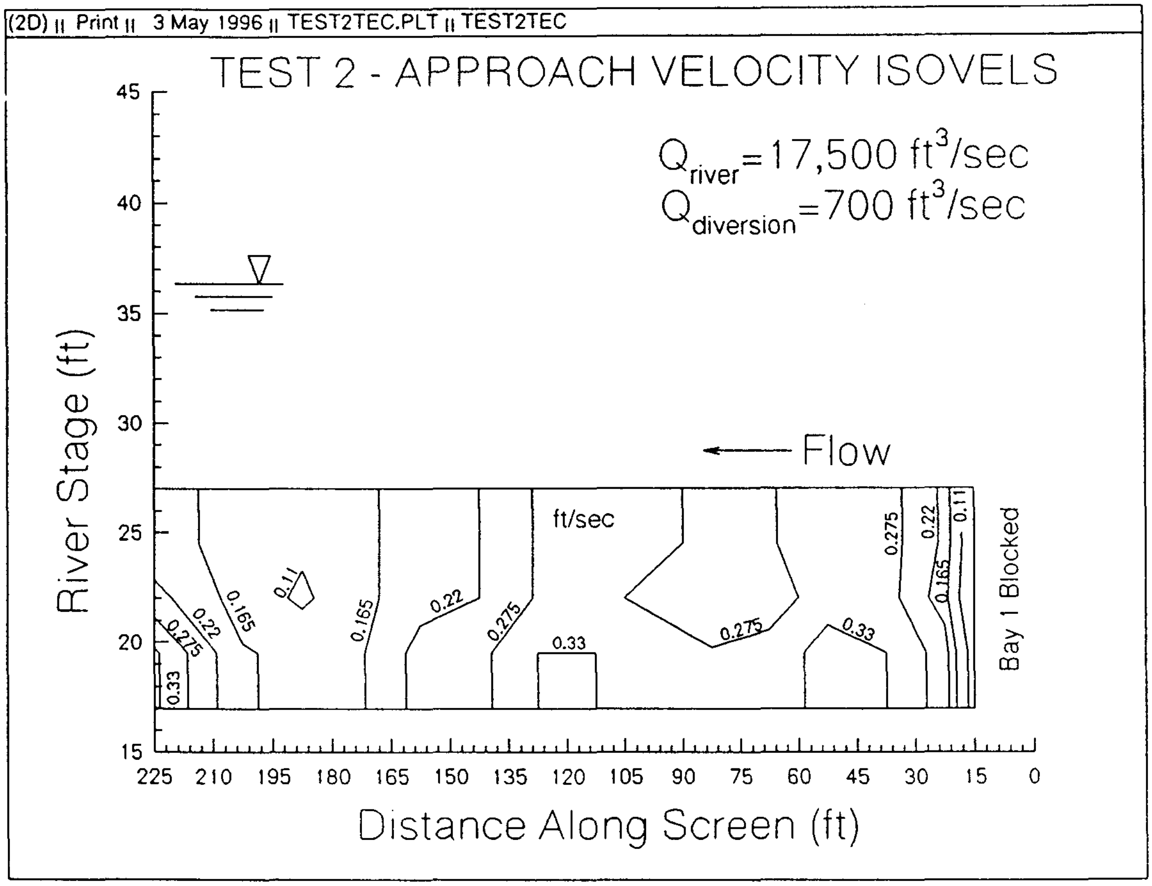


Figure 15. - Plot of approach velocity isovels over the Wilkins Slough positive barrier fish screen for test No. 2 flow conditions. Note that bay No. 1 was blocked and bay No. 15 was louvered 50° downstream.

A no diversion test was conducted with the pumping plant discharge equal to 0 ft^3/s. For these flow conditions, approach velocities ranged from a minimum of 0.01 ft/s at bay No. 2 to a maximum of 0.16 ft/s at bays No. 4 and 8. Outflow was measured at bays No. 11 through 15. The largest approach velocity was measured to be -0.45 ft/s (outflow) at bay No. 14. A complete list of the near-screen velocities is contained in table 5.

Test No. 3 Results

Near-screen velocities were measured at a prototype distance of 5.2 inches (model distance was 0.26 inch) from the screen face. Figure 16 shows the isovel plot for bays No. 2 through 15. The average approach and sweeping velocities over the entire screen were 0.24 and 1.74 ft/s, respectively. The average angle of attack on the screen was 8.07°. The approach velocity distribution is uniform for these flow conditions. Low velocities were not measured near bays No. 11 and 12 because the secondary currents are weak for this river flow. A complete list of the near-screen velocities is contained in table 6.

A test was conducted with a pumping plant discharge equal to 0 ft^3/s. For these flow conditions, near-screen velocity data showed outflow from bays No. 13 through 15. Inflows were observed in bays No. 2 through 12. A complete list of the near-screen velocities is contained in table 7. The sweeping velocities measured at bays No. 13 through 15 were quite low. However, this localized effect was caused by outflows and river bottom obstructions which deflected the river flow away from the screen face.

Table 3. - Test No. 2 prototype velocity data collected at elevations 19.5, 22.0, and 24.5 feet. This laboratory test was for modification No. 2 with bay No. 1 blocked and bay No. 15 louvered 50° (downstream).

