PAP-750

Areas of Investigation for Positive Barrier Fish Screen Applications

Fish Screen Research Program

FY96
Research Summary

United States Department of the Interior
Bureau of Reclamation
Technical Service Center
Water Resources Research Laboratory

October 1996

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Introduction

The Fish Screen Research Program was initiated in FY96 by the U.S. Bureau of Reclamation (Reclamation), Water Resources Research Laboratory (WRRL) in response to the increasing need for effective fish protection technology throughout the western United States. The purpose of the program is to develop new technology and capabilities for advancing current positive barrier fish screen technology. The scope of the program includes developing tools for small diversion applications (i.e. 5-25 ft^3/s) which can be used by Reclamation managers, various state and federal resource agencies, and the private diverter, for the effective implementation of such technology.

This report summarizes all FY96 efforts by the WRRL associated with the development of positive barrier fish screen technology. Executive summaries for both general (strategic research) and project specific (tactical research) investigations have been include. The approach is programmatic and intended to demonstrate the level of effort by the WRRL in this field. Most of the FY96 investigations were associated with applications along the Sacramento River. However, general results obtained from these investigations have potential for future applications along other river systems in the United States. This being realized, the objective of this document is to bring the results of all FY96 investigations together and to develop general conclusions which may be applied to other areas along the Sacramento River and other river systems in the future. This report has been peer reviewed by Brent Mefford, Technical Specialist, Water Resources Research Laboratory.

General Conclusions

From the FY96 research efforts, some general conclusions have been formulated and are given as follows:

- Flat plate vertical positive barrier screen technology has proven to be superior for river applications subject to large fluctuations in stage and discharge. In this case good hydraulic performance characteristics including screen velocity distributions, high sweeping to normal component velocity ratios, and low approach flow angles of attack have been achieved. These characteristics combined with excellent debris handling capabilities and low fish impingement potential represent significant success in meeting fish protection criteria.

- Hydraulic performance of baffled and unbaffled "V" screen configurations is strongly dependant on approach flow conditions. On-river screening with structures of this type generally will require inlet gated flow control to achieve acceptable performance.

- Computational Fluid Dynamics (CFD) numerical modeling has been successfully applied at the Pelger Mutual Screen Demonstration Site. CFD modeling is an effective tool for evaluating and optimizing screen performance subject to a variety of hydraulic field conditions.

- Recent developments in acoustic doppler velocimetry technology have led to improved laboratory and field evaluation capabilities for positive barrier fish screens. This new technology provides a means of characterizing screen hydraulic performance for ensuring optimum performance in fish protection.

Background

Currently over 2,000 unscreened diversions exist along the Sacramento River alone. Many of these diversions are considered small (i.e. 5 - 25 ft^3/s). However, together this represents a significant portion of the total system export. Under the terms of the Central Valley Projects Improvement Act (CVPIA), the implementation of small diversion screen technology will be required in the near future to protect the diminishing fishery resource. The Fish Screen Research and Technology Development Program has been structured to meet the future needs for improved fish protection technology and its implementation. In doing so, research and project funded investigations have been synthesized in order to identify common aspects and develop the required tools to assist in the implementation of this technology. These investigations include both laboratory and field studies for both general and project specific applications Under this approach, general observations, results, and conclusions taken from each of these investigations may be used to satisfy the program objectives.

Program Description

The focus of the Fish Screen Research Program currently includes:

- The evaluation of current small diversion screen technology for developing implementation guidelines.

- The development of improved field evaluation techniques and instrumentation for ensuring adequate performance after implementation.

- The development of numerical modeling capabilities for optimizing field performance.

The products generated under this program will consist of tools required for the effective implementation of current technology to a broad range of applications throughout the western United States. Based on this direction, specific objectives have been identified.

Program Objectives

The primary objective of this program is the development of tools required for the effective implementation of positive barrier fish screen technology and will be satisfied through specific objectives. The following specific objectives have been established to achieve the primary objective.

- The development of small diversion screen technology specifically applicable under the CVPIA Unscreened Diversions Program along the Sacramento River and Sacramento-San Joaquin Delta.

- The development of guidelines for use by Reclamation managers, resource agencies, and private diverters for the effective implementation of current small diversion, positive barrier fish screen technology.

- The development of improved field evaluation techniques and instrumentation for ensuring effective screen performance after implementation.

- The development of numerical modeling capabilities for the optimization of screen performance after implementation.

With these objectives in place, the WRRL has worked to establish partnerships with various state and federal resource agencies (i.e. California Department of Water Resources, California Department of Fish and game, National Marine Fisheries Service, and U.S. Fish and Wildlife Service). Based on meetings and discussions with these partners, the immediate need has been identified as the evaluation of various small diversion screen concepts which are commercially available. This is intended to be the focus of WRRL efforts in FY97. The specific objective here is to provide performance information and implementation guidelines to the resource agencies. The National Marine Fisheries Service (NMFS) and California Department of Water Resources (DWR) have shown strong support for this approach. This is required to assist them in their efforts to implement small diversion screens along the Sacramento River. In conjunction with these efforts, additional progress has been made at the WRRL toward advancing fish screen technology for other applications under both general and site specific conditions.

FY96 Investigations

In FY96 the WRRL was involved in various efforts associated with positive barrier fish screen technology. These efforts ranged from laboratory and field investigations for specific projects to the development of computer modeling capabilities for the optimization of screen performance for general applications. Although much of this work was funded by specific projects, a portion of these efforts were funded in part by the Fish Screen Research and Technology Development Program (AE CO-98.019). The specific FY96 research and project investigations in this area are described below.

General (Strategic Research) Investigations

Two particular strategic research investigations were conducted in FY96. The first consists of continuing investigations intended to identify the hydraulic characteristics of vertical-angled flat plate screen configurations. The second involves the study of a relatively new screen concept. Both investigations are limited to hydraulic laboratory testing and are listed below.

- *Hydraulic Laboratory Investigations of Vertical-Angled Profile Wire Screens, Joseph Kubitschek.*

- *Hydraulic Testing of Static Self-Cleaning Inclined Screens, Tony Wahl.*

Although neither site specific conditions nor biological considerations were involved in these investigations, the results likely have wide ranging application.

Project (Tactical Research) Investigations
The remainder of investigations in the area of fish screen technology for FY96 consist of project (tactical research) related efforts. These project efforts involved both laboratory and field investigations. Executive summaries of each project related effort have been attached and are listed below.

Laboratory Investigations

- *Hydraulic Model Study of the Proposed Positive Barrier Fish Screen at the Wilkins Slough Pumping Plant, Tracy Vermeyen.*

- *Glen-Colusa Irrigation District (GCID) Positive Barrier Fish Screen Physical Model Investigations, Brent Mefford.*

- *Durango (Animas-LaPlata) Pumping Plant Physical Model Investigations, Tony Wahl.*

Field Investigations

- *Physical Evaluation of the Lakos-Plum Creek Self Cleaning Intake Screens, Tracy Vermeyen.*

- *Red Bluff Research Pumping Plant Fish Screen Hydraulic Field Evaluations, Warren Frizell.*

Appendix A: Executive Summaries of FY96 Positive Barrier Fish Screen Investigations - Strategic Research/Research Funded

EXECUTIVE SUMMARY

Flat Plate Fish Screen Orientation Evaluation

Fish Screen Research Program

by Joseph P. Kubitschek

Water Resources Research Laboratory
Technical Service Center
U.S. Bureau of Reclamation

September 1996

Introduction

The Water Resources Research Laboratory has initiated testing to evaluate the hydraulic characteristics of two different flat plate screen sizes under a variety of orientations with respect to approach flow conditions. Those screens tested are consistent with current size requirements for typical positive barrier fish screen applications. This testing has been incorporated into the Fish Screen Research Program as a means of further developing fish screen technology and improving or optimizing the application of flat plate profile wire screen for fish protection. The hydraulic performance of this type of screen is known to vary with changes in screen orientation. This variation is observed as changes in velocity distribution and head loss characteristics. Consequently, there exists an ideal or optimum screen orientation for which head loss across the screen and velocity distribution skewness along the screen are minimized. Thus, the objectives of these investigations are to:

- Establish screen hydraulic performance characteristics for a full range of screen mesh sizes and orientations with respect to approach flow conditions.

- Establish natural or unbaffled screen velocity distributions for a full range of screen mesh sizes and orientations with respect to approach flow conditions.

- Determine optimum screen orientation for each screen mesh size with respect to approach flow conditions, by establishing head loss and velocity distribution characteristics.

Two commonly used profile wire screen sizes are currently being evaluated. The first is a 3/32-in profile wire screen with approximately 50% open area. The second is a 5/32-in profile wire screen with approximately 36.6% open area. Both screens will be tested over a range of orientations with respect to approach flow conditions which consist of 3, 5, 7.5, 10, and 15 degrees. The test facility has been constructed at the WRRL in Denver, CO using the 3-ft tilting flume. Figure 1 is a schematic of the test facility as constructed in the laboratory. To date, testing has been completed to determine the head loss characteristics of the 3/32-in screen for orientations of 10 and 15 degrees. The results have been presented in dimensionless form as head loss coefficient (k) verses Reynolds number (Re) for both screen orientations tested. Figure 3 is a plot of this relationship. The results indicate that head loss increases with decreasing orientation angle with respect to flow direction approaching the screen. That is, as the angle of attack is decreased, head loss across the screen increases. These results may be used for further understanding of the hydraulic characteristics of profile wire screens under various orientations and approach flow conditions. Furthermore, this information may be used in the determination of the most efficient or optimum screen design with respect to energy loss and velocity distribution characteristics. Testing will continue under the Fish Screen Research Program into FY97 and is scheduled for completion by December 1996. The above objectives are intended to be fully satisfied by that time.

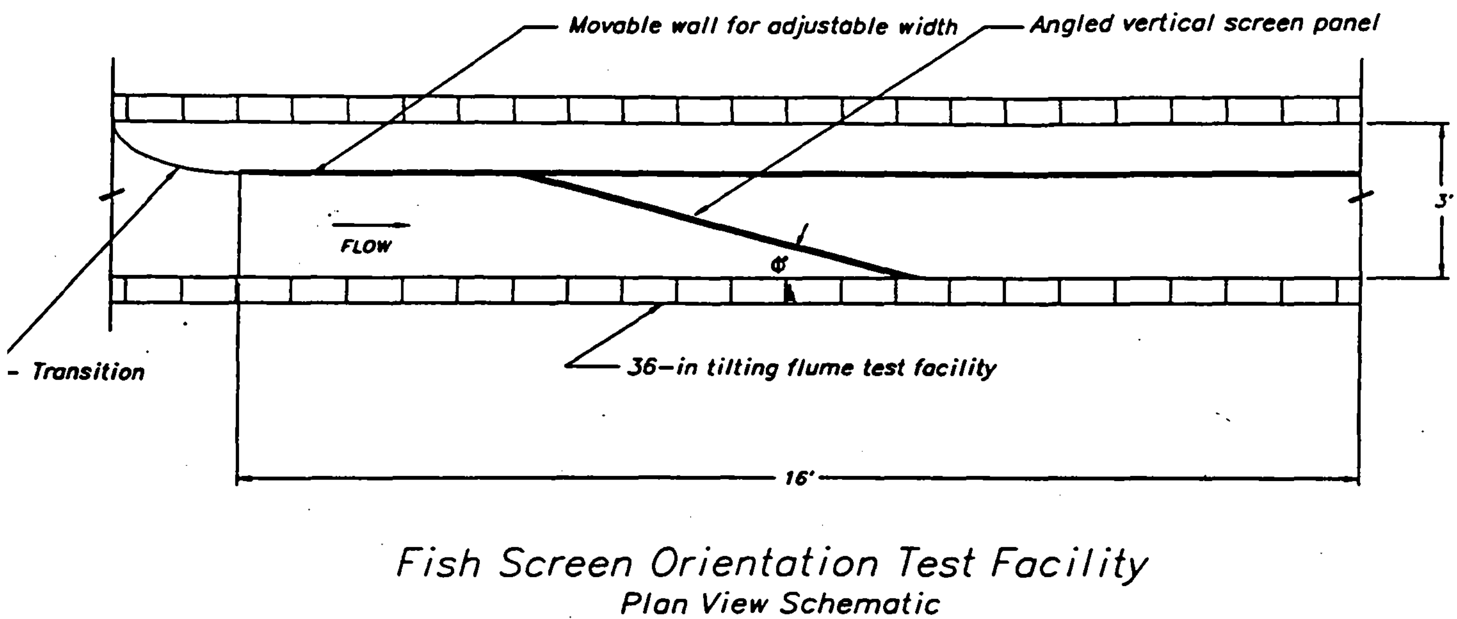


Figure 1 - Schematic of laboratory test setup.