Screen Bay No.	V_x-Avg (vertical) (ft/s)	V_y-Avg (sweeping) (ft/s)	V_z-Avg (approach) (ft/s)	Magnitude (ft/s)	Attack angle w/screen face (degrees)
			Elevation 19.5		
1	0.11	2.71	0.03	2.71	0.60
2	0.17	3.36	0.25	3.37	4.25
3	0.07	3.38	0.33	3.40	5.65
4	0.03	3.62	0.35	3.64	5.52
5	-0.13	3.35	0.30	3.36	5.11
6	-0.05	3.51	0.28	3.52	4.49
7	-0.09	3.40	0.31	3.42	5.27
8	-0.11	3.43	0.33	3.45	5.44
9	-0.27	3.27	0.33	3.29	5.73
10	-0.30	3.58	0.26	3.59	4.17
11	-0.17	3.62	0.24	3.63	3.73
12	-0.10	3.59	0.16	3.59	2.57
13	0.02	3.35	0.15	3.35	2.62
14	0.00	2.82	0.17	2.82	3.44
15/50°	-0.10	2.88	0.34	2.90	6.73
			Elevation 22.0		
1	0.16	3.00	-0.04	3.00	-0.85
2	0.29	3.46	0.19	3.47	3.09
3	0.11	3.53	0.30	3.54	4.87
4	0.14	3.71	0.31	3.72	4.80
5	0.12	3.73	0.24	3.74	3.68
6	0.12	3.86	0.23	3.86	3.48
7	0.15	3.89	0.26	3.90	3.82
8	0.15	3.82	0.29	3.83	4.28
9	-0.01	3.82	0.28	3.83	4.22
10	-0.13	3.96	0.22	3.97	3.15
11	-0.07	3.99	0.20	4.00	2.90
12	-0.06	3.99	0.15	3.99	2.15
13	0.00	3.55	0.10	3.55	1.57
14	0.06	3.12	0.14	3.12	2.65
15/50°	-0.12	3.19	0.24	3.20	4.24
			Elevation 24.5		
1	0.11	3.31	-0.02	3.31	-0.39
2	0.14	3.52	0.21	3.53	3.41
3	0.14	3.49	0.30	3.51	4.97
4	0.13	3.53	0.31	3.54	4.96
5	0.06	3.49	0.27	3.50	4.49
6	0.14	3.68	0.26	3.69	3.98
7	0.12	3.62	0.29	3.63	4.57
8	0.02	3.58	0.29	3.59	4.71
9	-0.08	3.55	0.28	3.56	4.46
10	-0.02	3.79	0.22	3.80	3.25
11	0.02	3.95	0.20	3.95	2.85
12	-0.08	3.97	0.15	3.97	2.19
13	-0.01	3.75	0.12	3.75	1.79
14	0.04	3.42	0.15	3.43	2.56
15/50°	0.04	3.39	0.18	3.39	3.04

Note: A positive V_x is downward, a positive V_y is downstream, and a positive V_z is into the fish screen.

Table 4. - Test No. 2 prototype velocity data collected at elevation 22.0 feet. This laboratory test was for modification No. 2 with bay No. 1 blocked and bay No. 15 louvered 40° downstream. The diversion flow rate was set at 250 ft^3/s. The low diversion flow results in outflow in bays No. 12 through 15.

Screen Bay No.	V_x-Avg (vertical) (ft/s)	V_y-Avg (sweeping) (ft/s)	V_z-Avg (approach) (ft/s)	Magnitude (ft/s)	Attack angle w/screen face (degrees)
			Elevation 22.0		
1	-0.02	2.10	0.04	2.10	1.10
2	0.18	2.80	0.10	2.80	2.07
3	0.13	2.98	0.22	2.99	4.24
4	0.08	3.49	0.23	3.50	3.80
5	0.01	3.38	0.16	3.39	2.66
6	0.06	3.71	0.14	3.71	2.16
7	0.08	3.65	0.17	3.65	2.67
8	-0.00	3.48	0.19	3.49	3.16
9	-0.15	3.03	0.15	3.04	2.79
10	-0.23	3.73	0.13	3.73	1.94
11	-0.17	3.09	0.03	3.09	0.52
12	-0.11	2.40	-0.01	2.40	-0.27
13	-0.08	1.27	-0.06	1.27	-2.55
14	-0.04	0.66	-0.13	0.67	-11.35
15/40°	-0.03	0.26	-0.25	0.36	-42.99

Note: A positive V_x is downward, a positive V_y is downstream, and a positive V_z is into the fish screen.

Table 5. - Test No. 2 prototype velocity data collected at elevation 22.0 feet. This laboratory test was for modification No. 2 with bay No. 1 blocked and bay No. 15 louvered 50° downstream. The diversion flow rate was set at 0 ft^3/s. The low diversion flow results in outflow in bays No. 11 through 15.

Screen Bay No.	V_x-Avg (vertical) (ft/s)	V_y-Avg (sweeping) (ft/s)	V_z-Avg (approach) (ft/s)	Magnitude (ft/s)	Attack angle w/screen face (degrees)
			Elevation 22.0		
1	0.31	3.29	0.00	3.29	0.00
2	0.32	3.06	0.02	3.06	0.35
3	0.16	2.70	0.12	2.71	2.61
4	0.08	3.26	0.16	3.27	2.84
5	0.08	3.40	0.10	3.40	1.71
6	0.08	3.36	0.05	3.36	0.83
7	0.03	3.12	0.06	3.12	1.15
8	-0.07	3.32	0.16	3.32	2.78
9	-0.11	3.32	0.15	3.33	2.59
10	-0.22	3.58	0.07	3.58	1.04
11	-0.19	3.10	-0.05	3.10	-0.96
12	-0.17	1.99	-0.07	1.99	-1.89
13	-0.05	0.77	-0.15	0.78	-10.86
14	-0.03	0.02	-0.45	0.45	-87.28
15/50°	-0.12	0.09	-0.33	0.34	-74.53

Note: A positive V_x is downward, a positive V_y is downstream, and a positive V_z is into the fish screen.

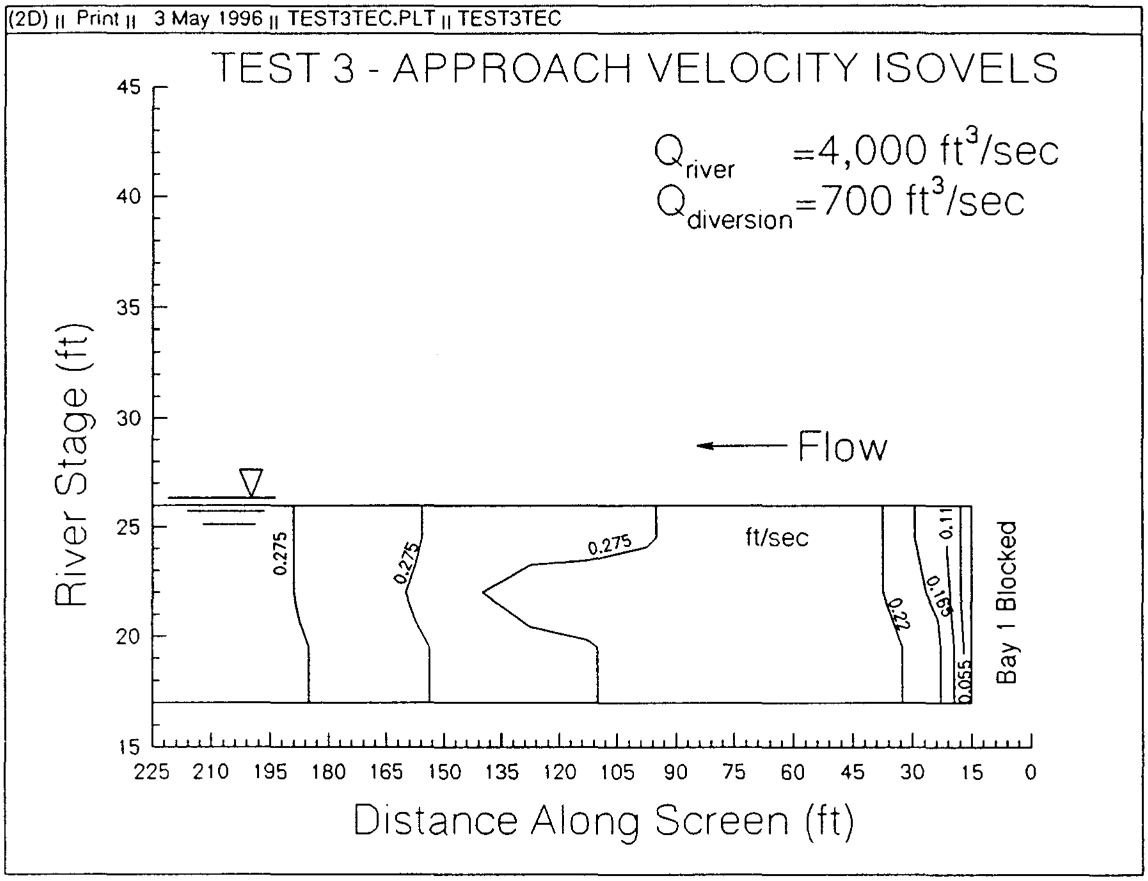


Figure 16. - Plot of approach velocity isovels over the Wilkins Slough positive barrier fish screen for test No. 3 flow conditions. Note that bay No. 1 was blocked and bay No. 15 was louvered 50° downstream.

Test No. 4 Results

On average, the approach velocities were measured at a prototype distance of 5.3 inches (model distance was 0.26 inch) from the screen face. For this test, bay No. 1 was open and bay No. 15 was louvered 50° downstream. For the high diversion flows, the majority of the approach velocities measured at elevation 22.0 feet exceeded the 0.33-ft/s velocity criteria. The average approach and sweeping velocities over the entire screen were 0.32 and 2.54 ft/s, respectively. The average angle of attack on the screen was 7.25°. These approach velocities were greater than those measured in test No. 1, which was expected for a higher diversion flow rate. Note that lower approach velocities were measured at bays No. 11 through 13 for the same reasons explained in the test No. 1 results section. A complete list of the near-screen velocities measured for this test is contained in table 8.

Table 6. - Test No. 3 prototype velocity data collected at elevations 19.5, 22.0, and 24.5 feet. This laboratory test was for modification No. 2 with bay No. 1 blocked and bay No. 15 louvered 50° (downstream).