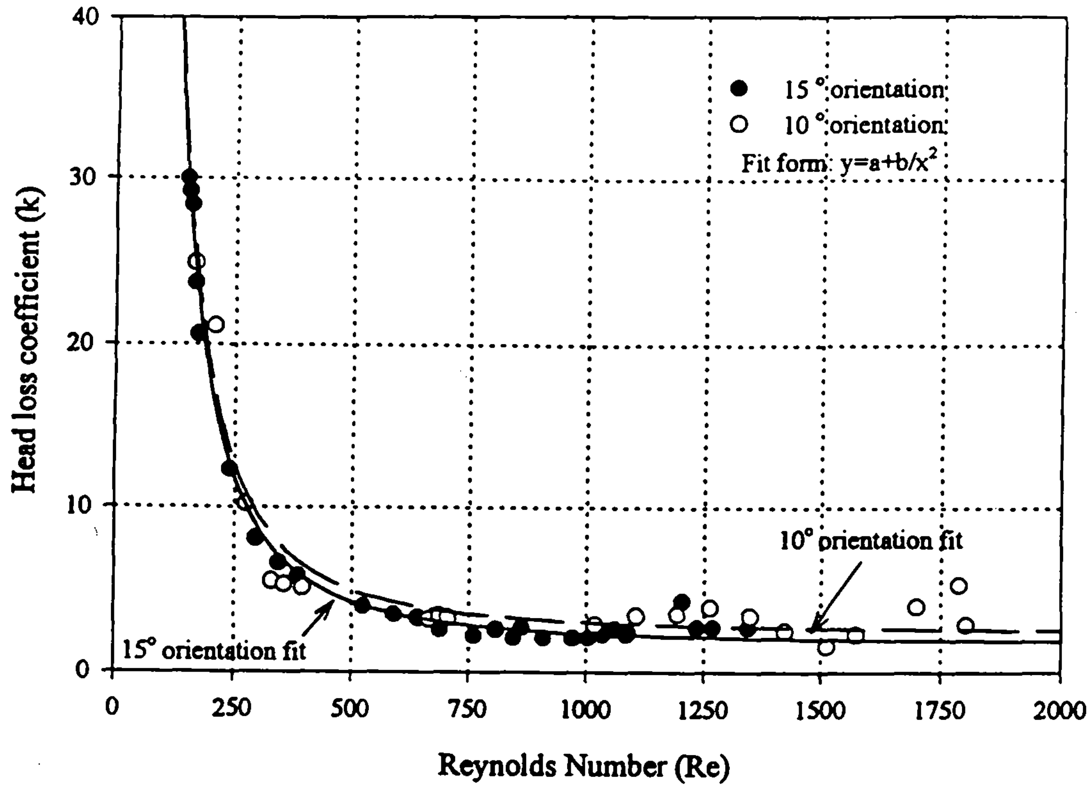


Figure 3 - Hydraulic characteristics of 3/32-in profile wire screen for orientations of 10° and 15° with respect to approach flow. Data is presented in dimensionless form as head loss coefficient (k) verses Reynolds Number (Re).

Conclusions

Although testing has not been completed, the following preliminary conclusions are based on those results obtained to date.

- Screen orientation with respect to approach flow direction and velocity has a significant influence on the hydraulic performance characteristics of vertical, flat plate profile wire screens.

- Preliminary data results indicate that head loss increases with decreasing approach flow angles of attack.

Hydraulic Testing of Static Inclined Self-Cleaning Screens

Executive Summary

Tony L. Wahl

There is a growing need on Bureau of Reclamation projects to screen water for very fine debris and small aquatic organisms. Unfortunately, as screen openings are reduced, maintenance effort required to keep screens clean is increased. One screen design that offers potential for screening fine debris with minimum maintenance is the static inclined screen (fig. 1).

The static inclined screen consists of a concave wedge-wire screen installed in the downstream face of an overflow weir. Flow accelerates down the face of the weir and across the screen. Clean water drops through the screen while debris is discharged off the downstream end of the screen. A small bypass flow ensures that debris is carried off the screen. The nature of the flow across the screen face makes the screen largely self-cleaning. This screen has been successfully used for debris and fish exclusion at several prototype sites (Ott et al., 1987), but there is little detailed design information available. Installations similar to those tested here have been reported to have screening capacities of 0.09-0.14 $m^3/s/m$ (1.0-1.5 $ft^3/s/ft$).

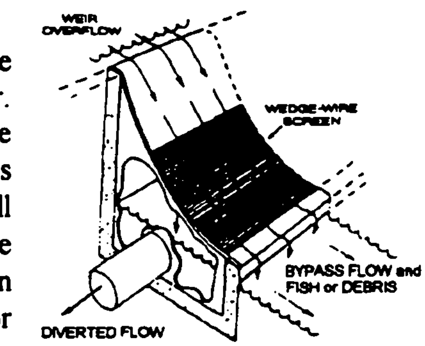


Figure 1. — Typical static inclined screen installation.

To develop design data for possible Reclamation use of static inclined screens, several screen configurations were tested in Reclamation's hydraulics laboratory. Objectives of the testing were to establish the flow capacity of a typical configuration and to qualitatively assess the tendency of the screens to clog with debris. The screens were tested in an overflow weir configuration with potential for fish exclusion and fine debris removal applications at water intakes and diversion structures. Similar screens are used in the mining industry, primarily in coal-handling applications, and in the wastewater industry.

The testing showed that the static inclined screen has an extraordinarily high flow capacity, considering its ability to screen very fine debris. The high capacity is due primarily to a tilted-wire construction in which each wire is tilted so that its upstream edge is offset into the flow. A thin layer of the flow is sheared off the bottom of the water column and directed through the screen. This shearing action depends to some degree on a phenomenon known as the Coanda effect. Past literature concerning these screens has attributed their high capacity to the Coanda effect, with little further explanation. Reclamation's testing program identified the mechanism by which the Coanda effect increases the screen capacity.

The Coanda Effect

The Coanda effect is familiar to most hydraulicians, although perhaps not by name. The effect was first observed in 1910 by Henri-Marie Coanda, in connection with exhaust flow from an experimental jet engine (Stine, 1989). The Coanda effect is the tendency of a fluid jet to remain attached to a solid boundary. When a jet is discharged along a solid boundary, flow entrainment into the jet is inhibited on the surface side. For the jet to separate from the surface there must be flow entrainment into the jet on the surface side beginning at the separation point. However, the close proximity of the surface limits the supply of flow to feed such entrainment. Thus, the jet tends to remain attached to the surface. If the surface deviates sharply away from the jet, separation will occur, but if the surface curves gradually away, the flow may remain attached for long distances. Primary applications of the Coanda effect have been in aeronautics; wings and engines using the effect have achieved increased lift and thrust. Reba (1966) describes experimental work on propulsion systems using the Coanda effect, including hydrofoils, jet engines, and a levitating vehicle. The Coanda effect has also been used in the design of improved nozzles for combustion applications.

Figure 2 shows the flow over a flat-wire screen and over a tilted-wire screen as it would occur with and without the Coanda effect. The flow is shown as it would appear near the top of the screen, where the flow direction has been established by the ogee crest. Without the Coanda effect, the flow separates off the high point of each wire and skips to the next wire, with essentially no flow being sheared off. Gravity, pressure forces and the curvature of the screen panel will force a small amount of flow through the screen, and as the flow continues down the screen the flow field will begin to deviate toward the screen. Once this deviation matches the tilt angle of the wires, the flow will be similar to that shown at the right of figure 2.

The Coanda effect causes the flow to remain attached to the screening surface of each wire, directing the flow into the offset created at the next downstream wire. A thin layer of the flow is sheared off by the next wire, which is offset into the flow due to the tilted-wire construction. The incremental discharge through the screen at any wire is a function of the flow velocity and the thickness of the sheared water layer. The elevation drop from the crest to the screen produces high velocity flow over and through the screen. Since the Coanda effect keeps the flow in contact with the screening surface of each wire, even near the top of the screen, it helps produce high capacity flow over the full length of the screen. The significance of this benefit is uncertain.

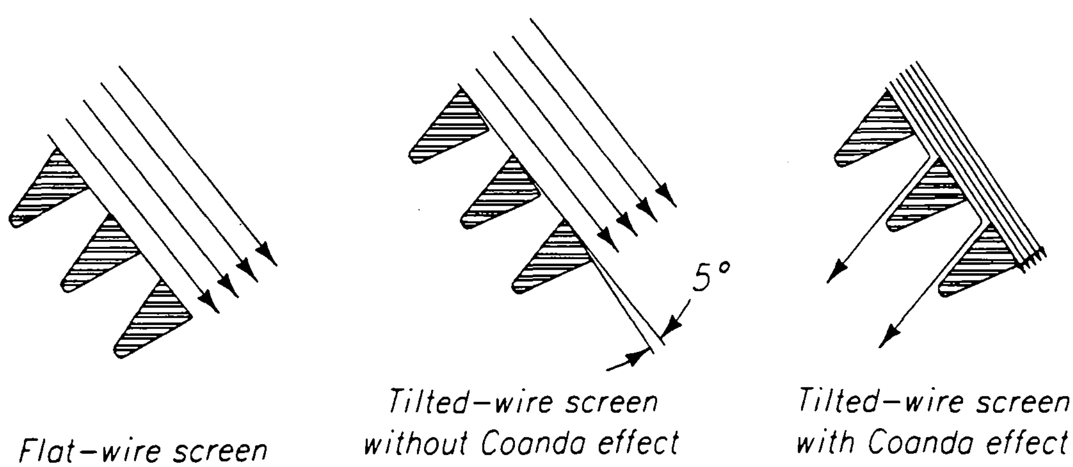


Figure 2. — Flow over tilted and non-tilted wedge wire screens.

Results

Figure 3 shows the results of tests on one screen configuration of varying lengths. At low discharges all of the flow is through the screen, and the figure shows the length of screen required to handle a given flowrate. For higher flows the figure shows the percentage of bypass flow off the bottom of the screen. These data can be used to design screen installations for Reclamation projects.

Figure 4 shows the screening capacities expressed in terms of the flow per unit screen area, and offers a model for predicting the screen flow capacity as a function of the specific energy input to the screen. Such a prediction equation could be applicable to a broad class of static inclined screen designs. The figure also shows that within the range of conditions tested, the discharge per unit area through screen A is a linear function of the input energy, even across several lengths of tested screens. This indicates that the Coanda effect is influencing the flow through the screen. If the Coanda effect were not a factor, the upstream portion of each screen would be less efficient, and there would be a significant reduction in the screened flow per unit area when the lower portions of the screen were covered.

Testing with debris showed that all screen configurations were resistant to clogging. Generating turbulence in the flow near the crest seemed to accelerate the self-cleaning process; a paddle wheel or other device that generates turbulence at the crest might prove beneficial.