Screen Bay No.	V_x-Avg (vertical) (ft/s)	V_y-Avg (sweeping) (ft/s)	V_z-Avg (approach) (ft/s)	Magnitude (ft/s)	Attack angle w/screen face (degrees)
			Elevation 19.5		
1	0.08	1.88	0.01	1.88	0.38
2	0.01	1.97	0.18	1.98	5.23
3	-0.03	1.96	0.24	1.97	6.95
4	-0.09	1.81	0.25	1.82	7.76
5	-0.11	1.72	0.23	1.74	7.71
6	-0.07	1.80	0.24	1.82	7.55
7	-0.11	1.63	0.25	1.65	8.57
8	-0.14	1.64	0.28	1.66	9.56
9	-0.17	1.62	0.29	1.64	10.24
10	-0.17	1.80	0.29	1.82	9.14
11	-0.10	1.67	0.27	1.70	9.31
12	-0.07	1.69	0.25	1.71	8.49
13	-0.05	1.67	0.28	1.69	9.44
14	-0.05	1.53	0.32	1.56	11.64
15/50°	-0.05	1.11	0.29	1.14	14.45
			Elevation 22.0		
1	-0.03	1.91	0.00	1.91	0.05
2	-0.08	1.91	0.15	1.91	4.37
3	-0.11	1.86	0.22	1.88	6.76
4	-0.09	2.02	0.26	2.04	7.21
5	-0.12	1.83	0.22	1.84	7.03
6	-0.04	2.01	0.24	2.02	6.72
7	-0.11	1.86	0.25	1.88	7.79
8	-0.11	1.58	0.24	1.59	8.64
9	-0.12	1.48	0.25	1.50	9.67
10	-0.11	1.66	0.28	1.69	9.60
11	-0.01	1.74	0.28	1.76	9.07
12	0.05	1.78	0.25	1.80	8.01
13	0.05	1.72	0.27	1.74	8.90
14	0.03	1.64	0.32	1.67	11.19
15/50°	-0.01	1.35	0.27	1.38	11.46
			Elevation 24.5		
1	-0.10	1.63	0.01	1.63	0.33
2	-0.09	1.51	0.13	1.51	4.98
3	-0.06	1.81	0.22	1.83	7.03
4	-0.03	1.98	0.26	2.00	7.40
5	-0.03	1.90	0.24	1.92	7.29
6	-0.04	1.95	0.25	1.96	7.42
7	-0.05	1.90	0.28	1.92	8.40
8	-0.08	1.83	0.30	1.85	9.29
9	-0.10	1.73	0.30	1.75	9.77
10	-0.08	1.84	0.31	1.87	9.60
11	0.06	1.81	0.27	1.83	8.51
12	0.07	1.81	0.26	1.83	8.06
13	0.04	1.79	0.27	1.81	8.48
14	0.04	1.69	0.32	1.72	10.72
15/50°	0.05	1.48	0.28	1.51	10.75

Note: A positive V_x is downward, a positive V_y is downstream, and a positive V_z is into the fish screen.

Table 7. - Test No. 3 prototype velocity data collected at elevation 22.0 feet. This laboratory test was for modification No. 2 with bay No. 1 blocked and bay No. 15 louvered 50° downstream. The diversion flow rate was set at 0 ft^3/s. A no diversion flow condition results in outflow in bays No. 13 through 15.

Screen Bay No.	V_x-Avg (vertical) (ft/s)	V_y-Avg (sweeping) (ft/s)	V_z-Avg (approach) (ft/s)	Magnitude (ft/s)	Attack angle w/screen face (degrees)
			Elevation 22.0		
1	-0.01	1.45	0.00 (blocked)	1.45	0.14
2	-0.03	1.19	0.03	1.19	1.44
3	-0.04	1.10	0.06	1.10	2.88
4	-0.05	1.33	0.08	1.33	3.37
5	-0.08	1.34	0.07	1.34	2.81
6	-0.03	1.39	0.04	1.39	1.55
7	-0.05	1.16	0.04	1.16	2.16
8	-0.05	0.88	0.05	0.88	3.07
9	-0.10	1.15	0.09	1.15	4.62
10	-0.13	1.46	0.06	1.46	2.34
11	-0.11	1.20	0.01	1.20	0.69
12	-0.09	0.67	0.00	0.67	0.04
13	-0.01	0.24	-0.03	0.24	-7.24 (outflow)
14	0.01	-0.05	-0.12	0.13	-65.84
15/40°	0.02	-0.09	-0.09	0.12	-44.11

Note: A positive V_x is downward, a positive V_y is downstream, and a positive V_z is into the fish screen.

Table 8. - Test No. 4 prototype velocity data collected at elevation 22.0 feet. This laboratory test was for modification No. 2 with bay No. 1 open and bay No. 15 louvered 50° downstream. The diversion flow rate was set at 900 ft^3/s and the river flow was 8,000 ft^3/s. The high diversion flow results in velocities in excess of 0.33 ft/s in bays No. 3 through 10 and bays No. 14 and 15.

Screen Bay No.	V_x-Avg (vertical) (ft/s)	V_y-Avg (sweeping) (ft/s)	V_z-Avg (approach) (ft/s)	Magnitude (ft/s)	Attack angle w/screen face (degrees)
			Elevation 22.0		
1	0.19	2.30	0.06	2.30	1.56
2	0.21	2.49	0.27	2.51	6.21
3	0.20	2.61	0.37	2.64	7.99
4	0.09	2.58	0.37	2.60	8.10
5	0.07	2.55	0.33	2.57	7.46
6	0.12	2.62	0.34	2.64	7.32
7	0.11	2.55	0.37	2.58	8.33
8	0.08	2.53	0.40	2.56	9.08
9	0.00	2.47	0.42	2.51	9.69
10	0.04	2.59	0.37	2.61	8.08
11	0.03	2.60	0.31	2.62	6.89
12	0.08	2.66	0.27	2.67	5.82
13	0.10	2.64	0.28	2.65	6.09
14	0.13	2.55	0.34	2.58	7.64
15/50°	0.05	2.31	0.35	2.34	8.51

Note: A positive V_x is downward, a positive V_y is downstream, and a positive V_z is into the fish screen.

Qualitative Sediment Deposition Test Results

Sediments used in the model were adjusted so that the model and prototype settling velocities were consistent with Froude scaling. Figure 17 shows the relationship between settling velocity (w) and particle diameter (d). An example of the sediment scaling procedure is included on the figure. Figure 18a shows the three grain size distributions: 1) prototype sediment dredged from the pumping plant forebay, 2) model sediment scaled using settling velocity, and 3) sediment that was geometrically scaled. Note that geometrically scaled sediment would be too fine and would not settle out in the model.

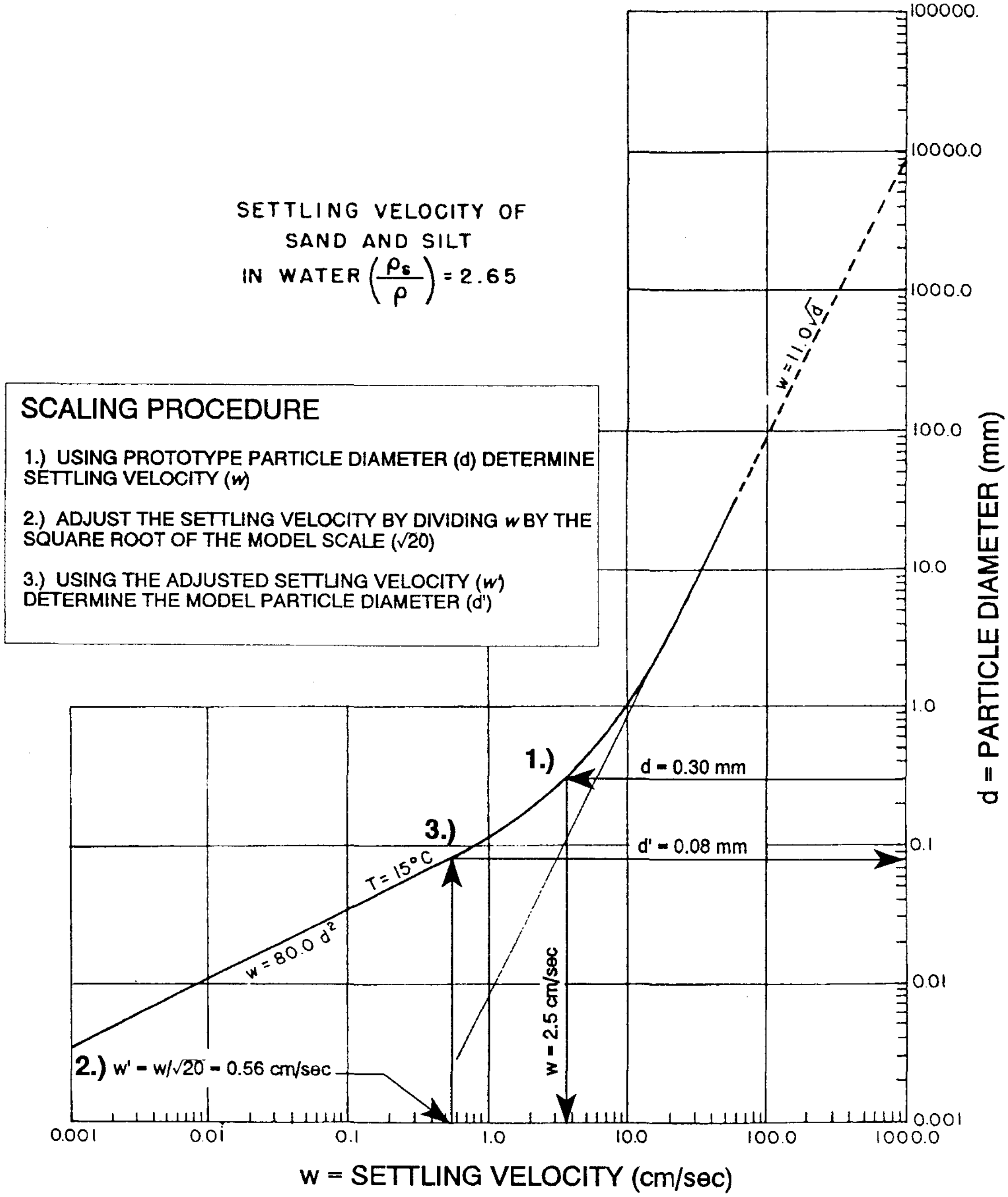
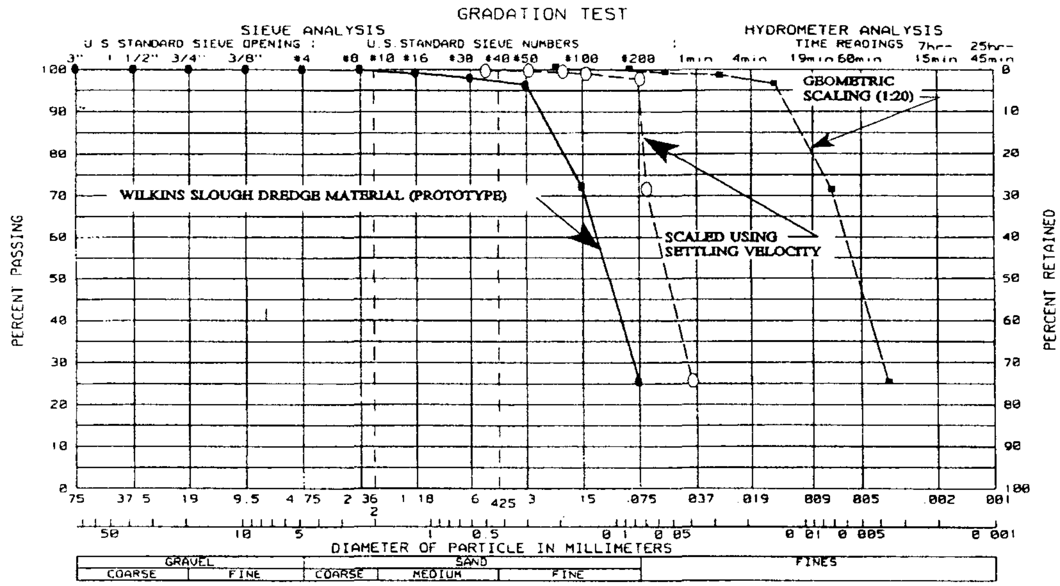
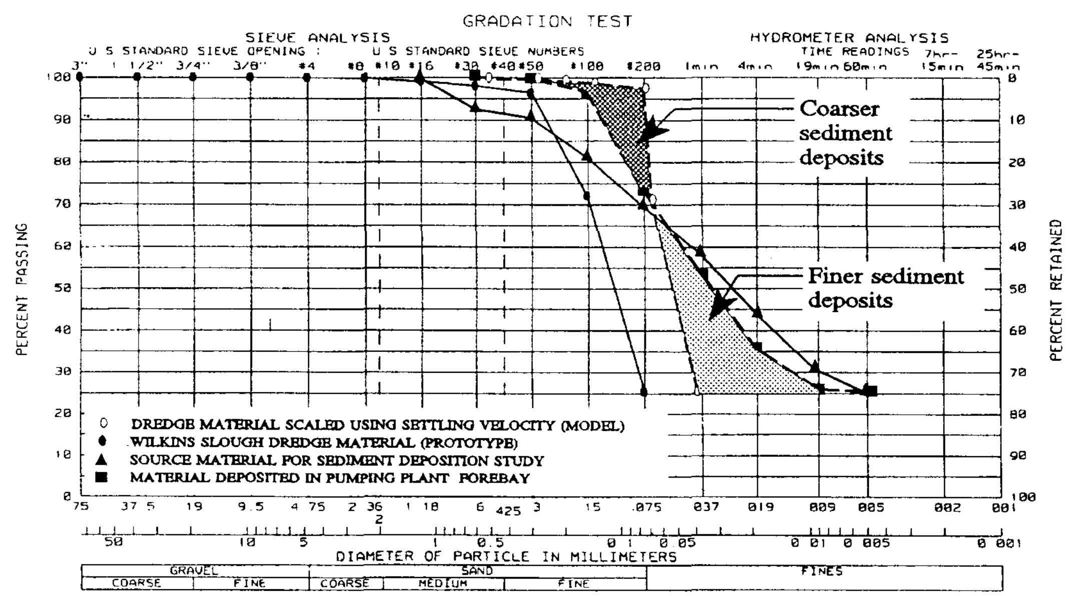