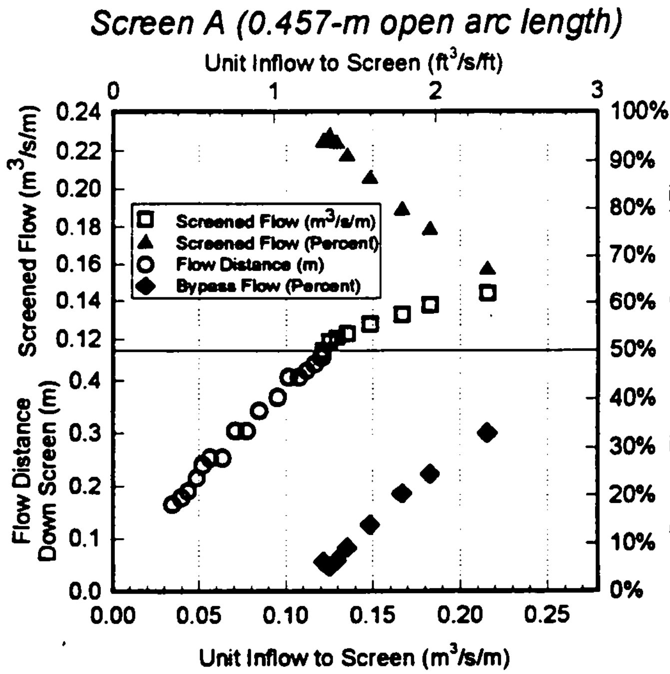


Figure 3. — Results of hydraulic capacity tests for screen A.

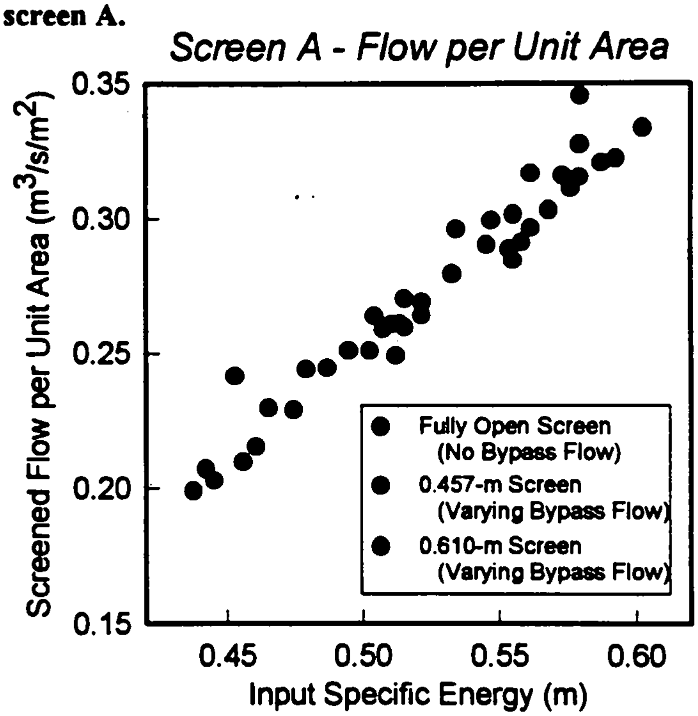
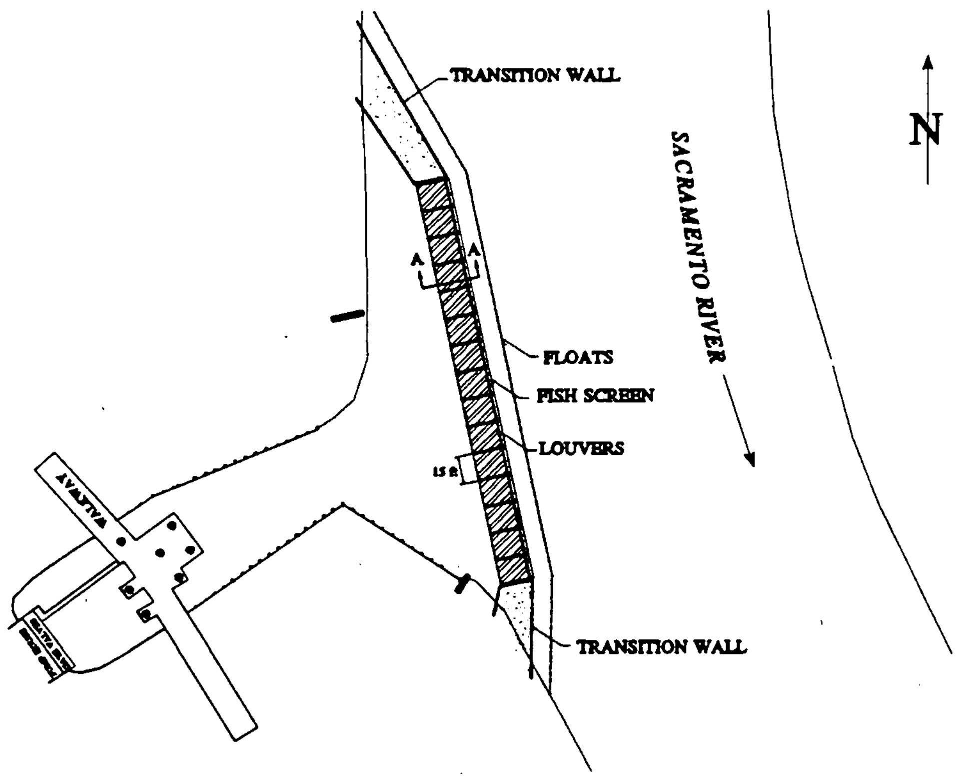


Figure 4. — Capacity of screen A as a function of input specific energy.

Appendix B: Executive Summaries of FY96 Positive Barrier Fish Screen Investigations - Tactical Research/Project Funded

Hydraulic Model Study of the Proposed Postitive Barrier Fish Screen at the Wilkins Slough Pumping Plant, California



Prepared for Reclamation District No. 108

By Tracy Vermeyen, P.E.

August 1996

EXECUTIVE SUMMARY

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 National Marine Fisheries Service and the California Department of Fish and Game.

INTRODUCTION

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.

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 the Bureau of Reclamation have entered into an agreement to assist Reclamation District No. 108 to develop a positive barrier fish screen at the Wilkins Slough Pumping Plant. The Water Resources Research Laboratory was asked by Reclamation's Mid-Pacific Regional Office to conduct a hydraulic model study to evaluate the preliminary positive barrier fish screen design.

Since 1993, the District has been testing electrical and acoustic fish guidance systems at Wilkins Slough pumping plant. The fish guidance systems were designed to keep juvenile Chinook salmon from being pumped out of the river. Preliminary test results of 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 to develop an alternative to electrical and acoustic fish guidance systems. If future tests show the electrical barriers (acoustic barriers 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.

Reclamation District No. 108, established in 1870, owns and operates an irrigation district encompassing approximately 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 west bank of the 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 are pumped each year from the Sacramento River under a water rights contract with the U.S. Bureau of Reclamation. About 120 miles of irrigation canals are used to convey the water to District farms.

THE MODEL

The physical model was constructed in a sealed box with dimensions of 44 ft long, 28 ft wide, and 4 ft deep. The model features include the Wilkins Slough positive barrier fish screen structure and approximately 800 ft of Sacramento River channel (fig. 2). 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. The site survey of river channel topography and the pumping plant forebay and structure were provided by Laugenour and Meikle Engineers.

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. The maximum river flow modeled was 17,500 ft^3/s at a river stage of 40 ft, and the maximum diversion flow was 700 ft^3/s.

The prototype fish screen dimensions are 225 ft long and 10 ft high (2250 ft^2), which was modeled using a 11.25-ft-long and 6-in-high fish screen. The structure consists of 15 screen bays that are 15 ft wide. Each screen bay was 9 inches wide and was backed by a louver system. The louvers are design to control the approach velocities. There were nine louvers per screen bay and each louver was 0.9 inches wide (1.5 ft prototype). The screen material used in the model was a stainless steel square mesh wire cloth (6 mesh) with a 1/8-in opening width, 18 gauge wire, and an open area of 52 percent. The prototype screen was specified as a stainless steel square wire cloth (5 mesh) with a 5/32-in opening width, 17 gauge wire, and an open area of 53 percent. For accurate modeling, it is important to use screen material with similar percent open area or porosity. Details of the screen design are shown in figure 3.

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

CONCLUSIONS

- The final screen design met the velocity criteria required by National Marine Fisheries Service and Cal Fish & Game 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 15) required a louver setting of 50 degrees (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, the percent opening value should be used for prototype settings.

- While the final screen design performed well with only fourteen screen bays (bay 1 was blocked), the fifteenth 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.

- A hydraulically smooth transition wall is required to introduce the river flow parallel to the fish screen. At least 45 ft of straight wall should extend upstream of the first screen bay (bay 1). The transition wall must be extended along the longitudinal axis of the fish screen.

- An elliptical transition from the 45-ft-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.

- For the flow conditions tested, screen louvers are necessary for screen bay 15. However, louvers may be required at other bays for flow conditions not tested or if as-built conditions or sedimentation changes the screen hydraulics. Model tests indicated that the screen bays most likely to require louvering are on the upstream and downstream end of the structure.

- 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 base of the upstream transition wall which indicates a potential for scour. The design of this transition wall should include scour protection.

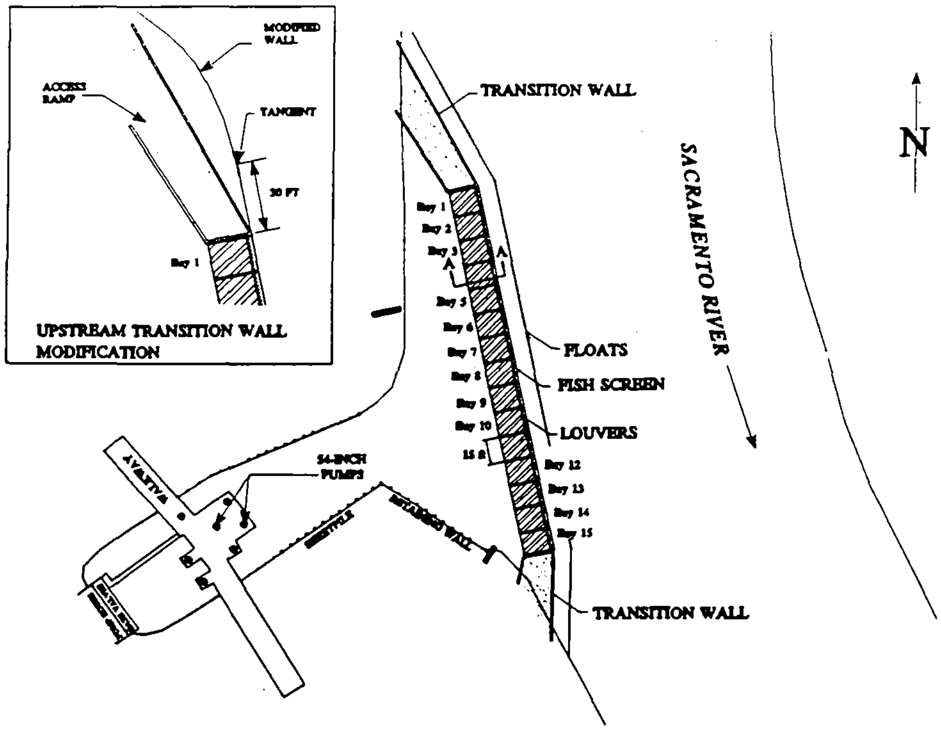


Figure 1. Plan view of the Wilkins Slough positive barrier fish screen as designed by Laugenour and Meikle Civil Engineers. A modification to the upstream transition wall is shown in the upper left corner of the figure.

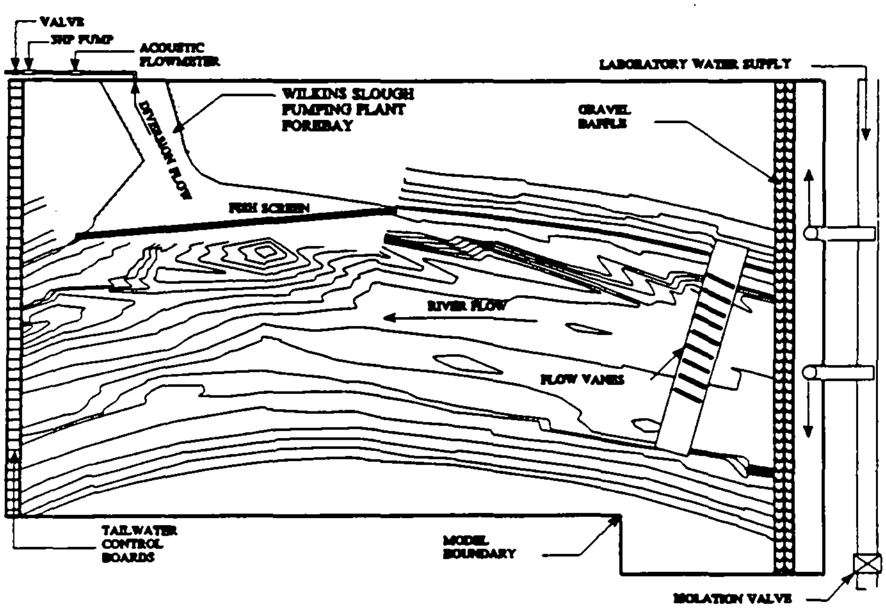


Figure 2 - Plan view of the Wilkins Slough positive barrier fish screen hydraulic model. The model was constructed at a 1:20 scale in a 44-ft-long by 28-ft-wide by 4-ft-deep watertight box.