Figure 17. - Settling velocity of sand and silt in 15 °C water and an example of the sediment scaling procedure (Pugh, 1985).



(A)



(B)

Figure 18. - (a) Model and prototype grain size distributions for sediment dredged from the pumping plant forebay. (b) Comparison of grain size distributions for the model and prototype deposition in the forebay.

Sediment used for the qualitative sediment deposition test was a uniformly graded sample of fine sands and silts; the grain size distribution for the model sediment is shown on figure 18b. This material was selected because the majority of the particles were in the same size fraction of the scaled prototype sediment.

Test No. 1 flow conditions were used for the sediment deposition test. A mixture of sediment and water was pumped from a constant head tank into the model about 150 feet upstream from the first screen bay. The sediment mixture was pumped in at a rate of 11 gallons per minute. Every 30 minutes, 12 pounds (a 1-gallon bucket) of sediment were added to the constant head tank. The sediment-water mixture was thoroughly mixed every 15 minutes. The test was run for a total of 22.5 hours over 3 days. A total of 540 pounds of sediment was introduced to the model. Typically, the coarse sediment would deposit immediately downstream from the injection point. The finer sediment either entered the pumping plant forebay or was carried past the screen structure and out of the model. Suspended sediment entering the forebay was deposited or pumped out of the model. At the end of the test, the depth of the sediment deposition was measured both inside and outside the fish screen structure. A contour plot of the sediment depths is shown on figure 19. Figure 19 shows that the bulk of the sediment was deposited outside the screen structure. Of the material that was deposited inside the structure, the majority was deposited in the 1-foot gap between the screen and the louvers. Sediment was also deposited between individual louvers (figs. 20 through 23). Another deposition zone occurred on the back side of the louvers where the elevation dropped from 17 feet to 15 feet;, this type of deposition was limited to bays No. 2 through 9 (figs. 20 and 21). The depth of deposition in the pumping plant forebay varied from 0.1 to 0.3 foot. The sediment distribution, both particle size and quantity, in the forebay was skewed toward the upstream end. The reason for the skewed distribution is that some coarser material was still in suspension when it reached the screen and was drawn into the structure while it was settling. This resulted from introducing the sediment too close to the structure. As a result, the coarser material deposited in the upstream screen bays is not representative of what would be deposited in the prototype screen structure.