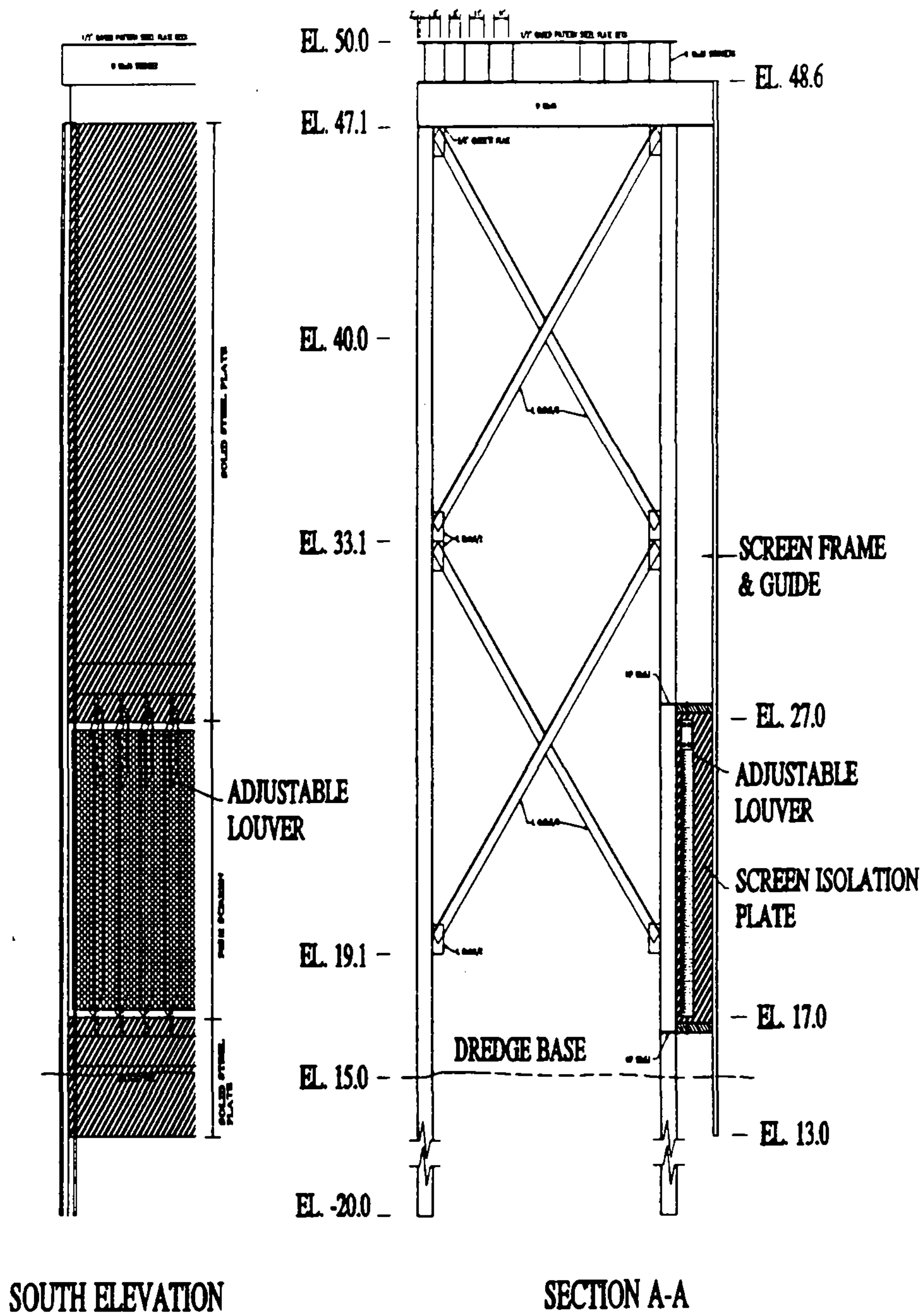


Figure 3 - Laugenour and Meikle's design drawings of the south elevation and section A-A (from figure 1) for the Wilkins Slough positive barrier fish screen.

GLENN COLUSA IRRIGATION DISTRICT FISH SCREEN CONCEPT STUDY
EXECUTIVE SUMMARY

Brent W. Mefford

INTRODUCTION

The Glenn-Colusa Irrigation District Pumping Plant is located in north-central California, approximately 100 miles north of Sacramento, on an oxbow of the Sacramento River. The pumping plant exports water from the Sacramento River to the west side of the Sacramento River Valley for irrigation purposes.

In 1972, a rotary drum screen facility was constructed to provide fish protection from pumping plant entrainment. The facility originally consisted of 40 drum screens 8-ft wide and 17-ft in diameter. In 1970 the Sacramento River experienced the largest flooding since the construction of Shasta Dam. The result was a meander cutoff downstream of Montgomery Island which caused a decrease in river length of almost 1-1/2 miles. The implications of this meander cutoff have been a drop in water surface elevations of approximately 3 ft at the north end of Montgomery Island. These changes occurred over several years as the river stabilized. Lower water surface elevations resulted in lower than desired water depths in front of the drum screens. As a result, through-screen velocities exceeded resource agency fish screening criteria during high diversions. In 1991 the National Marine Fisheries Service (NMFS) filed an injunction against the irrigation district to restrict pumping during the peak winter-run Chinook salmon downstream migration period.

An aggressive program was initiated by the district in conjunction with resource agencies to identify options for both short- and long-term resolutions of the screening problem. To improve interim screen performance, flat panel wedge wire screens were placed in front of the drum screens in 1993. In 1995 the drum screens were removed from service.

Pursuit of a long-term solution has generated a number of screening alternatives which have, in turn, been subjected to detailed evaluation. In 1994, HDR Engineering, Inc. prepared a draft feasibility report which reviewed eight alternatives for replacement or modification of the existing screen facilities. Since then, these alternatives have been reduced to two. The two remaining alternatives, labeled "A" and "D" are shown as figures 1 and 2, respectively. Both of these alternatives contain design and operation aspects that reach beyond available precedents of fish screening technology.

MULTIPLE "V" SCREEN CONCEPT[1]

The Alternative A fish screen concept consists of a four-bay-multiple-V structure with bypass and evaluation facilities. There are four V-shaped screen bays with a total screen length of 912 feet. The length of screen each side of a "V" is 114 feet. The invert of the screens is set at elevation 125 which is approximately 3 feet below the dredged intake channel invert. The top of the deck is set at El. 160.0 which is approximately 1.5 feet above the previous known high water mark but 1.0 foot lower than the anticipated 100-year flood event water surface elevation. The minimum water depth at the screens would be 10 feet for the river design flow of 7,000 ft^3/s upstream from the oxbow and 3,256 ft^3/s into the oxbow. The top of the fish screens is at El. 137.0. A false wall (metal plate) extends from the top of the fish screens to the operating decks. Baffles are located behind the fish screens to provide for flow adjustment to achieve a uniform flow distribution through the screens. A fish bypass bay is located at the apex of each V screen bay.

The weir wall adjacent to the fish screen structure prevents flow from passing down the lower oxbow channel during non-flood flow conditions and serves to guide flow into the fish screen structure. The weir wall is designed with a top elevation of 139.0. The weir contains three gates, a 35-feet wide river flood gate located near the weir's upstream end, a sediment sluice gate and a trash sluice gate located next to the screen structure. The trash gate and sluice gate are only operated when needed to sluice material. The river flood gate is opened to pass a minimum of 500 ft^3/s flow when the river stage exceeds the top of the weir wall, elevation 139.0. When the river flood gate is closed no flow is passed down the lower oxbow channel.

The oxbow channel provides insufficient head to drive closed fish bypasses. Therefore, bypass flow must be pumped requiring large diameter fish friendly pumps such as being tested at Reclamation's Red Bluff Research Pumping Plant. The bypass pipes terminate in the river thalweg near the downstream end of the oxbow channel.

OBJECTIVES OF THE "V" SCREEN MODEL STUDIES

The objectives of the river model study were to evaluate and determine the best site, structure orientation and screen structure design for a "V" screen alternative based on approach flow conditions and screen flow performance. The major flow performance objectives for the study were:

- The approach channel should provide a nearly uniform distribution of flow into the screen bay entrances for all flows.

- For all flow conditions, the normal velocity to the screen face measured 3 inches in front of the screen should not exceed 0.33 ft/s.

[1] Physical model studies of the GCID pumping plant fish screening alternatives, Alternative A - multiple bay "V" screens, Draft report, August 1996.

- The flow velocity component parallel to the screen face, termed sweeping velocity, should be twice the normal component. A design objective of 2 ft/s minimum sweeping velocity was chosen.

- The screen exposure time should not exceed 60 seconds.

- The upper oxbow channel, screen forebay, and screen bays should be designed to minimize or eliminate areas of reverse flow or slack water. These conditions should be achieved for all pumping flows up to 3,000 ft^3/s. Between one and four bays may be operated to accommodated GCID canal flow diversion.

- The structure must allow for upstream migrants to move through the oxbow when flood flows are passed down the lower oxbow channel. This would occur when the river stage at the screen structure exceeds elevation 139.0.

Of the screen performance objectives two stand out as unique for a "V" style screen. First, "V" screens were developed for canal applications where a long straight approach and small water surface fluctuations are the norm. At GCID, the structure must be placed on a river bend and operate over a wide range of river stage. Second, GCID diversions also vary considerably. Therefore, individual screen bays must be closed during low diversions if screen exposure criteria is to be met. Closing individual screen bays fosters the problem of maintaining good approach conditions to the screen structure. Closing bays cannot result in slack water areas as these are likely havens for predator fish.

MULTIPLE "V" SCREEN DESIGN - MODEL STUDY CONCLUSIONS

The results of these investigations demonstrate that the A-alternative must be properly aligned relative to the oxbow channel and pumping plant to achieve desirable flow conditions. The study results show the multiple bay "V" screen concept is very sensitive to approach flow conditions. A brief summary of screen performance for the A-alternative screen configuration is given below.

- Approach flow conditions - Two orientations of the screen structure to the approach channel were model tested. Initially, the screen structure was aligned with the approach channel to maximize the straight length of approach to the structure, figure 1. Test data for this configuration shows good uniformity of flow approaching and along the screens for four bay operation. However, closing bays during reduced pumping resulted in large slack water areas forming in front of the closed bays and increased non-uniformity of screen approach flow.

The screen structure was then moved downstream and rotated slightly to position the screen structure entrance just upstream of and at a 4° angle to the existing screen structure. The alignment of the screen bay entrances was set to enhance continuous sweeping flow along the entrance to the screen structure. Flow approaches the structure parallel to the screen bay entrances then turns about 30° as it enters the screen structure. This configuration showed greatly improved approach flow conditions when one or more bays were closed. Starting with the upstream most bay, bays could be closed without adversely effecting the approach flow. However, turning the flow approximately 30° as it entered the screen structure resulted in added non-uniformity of screen approach velocities.

- Normal approach velocity to the screens - The screen structure is sized to meet 0.33 ft/s screen approach flow velocity (velocity component measured normal to the screen) at peak pumping. However, both alignments of the screen structure tested showed considerable skewness of flow distribution on the screens for unbaffled conditions. Non-uniformity of screen approach velocities were found to occur both along the screen and across screen bays.