The sediment deposited in the screen structure and forebay was collected and analyzed. The grain size distribution of this sample is shown on figure 18b. The dry weight of the sample was 29.6 pounds or 5.5 percent of the total amount of sediment added to the model.

The coarser sediments (greater than 0.15 millimeter in diameter) represent about 30 percent of all the sediment deposited inside the fish screen and are identified on figure 18b. The remaining 70 percent of the deposited sediment (less than 0.15 millimeter in diameter) is the same size or finer than the prototype sediment deposits (figure 18b). Very fine sediments (less than 0.037 millimeter in diameter) are not likely to settle out in the prototype forebay as indicated by the lack of that particle size in the grain size distribution of the dredged sediment. This size particle was deposited in the model because the model had a lower Reynolds number, or lower turbulence intensity, so these particles were able to settle out. However, in the prototype, this finer material either does not exist in large quantities or does not settle out and will be pumped into the canal system. The sediment entering the canal may or may not be deposited depending on the velocities in the canal.

Observations of the sediment deposited outside the screen structure revealed no areas of scour. However, scour was observed at the base of the upstream transition wall. Scour caused by a horseshoe vortex was observed along the entire length of the transition wall. This scour is very similar in nature to bridge pier scour. Sediment deposition was observed

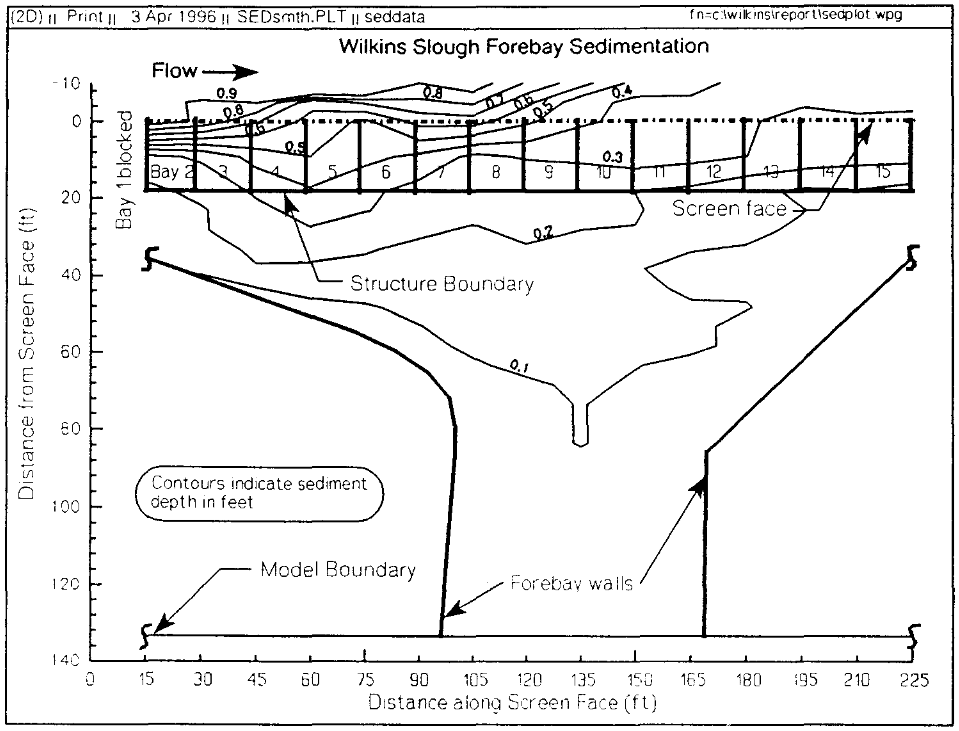


Figure 19. - Prototype sediment depth contours developed during the 3-day sediment deposition test. The model test showed that the majority of deposition occurs inside the screen structure and smaller depths on the forebay.

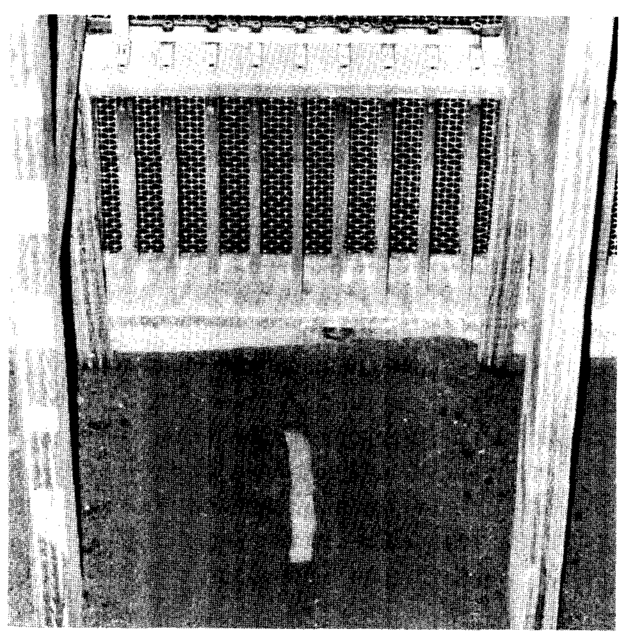


Figure 20. - Bay No. 3 sediment deposition. About 0.5 foot (prototype) of sediment was deposited in the screen structure. A 0.5-inch-wide strip (model) was excavated to show sediment depth.