Increases in normal screen velocity from the head of the screen bay to the "V" apex or fish bypass entrance are typical of "V" shaped screen bays. This trend was evident for all configurations tested and varied in magnitude with operation. In addition to streamwise variations, screen approach velocity also varied across screen bays for all conditions where the flow made a significant turn at the entrance to the screen structure. Screen approach velocities were typically highest on the downstream side of each screen bay referenced to the screen bay centerline. Flow passing through the downstream side of the "V" bays follows the outside of the turn into the structure and the inside of the turn when exiting the structure and approaching for the pumping plant. Both turning the flow into the screen structure and the screen structure downstream alignment with the pumping plant likely influence the across bay skewness in the approach velocity distribution. Attempts to improve the velocity distribution by extending the straight length of the screen structure by 120 ft and aligning the screens with the pumping plant provided little improvement. Across bay approach velocity differences were evident for all conditions tested. The test results indicate a greater length of straight approach to the screens and/or full baffling of the screen bays is needed to achieve the targeted magnitude and uniformity of screen approach velocity. Screen baffling was not tested in this study.

FLAT PANEL SCREEN CONCEPT[2]

Screen alternative D, figure 2, consists of modifying the existing screen facilities by increasing the length of the flat panel screen structure. The proposed screen is about 1,000 ft long, extending approximately 500 ft upstream of the existing structure. The concept was initially tested without fish bypasses within the screen structure. Only an open-channel terminal fish bypass wit a minimum flow of 500 ft^3/s was included.

The following major objectives were identified for the D alternative screen concept development:

- The approach channel shall provide a nearly linear distribution of flow to the screen face.

- For all flow conditions, the normal velocity to the screen face measured 3 inches in front of the screen shall not exceed 0.33 ft/s. This is a State of California fish screening requirement.

- The flow velocity component parallel to the screen face, termed sweeping velocity, must be twice the normal component. This is also a State specified design criteria. However for the D alternative with no fish bypasses, high sweeping velocities are desirable for the long flat plate screen design. A minimum sweeping velocity of 2 ft/s was targeted.

- The terminal open channel bypass should provide a minimum of about 500 ft^3/s of flow at an average velocity of 2 ft/s.

- The oxbow channel, bypass channel, and screen facility should be designed to minimize or eliminate areas of reverse flow or slack water. These areas are considered predator habitat.

- The structure must allow for upstream migrants to move through the oxbow should they enter the bypass channel.

Not present in the objectives for the 1:30 model are evaluation of: operating criteria, intermediate screen bypasses, and screen baffling. These topics are being addressed using a larger scale (1:16) model of the screen structure.

National Marine Fisheries screen criteria specify intermediate fish bypasses should be used to limit time of screen exposure to ≤ 60 seconds. The passage time in front of the D-alternative screen, assuming a sweeping velocity of 2 ft/s, is about 500 seconds. Hydraulic data obtained

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[2] Physical model studies of the GCID pumping plant fish screen structure alternatives, Alternative D - Flat panel screen, Draft Report, December 1995.

from the models will be used to assess the need for, or spacing of, intermediate bypasses.

FLAT PANEL SCREEN - MODEL STUDY CONCLUSIONS

The flat panel screen concept is unique in it's size and fish bypass concept when compared to other screens built to date. There was considerable uncertainly as to if a 1000 ft long screen could be designed as a river bank screen and achieve the desired screen through-flow uniformity and high sweeping flow conditions .

- Approach flow conditions - A good distribution of flow along the entire screen face was achieved by adding an opposite bank guide wall and two 4° breaks in the screen alignment. The 4° breaks were used to conform the long screen to the natural bend of the oxbow channel.

- Screen approach velocity - Flow distribution problems resulting from the curvature of the channel approaching the screening site were corrected by constructing an opposite bank guide wall and adding shallow 4° breaks in the screen alignment. The design resulted in good uniformity of screen approach velocity along the length of the screen However, we did find that unusual conditions occur when river flows are significantly greater than diversion flows. During high river or low pumping conditions, excess flow passes through the upstream end of the screen and reverse flow passes out the downstream end. This condition occurs because the strength of the sink, being the pumping plant, is small compared to the strength or momentum of the approaching flow. From the view point of fish protection, reverse flow out the downstream end of the screen does not present a particular concern if inflow screen criteria is achieved.

- Screen sweeping velocity - Sweeping velocity in front of the screen exceeds twice the approach velocity for all conditions. Depending on river and pumping combinations, sweeping velocities range from about 0.75 ft/s to over 3.0 ft/s. Low pumping and low river conditions yield the lowest sweeping velocities. Sweeping velocities of between 1.5 and 2.0 ft/s were achieved for most flow combinations.

- Bypass flow - For the 1991 river conditions, the 500 ft^3/s bypass flow objective requires a trapezoidal channel (2:1 side slopes) with a bottom width of 14 ft at an invert elevation of 127.0. For this channel, bypass flows in excess of 500 ft^3/s can be attained when pumping 3,000 ft^3/s for north gauge river elevations higher than about 136.5. At lower river elevations the target bypass flow can be achieved under reduced pumping.

- Predator habitat - Transitions upstream and downstream of the screen structure were added to the design to eliminate reverse flow and slack water zones. Under weak pumping conditions or high river conditions, reverse flow conditions do occur near the downstream end of the screen. This condition occurs when flow in excess of pumping demand moves through the upstream portion of the screen. However, this condition does not create likely predator habitat. Flow exiting the screen merges smoothly with flow entering the bypass channel.

• Fish passage - The open channel bypass design allows for free upstream and downstream movement of fish.

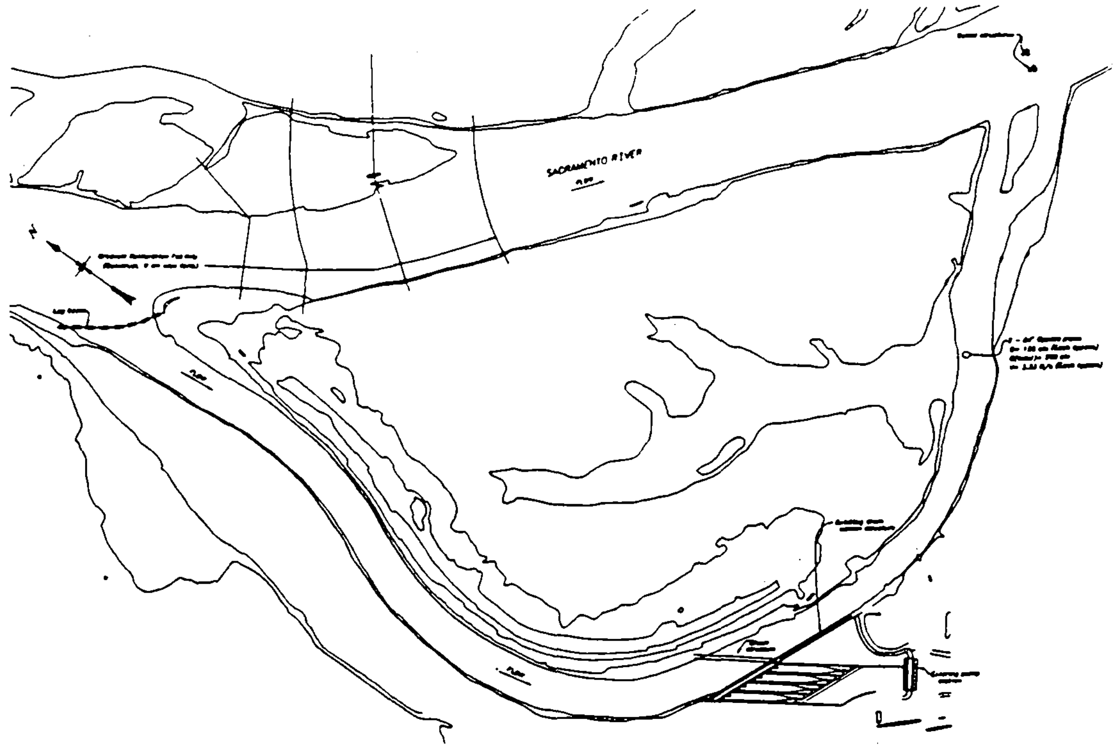


Figure 1. Conceptual layout: Plan view of the proposed A alternative multiple "V" fish screen structure.

Figure 2. Conceptual layout. Plan view of the proposed D alternative flat panel fish screen structure.

Executive Summary

Durango Pumping Plant Model Studies - FY96

by Tony L. Wahl

Physical hydraulic model studies to support the design of Durango Pumping Plant were conducted in FY96 (October 1995-September 1996) by Reclamation's Water Resources Research Laboratory (WRRL) in Denver. These studies complemented previous model tests conducted on an earlier design in 1994. The pumping plant and fish screening structure design was revised during FY95 to accommodate an increased maximum pumping rate (raised from 550 to 670 ft3/s) and a modified pumping arrangement, using four large spiral case-type pumps to deliver the majority of the flow. The present screen structure design is intended to screen juvenile trout with a length of 2 inches or greater. The screens are designed to maintain a 0.5 ft/s average velocity component normal to the screen face. The major issues considered in the study were:

- Velocity fields approaching the fish screens
- Intake structure flow capacity
- Sump and pump intake flow conditions
- Velocity fields in the river approaching the intake structure

Principal conclusions of the study related to the fish screening structure are as follows:

- A single turning vane should be installed in the forebay to the left-hand fish screen structure. This vane is needed to maintain adequate sweeping velocity on the upstream end of the left-hand screen panel in the left-hand V-screen bay.
- The inflatable weir gates in the riverside intake structure must be used to equalize flows through the six bays of the intake structure during periods of high river flow (above about 1500 ft^3/s). If the gates are not used to balance the inflow, there will be an unequal distribution of flows through the two fish screen structures (more flow through the left structure), which causes screen through-velocity criteria to be exceeded in the left screen structure.
- With the addition of the turning vane and proper operation of the intake weir gates, the screen structures can meet the approach velocity requirements for this application for all flow conditions up to the maximum pumping rate. Although through-velocities tend to increase toward the downstream ends of the screens, it does not appear that additional screen baffling is necessary.
- For a given pumping rate, fish screen approach flow conditions were insensitive to changes in the downstream sump geometry and alternative combinations of pump operations (e.g., pumps closest to screen operating vs. pumps farthest from screens operating).

Background and Scope of Hydraulic Model Studies

A 1:12 scale model of the pumping plant was constructed in the laboratory. The model included the riverside intake structure, the fish screening facilities, and the main pumping plant sump. The fish screens are a pair of V-style screen structures that will separate fish from the flow to be pumped, and return them to the river through a gravity-driven bypass system. Figures 1 and 2 show plan and elevation views of the fish screen structures. The prototype screens will be 3/16" clear-spacing wedge-wire panels oriented so that the wires run horizontally down the length of the screen. An automated cleaning system will be supplied, but was not included in the hydraulic model. This screen structure design is a dramatic modification from the fish screen design tested in the first series of model studies. That design used a flat-plate screen running the full length of the pumping plant. The new configuration was necessitated by the concentration of the majority of the plant discharge capacity in the four spiral case pumps which are located in one end of the pumping plant.

Fish screen approach velocity fields were measured for a range of river flows and pumping conditions, with the greatest focus placed on maximum and median pumping rates for given river levels. Tests were also conducted to identify the influence of different pump operating combinations and intake structure gate operations. Sweeping- and through-velocities were measured using a 2-D acoustic doppler velocimeter deployed on a traversing table. Measurements could be made at three different elevations on the most upstream 86% of the screen area. Velocities could not be measured on the most downstream 6 ft of each 42-ft long screen panel due to limited access space for the probe in the 1:12 scale model.

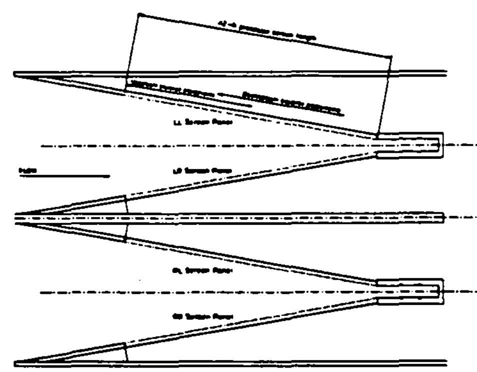


Figure 1. — Plan view of fish screening structures, showing the location of traversing table placements used for the measurement of screen approach velocity fields.

Velocity Measurements

Measurements of the velocity fields approaching the fish screens were made with a SonTek acoustic doppler velocimeter (ADV probe), shown in place on the fish screen structure in figure 3. The probe measures the two horizontal components of velocity at

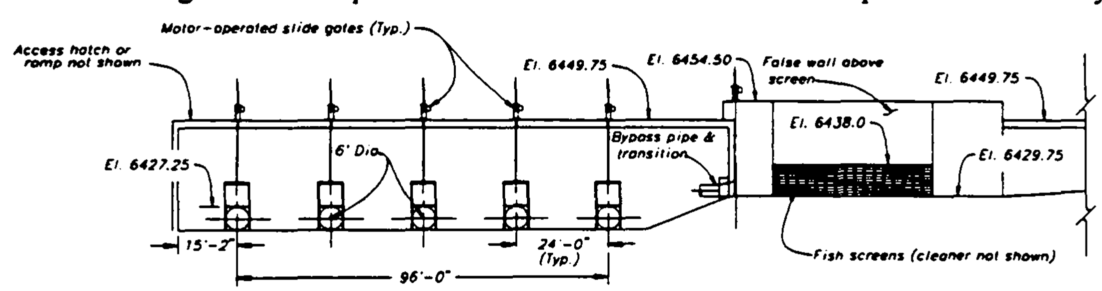


Figure 2. — Elevation view of initial design for fish screen structures and main sump.

user-selected rates ranging from 0.1 Hz to 100 Hz (a three-dimensional probe is also available). The probe uses an ultrasonic signal to measure the velocity of acoustic scatterers in the flow (e.g., suspended sediment, microscale air bubbles, etc.), in a small (approximately 6×6 mm cylinder) sampling volume located about 5 cm (2 inches) away from the probe. The probe also records the signal-to-noise ratio and a correlation score ranging from 0 to 100 for each measurement. The probe manufacturer recommends discarding measurements with a correlation score less than 70. This was accomplished using a Windows-based computer program developed by the author for this project and for other applications of this probe in the hydraulics laboratory.

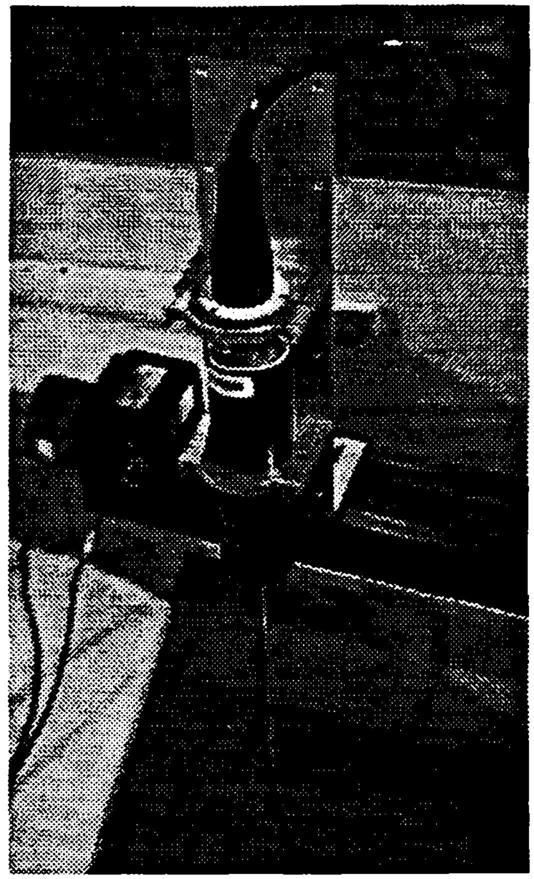


Figure 3. — SonTek acoustic doppler velocimeter installed in the model for measurement of fish screen approach-velocity fields. The probe is mounted on a computer-controlled traversing table.

Most measurements were made at a data collection rate of 4 Hz. The probe was mounted on a traversing table with a 21-inch travel, that was operated at a velocity of 0.050 ft/s. Two passes of the probe were made on each measurement, so that the probe stopped at its original starting position. The computer program mentioned previously computed the probe position corresponding to each measurement and produced output files that could be used for plotting. The program also computed summary statistics for each complete traverse, including mean velocities and turbulence parameters.

Velocities approaching the fish screens were measured using eight different placements of the traversing table, four placements for each of the two V-screen structures. The probe was positioned so that the sampling volume would be located about 0.25 inches from the screen face, equivalent to a prototype distance of 3 inches. Two traversing table placements were used for each of the four 42-inch long model screen panels. The upstream placement spanned the distance from the upstream edge of the screen to the midpoint of the screen, while the downstream placement spanned the distance from a point 15 inches downstream of the start of the screen to a point 6 inches from the downstream end of the screen. The prototype fish screen panels are 8.25 ft high and located with their base at elevation 6429.75. Velocity measurements could be made in the model at three elevations, 6431.0, 6434.0, and 6437.0. However, for the majority of the tests, only the 6434.0 elevation was used.

Figures on the following pages illustrate the types of data collected. Each figure shows the through-component and sweeping-component of approach velocity as a function of the position along the screen. The figures are presented as they would appear to an observer looking downstream into the fish screen structures. Although there is a great deal of scatter in many of the plots, the 95% confidence interval lines for the linear regressions of the data indicate that the measurements define the average velocity quite well. The degree of variation in the individual data provides a good indication of the relative turbulence levels for different operating conditions.

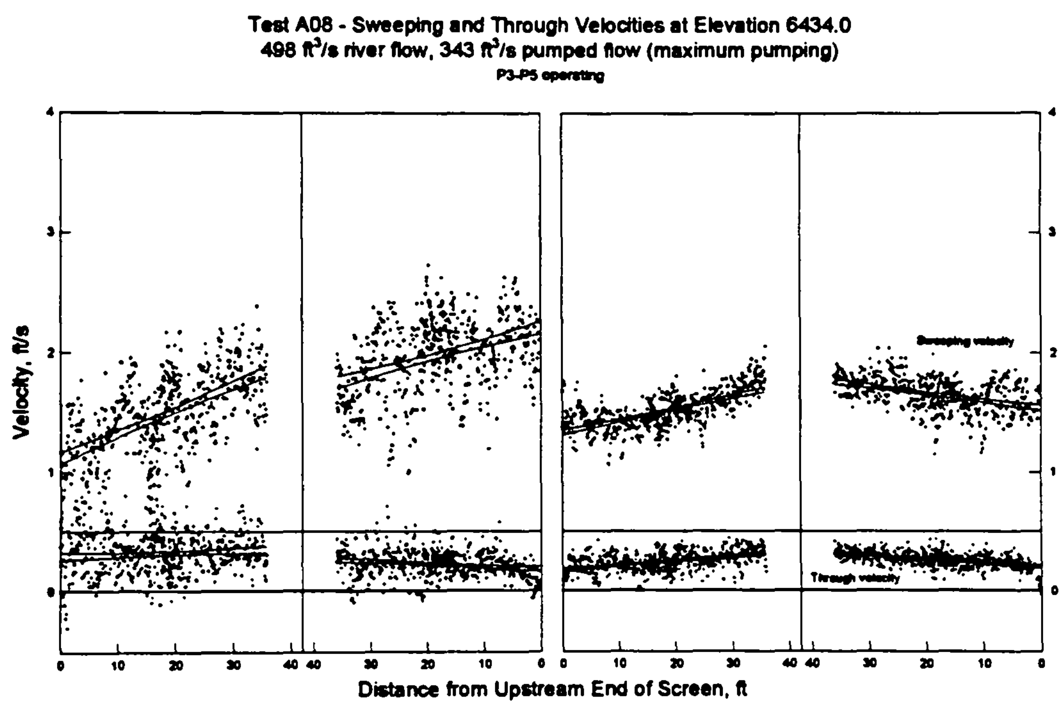
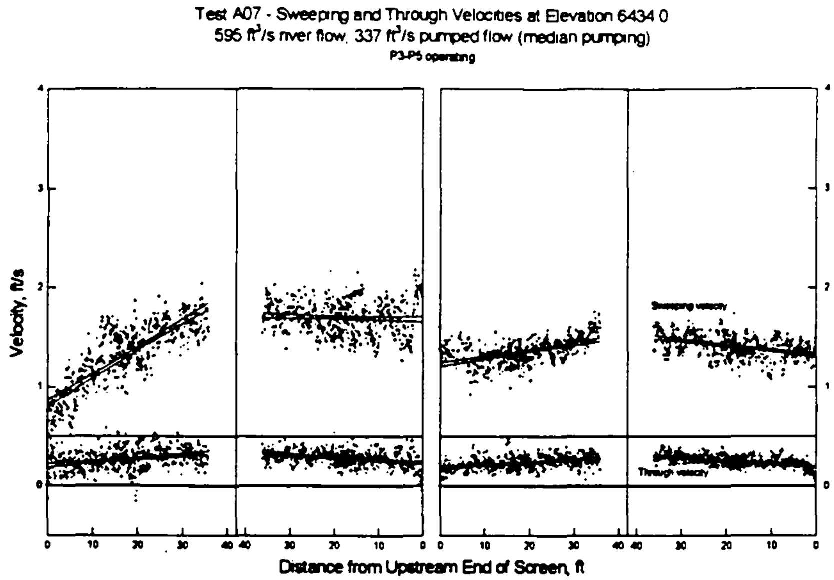


Figure 4. — Velocity measurements from Test A08, illustrating poor flow conditions in the left fish screen bay due to separation of flow from inside radius of left-hand screen structure forebay.



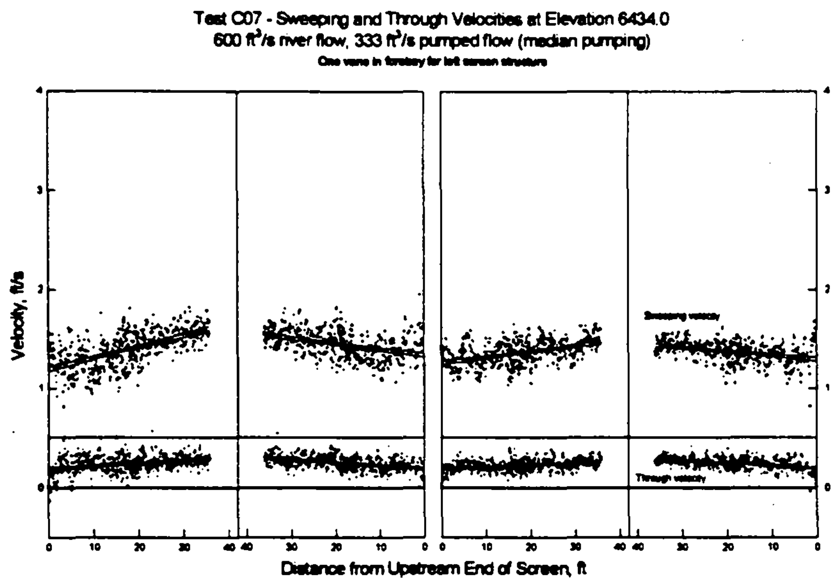


Figure 5. — Comparison of fish screen velocity fields at 600 ft^3/s river discharge and median pumping rate (~335 ft^3/s) for the initial design (top) and with turning vane installed.