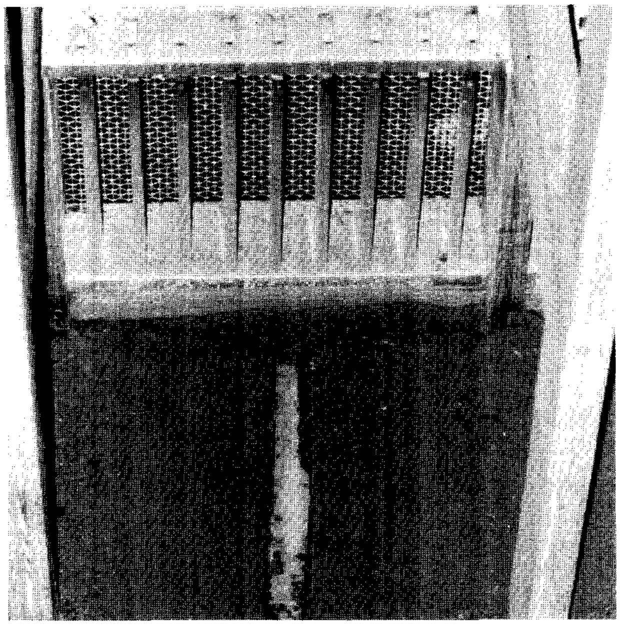


Figure 21. - Bay No. 9 sediment deposition. About 0.3 foot (prototype) of sediment was deposited in the screen structure.

Figure 22. - Bay No. 12 sediment deposition. About 0.3 foot (prototype) of sediment was deposited in the screen structure. Note the absence of coarse sediment this far down the structure.

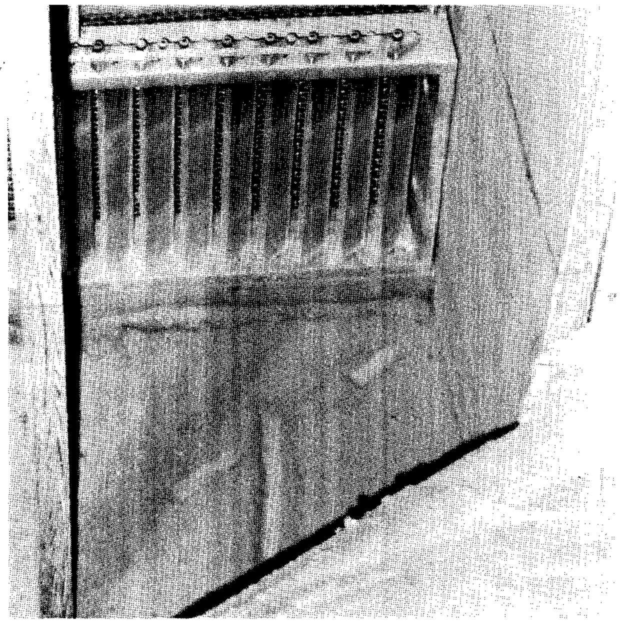


Figure 23. - Bay No. 15 sediment deposition. About 0.2 foot (prototype) of sediment was deposited in the screen structure. Note the louvers are set at a 50° angle.

along the entire length of the fish screen structure, where it partially filled in an existing scour hole. The depth of sediment did not reach the bottom of the screen at any location along the screen (elevation 17 feet). Bedforms (ripples and dunes) in the river channel were observed moving along the structure, which confirmed that the majority of the bed material transport was along the screen rather than through it.

In conclusion, the qualitative sediment deposition test showed that the positive barrier fish screen structure should not create a sedimentation problem greater than what already exists. The high sweeping velocities and uniform velocity distribution along the screen face should keep the majority of the bed material and suspended sediment moving downstream. The areas of greatest sedimentation can be expected to occur immediately inside the fish screen panels, and the sediment deposits may prevent the louvers from being rotated.

Trash Deflector

Flow visualization observation for tests No. 1 through 3 were conducted on the final fish screen design to determine the location for a trash deflector. Dye was injected 300 feet above the upstream edge of the fish screen at various distances measured perpendicular to a line extended along the longitudinal axis (face) of the fish screen. For this location, dye streaks indicated that a trash deflection system should extend 110 feet into the channel to intercept and deflect submerged debris moving downriver. This distance results in an approach angle of 12° between the streamlines and the fish screen's longitudinal axis. The attack angle can be used to determine the distance the deflector should extend into the river for any distance upstream from the screen. For example, if the trash deflector is located 100 feet upstream from the fish structure, the distance into the river would be calculated as (225 feet [structure length] +100 feet) × tan(12°), which equals 69 feet. The trash deflector should be constructed at an angle greater than the attack angle but small enough so material does not accumulate on the structure. The trash deflector should be located far enough upstream so it does not impact the approach flow to the fish screen structure.

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Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.