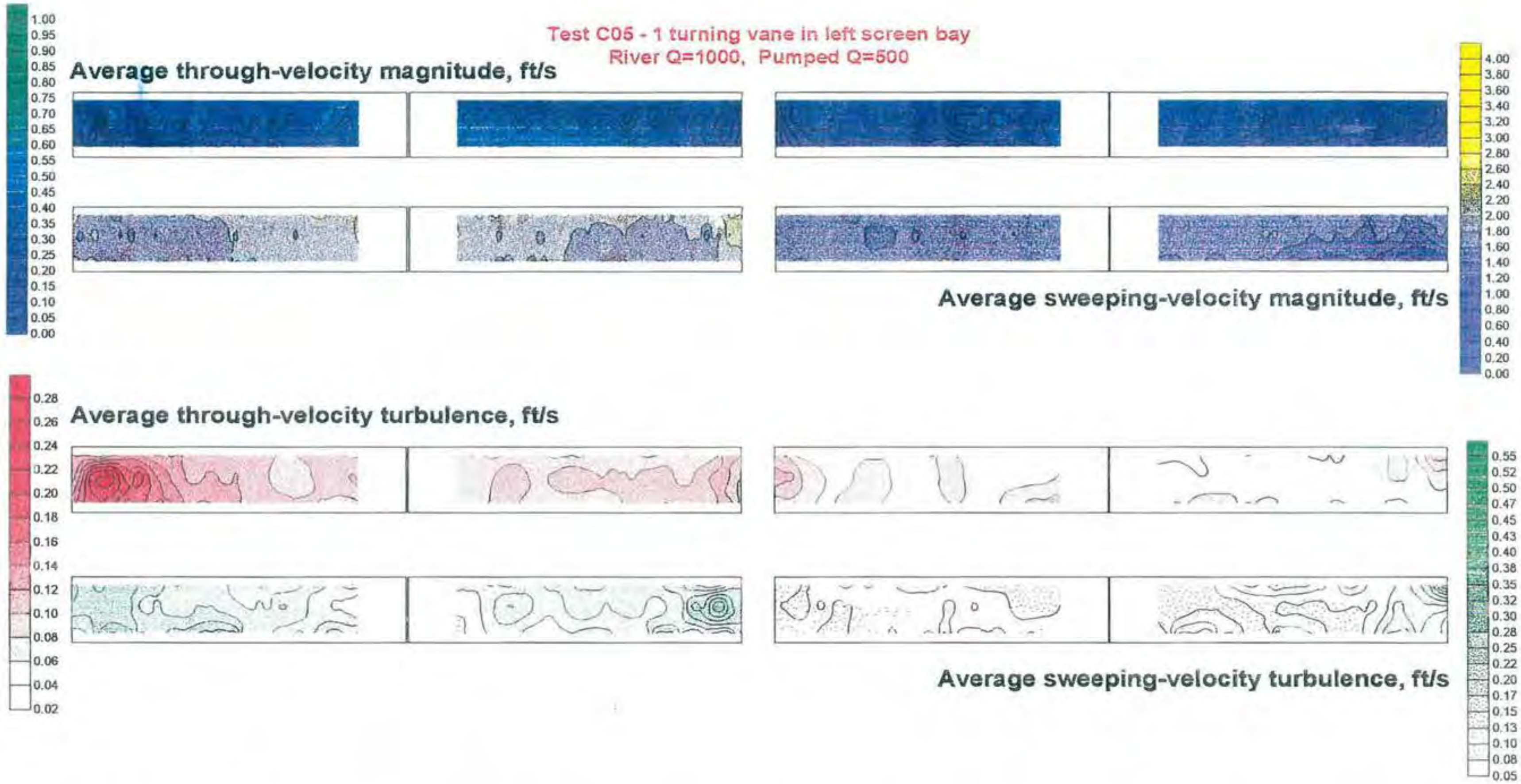
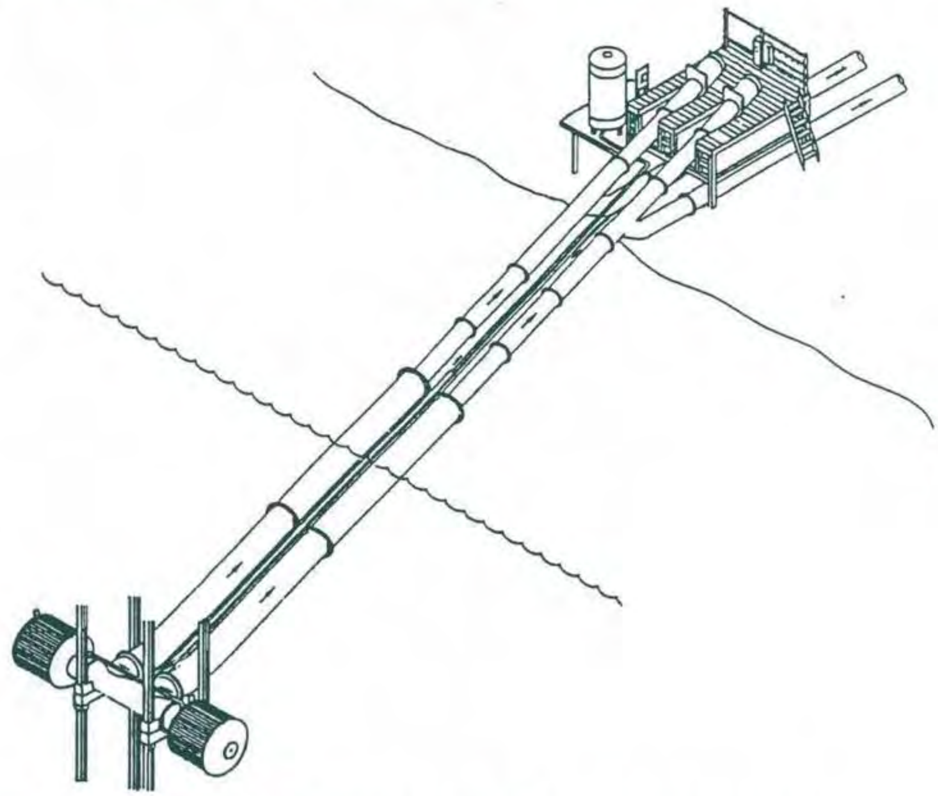


Figure 6. — Contours of average through and sweeping velocities, and through- and sweeping-velocity turbulence levels.

Physical Evaluation of the Lakos-Plum Creek Self-Cleaning Pump Intake Screens at the



Pelger Mutual Water Company's Pumping Facility

by Tracy Vermeyen

November 1995

Executive Summary

Introduction

The Water Resources Research Laboratory was requested by Reclamation's NCAO (Northern California Area Office) to assist them in the physical evaluation of three demonstration fish screening facilities on the Sacramento River in northern California. Under terms of the CVPIA(b)(21), the Bureau of Reclamation (Reclamation) is assisting with funding and technical support to install approved positive barrier screens at three sites on the Sacramento River. One of the selected sites is owned and operated by the Pelger Mutual Water Company. The demonstration screen program is being implemented in accordance with the National Marine Fisheries Service (NMFS) Biological Opinion and Incidental Take Statement dated February 12, 1993, directing Reclamation to "develop and implement a demonstration screening program designed to advance the state of the art of positive barrier screening technology at small unscreened diversions along the Sacramento River" and within Delta waterways. The Biological Opinion and Incidental Take Statement requires that field evaluation programs for all demonstration screening sites must be developed and implemented.

The subject of this report is the physical evaluation of the Pelger Mutual pumping facilities conducted on August 16 and 17, 1995. The Pelger diversion is located on the east bank of the Sacramento River at river mile 111.72. The diversion includes two side-by-side slant pumps (see figure 1), one with a capacity of 38 ft^3/s and one with a capacity of 17 ft^3/s. Normally, the pumps are not used simultaneously, but for these tests we used a maximum pumping discharge of 55 ft^3/s. The pump intakes have been fitted with Lakos-Plum Creek self-cleaning pump intake screens. Pumped irrigation diversions are typically made between April and October. However, in the future, occasional winter diversions may be made to flood rice stubble fields.

In addition, a computational fluid dynamics (CFD) model was developed as part of this study. Cerros Systems operated by Ken Williams, Ph.D., P.E. was contracted to create a three dimensional model of the fish screens and piping along with the river channel geometry. A summary of the CFD work is included later in this report.

Field Evaluation Conclusions

This physical evaluation, along with a concurrent biological evaluation, will assist biologists and engineers from Reclamation and NMFS to evaluate and document the performance of the Lakos-Plum Creek self-cleaning pump intake screens at the Pelger Mutual pumping plant. The conclusions derived from this field evaluation are as follows:

- Near- and far-field velocity measurements at the Pelger fish screens were successfully collected. A RD Instruments ADCP (acoustic Doppler current profiler) was successfully used to measure discharge, map the river bottom, and define the velocity

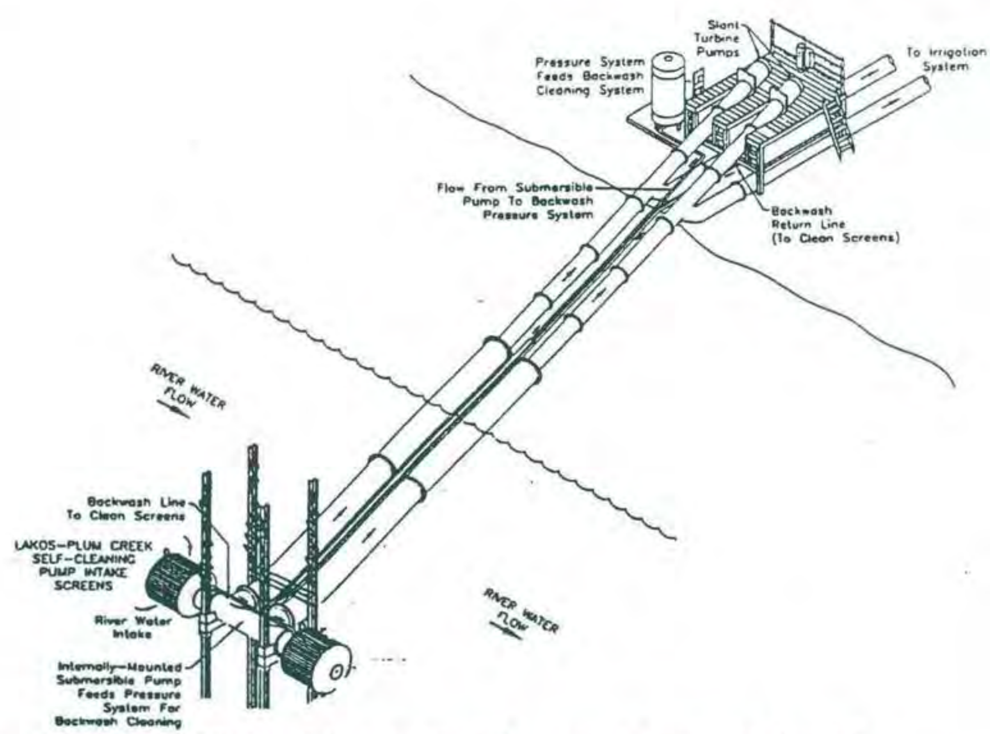


Figure 1. Schematic of Pelger Mutual Water Company's pumping facility.

fields at five cross sections upstream and downstream of the pumping plant. The near-screen velocity data were collected using a Sontek ADV (acoustic Doppler velocimeter) under difficult diving conditions.

- The far-field velocity measurements identified velocities of 3 to 4 ft/s approaching the fish screen at an angle of 20 to 40 degrees to the fish screen's longitudinal axis.

- For most point velocity measurements, near-field velocities collected for a diversion of 55 ft^3/s failed both the sweeping and approach velocity criteria. The reason was attributed to the skewed alignment of the screens to the approach velocity.

- For a diversion of 17 ft^3/s, velocity measurements satisfied both the sweeping and approach velocity criteria. However, the sweeping velocity distribution over the screen face for both the upstream and downstream screens was not uniform. The sweeping velocities along the back side of the screen (facing the riverbank) were substantially smaller than velocities along the front side of the screen.

- Screen orientation with respect to the approach flow direction is skewed and results in an uneven sweeping velocity distribution. If the screen's longitudinal axis was oriented parallel to the approaching flow direction the sweeping velocity distribution would be more uniform. Likewise, screen orientation also effects the approach velocity distribution on the screen face because the impinging current increases the approach velocities.

- Diver observations confirmed that the screen cleaning system was keeping the screen free of debris.

- This evaluation has established a viable field method of collecting velocity data near fish screening structures and will be used at the two remaining fish screening demonstration sites.

Additional Studies

In an effort to further describe the performance of the Pelger fish screens, the WRRL contracted for the development of a CFD (computational fluid dynamics) model to study the velocity distribution on a cylindrical screen for a variety of flow conditions. The CFD model was developed using the program FLOW-3D by Cerros Systems, Inc. from Albuquerque, New Mexico. The goal of this study was to demonstrate the benefits of using CFD simulation technology as another tool in evaluating the performance of hydraulic structures. The objectives of this study were as follows:

- Evaluate the three-dimensional, transient flow behavior around the Lakos-Plum Creek fish screen for hydraulic conditions similar to those measured at the Pelger Mutual pumping plant.

- Quantify the velocity components at locations around the screen where field measurements were collected.

- Develop a logical approach to CFD simulation including geometry setup, boundary condition modeling, fluid physics selection, problem solution, and graphical output.

The CFD simulation was developed using a series of four "build-up" tests: 1) a static condition with no river flow and no pumping, 2) a stagnant river and pumping at 55 ft^3/s, 2) a 2.5 ft/sec and 0° approach velocity vector with and no pumping, 3) a 2.5 ft/sec and 30° approach velocity vector with no pumping. Once confidence in the model was developed the model was used to study two flow conditions: 1) a 2.5 ft/sec and 15° approach velocity vector with a pumping rate of 55 ft^3/s, and 2) a 2.5 ft/sec and 30° approach velocity vector with a pumping rate of 55 ft^3/s.

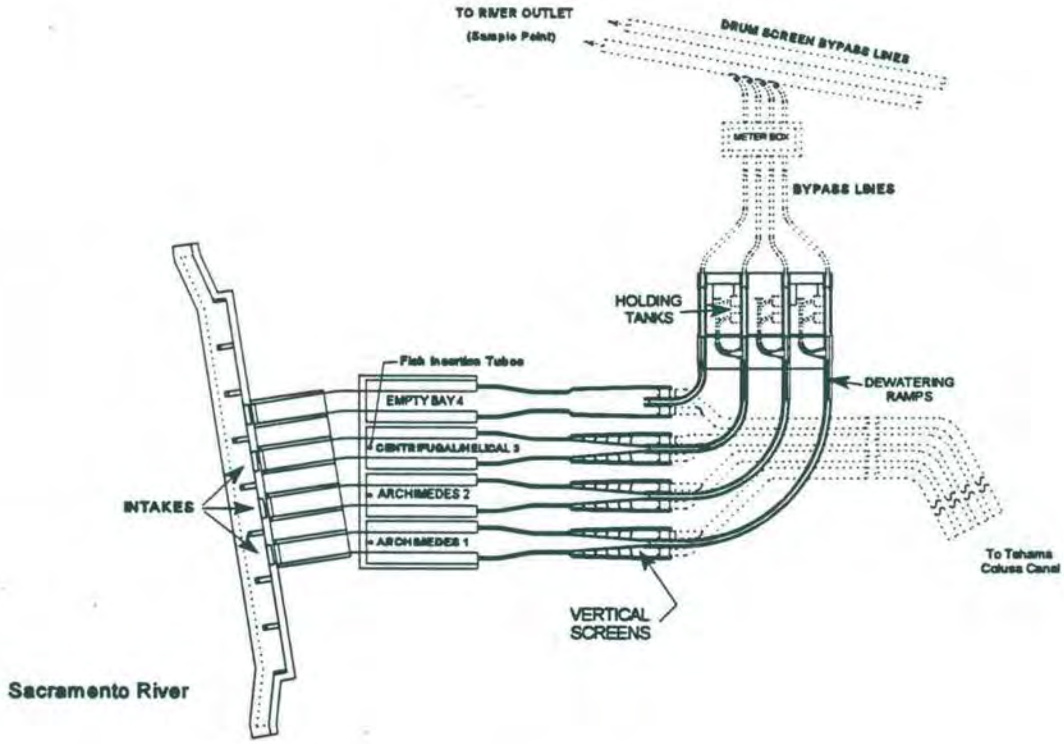
The FLOW-3D model results provided a detailed description of the three-dimensional velocity fields near the screen face. The model was also used to investigate a variety of approach flow conditions. The CFD model output consisted of velocity fields located 0.5, 3, and 6 inches away from the screen face. The velocity values at 3 and 6 inches from the screen were compared with the field evaluation velocity measurements as a verification of the CFD results.

Results - The Pelger Mutual field data were consistent with the overall qualitative findings from the CFD analytical study. Quantitative agreement was good at the near-field measurement locations. In general the directions were accurate, but the magnitudes varied for several locations. However, influence from upstream non-uniform flow fields were not considered in the CFD simulation. The main difference was the presence of strong secondary currents which were not modeled, but have a strong influence on the near-field velocities.

CFD Conclusions - The following conclusions were summarized from a detailed report submitted by Cerros Systems as the final product of the contract. If more information is needed the report is in the WRRL's permanent files.

- For underwater structures like the Pelger fish screens, CFD packages like FLOW3-D are capable of representing the overall physical domain with internal obstacles, boundary conditions, fluid turbulence, and free surfaces.
- Flow fields identified by the CFD simulation can be complex and exhibit counter intuitive behavior.
- Developing the model with a logical progression of model complexity generates confidence in final results.
- Combining CFD simulations with field and laboratory studies of hydraulic structures is cost effective and complementary.
- The Pelger Mutual field data were consistent with the overall qualitative findings from the CFD analytical study.
- Quantitative agreement between CFD and field velocities were good in most locations even though secondary currents and vertical velocity components were not considered in the CFD simulation, but were present during the field measurements. Given the significant difference in approach flow, the CFD results were considered satisfactory.

Fish Screen Evaluations Associated with the Red Bluff Research Pumping Plant



K. Warren Frizell
October 1996

Executive Summary

The Red Bluff Research Pumping Plant is a unique research facility built for studying pumped fish diversions/bypasses. The present configuration features three pumps, two Archimedes pumps and a centrifugal-helical pump. Water is pumped out of the Sacramento River, with the pump outfalls emptying into separate channels. These channels lead into flat-plate vertical screening structures (figure 1) where 90-percent of the flow is screened and passed into the headworks of the Tehama-Colusa Canal System. The remaining 10-percent of the flow, containing fish and debris, pass through a bypass channel and can be diverted into holding tanks where fish can be captured and observed for injury or held to allow for extended studies or passed straight through the system, returning to the river through existing bypass lines of the Tehama-Colusa canal drum screens.

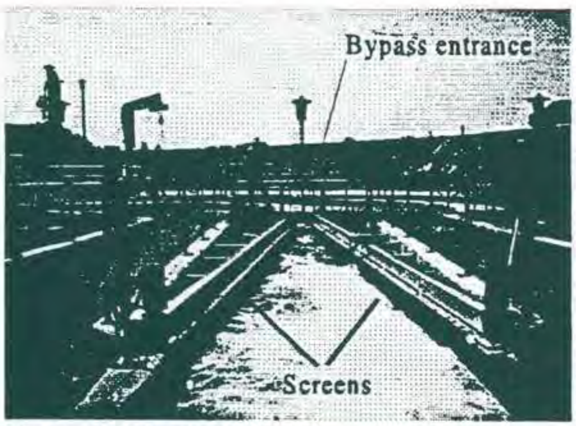


Figure 1: Vertical screening structure.

The engineering study plan involves the overall evaluation of the entire pumping plant facility, including the riverine environment around the intake structure. These studies will be closely tied to the fisheries evaluations throughout the duration of the research program. Initially, an engineering shakedown of the facility is planned. This shakedown will address any design deficiencies or oversights and will prepare the pumping plant for the battery of tests planned for the fisheries and engineering evaluations. Gaining experience in operating the facility is especially important during this phase.

The engineering evaluations concern all major features in and around the plant. The vertical screen structures are just part of the overall evaluation plan. The vertical screening structures feature a typical chevron pattern with a half angle of 4.89-degrees. The screens are constructed of 3/32-inch stainless steel wedgewire with a 3/32-inch open spacing. The screen panels are continuously cleaned by moving brushes.

The screens fall under the velocity criteria for salmon as required by the National Marine Fisheries Service (NMFS). This allows an approach velocity (perpendicular to the screen face) of 0.33 ft/s at a point 3-inches off the panel face. The sweeping velocity (parallel to the screen face) should be at least twice the approach velocity, or 0.66 ft/s.

This facility allows for actual prototype measurements of working screens with fish in the system. Preliminary measurements have shown the importance of the design of the bypass entrance. A low velocity present at the entrance to the bypass in conjunction with the ramp which transitions into the bypass causes a large eddy to form. The eddy extends well up into the screen structure and causes reversing flow in the lower half of the flow depth, figure 2.

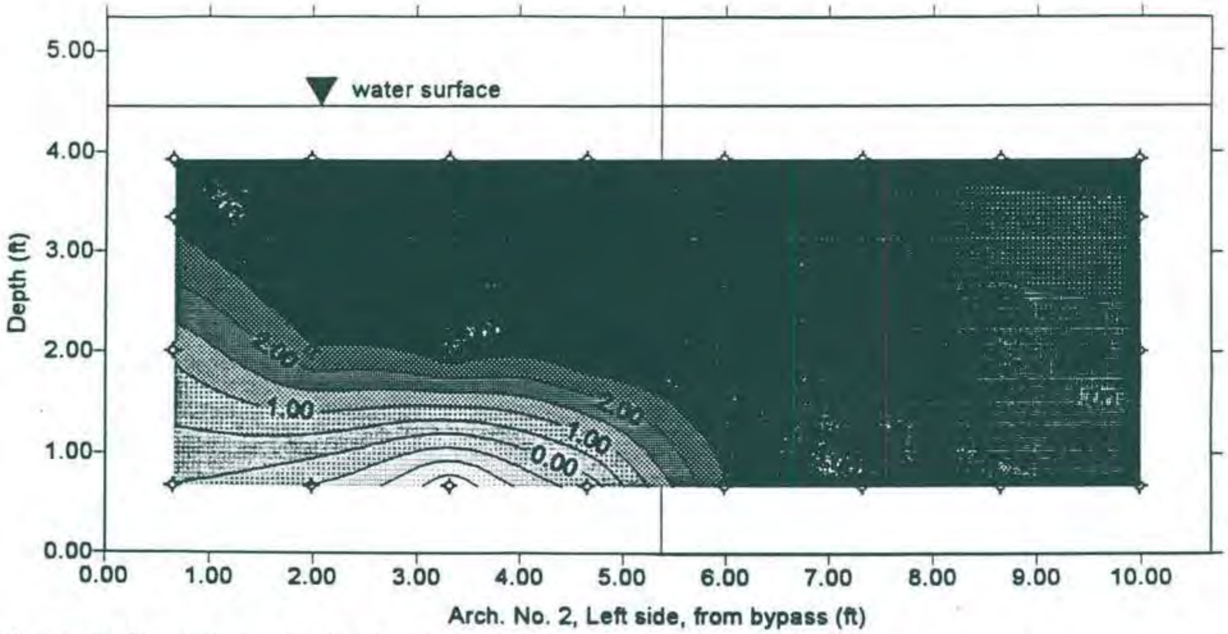


Figure 2: Sweeping velocity, last two screen panels closest to the bypass entrance.

Baffling behind the screen panels is required to create a uniform flow distribution through all screen panels. In addition, an inverted weir was installed in the throat of the 18-inch wide bypass. The effect of this weir, as well as the setting of the baffles is still being determined through testing.

Additional data collections and observations will be made throughout the study in order to fully evaluate the screening facilities. These include:

- Wave action and reflection off side walls.
- Head loss through the screens.
- Detailed velocity measurements to set baffling required to achieve uniform flow distributions within the set criteria.
- Characterization and quantification of debris and sediment passing through the pumps.

Evaluations were limited in FY96 due to numerous problems associated with the operation of both types of pumps. In addition, numerous shakedown activities were still taking place. Much of the engineering evaluation, particularly on the screen structures, should be completed in FY97, assuming that the pumps continue to operate dependably throughout the year.